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RF-E - RFID Tagging - Features and Applications

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Short Description

RFID is one of the fastest growing technologies in the automatic data collection industry. The widespread use of RFID in such varied applications as electronic article surveillance, animal tagging and high volume logistics supply has resulted in low prices of the tags. It is conceivable with the affordability of tags that they can be permanently used to identify foodstuffs and clothing items.

Description

RFID is one of the fastest growing technologies in the automatic data collection industry. The widespread use of RFID in such varied applications as electronic article surveillance, animal tagging and high volume logistics supply has resulted in low prices of the tags. It is conceivable with the affordability of tags that they can be permanently used to identify foodstuffs and clothing items.

There are still a number of questions raised about issues such as cost and in particular privacy. This manual will cover all the essential aspects of RFID systems to not only provide you with a broad understanding of its technology but also the various types of applications and uses where it can be applied to.

The manual will provide an overview of RFID technology, explain the physics and electronics driving this technology whilst also focusing on communication protocols, industry standards and security issues. It also covers software requirements, middleware and integration with various business applications and practices. Implementation strategies and challenges, cost analysis, market opportunities and the road-ahead will be discussed.

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Introduction to Radio Frequency Identification

1 Introduction to radio frequency identification

Learning objectives:

On completion of this chapter, you will:

- Obtain an overview of the radio frequency identification (RFID) technology
- Appreciate the evolution of RFID
- Enumerate various applications and benefits
- Understand key technology challenges and limitations
- Appreciate efforts towards evolving RFID standards
- Identify RFID opportunities and market players

1.1 Radio frequency identification - an overview

Radio frequency identification [RFID] is a technology that facilitates electronic labeling and identification of objects using wireless communications. In fact, RFID is an offshoot of a broader technology domain viz. automatic identification and data capture (AIDC) which includes barcode, optical character recognition and infrared identification system.

Essentially, a RFID system comprises three basic elements:

(a) Electronic tags: These are attached to various objects and carry relevant data about them. The tags are technically referred to as transponders or contact-less data carriers and each tag has its own embedded antenna.

(b) Readers: These include antennas that read data from RFID tags. The readers are also capable of writing/modifying data onto tags, pending the different applications.

(c) Communication/software application: The tags and readers communicate using well defined radio frequency and associated protocols.

A schematic of a typical RFID system is shown in Figure 1.1 (a) and (b).

1.2 Evolution of RFID

Science postulates that the universe was created with the "*Big Bang*." Electromagnetic energy is considered to be the first form of energy. The electromagnetic remnant of the '*Big Bang*' survives today as a background microwave hiss. The harnessing of this electromagnetic energy in the radio region forms the core of RFID development. Details of electromagnetic energy propagation are discussed in Appendix 'A'.

The combination of radio (first demonstrated in 1906 by Ernst F W Alexanderson) and Radar (developed around 1922, Manhattan Project) forms the basis for RFID technology.

An early paper on RFID, authored by Harry Stockman, appeared in the *Proceedings of the IRE*("Communication by Means of Reflected Power," 1948). But it took another 30 years to develop other related technologies – the transistor, the integrated circuit, the microprocessor and communication networks that contributed to the emergence of RFID for commercial applications (see Figure 1.1 (a) and (b)).

Figure 1.1 (a)

Typical RFID system

Figure 1.1 (b)

Components of RFID system

An early application of RFID surfaced in the 1960s with the introduction of electronic article surveillance (EAS). These systems often used a 1-bit tag, whose presence or absence was detected using microwave or inductive technology. In the 1970s, research and development in RFID continued and work in areas such as radio-telemetry, electronic identification systems, passive microwave transponder etc. were reported. The intended applications ranged from animal tagging and vehicle tracking to factory automation. The potential of RFID was beginning to be realized.

The 1980s saw the implementation of RFID in a myriad of applications. The major thrust was in areas of transportation, personnel access (in USA), animal tagging, industrial and business applications (in Europe) and toll collection (in Italy, France and Spain). In the 1990s, RFID technology began making giant strides and was deployed across diverse industries and business sectors.

