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## APPLICATIONS OF RFID TECHNOLOGY AND SMART PARTS IN MANUFACTURING

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### ABSTRACT

Industrial and consumer applications of Radio Frequency Identification (RFID) are explored. The state-of-the-art and development in RFID technology is reviewed. A currently operative smart parts based manufacturing system is described which uses RFID as the key technology. The role of RFID in the emerging Wireless Internet Manufacturing field is highlighted.

**Keywords:** RFID (Radio Frequency Identification); Smart Parts; Manufacturing

### INTRODUCTION

Personalized products and tailor-made solutions are taking over large shares of the marketplace from mass produced goods and standardized solutions respectively. The so-called smart parts based manufacturing system addresses these concerns well. The smart part carries operating instructions for the operating workers or automatic machines. Uniquely identified individual parts can be processed according to their specific requirements based on individual customer preferences. Therefore, there is the need to correctly identify every part to

ensure reliable process control in such a flexible and customer oriented manufacturing system.

Radio frequency identification is a technology that has been in use for some time. It offers features that are well suited to be adapted for such flexible smart-parts manufacturing. As the use of this technology grows, it will come into the industrial mainstream just as it has already done in retail outlets where it is used for electronic surveillance.

### 1. RFID TECHNOLOGY

#### 1.1 Operating Principle

The structure of RFID system is showed on the Fig 1. The RFID system consists of three basic components: Reader/Programmer, Antenna and Tag or Transponder.

Today the vast majority of 13.56 MHz systems operate "passive", without the need for an integrated battery. They have positive implications on cost, lifetime and the environmental situation. The basic operating principle of passive 13.56 MHz and below 135 KHz RFID systems is energy and data transmission using inductive coupling (Fig 2). This is exactly

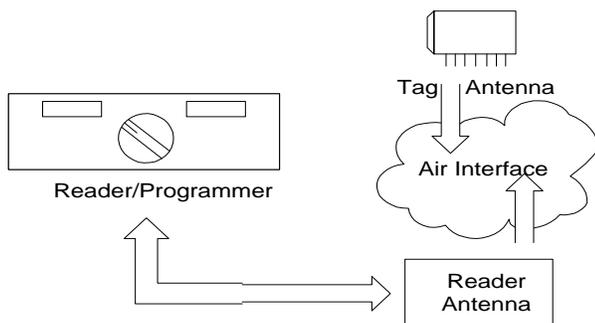


Fig 1. Structure of RFID System

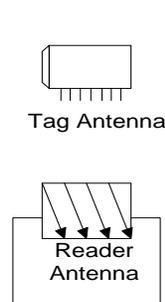


Fig 2. Inductive Coupling

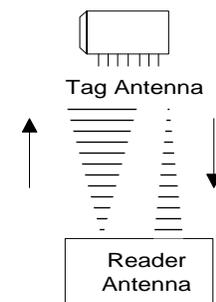


Fig 3. Propagation Coupling

the same principle as used in transformers. By changing one parameter of the transmitting field (amplitude, frequency or phase), the data transmission from the reader to the tag can realize. The return transmission of the tag concerns the load (amplitude and/or phase).

UHF and MW (e.g. 400-1000 MHz, 2450 MHz & especially 5.8- GHz) RFID systems make use of conventional electromagnetic wave propagation (see Fig 3) to communicate their data and commands, and in the case of batteryless tags also to power the RFID transponders. The basic operating principle of this RFID system is energy and data transmission using propagating radio signals ("E" field transmission).

### 1.2 Operating Distance

The operating zone of passive inductive RFID systems (13.56 MHz and below 135 KHz) is in the "near field" of the read transmission antenna, which results in achievable operating distances of approximately the diameter of the transmission antenna. Differences are mainly given by the output power of this RF-module and by the sensitivity and the selectivity of its receiver. The ranges are denoted as "proximity" (below 100mm), "medium range" (below 400mm), "vicinity" (long range - 1.5m), "far field" (0.5 to 12 meters - 2450 MHz, passive power), and up to 30 meters (active power tags depending on microwave frequency).

### 1.3 Tag characteristics

**Memory:** On lines similar to computer memories there are three types at this time: Read-only (ROM); Write-once-read-many (WORM); Read/write (EPROM or EEPROM). Available sizes are 1 bit, 48 bits, 64 bits (8 byte) to several Mbytes.

