Implementing RFID in Library: Methodologies, Advantages and Disadvantages

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Abstract

A library is a growing organism. As it grows in size the problems associated with the maintenance and security of the documents also grows. The researchers have always helped the librarian in solving their problems. To solve the problems of arranging documents in order they have given classification schemes. To solve the problems of searching documents they have given cataloging guidelines. To solve the problems of space and time they have taught librarians to digitize the documents and share over network. To automate the counter activities they gave us bar-codes. Bar-codes have served the librarians and libraries for a long time, and now it is slowly getting replaced by RFID.
This paper discovers the technology, implementation methodologies, advantages and disadvantages of RFID in Library.

1. Introduction

RFID (Radio Frequency IDentification) invented in 1969, patented in 1973, first used in harsh industrial environment in 1980s', and standards presented in 2001, is the latest addition of technology to be used in the libraries for a combination of automation and security activities in the well maintenance of documents either inside the library or goes out-of library. RFID uses wireless radio communications to uniquely identify objects or people, and is one of the fastest growing automatic data collection (ADC) technologies, which is comprising one or more reader/interrogators and RF transponders in which data transfer is achieved by means of suitably modulated inductive or radiating electro-magnetic carriers. In addition it can be used as a data carrier, with information being written and updated to the tag on the fly. RFID systems carry data in suitable transponders, generally known as tags, and retrieve data, by machine-readable means, at a suitable time and place to satisfy particular application needs.

RFID is a combination of radio-frequency and microchip. RFI chips are of particular interest, because they have become smaller and smarter to the point where they can be added every kind of document and can be read and updated from a distance [1]. The data capacities of transponder normally range from a few bytes to several kilobytes. There are also 1-bit transponder (without chip) to fulfill monitoring and signaling functions called Electronic Article Surveillance (EAS). In writable transponders, the reader can write data to the transponder in three procedures. Inductively coupled RFID system uses EEPROMs, FRAMs and microwave systems commonly use SRAMs. The important feature of power supply to the transponder is drawn either from the field of reader (Passive tag) or from the battery incorporated in the tag (Active/Semi-active tag).

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2. RFID Technology in Libraries

The concept of RFID can be simplified to that of an electronic barcode and can be used to identify, track, sort or detect library holdings at the circulation desk and in the daily stock maintenance. This system, consist of smart RFID labels, hardware and software, provides libraries with more effective way of managing their collections while providing greater customer service to their patrons.

The technology works through flexible, paper-thin smart labels, approximately 2”X2” in size, which allows it to be placed inconspicuously on the inside cover of each book in a library’s collection. The tag consists of an etched antenna and a tiny chip which stores vital bibliographic data including a unique Accession number to identify each item. This contrasts with a barcode label, which does not store any information, but merely points to a database. These smart labels are applied directly on library books and can be read with an RFID interrogator/scanner. Line of sight is not essential for reading the tags with the scanner, therefore, the books require much less human handling to be read and processed. A middleware or Savant software integrates the reader hardware with the existing Library Automation Software for seamless functioning of circulation.

The information contained on microchips in the tags affixed to library materials is read using radio frequency technology regardless of item orientation or alignment. It provides a contact less data link, without need for line of sight, for example, the documents in the shelves or cardboard boxes can be checked without removing or opening. RFID has no concerns about harsh environments that restrict other auto ID technologies such as bar codes. Tags have a discrete memory capacity that varies from 96 bits to 2kbytes. In addition to tags, an RFID system requires a means for reading or "interrogating" the tags to obtain the stored data and then some means of communicating this tag data to library information system.