1.3 RFID initiatives/applications

Some initiatives in RFID applications in industry and commerce are as follows:

Toll collection: In the United States, seven regional toll agencies formed the E-Z Pass Interagency Group (IAG) to develop a regionally compatible electronic toll collection system. The world's first open highway electronic tolling system opened in Oklahoma in 1991. The combined toll collection and traffic management system was installed in Houston.

Ticketing: RFID wristbands are used for large event access control. These applications range from public transportation (access to trains, busses, subways) to amusement parks, resorts, theatre etc. San Francisco and London Heathrow airports for instance, are reportedly using RFID tags to track and manage bags. Tagging bags on international flights ensures that the bags have gone through requisite security stages.

Cashless payments: Cashless payments have been implemented in toll collection and gasoline pumps. For instance, Exxon Mobil's 'Speedpass' program, saves millions of driver hours at the pump. Participating consumers can opt for either a passive tag, which is clipped to their key chain, or a batterypowered active tag attached to a car window. Automatic charges to the consumer are effected through registered credit cards.

McDonald’s restaurants now are now offering similar application to speed transactions at the counter and drive-thru window. It has been reported that a branch of McDonald's is conducting a marketing test to study the efficacy of using a tiny, gray plastic wand to pay for meals, instead of cash.

Automobile: Texas Instruments (TI) introduced the TIRIS system, which is used in automobiles for engine starting control. New applications for dispensing fuel, gaming chips, ski passes and vehicle access surfaced in a big way. The standardization efforts for RFID technology began in the late 1990s.

Animal tagging: Cleanliness and freshness of food has been a matter of serious concern and an important driver for change in the meat industry. The case of Bovine Spongiform Encephalopathy (Mad Cow Disease) for instance, serves as a trigger for deployment of RFID in animal tagging. A major initiative by the Australian Government in the mid 1990s recognized the need to provide ‘paddock to plate traceability’. The cattle ID system based on transaction tags captures details like recent parcel of land where the cattle grazed, slaughter date and other animal history.

Personnel identification: RFID provides an easy method for personnel identification, allowing access to certain restricted areas (e.g. military or nuclear stations). Button type RFID transponders that contain information like identification number, action/peace station location, blood type, drug allergies etc. can be sewn into the clothing of military personnel for instance.

Blood, tissue and organ identification: Precision Dynamics Corporation (PDC) in the year 2004, launched a pilot study with Georgetown University Hospital’s blood bank using RFID wristbands to track the source of blood samples, time of collection and analysis details so as to increase safety in blood transfusions. Similar applications can also be extended to organ transplants. RFID adoption in the hospital management system provides a convenient means to tag patient’s movement in confided areas; track medicine/test dispensing systems, tag blood samples, ECG reports to reduce manual errors and improve reliability and safety.

Product security: RFID facilitates lifetime product tracking to establish accurate warranty claims/authorization and offer counterfeiting protection. In 2004, the U.S. Food and Drug Administration (FDA) Anti Counterfeiting Task Force recommended wide-scale adoption of RFID to stop counterfeiting, which now accounts for between six percent and 10 percent of all pharmaceuticals worldwide (see Figure 1.2 (a)-(c)).

Figure 1.2(a)

RFID handheld applications

Manufacturing: The automobile industry is perhaps the first in the manufacturing sector to adopt the RFID technology. General Motors and Ford are the forerunners in implementing RFID-driven tagging in the manufacturing processes. Smart labels are used for work-in-process and lifetime tracking, materials management, inventory control, equipment service and maintenance. As products are incrementally assembled, tested and packaged they move through the production/distribution line. By monitoring real time progress of product creation and movement, manufacturers can tighten supply chains and gain visibility into manufacturing/distribution operations.

