5 Design Considerations

The problem facing a prospective user of RFID technology is which of these technical solutions to select, and further which of the numerous supplier solutions to select amongst. The following discussion will assist in this selection process, but cannot provide an all encompassing selection solution.

5.1 Selection Methodology – Economic Evaluation

Fundamentally all technology selection processes will eventually revolve around the economic viability to the technology selected. The impact of the tag solution must be evaluated in relation to the cost savings or increased sales potential achieved by the adoption of the technology on a per unit basis. This involves estimation of project costs and unit price costs for the development / implementation project, and arriving at a cost per RFID tag.

This cost estimate should incorporate an allowance for the reusability of the RFID tag itself. For example, if a read – write system can be used many times then the effective cost per application will be significantly reduced.

Sharp (reference "Look before you make the [RFID] leap", www.idsystems.com) argues that the acceptable cost estimate on a per tag basis need not be precise. As indicated in Table 1 indicates Sharp suggests approximate cost bands can be applied to result in the evaluation of the feasibility of the technology choice.

APPLICATION VALUE PER TAG	ECONOMIC IF THE FOLLOWING CONDITIONS ARE TRUE:
More than 10 Euro	Application probably makes sense unless the tag must survive extremely demanding environmental conditions or provide very large data capacity
5 to 10 Euro	Annual tag volume greater than 1000
2 to 5 Euro	Moderate environmental challenges. Annual tag volume greater than 10,000
0.75 to 2 Euro	Moderate environmental challenges. Annual tag volume greater than 100,000
0.50 to 0.75 Euro	Moderate environmental challenges. Annual tag volume greater than 1,000,000
Less than 0.50 Euro	Application probably not economically feasible at this time

Table 1: Cost Estimate / Value Trade-off For RFID Applications

The information contained in the Table 1 can be applied to be determine roughly whether the application is economically viable. However, this approximate evaluation should be followed up with an analysis conducted with potential suppliers.

5.2 Selection Methodology – System Requirement Specification

The technology selection process will require the definition of the system requirements that the RFID tag system have to meet. This system specification process will define the general requirements of the system and not the specific implementation technology, and therefore the system requirement document will consider the following:

5.2.1 RFID Data Memory Requirements

The memory requirement will include an assessment of:

- The amount of storage required for a particular application.
- The need to process information (or not) in the RFID device.
- The range of unique identification numbers required, and whether the device is to be uniquely identified (for example, with a dedicated company code).

The information requirements of an RFID tag will require careful consideration, and specification in the system specification before RFID device selection.

The application will define the required amount of memory. For example, the anticipated production volume for a product, with the addition of an adequate estimation margin, will define the maximum number of unique identity codes required for the RFID device.

Finally memory size should not be over specified if not absolutely required. This is because the rate of transfer of the information from a tag to a reader device will be defined for a specific tag frequency, and the larger the RFID memory then the longer the read time for any interrogation transaction. This could limit the rate, at which units pass a reader and may therefore, prejudice the application of RFID technology.

5.2.1.1 Memory Types

The RFID transponder device may have one of the following form of memory:

1. ROM (Read Only Memory). These devices have an unique identification code programmed into the device at the time of manufacture, and this identification number cannot be altered thereafter. The relationship between an unit or item fitted with this tag requires therefore, a conversion from unique identification code to unit / item serial number using a lookup table. Because the code cannot be changed, the ROM memory option provides a highly secure, if inflexible, tagging solution.

2. WORM (Write Once Read Many) devices are programmed by the user, enabling the user to introduce their own identity numbers on a once off basis. No further changes can then be made to the tag information. This provides some flexibility, and a reasonable level of security.

3. RW (Read /Write) devices contain memory than can be altered several times in use, and therefore offer low security but a high degree of flexibility.

Some RFID device technologies may offer a combination of the above memory options. For example, a device may be pre-programmed at manufacture with an unique identity code but offer a limited RW (read write) memory facility as well.