**Physical Forms:** Tags are not limited by forms, shapes or nature of protective housings. A 0.3 mm<sup>2</sup> tag (2450 MHz, 128 bits, 300mm range) is currently available. Another version available for inserting beneath the skin to track animals is 0.16 mm<sup>2</sup> in size. Screw shaped tags to identify wooden items or credit card shaped tags for access applications are other examples.

**Cost:** Prices have dropped to a low range of 1 to 10 cents though active and long-range tags are still expensive. With increasing use, the production costs and hence prices will drop.

### 1.4 Miniaturization

In Japan, an ultra-small (0.4 x 0.4=0.16mm<sup>2</sup>) RFID chip has been developed named the "mu-chip" [1,2]. This 128-bit memory, 0.06 mm thick chip can be applied to paper and to thin paper-like media. At 2450MHz the maximum communication distance between the mu-chip and a reader is 300 mm

### 1.5 Limitations & Cautionary Notes

**Absorption, Reflection & Transmission through different media:** The RF field at 13.56 MHz is not absorbed by human tissue or water permitting operation in and through water and through human barriers. The influence of moisture upon performance is negligible. 2450 MHz UHF and microwave signals are attenuated and reflected by human tissue and

moisture bearing objects and must be used with caution where human contact is involved. These signals easily penetrate wood, paper, board, clothing, paint, dirt etc. Short wavelengths of radio signals and reflective properties off metallic objects permit reader systems to be designed with high reliability for performance in regions having high metallic content. These offer higher data rates than inductive systems and allow many systems to operate independently without human intervention in confined operating areas.

**Spectrum:** The choice of field or carrier wave frequency determines data transfer rates. In general higher frequencies enable higher data transfer rates. Channel bandwidth is required to be at least double the bit rate for the specific application.

## 2. APPLICATIONS

### 2.1 Specific examples of general applications

Some general applications where successful use of the RFID technology has been reported in the literature include monitoring oil drill pipe [3], Florida's Jacksonville International Airport which will have the world's first all-radio frequency identification baggage tracking and identification system [4], active implantable medical devices [5]; applications in biology [6-8] and investigation of insect movements [9]. There are applications in commerce and clothing [10, 11], RFID technology increasing profits in industry [12], collision avoidance in mines and in identification systems [13]. To meet the growing needs for identification and automated manufacturing and engineering, the two-dimensional codes, the data matrix code and the Rolls-Royce DMT code [14, 15] have been developed. Timely availability of manufacturing information in the right place and in a usable format has a direct bearing on how organizational resources are used to affect the required value-added activities on a product to impart economic value to the end product. A number of Automatic Identification (**Auto ID**) technologies [16, 17] exist to aid in dealing with information capture and dissemination in an automated manufacturing environment. These facilitate implementation of CIM architecture to address the time-value of information in decision-making.

### 2.2 An example of an application in manufacturing

The Ford Motor Company has successfully implemented RFID to improve products quality on the automated assembly production line at its facility in Cuautitlan, Mexico. Here, Ford produces cars and trucks using the just-in-time (JIT) manufacturing model. Johnson [18] reports that: "As a vehicle passes through the different stages of production, different parts of the 22- to 23-digit serial number are referenced, indicating what needs to be done at each station. This is one of the biggest benefits of RFID. Where the former manual coding system required each identification sheet be manually updated at every turn in the production line, RFID allows updates to be written to the tag, so that it is constantly being updated without risk of operator error."

### 2.3 Some current and possible application areas

Almost 100 million contactless 13.56 MHz cards have been sold worldwide. They are being used in: It is used in

library field, carton marking, airline baggage sector, express parcels and high value/big ticket item management, advanced shipping label and item level identification where the primary identifier, barcode, suffers from a line of sight problem. The normal application areas are: Transportation and logistics management; Security; Waste management; Postal tracking; Electronic article surveillance - clothing retail outlets being typical; Protection of valuable equipment against theft, unauthorized removal or asset management; Controlled access to vehicles, parking areas and fuel facilities - depot facilities being typical; Automated toll collection for roads and bridges - since the 1980s, electronic Road-Pricing (ERP) systems have been used in Hong Kong; Controlled access of personnel to secure or hazardous locations; Time and attendance - to replace conventional "slot card" time keeping systems; Animal husbandry - for identification in support of individualized feeding programs; Miniature tags can be placed within tool heads of various types such as block or Cat V-flange, or even within items such as drill bits where individual bits can be read and selected by reader guided robot arms. Automatic identification of tools in numerically controlled machines - to facilitate condition monitoring of tools, for use in managing tool usage and minimizing waste due to excessive machine tool wear; Identification of product variants and process control in flexible manufacture systems; Sport time recording; Electronic monitoring of offenders at home; Vehicle anti-theft systems and car lock; etc.