Figure 1.2(b)

RFID assembly line application

Retailing business: Wal-Mart, the largest supermarket chain, has issued a mandate for RFID compliance by its suppliers by Jan 2005. According to estimates, Wal-Mart receives almost eight billion cartons of items per year. Reportedly, the company intends to tag the cartons/pallets with electronic RFID labels measuring 10 cm x 15 cm and adhere to the Electronic Product Code (EPC) standards. In addition, Wal-Mart plans to introduce smart shelves, where traceability of each item/transactions can be logged in the enterprise database. It is estimated from various RFID impact studies for retail industry that improved shelf availability can lead to improved sales – anywhere from about 0.1 to 4 percent.

Logistics: Undoubtedly, logistics is tipped to become the largest sector to adopt the RFID technology. According to an Aberdeen consulting report released in June 2004, 69 percent of study respondents planned to implement the RFID system to manage logistics assets by year 2006. The ability of RFID readers to identify multiple tags simultaneously through the packaging creates interesting opportunities for the unattended tracking of the entire content of pallets and transit containers. Managing returnable containers is perhaps the most challenging and cost saving opportunity. Higher degrees of tracking will enable organizations to lower their material costs and provide an audit trail that can be used to bill customers if containers/materials are not returned.

Warehousing: Material handling/storing processes can gain the optimum from RFID adoption. Strategic reading zones can facilitate automatic surveillance and tracking of spares, components and assemblies indicating shelf location, storage area and container yard throughout their movement across the facility. When integrated with enterprise networks and applications, resource optimization can be achieved in asset and warehouse management systems.

Shipping: RFID implementation in shipping products can eliminate manual recording/ data entry errors and enable instant identification of a huge volume of inventory, both at aggregate (cartons) and individual (item) levels. Order compliance and shipping invoices can be automated and integrated with an enterprise database for improved distribution operations.

Figure 1.2(c)

RFID shipping portal application

Hazardous waste management: Toxic wastes can be carefully controlled by tagging their storage identification, handling and disposal details which can be electronically conveyed to various monitoring centers through RFID based systems.

Libraries and video stores: RFID applications include inventory check-in, check-out, shelf management and security. Smart labels are inserted in books and scores of books can be issued or received without manual intervention. The tags could also be used to arrest shop-lifting and theft. In large libraries stocking of books/periodicals in the correct shelves can be managed using portable computers with RFID readers.

Chipless ID: Unlike RFID chips that contain an antenna, a processor and associated memory, each chipless ID transponder comprise just a passive antenna. These antennas are made from nano-resonant fibers (5 microns in diameter, 1 mm in length) that can be detected by special readers. The readers transmit a coherent pulse toward a transponder and receive an interference pattern in return that is processed and identified. The frequencies used range from 24 GHz - over 60 GHz. One major advantage of chipless ID is the cost. The read range would be around a few inches. The immediate interest in the use of such chipless ID comes from security/tracking related applications.

Tapemark is introducing chipless ID into packaging materials and paper labels to create passive antennas that are undetectable making them ideal for product security applications.

Figure 1.3 shows some examples of RFID deployment.

Figure 1.3

Examples of RFID deployment

A summary of different RFID applications has been enumerated in Table 1.1

Table 1.1

Summary of RFID applications and salient benefits

Application	**Some specific benefits**
Retail	Track & trace
	Product recalls
	Shrinkage reduction
	Out-of-stock cutback systems
	Customer loyalty programs
	Automated invoice reconciliation
	Demand forecast/decrease safety stock
	Streamlined shipping & receipts
	Decreased order lead time

Shipping	Automated shipment sequence & tracking
	Accurate order staging
	Decreased shipment delay
	Quick & accurate bill of lading
	Reduces lost shipments
	Dynamic routing
	Automated customs
Warehousing/inventory management	Decrease unloading process times
	Increase compliance of accepted shipments
	Increased accuracy of orders
	Location & item matching
	Automatic item reorders
	Eliminate search & identify activities/fewer misplaced items
	Excess inventory reduction
	Effective warehouse space management & cost reduction
	Lower insurance costs
Manufacturing	Improve asset utilization: by tracking reusable assets and providing visibility to their location and usability
	Improve production: by providing timely and accurate information into ERP
	Improve inventory: by tracking and providing visibility in rea time
	Improve quality: by tagging raw material, WIP and final goods