The specification will define which of these memory types is required. For example, a system required to track an item may only require unique identification of the item, and therefore a ROM device programmed by the supplier would suffice. However, a reusable system used to identify and record process stages in a production environment might require a RW memory RFID device solution.

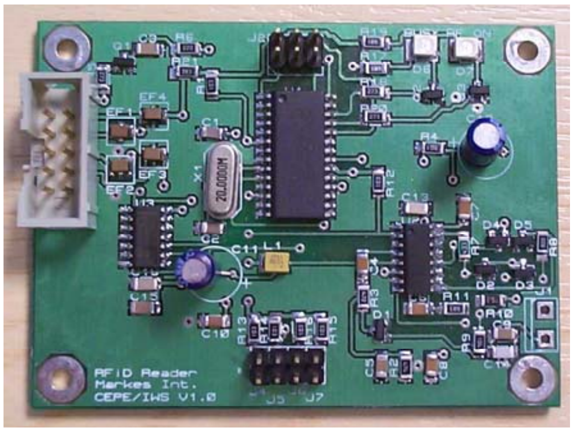
Finally, whilst a read only RFID tag may be sufficient for identifying an item there may be the requirement for several transactions to an information database to identify process information. If the transaction costs to an information database are high enough then it could justify the use of a more expensive RFID tag capable of storing the process or status information without incurring these transaction costs. A careful analysis of the use of the data is therefore required.

Case Study:

Markes International required a radio frequency identification (RFID) technology to develop a system for labelling and identifying the sample tubes used in thermal desorption analysis.

The objective was to provide customers of the existing product with the improved traceablility of test samples they required. The system required the following data to be stored in each tag:

- Each sample tube has a unique number.
- Details of sampling parameters are stored with tube, these include;
    - Identification number
    - Date
    - Period (start and stop times)
    - Type (diffusion or pump)
    - Volume (in litres)
    - Location
    - Operator



RFID Tag Reader Unit

5.2.2 Interrogation Space Definition.

The specification must define the maximum space envelope that the tag will be present in when energisation and data transfer must occur reliably. The specification should therefore specify the set of maximum interrogation distance from the reader unit and the position relative to the reader unit, as a 'capture / reading volume'. If the tag can always be guaranteed to be in one plane relative to the reader unit this will obviously reduce to a maximum reading distance. In defining this parameter, a key factor is whether the reader can be moved relative to the tag. This will minimise the reading distance required, but will obviously increase reading transaction times.

The 'capture /reading volume' is the most basic requirement for the selection of an RFID technology.

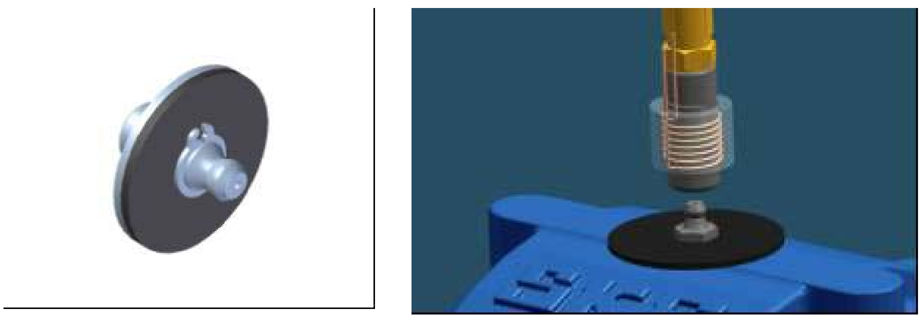
The actual reading distance that will be realised by the selected RFID technology will depend on several factors including the RFID device type, transponder size, and antenna design, relative orientation, and electrical noise levels.

5.2.3 RFID Device Size

The maximum size of the RFID device that can be used is an important design consideration. For a given RFID device, the larger the associated tag antenna (and hence the tag itself) then the greater its reading distance. In general, therefore the specification should state the maximum RFID tag size consistent with the product application.