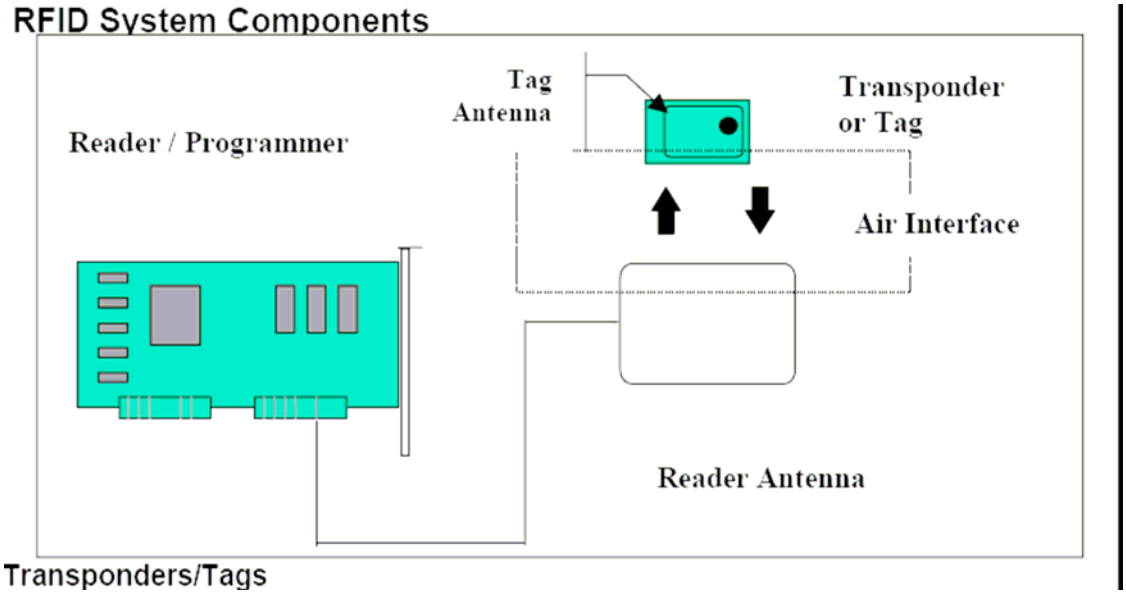
RFID-based systems have been implemented for efficient document tracking purpose through out the libraries that combine, easier and faster charging and discharging of documents, security of materials, inventorying, stock verification and shelf handling. RFID tag’s transponder listen for a radio query from the reader and respond by transmitting their unique ID code. Most RFID tags have no batteries, they use the power from the initial radio signal to transmit their response.

2.1 RFID Components

Normally a RFID package for library consists of eight components: RFID tags, a self check-out station, a staff check-out station, a self-return book drop with an automatic check-in feature, a tagging station, a set of security gates, a shelf scanner for inventory and an administrative station. The self-checkout station allows patrons to borrow books without assistance from the library staff. The staff checkout station is used when patrons prefer staff assistance. The book drop allows returned books to be processed instantly by updating the database the moment the items pass through the chute. The shelving station speeds the process of sorting the returned books for re-shelving. The shelf scanner allows library staff to take inventory and find wrongly shelved books without having to pull the books off the stacks.

3. How RFID Works

Figure-1



3.1 RFID systems:

In typical system tags are attached to objects. Each tag has a certain amount of internal memory(EEPROM) in which it stores information about the object, such as its unique ID, or in some cases more details of bibliographic data and product composition. When these tags pass through a Radio Field generated by a reader, the transponder in the tag transmit the stored information back to the reader, thereby identifying the object.

3.2 How Tags Communicate

The communication process between the reader and the tag is by wireless. The major differences between the different types of waves are the distances covered by one cycle of the wave and the number of waves that pass a certain point during a set time period. The wavelength is the distance covered by one cycle of a wave. The frequency is the number of waves passing a given point in one second. For any electromagnetic wave, the wavelength multiplied by the frequency equals the speed of light. The frequency of an RF signal is usually expressed in units called hertz (Hz). One Hz equals one wave per second. Basically what happens is that when the reader is switched on it starts emitting a signal at the selected frequency band (**in library HF is used with 13.56 MHz**). Any corresponding tag in the vicinity of the reader will detect the signal and use the energy from it, to wake up and supply operating power to its internal circuits. Once the tag has decoded the signal as valid, it replies to the reader and indicates its presence by modulating (affecting) the reader field.

Table 1. 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 850-950 MHz 2.4-5.8 GHz	Long read range High reading speed Line of sight required Expensive	Railroad car monitoring Toll collection systems

3.3 Anti-collision

If many tags are present (in a row of books) then they will all reply at the same time, which at the reader end is seen as a signal collision and an indication of multiple tags. The reader manages this problem by using an anti-collision algorithm designed to allow tags to be sorted and individually selected. The number of tags that can be identified depends on the frequency and protocol used, and typically range from **50 tags/s for HF and up to 200 tags/s for UHF**. Once a tag is selected the reader is able to perform a number of operations such as read the tags identifier number, or in the case of a read/write tag write information to it. After finishing dialoging with the tag the reader can then either remove it from the list, or put it on the stand by until a later time. This process continues under the control of anti-collision algorithm until all tags have been selected.