	Reduce scrap: by controlling operations using tagged information
	Facilitate: Just-in-time work in process inventory
	Permit: decrease production downtime
	Allow: correct matching of parts & assemblies
	Permit: quick changeover & reloading of materials
	Allow: optimized warranty & recall reduction
Plant maintenance	Facilitates correct location of equipment & tools
	Quick reference to maintenance specifications
	Immediate update of parts replacement
	Eliminate delays & wastage in search activities
Pharmaceutical & health care	Effective anti-counterfeiting
	Easy product identification & recall
	Effective tamper proofing
	Improved drug visibility in distribution & logistics
	Improved drug traceability
	In hospitals:
	Monitoring medication routes
	Effective wander prevention
	Improved infant protection
	Improved medical record storage
Automotive	Effective parts tracking

	Effective tool management
	Just-in-time assemblies
	Reduced inventory
	Improved brand identification
	Product support & recall
	Improved distribution
	Improved recycling
	Theft control
	Increased productivity of assets
Food industry	Cow/bird pedigree
	Herd/flock history
	Details about release into food chain
	Responding to outbreaks/food poisoning
Airline	Automatic ticketing
	Baggage handling
	Increased customer satisfaction

1.3.1 How does the RFID system work?

RFID employs low-power radio signals to transfer data wirelessly between the tags and readers. Therefore, direct line of sight between the tag and read/write device is not necessary. Furthermore, RFID readers can simultaneously recognize and process hundreds of tags within their read fields. These features open new vistas of applications in the automatic identification of objects. In particular:

(a) The RFID system's capability to read and write data to tag enables the dynamic real-time update of data. Consequently, RFID tags can be reused.

(b) The RFID system's capability to read multiple object tags (a.k.a. cluster reading), enables error-free, high volume data handling.

(c) The RFID system permits hands free operation, since no contacts are needed between the tag and reader.

(d) The RFID system allows the tags and readers to be placed in harsh environments with relatively long read ranges and life.

RFID tags

(a) These consist of an integrated circuit (IC) attached to an antenna, which are typically printed or etched conductors on a thin plastic sheet. Data is stored on the IC and transmitted through the antenna. Data transmission speed and range depend on the radio frequency, antenna size, power output and interference.

(b) RFID tags can be passive (no battery) or active (with battery). The tags can be read-only, read-write or a combination of both, where some data (e.g. product serial number) is permanently stored while the remaining memory is available for updating data during usage.

(c) In passive systems, a RFID reader transmits an energy field that triggers the tag and provides power to the chip. This enables the tag to transmit or store data. Encryption algorithms can be employed to ensure the security and integrity of the data that are communicated between the tag and reader.

(d) In active systems, batteries are used to boost the effective range of the tag. Active tags may transmit a signal periodically so that data may be captured by readers distributed throughout a facility.

(e) Tags can be applied to diverse objects such as people, items, cartons and pallets. System designers can place ‘handling codes’ directly on the object as it traverses through a system. Some examples of the types of RFID tags available for varied applications are shown in Figure 1.4.

Figure 1.4

Types of RFID tags

RFID readers

1. Readers come in many forms. They may be integrated into portable handheld terminals; or are fixed and positioned at strategic points, such as portals, gate entrance, assembly line, store shelf, tables etc. Alternately, they could be integrated into forklifts, trolleys, wands or other equipment.
2. Readers may have one or more antennas which send and receive signals, to/from the tags. Incorporated with the reader, is a processor for decoding received signals and data. The collected data is then transmitted through networked systems (cabled or wireless LAN, for instance) to the host computer system.
3. Based on the type of tag and its design, readers also may write new data into tags. Readers operate in accordance with local (National) RF emission regulations. It is imperative that tags and readers must conform to these specifications and standards.
4. “Frequency agile” readers are capable of recognizing multiple frequencies. These integrated readers can support multiple tags that operate with different frequencies.
5. Application requirements determine the frequency, memory and performance requirements of the tags. Special consideration should also be given when tags are required to be used on a global scale and must meet the requisite interoperability standards (if any).