5.2.3.1 RFID Shape

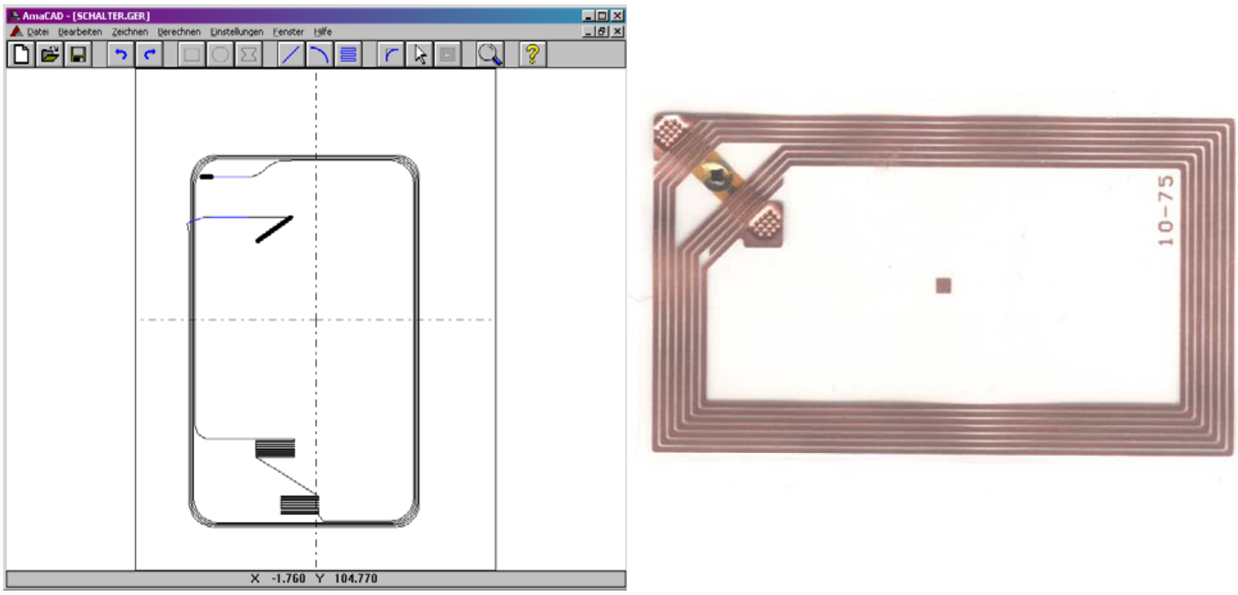
An associated factor would be the allowable shape of the encapsulated RFID tag unit. The directionality of the coupling between the RFID tag and the reader unit will depend in part upon the shape of the tag antenna, and a product shape definition might allow the tag antenna to be designed so as to minimise the directionality response.



Tag Size and Shape Limitations for Assulub SA Application

5.2.4 Reader Antenna Specification

A related size requirement is the maximum size of the reader unit's antenna. Again, in general, for a specific tag type the larger the size of the antenna then the better the reading range. The directivity of the electro-magnetic field emanating from the RFID device will also influence the size and shape of the readout antenna required.



Antenna Design file and Layout used by PAV Card Gmbh

5.2.4.1 Potential for Orientating the Transponder

The freedom to orientate the transponder with respect to the antenna also impacts on the reading range performance of the system. To achieve maximum reading range the orientation of the antenna with respect to the transponder can be optimised to achieve maximum coupling, and the freedom to achieve this will improve performance.

The field generated by a reader unit at the RFID tag location has a direction. As the orientation of the tag in this field changes the power transferred to the tag can vary from a maximum when the tag antenna is perpendicular to the reader antenna, to zero when the edge of the tag is perpendicular to the reader antenna.

If the tag orientation cannot be controlled this will require a more sophisticated reader unit / antenna design to compensate for this physical reality. For example, this may introduce the need for gate reader antennas with rotating fields. The reader unit design will be simplified if tag orientation can be controlled.

5.2.5 Tag Speed

The speed at which the RFID tag will move through the tags can move through the interrogation space volume will determine the amount of time available for a complete interrogation transaction for the device. This transit time must exceed the minimum time for a data transaction to occur.