2.4 Some current research areas:

Though the RFID technology had been used in many fields, research is still continuing. Intelligent systems for decoupling multiple RFID tags had been researched [19]. Miniaturization is a growing trend [20]. Micro controller based contactless identification systems and access controls have been studied. An on-chip RFID receiver stage [21] will arrive. The collision is a big problem in the RFID technology. [22, 23] told us how to avoid it. Before any applications of the RFID technology, the correct systems and optimizing ranges [24] must be properly selected.

3. RFID SMART PARTS IN THE PROCESS OF MANUFACTURING

3.1 RFID Smart Parts and Manufacturing System

The concept of smart parts manufacturing involves the following aspects:

1. Self identification of unique parts
2. Communication between parts and equipment for flexible manufacturing
3. Automation in manufacturing, quality control, packaging, storage and delivery
4. Enabling concurrent manufacturing

Self-Identification of unique parts: Tagging of individual parts in a mass production or batch production set-up enables each part to be treated as a unique, tailor-made item. The vital statistics of the individual part design can be stored as information on the RFID tags. This information would serve to distinguish the part from other similar parts in the same production line.

Communication between parts and equipment for flexible manufacturing: Tag readers can read the process information stored on each tag and instruct manufacturing stations to carry out the necessary processes required for a specific part. After the processing is carried out, the tag can be updated to indicate the operations that have been performed and this data can be read by the quality assurance station at which can run the necessary inspection. In turn, the inspection results can be uploaded on to the tag. Real time monitoring of the production process is thus made possible.

Automation in manufacturing, quality control, packaging, storage and delivery: Tags can be made integral with the part by methods like embedding for the purpose of subsequent identification during packaging, storage, and delivery. They could also be used for subsequent field service records so that they may retain the part performance history which can be read off periodically and fed back into the manufacturer's management information system for the purpose of warranty enforcement and continued improvement of products and services.

Enabling concurrent manufacturing:

Response times to customer inputs can be dramatically reduced by integrating RFID technology with the concurrent manufacturing model. Let us imagine that a truck is to be assembled. The customer usually specifies the engine, possibly the transmission, make of tires, body paint and cabin accessories like the stereo and the upholstery. Designers and customers would have the flexibility to change specifications midway through manufacturing with each chassis being RFID tagged and labeled a smart part. At any moment of time, the specifications written onto the tag could be modified and production could proceed normally. This would shorten response times because design and manufacturing periods would have overlaps as shown in Fig 4. Moreover, designers &

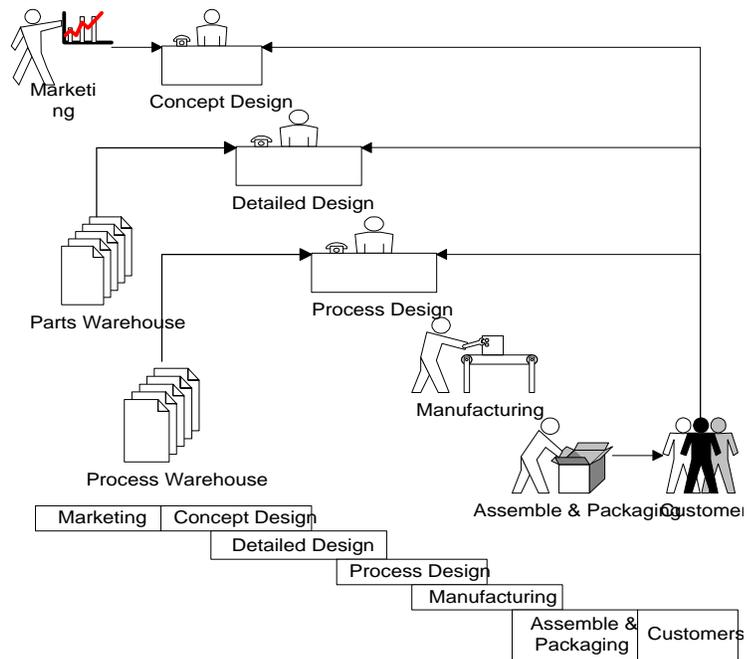


Fig 4. Concurrent Manufacturing

process engineers would be able to control the process changes using wireless signals to directly update the RFID tags, thus reducing paperwork and human interference and improving the efficiencies obtained through automation. Customers could obtain status updates and would be able to track the progress of their order in real time through the wireless internet based feedback made possible using the RFID system.