Some types of RFID readers available in the market are shown in Figure 1.5.

Courtesy Epic Data

Figure 1.5

Types of RFID readers

Figure 1.6 depicts a composite RFID system indicating its components and functions.

Figure 1.6

RFID components and functions

Key benefits of RFID

Major benefits that accrue across various applications by adopting RFID technology are listed in Table 1.2

Table 1.2

Major benefits of RFID technology

Elimination of cost in search & find activity
Reduction in inventory carrying costs & inventory levels
Reduction in lost shipments
Improving tracking of returnable containers from customers
Reduction in stock outs
Enabling product recall from market, especially in faulty drugs distribution
Reduction in production down-time thereby improving plant utilization
Enabling quick matching of correct parts/assemblies during production
Improving utilization of plant infrastructure & processes
Improves authentication of products and warranty management
Allowing capture/utilization of complete product life cycle data
Improving shelf management/point of sales process in retailing business
Reducing counterfeiting/theft of currency/drugs
Improving security and safety of baggage/personnel

Key technology challenges

(a) Data volume: RFID-tags would generate an enormous amount of data to the existing enterprise-wide data management systems. With trillions of data tags populating the data-space, it is estimated that RFID applications would generate 30 times more data compared to the current environment. Therefore, the back-end and middle ware system architecture should be robust to handle such data volumes from external/internal sources.

(b) Data security: Privacy and security issues require urgent attention to ensure wide-spread applicability of RFID systems. Three issues that need to be addressed are:

- End-to-end security to prevent unauthorized use of data
- Provision for write protection to tags
- Tag data encryption and selective response from tag

(c) Packaging: When it comes to packaging, radio waves exhibit certain limitations. Broadly:

- Metal packaging tends to reflect radio waves. Therefore RFID tags on metallic items need to be fixed through appropriate spacers
- Water or items with a liquid content reduce the read range of RFID tags. Innovative tag design and reader placement become pertinent implementation issues
- In certain industries, such as manufacturing, readers may interfere with other existing wireless equipment. There is thus a need to carefully select an appropriate radio frequency to avoid interference

To provide the maximum power transfer between reader antenna and tag antenna they should have the same polarization. If the polarization between them is 90 degrees, the power is negligible and read ability suffers. Figure 1.7 illustrates the effect of tag and reader antennas orientation.

Tag orientation and placement of multiple readers at different orientations could be a possible solution. Alternately, a circularly polarized tag antenna is preferable.

Figure 1.7

Reader and tag: effect of antenna orientation

(d) Jamming of signals. Because RFID use an electromagnetic spectrum, they become susceptible to jamming with signals at the right frequency. Even two readers operating at the same frequency can, if they are close enough to each other, make tags undetectable. The prime reason for this happening is because the tags often use backscatter modulation (reflect energy); reflected energy is much lower than the energy radiated by the readers.

(e) Tag collision. Tags operating in close proximity can respond to a reader(s) at the same time and cause a communication collision. It is therefore imperative to adopt efficient anti-collision protocols.

RFID standards

Adoption of standards is essential in furtherance of new technology and ensures uninterrupted trouble-free service to consumers. Standards help to:

1. Ensure different products don't interfere with each other's functions - irrespective of the manufacturer.
2. Enable seamless interoperability between devices or applications

In the early days of RFID technology, companies developed proprietary standards such that readers from a particular vendor would often read tags produced by the same vendor. RFID application of the yesteryears such as electronic toll collection, live stock tracking etc. was developed with proprietary based systems.

The initiative of the auto-ID center, headquartered at the Massachusetts Institute of Technology, changed the scenario with respect to the adoption of RFID standards. It is a non-profit collaboration between industry and academia to develop an internet-like infrastructure for tracking goods globally through the use of RFID tags. The center initiated the creation of a standard to facilitate full scale interoperability between multi-vendor RFID systems.