The available reading time will be severely reduced if more than one RFID transponder device enters the reading volume or if the system is used in extremely electrically noisy environments where an allowance may be required for further interrogation to be made. This would however depend upon the reliability of the data transfer mechanism discussed later in this document.

As noted previously, the speed at which the RFID tag moves through the read volume is one factor that determines the selection of the data contents and signal transmission protocols used.

At low frequencies (120 –130 KHz) a standard reader unit will complete one read transaction in approximately 120ms, enabling RFID tags to be read at a speed of 3m/s with 'standard' antenna designs. Much higher speeds can be accommodated by using larger antennas. For example, read speeds of 65m/s or about 240km/hour have been recorded. 2.4 GHz systems can accept and transfer large packets of data quickly: 1,000 to 2,000 kilobaud, versus 100 to 400 kilobaud in 902 MHz systems.

5.2.5.1 The Reliability of Data Transaction

So as to obtain an error-free data exchange between the RFID tag and the reader unit additional, redundant data can be added to the RFID memory contents to enable error correction to be conducted. For example, the Texas TIRIS system uses a 16-bit Cyclic Redundancy Check algorithm which ensures that only 'valid' data is transferred to the reader. The use of well known error correcting algorithms therefore, results in a high reliability data transfer system.

However, whilst increasing the data length to add a number of error checking / correcting bits increases the reliability of the system it will result in a more complex and costly RFID tag design solution and an increase in the data transaction time.

5.2.6 Multiple Device Scanning

If a reader unit to tag reading range is a few centimetres it is improbable that in most operating conditions that several RFID devices will reside in the read volume. However, with longer range RFID devices, often having operating read ranges measured in metres, it is probable that there will be more than the one transponder in the reading volume at any one time. This multiple RFID transponder situation will cause significant system complications through the occurrence of data contention.

Data contention occurs where there is only one communications channel to transfer information over, and several units attempting to transfer data at any one time. This will result in signal level corruption causing a major problem in attempting to extract meaning from the confused messages. For RFID devices, there is a single frequency available to transfer data from the transponders to the reader.

The system must have an anti-contention communications protocol to be able to operate in a multiple RFID tag environment, otherwise it can only communicate with one transponder at a time.

5.2.6.1 Protocols for multiple transponder situations.

For application systems in which multiple occurrences of tags within the reading volume can occur and all of these must be recognised and read, an "anti-collision" protocol system must be used.

The most common anti-collision methods use algorithms designed to ensure that the multiple tags active in the reader's energisation field transmit their information such that only one tag at a time is active at any one time, and hence is interacting with the reader.

In a multiple transponder situation, the minimum transaction time for the group of tags in the reading volume will exceed the transaction time of a single tag multiplied by the number of tags in the reading volume.

For example, multiple transponder situations can occur where the 13.56MHz frequency range magnetic transponders are applied. The manufacturers of RFID devices operating in this frequency range have realised the necessity of implementing anti-collision protocols, and many have proprietary anti-collision protocols incorporated into their products. The majority of these systems operate by providing a continuous energising field during the scanning period to power the tag devices and to separate the replies from the separate tags using response times to separate replies. Generally, this is achieved by ensuring the transponder transmits its data at random times over the relatively long read time thereby increasing the probability that each RFID tag transmission will be received without error. This is normally acceptable where the number of transponders in the reading volume is relatively few in number.

An alternative design solution which however incurs additional cost for the onboard receivers is to implement a communications protocol whereby each transponder can be individually addressed using unique identities, and the transponders individually polled.

With an appropriate choice of operational frequency and data contention algorithm it is possible to read 1000 transponders in a reading volume zone accurately and quickly.

5.2.7 Future Proofing of the System Designs

In specifying the reader unit requirements it is worthwhile considering that the rapid growth of RFID applications will invariably lead to further tag designs and applications arising in the future. Therefore, it would be an advantage if the reader unit is compliant with existing reader standards such that it provides the maximum possibility for commonality with these emerging devices and solutions.