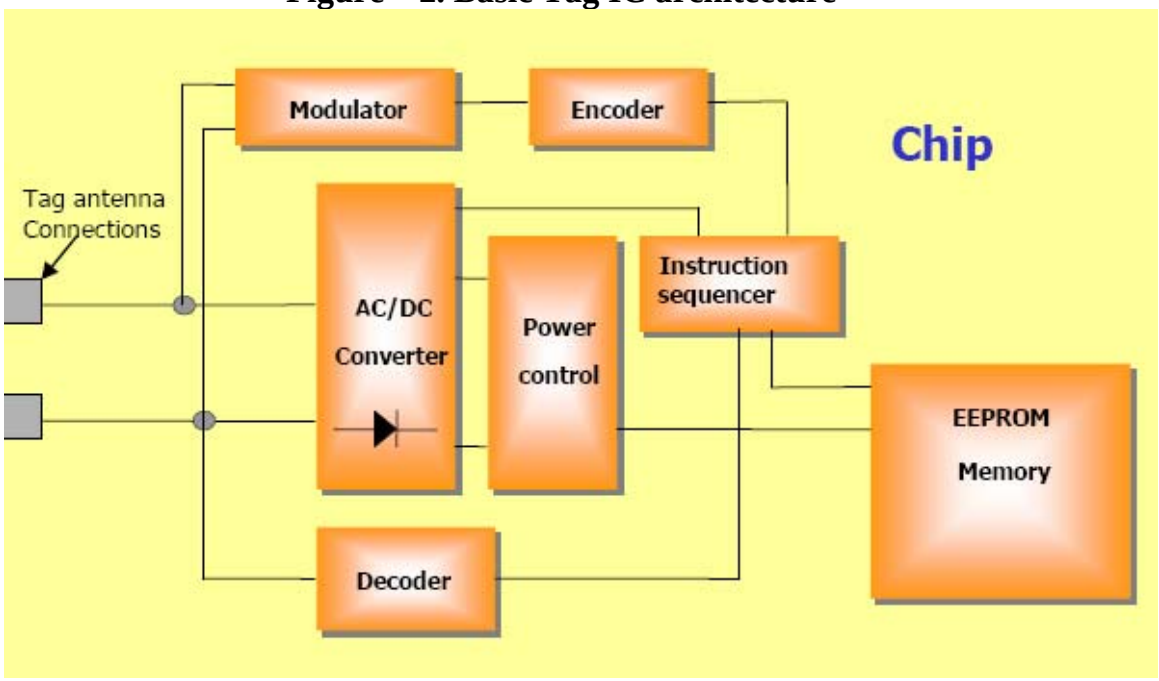
In fact very real challenges for the ICs'exist such as achieving very low power consumption, managing noisy RF signals and keeping within strict emission regulations. Other important function of the circuit is to allow the chip to transfer power from the reader signal field, and convert it via a rectifier into supply voltage. The chip clock is also normally extracted from the reader signal. Most RFID tags contain a certain amount of NVM (non-volatile memory) like EEPROM in order to store data.

The amount of data stored depends on the chip specification, and can range from just simple identifier numbers of around 96 bits to more information about the product with up to 32Kbits. In 1999 the AUTO-ID centre (now EPC Global) based at the MIT-USA, together with the number leading companies developed the idea of an unique electronic identifier code called the EPC(Electronic Product Code). The EPC is similar in concept the UPC used in barcodes today. Having just a simple code of up to 256 bits would lead to smaller chip size, and hence lower tag cost, which is recognized as the key factor for wide spread adoption of RFID. Like a barcode, the EPC is a 96 bit unique number which is divided into numbers that identify the manufacturer, product, version and serial number.

3.4 Tag IC's A single-chip design led to the RFID tag, a small device composed of a chip, an antenna, and an optional power source, that carries a unique identifier. The 1990s witnessed the use of such tags for card-keys, fuel-station payment systems, and automated toll payment. Such tags were typically specialized for a certain class of

applications and cost a few dollars each. The tags typically stored application-specifc data and were capable of modest processing on-tag [2].