The auto-ID has since transferred its role to the EPCglobal in Oct 2003. The responsibility of evolving and propagating RFID standards amongst users now rests with EPCglobal. A brief write-up on EPCglobal is placed in Appendix 'B'.

Prior to discussing various versions of EPCglobal specifications/ISO standards, it would be worth noting the specific frequency ranges that are available for RFID communication. These are:

- Low frequency (LF) 125-135 KHz
- High frequency (HF) 13.56 MHz
- Ultra high frequency (UHF) 868-930 MHz
- Microwave 2.45 GHz
- Microwave 5.8 GHz

However, different countries regulate these frequencies and only a specific band of frequencies are available for actual use. The impact of the frequency range on the design of RFID systems is shown in Table 1.3.

The standards evolved by EPCglobal define various functional requirements such as encoding schemes and communication interfaces. The details of EPCglobal schema, standards and various versions are discussed in detail in Chapter 2.

Technology standards

(a) A major reason for a relatively slow market penetration by RFID products is that the RFID standards are still evolving. Most firms are reluctant to make large investments because the new RFID standards could render their hardware investment obsolete.

Table 1.3

Impact of frequency ranges on RFID systems

Frequency Range	Advantages	Disadvantages	Some Applica
Low frequency	Propagates through most things No radiation problems No reflection problems Cheap electronics	Range usually < 1 meter Slow data rate Bulky tags Coil tag antennas	Animal identifi Automobile ke (anti-theft syst
High frequency	Propagates to about 1 meter Tolerant to metal & fluids	Limited range Slow data rate Coil tag antennas	Library-books baggage, item Access contro
Ultra high frequency	Propagates several meters High data rate	Signals easily reflected or absorbed Large tags Expensive readers	Pallet & conta trailer tracking
Microwave	Propagates to long ranges High data rate Small tags	Signals even more easily reflected or absorbed Expensive readers	Access contro

(b) ISO/IEC 15693-2 stipulates standards for contact-less cards and RFID smart labels that operate in the 13.56 MHz band. This standard is sponsored by Texas Instruments and Philips Semiconductor and governs the data exchange between the RFID tag and the reader. There are several other existing and evolving RFID standards including the following:

- ISO 11784/11785 (Animal Identification RFID Standard)
- ISO ANSI/NCITS T6 256 - 1999 (Item Management RFID Standard)
- ISO/IEC 15693-2 (13.56 MHz Vicinity Cards and Smart Labels RFID Standard)
- ISO 18000 series of standards (Air Interface Protocol)
- GTAG (On-going RFID Global Tag Initiative)
- Consumer Products Manufacturers Association (CPMA) Consumer Goods ID Proposal (ongoing RFID Standard Initiative)
- The MIT Auto-ID Center's on-going RFID standards initiatives

(c) The ISO also promulgates standards for the selection of radio-spectrum frequencies for various RFID applications. Such standards promote inter-operability and ensure communication across devices of different manufacturers. Major ISO standards applicable to RFID applications are enumerated in Table 1.4.

Table 1.4

Applicable ISO standards for RFID

ISO Standard	Applicable frequency	Major specifications
ISO 18000-2	>135 KHz	· Communication: inductive coupling · Unaffected by presence of water · Short range, up to few cm · Relatively costly
ISO 18000-3	13.56 MHz	· Communication: inductive coupling · Relatively lower cost · Thin flexible form factor (smart label) · Read/write capable

		· Unaffected by water (but has to be tuned to item
		· Mid range, 70 – 125 cm
ISO 18000-4	2.45 GHz	· Communication: propagating · Long range in active version (100+ m) · Affected by water · Read/write capable · Moderate cost · Small antenna · Incorporates Bluetooth, etc.
ISO 18000-6 A/B 860	960 MHz	· Communication: propagating · Long range 2-5 m · Low cost · High data rates · “Frequency agile” · Read / write capable · Relatively large antenna · Mass application
ISO 18000-7	433 MHz	· Active · Long range - many meters · High cost · High data rates · Read / write capable