5.2.8 Environmental conditions

The environmental conditions under which the tag must (i) operate and (ii) survive will be a critical factor in the selection of the appropriate RFID technology.

In general, the need for the RFID tag to operate in demanding environments will result in higher per unit costs for the devices, due to the significant increase incurred by adding suitable protective packaging.

The main environmental conditions to be specified for the RFID tag include:

- Temperature.
- Humidity
- Vibration & shock.
- Dirt, dust and chemical conditions.

Operational and survivable levels for each of these parameters must be specified.

Illustration of End environment of RFID Application faced by Assulub AB

5.2.8.1 Metallic and Other Surfaces & Obstructions

A significant aspect to consider in specifying the operational environment will be the presence of metallic surfaces in the vicinity of the tag unit. The presence of such surfaces could cause shielding or reflections to occur that could influence operational factors such as reading range, and therefore must be defined. Therefore, ensuring that the signal is reliably transferred from a reader to the RFID tag is a challenge.

The presence of metals can also affect RFID tag performance in more ways than just reflecting signals. An antenna in a near-field tag acts an inductor in a circuit tuned to the reader unit's transmission frequency, and a conducting metal close to the tag can change this inductance, introducing a frequency shift in the system resulting in a reduction in overall system performance. In some instances RFID tags optimised for maximum read range with a highly tuned circuit will experience a significant frequency shift preventing these tags from gathering enough power to be energised.

The signal coming from the reader can also be absorbed. For example water, and therefore ice and bodies, absorb high-frequency far fields better than lower-frequency near fields. RFID systems operating at 2.4 GHz are susceptible to absorption by water, and therefore this communications link could be affected by animal tissue making it unsuitable for animal tagging. However, RFID tags operating at 135 KHz and 13.56 MHz would not be affected.

5.2.8.2 Noise Sources

The presence of electromagnetic interference noise sources in the vicinity of the reader unit will result in the potential for errors to occur in reading process. The EMC Directive and related specifications define field levels and modulation indices under which systems should operate correctly. In many instances the close proximity of the reader unit to machinery etc. may result in higher levels of interference noise occurring. The device specification should therefore attempt to quantify the interference noise sources present in the local reader's environment, using appropriate EMC standards as the minimum requirement.

5.2.9 Regulations and Standards

International standards are a major issue when looking at applications.

This document cannot provide a comprehensive review of all applicable International standards for RFID systems, because of the dynamic rate of the market growth for the technology and the increasing rate of product introduction in the field.

5.2.9.1 Standards

The standards defined worldwide for the application of RFID products are being developed by ISO (International Standards Organisation). Other regional standards (for example, ANSI standards in the USA) further complicate the position regarding relevant standards.

These standards are generally defined for low frequency applications (135 KHz and 13.65 MHz applications). However, other potential frequencies of operation are possible; for example a solution for UHF operation is the 868 MHz band in Europe and the 915 MHz band in America, or the 2.45 GHz band (worldwide). Each of these bands has relevant specification limitations which address the allowed bandwidths and the power limitations at this frequency. In Europe the power limit is the most important limitation. For example, using the 868 MHz band only 0.5 W is allowed. Therefore if higher frequencies are being used it is advisable to check the local radio standards for that country as world-wide commonality cannot be assumed.

Note: It is important to realise that there exists a possibility that some of the elements of an International Standard may be the subject of patent rights. Therefore, it is important that if independent design of an RFID tag is undertaken that a full evaluation of all patents in the field is undertaken. Finally, standardisation is an evolving process; readers are recommended to review current status before proceeding with an implementation.

5.2.9.2 Communications Standards for Readers

The ANSI 256 standard specifies an application-programming interface (API) for RFID readers. The adoption of this API specification will provide companies with the possibility of producing a single software program interface for identification devices which is compatible with any selected RFID technical solution for a specific application.

5.2.10 Conclusion

Knowing what your business wants and how the tags must perform in the application situation and environment places the customer in a strong position when discussing a specific technology with vendors. For example, when the vendor proposes a frequency of operation this can be related to the definition of read range for the required system.