Figure – 2. Basic Tag IC architecture



3.5 Tag Classes: one of the main ways of categorizing RFID tags is by the capability to read and write data. This leads to the following four classes and EPC global has also defined five classes which are similar to the one below:

3.5.1 Class 0: Read only – factory programmed. These are simplest type of tags, where the data, which is usually a simple id number is written only once into the tags during manufacture. The memory is then disabled from any further updates. Class 0 is also used to define a category of tags called EAS or anti-theft devices which have no id, and only announce their presence when passing through an antenna field.

3.5.2 Class 1: Write Once Read Many(WORM) - Factory or user programmed. In this case tag is manufactured with no data written in to the memory. Data can then either be written by manufacturer or by the user – one time. Following this no further writes are allowed and the tag can only be read. Tags of this type usually act as simple identifiers.

3.5.3 Class 2: Read-Write – This most flexible type of tag, where user have access to read and write data into the tags memory. They typically used as data loggers, and there fore contain more memory space than what is needed for just a simple id number.

3.5.4 Class 3: Read-Write (with on board sensors) – These tags contain on board sensors for recording parameters like temperature, pressure and motion, which can be recorded by writing into the tags memory. As sensor readings must be taken in the absence of a reader, the tags are either **semi-passive or active.**

3.5.5 Class 4: Read-Write (with Integrated Transmitters) – These are like miniature radio devices which can communicate with other tags and devices without the presence of the reader. This means that they are completely active with their own battery power source.

3.6 Active and Passive tags:

First basic choice when considering a tag is either passive or semi-passive or active. Passive tags can be read at a distance of up to 4 – 5 m using UHF frequency band, whilst the other types of tags (semi-passive and active) can achieve much greater distance of up to 100m for semi-passive, and several KM for active. This large difference in communication performance can be explained by the following;

- passive tags use the reader field as a source of energy for the chip and for the communication from and to the reader. The available power from the reader field, not only reduce very rapidly with distance but is also controlled by the strict regulations, resulting in a limited communication distance of 4 -5 m when using UHF frequency band (860 MHz – 930 MHz) .
- Semi-passive (battery assisted back scatter) tags have build in batteries and therefore do not require energy from the reader field to power the chip. This allows them to function with much lower signal power levels, resulting in greater distance of up to 100meters. Distance is limited mainly due to the fact that tag does not have an integrated transmitter, and is still obliged to use the reader field to communicate back to the reader.
- Active tags are battery powered devices that have an active transmitter onboard. Unlike passive tags, active tags generate RF energy and apply to the antenna. This autonomy from the reader means that they can communicate at the distance of over several KMs.

Table No.2 : Different Tag Classes

class	Known as	Memory	Power source	Applications
0	EAS/EPC	None/EPC-1bit on/off	Passive	Anti-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

4. Selecting tags:

Choosing the right for a particular RFID applications is an important consideration, and should take into account many of the factors listed below:

- Size and form factor – where does the tag have to fit?
- How close the tags be to each other
- Durability – will the tag need to have a strong outer protection against regular wear and tear
- Is the tag re-usable
- Resistance to harsh environment(corrosive, steam…)
- polarization – what will be tag orientation with the respect to the reader field
- exposure to different temperature ranges
- communication distance
- influence of the materials such as metals and liquids

- environment(electrical noise other radio device and equipments)
- operating frequencies(LF,HF, UHF, MW)
- supported communication standards and protocols
- regional regulations(Europe, Asia, USA..)
- will tag data need to store more than just an id number like an EPC
- anti-collision how many tags in the field at the same time how quickly must they be detected
- how fast will tags move through the reader field
- does the tag need to have security data protection by encryption
  reader support – which readers products are able to read the tag read the tag

4.1 Difference between Barcode and RFID

- Information can be read from RFID tags much faster than from barcodes
- Several items in a stack/counter can be read at the same time using RFID
- Items do not have to be handled one-by-one nor removed from the shelves
- Inventory-taking is no longer a tedious operation
- RFID can stand more than 10,000 read/write
- RFID can have theft bit which can be in two states "ON/OFF"
- Shelf verification/rectification can be done on daily basis
- More information can be written in the RFID tag on incremental basis
- Need not open/remove books to capture information
- Items are identified on upper and lower shelves more comfortably

Basic technology comparison Barcode versus RFID:

RFID	BARCODE
Can be Read and Write	Read only
No line of sight required	Needs direct visible contact to reader
Multiple items can be read simultaneously (anti-collision)	Single item scan only
Item attendant data (mobile data-carrier)	Database look-up is always necessary
Guaranteed data retention of at least 10 years	Limited lifetime due to printing.
Stock verification made easier as No need of taking the books out from shelf. You can read multiple books from the shelf at a time.	Stock Verification Takes time because of the fact that each book has to take out from shelf and then scanned with the scanner.