In this way, the smart parts concept using RFID technology has the possibility of integrating the relationship between customers, vendors, design & and process planning, marketing and warehousing with real time information (Fig 5). The business is thus enabled to provide customer satisfaction through tailor made products supplied reliably and efficiently with competitive response times. After-sales-service and warranty obligations are better fulfilled because the RFID tags enable the manufacturer to track and record performance histories and continuously improve products based on real time performance feedback.

The RFID tagging of engines in the Ford Motor Co. case study cited above [25] is an example of smart part manufacturing. A key part can be identified as a smart part and its progress followed closely through its manufacturing cycle. If, for instance, it has the longest machining cycle, then its progress determines the productivity of the line.

### 3.2 Selection of Smart Parts

Not all parts in a product need to become smart parts. There is an optimization selection that decides which parts need to be designated as smart parts and when. In the manufacturing process, the smart parts status is monitored in the entire control period. According to the control demands, some smart parts will retain smart-part status in the entire manufacturing process, others in special machining process and others in whole life cycle of the product. Different smart parts would have differing start and end times according to the needs of concurrent manufacturing.

Key parts are selected as smart parts and controlled with RFID tags. In the production cycle, the smart parts usually have the longest machining cycle, or undergo the most difficult machining process, or have the most important function in the assembled final product or are patented parts. At the same time, smart parts form a good security ID of a product helping to prevent counterfeit and protect the rights of the producer.

## 4. CASE STUDIES IN RFID IMPLEMENTATION

In his article, Sharp [25] reviewed three companies which were implementing RFID namely The Ford Motor Co at their Essex engine plant at Windsor, ON, the J. Sainsbury Plc. supply chain tracking system in UK and the Rockefeller University, NY library circulation control system. His observations are as follows:

Concerning the Ford operations, he reports: "When an engine starts down the line, its entire work sequence is loaded onto the tag. Each station interrogates the tag to determine what tasks it should complete. Test results are written directly to the tag."

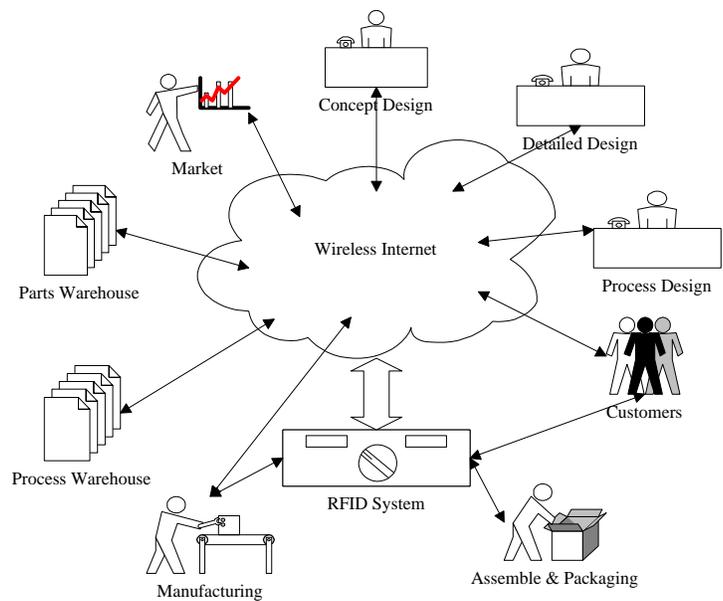


Fig. 5 RFID & Wireless Internet

At the J. Sainsbury Plc. Operations, he found that "They wanted to see whether it was possible to implement a tracking system that could automatically record every unit of trade (box, carton, or pallet) every time it moved and to immediately report each movement to a central logistics database."