(d) ISO standards applicable to RFID supply chain applications are as follows:

- ISO 17358 - Application Requirements, including Hierarchical Data Mapping
- ISO 17363 - Freight Containers
- ISO 17364 - Returnable Transport Items
- ISO 17365 - Transport Units
- ISO 17366 - Product Packaging
- ISO 17367 - Product Tagging (DoD)
- ISO 10374.2 - RFID Freight Container Identification

1. Other standardization initiatives: In addition to ISO and EPCglobal, several other organizations have contributed to RFID and automatic data capture standards. For instance, ANSI provided ANSI-256 (INCITS 256-2001) which defines a common Application Programming Interface (API) between RFID tag and reader software.

The Chinese Government set up a working group in 2004 to define RFID standards/ protocols. This is particularly relevant to mushrooming factories in China that are exported all over the globe.

OSI Model & RFID

Open System Interconnection (OSI) is a versatile proven protocol and comprises seven layers as mentioned below (see Figure 1.8):

OSI Model - Layers
Layer 7: Application
Layer 6: Presentation
Layer 5: Session
Layer 4: Transport
Layer 3: Network
Layer 2: Data Link
Layer 1: Physical
Figure 1.8

Seven layers of OSI model

The OSI model provides a logical way to present data communication and is governed by the following guidelines:

1. Each of the seven layers must perform a clearly defined set of unique

tasks
2. Each layer depends upon the services of layers below and above it to perform its own tasks

- The layers themselves have no idea how and what the layers around them do. They only know that they do it, which is often referred to as transparency.

1. There is nothing sacrosanct about 7 layers. If the industry requires adding another eighth layer or remove one of the layers, the model can be changed. The key issue is functionality.

The OSI model is a conceptual framework for data communications. The layers can be categorized into two parts:

- Chained layers (layer 1 to 3) - responsible for providing connectivity services
- End-to-end layers (layer 4 to 7) - responsible for providing interoperability services

With respect to RFID, the process of initiating a physical (connectivity) and logical (interoperability) linkage between a transponder (tag) and reader and ensuring flawless data transmission are governed by the guidelines enumerated in the OSI model as follows:

1. Layer 1: (Associated Standards: ISO 14443-2 & 7816-2) manages the physical interface between the tag and reader (an air interface) and defines parameters such as bit rate, signal representation (ASK, NRZ, Manchester signaling etc.)
2. Layer 2: (Associated Standards: ISO 1443-4 & 7816-3) manages functions like error detection and correction, framing, link control, transparency, point-to-point addressing etc.

- Layer 3, 4 & 5: Not really used in RFID

1. Layer 6 & 7: (Associated Standards: ISO 7816-4 & 7816-7) manage security issues (encryption implementations often through hard coded functions embedded on the chip) and ensure applications executed by transponder are sent and received by the reader

RFID opportunity landscape

RFID systems are rapidly spawning retail and distribution markets around the world. Venture Development Corporation estimates that the shipment of RFID systems has increased from $900 million in 2000 to $1.2 billion by the end of the year 2002, and is expected to reach $2.7 billion in 2005. In the year 2000, the share of America in the world market was about 48%.

The mandate issued by the US Department of Defense (DoD) and Wal-Mart for their suppliers to become RFID compliant by Jan 2005 is the prime mover for the RFID market. Various market surveys and estimates indicate that RFID products and services would create roughly $10 billion by 2010. While numbers and percentages vary, virtually every market research and industry analyst affirms a bullish outlook for increased RFID deployment. The projection of the RFID market worldwide based on different reports between the years 1998 and 2008 is summarized in Figure 1.9.

Some of the major players in the RFID market have been succinctly depicted in Figure 1.10 (the list is merely indicative and does not purport to advertise products of the listed manufacturers).

Figure 1.9

RFID application market: revenue forecast

Figure 1.10

RFID major players

A list of manufacturers/RFID players is placed in Appendix ‘C’ for easy reference. The list is certainly not exhaustive but should give the readers an idea of the RFID landscape in the global market today.