Key features of an RFID-Library versus a Barcode solution:

- Fully transparent stock control on all available books and medias in the library.
- The Electronic Article Surveillance (EAS) feature offers a secure stock control system and no books get "lost". This feature is especially important for rare books or unique books, which should not get lost because of their value.
- Due to the fact that RFID-labels can be identified (read) very easily (without line of sight, over a certain distance, several books simultaneously), the so-called self-check-out system can be used and this will save manpower and increases the attractiveness of the library.
- Because the RFID-Library offers a fully controlled and categorized library stock, the number of similar books can be reduced because the turn-around time of each book can be shortened drastically.
- RFID-label stores data of the book and its system status that gives the possibility to check the book without the database.

5. Implementation of RFID:

The methodology for implementation can be divided into many phases taking into consideration of budget provision, the types of document holdings, number of volumes, types of items meant for circulation, and the number and types member the institution has. Care should be taken to integrate the library automation package while detailed tender specification are drawn. Since the technology is new to Indian library environment proper demonstration of the system can be arranged and should visit the library where the system is successfully running. While evaluating the tender the past experience of firm supplying the equipment, tags, reader and software should be thoroughly investigated. The fixing of tags to documents can be initially outsourced then in house arrangement can be done after proper training. The reader should be able to read the other manufacturers RFID Tags. The provision for reading the existing barcode in the document can be made and the required data can downloaded by interacting with the present database and can be written to the tag. The tags can be over layered with the self adhesive sticker containing the logo of the library or the institution for longer life. Until sufficient confidence is gained with the system, old system in practice can be continued.

5.1 Retrospective conversion of already existing stack requires a "programmer" or "conversion station." The conversion of existing barcoded items, including affixing the tags to library materials, takes 15-30 seconds per item depending on the amount of information added to the tag and the skill of the person doing the tagging. Pre-programmed tags, which are used for new acquisitions in libraries that want only identification numbers on the tags, take even less time because they do not involve scanning existing barcodes. The speed of conversion can be increased by dividing responsibility for removing and replacing library materials, converting the barcodes, and inserting the tags among at least three people. It is essential that the tasks be rotated so that no one repeats the same motions over an extended period of time. Almost all libraries tag **new acquisitions** as part of the cataloging process, however, libraries that have experienced losses of unprocessed library materials from technical services, might consider doing the tagging at the time of receipt in acquisitions. While inadvertent duplicates cannot then be returned, it should significantly reduce losses and facilitate tracking of items in technical services.

5.2 Readers: A typical RFID system includes three different kinds of readers, also known as sensors or scanner/wand. These devices designed to detect and read tags to obtain the information stored thereon.

(i)The types of readers include staff workstations for circulation desk charging and discharging, patron self-charging stations, and longer-range walk-through exit sensors to detect and read an RFID tag passage for purposes of determining whether it is a charged or discharged.

(ii)RFID exit sensors at exits are of two types, one reads the information on the tag(s) going by and communicates that information to a server. The server, after checking against the circulation database, activates an alarm if the material is not properly checked-out. Another type relies on a "theft" byte in the tag that is turned on or off to show that the item has been charged or not. It is then not necessary to communicate with the circulation database. The security system will work even though the online library server is not working.

(iii)The portable scanner or inventory wand, can be moved along the items on the shelves without touching them. The data goes to a storage unit, which can be downloaded at a docking station or a server later on, or it can go to a unit which will transmit it to the server using wireless technology.

6. Advantages of RFID systems :

6.1 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. While initially unreliable, the anti-collision algorithm that allows an entire stack to be charged or discharged now appears to be working well.