The Rockefeller University, NY library was concerned with installing a system that "Solves the same problems faced by any manager trying to keep track of a large number of movable assets"

Sharp observes that "They all had needs that could be met only by RF tags, but they relied on integrators to handle the technological details. In each case, this was one decision that was strictly business." Sharp summarized his observations saying: "First, these companies adopted RFID because a compelling business need could not be filled by any other technology. These firms are technology leaders, but they implemented RFID for purely business reasons. Second, they paid careful attention to the systems integration aspects of the adoption. The competitive advantage to be gained comes not from RFID technology itself but from the improvements to software systems and business processes that would be impossible without the RFID devices. Finally, each company sees its RFID project as but one phase in a continuous improvement process. The lessons they've learned are already being put to use in revised procedures and new system designs."

Followings will use some good examples and our model to show how RFID works or can work within a manufacturing context.

### 4.1 Successful cases

#### Assembling:

The Ford Motor Co.'s facility in Cuautitlan, Mexico, produces 300,000 to 400,000 cars and trucks each year. It's crucial that inventory and tracking in the plant be precise and closely monitored. However, keeping track of inventory and production automation in a large facility can be a daunting task.

Before Escort Memory Systems (EMS, Scotts Valley, CA) was called in, Ford used a manual coding system to track auto and truck frames as they went through the final assembly, paint and body shop areas of the production line. Unfortunately, this manual system was very ineffective due to frequent error and costs associated with production oversights. Paper identification sheets, used to track the vehicles, were being lost, switched or ruined, making quality control difficult. The 48-byte memory and 1,200bytes/sec transfer rate could easily handle Ford's 23-digit reference serial numbers and production rates. At Ford's ESSEX PLANT in Windsor, Ontario, Escort Memory Systems tags carry all instructions needed to assemble each engine, as well as all test data accumulated during manufacturing.

- Integrated into a complete system.
- Reused at the end of assembly.
- Used under harsh conditions because they are maintenance-free and battery-free.

#### 4.2 New Model

From above it shows that RFID can work within a manufacturing context flexibly. It can work in a definite area or whole production process especially including markets and customers. In our new model, the instruction can be transferred by wireless and a wireless Internet manufacturing system [28] can be set up. Though some RFID tags have great memories to store the manufacturing instructions, the small ones will be better in manufacturing shops for the reliability and price.