The first process of technology selection is therefore to carefully define your requirements as outlined above.

Section 5 Annex – Bestel s.a.s. Flyer

REFLEX

REfectory service FLEXible management, through an innovative transponder providing a visual feedback

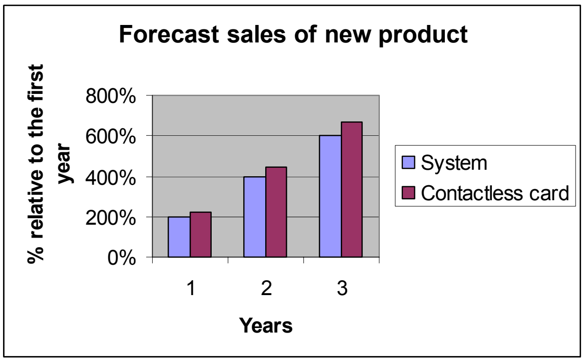
An innovative contactless, battery-free card embedding a transponder and a display - for an easier and quicker management of booking and distribution services. The idea for the new product was born to answer for a newly rising market need, that of having an individual displaying of private information

BESTEL S.a.s. is small Italian company based in Florence, Central Italy. The company supplies "turn key" solutions for system integration in IT-Information Technologies.
Services and products that constitute its two main businesses are:

- Technical services and maintenance of biomedical equipment
- Information technologies services and products, like Internet and Intranet development
- Basic Computing
- Software Development

Bestel s a s	
Employees	7
Turnover	0.5 M€
Industrial Sector	NACE CODE 30
Technology Introduced	RFID – radio frequency identification

ECONOMIC BENEFITS



The total additional profit to the Company, due to the adoption of the new technology, comes out from two different contribution: one for the sales of the system, another from the sales of the contactless card parts to be delivered to users. For a more conservative estimation, forecast was done by limiting sales on the same segment where the company already sold its current product, i.e. schools.

PRODUCT IMPROVEMENTS

The contactless RFID technology adopted by BESTEL with the REFLEX project not only has improved the existing product of the Company (including new features of non-contact and confidential data handling through a battery-free display), but it has also offered a completely new solution, not yet available on the market from other suppliers, and suitable for a variety of different applications.

Improvements have been made in two directions:

- Towards the users, by simplifying the users' interface thanks to contactless RFID and thanks to enhanced card embedding data display
- Towards the system management, with easier (contactless) procedure for users' registration and payment

How to go about it

Company goals for the new product were:

- Contactless interface to avoid problems of person-machine interactions
- Possibility for display individual data in a private, confidential way, although allowing simultaneous, access to information by several users. Private information could also be provided by means of a small monitor accessible by a single user. With a typical presence of tens or even hundreds of users this would be practically unacceptable, leading to long queues. The idea is that each user has its own confidential display.
- Cost of the new product comparable with that of the existing one and lower system maintenance costs

The need for a contactless solution in order to get the easiest user interface to access the services and the reduction in maintenance costs caused the company to discard other traditional solutions like magnetic strip cards and contact smart cards.

TECHNICAL IMPLEMENTATION

The new system has been developed by taking into account the needs for overcoming limitations shown by the existing system, as well as the requisites for its short term application in automation of the refectory service for schools, considering just as further possibility that to apply it also in a wider set of different applications, both in private companies and Public Administration.

The choice of 125 KHz frequency within the range of the different operational frequencies for RFID transponders is moreover justified by the following design key issues:

The low power consumption for systems operating at this frequency

- A better proximity electro magnetic coupling (higher gain)
- A better read/write operation in proximity of metal
- A cheaper cost for the read/write units

Task	Planne d Person	Actual Person Days
Management	25	25
Training	35	35
HW Design and	62	66
SW Design	54	61
Testing	38	38
Total	**214**	**225**

This project was conducted over a period of 11 months. The subcontractor highly contributed to the project realisation as far as concerns the technological and technical design assistance.

BENEFITING FROM BEST PRACTICE

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