6.2 Simplified patron self-charging/discharging: For patrons using self-charging, there is a marked improvement because they do not have to carefully place materials within a designated template and they can charge several items at the same time. Patron self-discharging shifts that work from staff to patrons. Staff is relieved further when readers are installed in bookdrops.

6.3 High reliability: The readers are highly reliable. Some RFID systems have an interface between the exit sensors and the circulation system to identify the items moving out of the library. Were a patron to run out of the library and not be intercepted, the library would at least know what had been stolen. If the patron card also has an RFID tag, the library will also be able to determine who removed the items without properly charging them. This is done by designating a bit as the "theft" bit and turning it off at time of charge and on at time of discharge.

6.4 High-speed inventorying: unique advantage of RFID systems is their ability to scan books on the shelves without tipping them out or removing them. A hand-held inventory reader can be moved rapidly across a shelf of books to read all of the unique identification information. Using wireless technology, it is possible not only to update the inventory, but also to identify items which are out of proper order.

6.5 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. Given the high cost of the equipment, this application has not been widely used.

6.6 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.

6.7 Fast Track Circulation Operation

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several items in a stack can be read at the same time. While initially unreliable, the anti-collision algorithm that allows an entire stack to be charged or discharged now appears to be working well.

7. Disadvantages of RFID Systems:

7.1 High cost: The major disadvantage of RFID technology is its cost.

7.2 Vulnerability to compromise: It is possible to compromise an RFID system by wrapping the household foil to block the radio signal. It is also possible to compromise an RFID system by placing two items against one another so that one tag overlays another. That may cancel out the signals. This requires knowledge of the technology and careful alignment.

7.3 Removal of exposed tags: The RFID Tags can not be concealed in either spine or gutter of the books and are exposed for removal. If a library wishes, it can insert the RFID tags in the spines of all except thin books, however, not all RFID tags are flexible enough. A library can also imprint the RFID tags with its logo and make them appear to be bookplates, or it can put a printed cover label over each tag.

8. Evaluating RFID from different vendors

It is potentially overwhelming to evaluate competitive offerings of a new technology; hence the following guide lists some of the characteristics to be considered.

8.1 Security feature

The same RFID tag used to manage inventory can also be used to protect it from theft. Current offerings provide the choice between a purely RFID solution, or RFID with an EM (electro-magnetic) add-on for theft.

8.2 Tag memory capacity

More memory is not necessarily better than less - it often correlates with price, and data transmission speed. As a first step, consider what information you need to program into each tag, and then discuss with vendors.

8.3 Tag functionality

8.3.1 Read/Write vs. Read Only

- Some vendors offer tags which can only be “written to” once. That is, once the tag is programmed, the information stored in the tag’s memory cannot be changed. Alternatively, information stored in the memory of read/write tags can be updated as required.

8.3.2 Anti-collision

- All RFID vendors in the library market offer a product with anti-collision (the ability to read several tags simultaneously). However, the speed at which this can be performed, and the total number of tags that can be read, will vary. This relates specifically to inventory management with a hand-held reader, and check-in processes.

8.3.3 EAS (Electronic Article Surveillance) mechanism

- As mentioned above, RFID can be used to prevent theft in the library. This approach varies from vendor to vendor – the security mechanism may be integrated into the chip itself, or security gates may be linked to a separate server which interrogates the database to conclude whether an alarm needs to be triggered.

8.4 Cost

- Expect to pay from US$0.85 to over US$1 per tag.
- The price of hardware (per unit) varies extensively from different suppliers. However, the infrastructure requirement also varies.

8.5 Standards

- The emerging standard for library RFID solutions is to employ a frequency of 13.56MHz. However, no formal standards are currently in place [6].

9. Conclusion

Though the unique advantages and flexibility of RFID is the good news, the technology is still not yet widely understood or installed in the library environment, and the cost/ROI models far from established. RFID, its application, standardization, and innovation are constantly changing. Its adoption is still relatively new and hence there are many features of the technology that are not well understood by the general populace. Developments in RFID technology continue to yield larger memory capacities, wider reading ranges, and faster processing. The interest in RFID as a solution to optimize further the automation and tracking of documents are gathering momentum at an increasing pace, with more libraries joining the trails.
"RFID is increasing in popularity among libraries, as the early adopters of this technology have shown that, it makes good economic sense, both for large and small libraries."

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