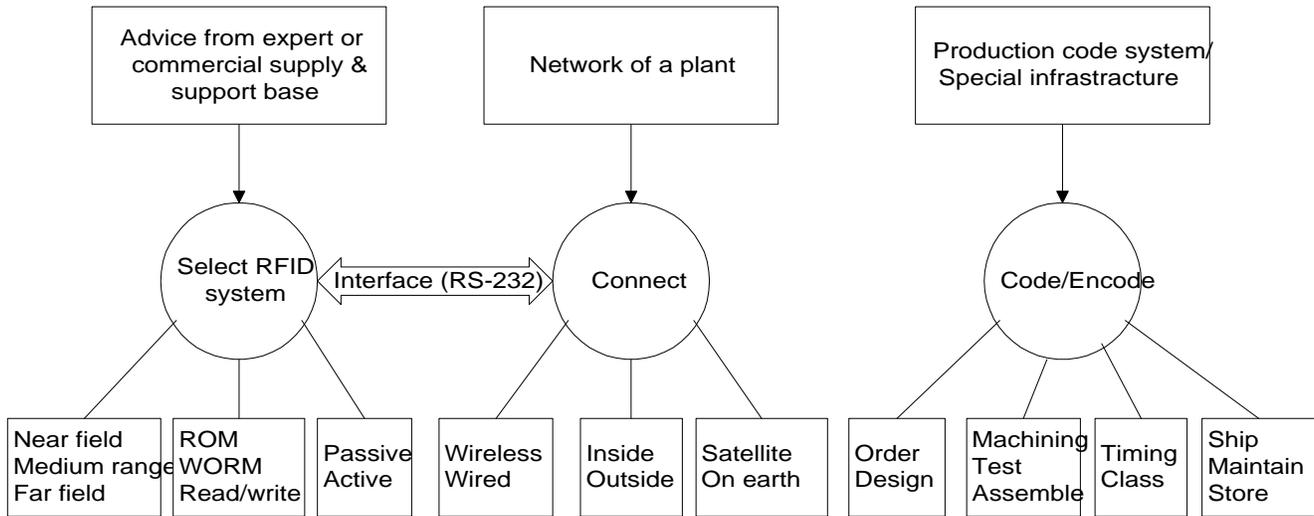


Fig 6. RFID Control System

Fig 7. Code/Encode System

#### Supply Chain:

RF technology has been successfully used in some portions of the supply chain. Copperweld [26], a Pittsburgh-based steel tubing and wire manufacturer, has taken the first steps toward RFID. They have implemented an infrastructure of RF units to handle a barcode-based inventory system. Through the use of a contactless system to read a variety of barcodes, they have managed to reduce the time needed to complete their original tracking process by two thirds. Currently, the system builds the manifest of outgoing goods by simply scanning a product's barcode and entering an amount. Future plans include the use of this system in their receiving department as well.

#### Individual Production:

BMW and Vauxhall use RFID tags [27] to enable accurate customization of customer orders. A read/write smart tag is programmed with the customer order. The tag is then attached to and travels with the car during the production process. This tracking ensures that the car is manufactured with the correct color, model, interior, and any other option the customer specifies. Some of the major advantages cited for this system are:

- Read without direct line of sight.
- Reprogrammed to reflect different requirements.

Before successful using the smart parts technology, a production code system should be set up. A simple code can be used to express complex technology problem. It likes coding and encoding system. The RFID system will help to track intelligently the smart parts. Different tags have different functions. If the RFID tag only replaces the barcode, it will be a passive and ROM one. A RW one can be renewed or updated. An active one can transfer data far away and store much message. But it is expensive and needed to be recharged.

As showing in the Fig 6-7, the RFID system must be selected according to the production and advice of experts or commercial supply & support base. Generally the near field is for small parts, medium range for middle plant and far field for big plant. ROM and WORM are good to replace barcode. The first will be made in RFID factory and the second will be made by users. The second is convenient but little expensive. The Read/write one is the most convenient and the most expensive but it can be reused and updated. A dynamic scheduling and more smart parts need the kind of RFID tag. Passive and Active RFID system will decide the transferring distance and the tag's life.

If there is an existing wireless system or will set up this kind system, it will realize wireless tracking system and the

smart parts will be control in a bigger area. If not, the RFID can be used in the wired network system too. The wireless range is only limited in the Reader to Tag. Connecting with system will make the control range expand outside the plant easily and it will be decided by the price and necessary. Until now no people had realize a satellite and RFID system but it is possible in the future.

The code/encoder system is the core of RFID users. It will base on the production process database. It will be secret for a factory and the code can be encoded by special infrastructures with encoding software and based on database. The coding process will make smart parts and they are the control fundament for whole production process. For example, if a part is instant, the system can make it pass through green pass and within the shortest time the whole machining process can be finished.

After the RFID system operates smoothly it will help improve the design and vendition. The quality of product will be raised. The manufacturing and shipping time will be decreased. The waste for unable to find the key parts or wrong assembling or miss shipping will be avoided. The maintaining service can be tracked and controlled.

#### 4.3 The commercial supply & support base

A large industrial supply and service base has developed for the commercial supplies of RFID solutions.

The AIM (Automatic Identification Manufacturers) serves over 1000 member worldwide and has some fourteen licensed national and regional affiliates worldwide.

Texas Instruments Radio Frequency Identification (TI-RFid™) Systems, Philips Semiconductors and Escort Memory Systems (EMS) are among the leading suppliers of hardware and solutions of which there are many.

## 5. CONCLUSION

There is an accelerating trend in the adoption of RFID technology for various industrial and consumer applications. The full potential of this technology has not yet been realized in practice. There is sufficient potential for systems integrators who need to address the requirements of customers and help integrate RFID based systems into enterprise wide Management Information Systems networks. Business leaders need to look at this new technology more closely because it has the potential for value addition to any business engaged in large-scale data processing in any form. So far, the technology has gained prominence in retail and supply chain management. Its use in manufacturing has not yet reached the critical point but that is only a matter of time. The hardware is available. Cost effective and robust components are available with tags able to withstand even high temperatures like those found in baking ovens. Miniaturization and moisture resistance are no longer the issues. Many businesses selling RFID solutions are well entrenched but there is room for more. The RFID technology will play an increasingly important role in the manufacturing and wireless Internet manufacturing in the future.

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