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Practical RFID – What Works and What Does Not

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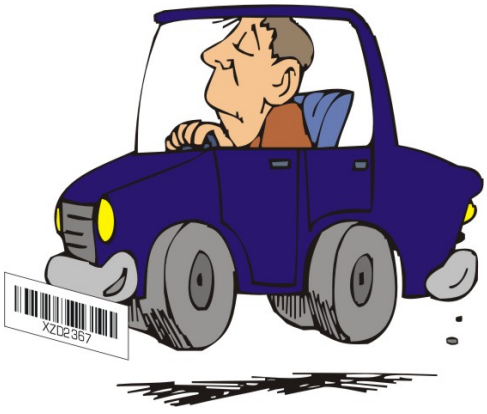
Introduction

RFID is generating a lot of "buzz" in the trade press as the next great breakthrough technology in supply chain management. It has been claimed to supplant barcode technology and to be the silver bullet that will solve every problem confronting supply chain managers today. The reality is a little different.

In this document we will described how RFID works, where it is useful and where it is not, and look at some of the forces driving its adoption despite the technological challenges.

"License Plate" Material Tracking



All of RFID tracking is based upon the concept of "license plate" tracking. In this, the originator of each container or serialized item issues a unique tracking code to that item. The tracking code may be in the form of a barcode or an RFID tag or both.

The concept is named after the issuance of license plate tags by the registry of motor vehicles in each state. Each state guarantees that each license plate number it issues is unique. All the data about the automobile is stored in a database or can be sent electronically.

As with automobiles, all the data about each container or serialized item is stored in a computer database. It can then be exchanged electronically over the Internet as materials are moved along the global supply chain. Materials shipped from one point to another can be preceded by an Advanced Shipment Notice (ASN) which describes the

complete contents of boxes and pallets in relation to their license plates. All that is needed is to read the RFID tags upon receipt to access all that information, with no manual data entry or attendant mistakes.

The "license plate" tracking code consists of three parts:

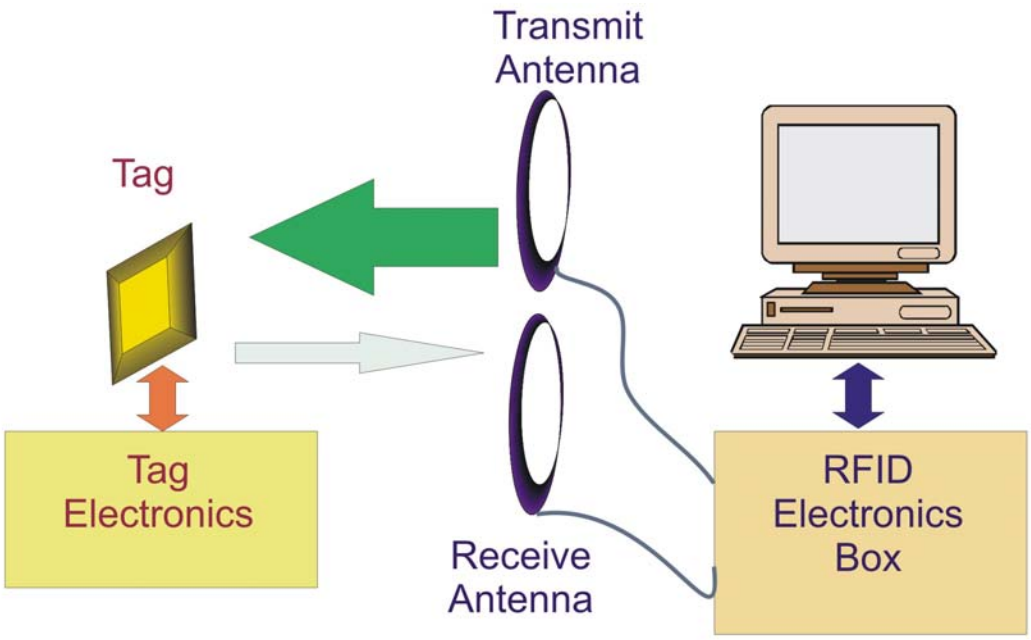
a) An identification as to the coding method used

b) The unique identification of the originator

c) A unique serial number assigned by the originator. This sometimes consists of a product code plus a serial number code.

Different coding methods are used depending on whether this is a serialized product, a product box, or a shipping container and whether it is an RFID tag or barcode tag. The coding method also indicates whether this is following DOD or UCC/EAN commercial standards. Fortunately, ISO, UCC/EAN, DOD, and EPC standards now in effect all work together to enable a unique world–wide "license plate" identification code to be issued for each serialized item and container on a global basis without the need for a centralized issuing authority.

How RFID Works



An RFID system consists of the following components:

a) A computer that issues commands to read or write an RFID tag. These commands are communicated to the electronics box either through a direct USB or RS232 connection or over a local area network.

b) An electronics box that contains a transmitter and a receiver as well as electronics to encode and decode the signals exchanged with the RFID Tag.

c) Antennas that are connected to the Electronics Box. A single antenna may be used for both sending or receiving or a separate sending and receiving antenna are used. This latter arrangement results in higher performance if cross polarized antennas are used for communications.

d) The RFID tag that consists mostly of a copper antenna printed on a plastic substrate.

e) The Tag Electronics, which is a very small integrated circuit connected to the antenna. This integrated circuit contains a receiver, a transmitter, a memory and some electronics to decode and encode the signal exchanged with the electronics box.

To write a "license plate" number into the RFID tag, the computer sends the tag number to the electronics box. The electronics box transmits the signal through the antenna. The resultant radio wave is picked up by the tag antenna and decoded by the tag electronics. The tag electronics write the "license plate" number into the memory of the RFID tag and transmit back a confirming signal to the electronics box. This decodes the signal and sends a confirmation to the computer.

Reading the tag follows a similar process except that the computer sends an interrogation request to the electronics box. The electronics box sends this to the tag, which responds with the license plate number in its memory.

There is no physical contact between the antenna connected to the electronics box and the tag. All communications is by radio waves sent between the tag and the antenna attached to the electronics box.

Tag Issues

There are two types of tag, active tags and passive tags. An active tag is powered by a battery. A familiar use of these tags is the vehicle identification systems that are used for automated highway toll payment systems. These tags power their electronics by battery and are able to transmit back a relatively high level of signal giving them a range of 25 feet or more.

A passive tag collects the energy it receives from the radio wave transmitted by the electronics box and saves this up on a capacitor. This energy is then used to power the electronics and the transmitter that sends the signal back from the tag. As a result, the signal transmitted by the tag is only a small fraction of the signal level it receives. As a result, the interrogation range of passive tags is limited to a few feet.

The benefit of passive tags is that they are an order of magnitude less expensive than active tags and they do not have a battery which will wear out after a couple of years.

Tags come in a variety of frequency ranges. Three of the common frequencies used are

- 13.56 MHz – Passive VHF (Very High Frequency) Band used primarily in Europe for material tracking. Also used in Europe and the USA for assembly line tracking.
- 433 MHz – Used for Active Tags on Shipping Containers
- 860–930 MHz – Passive UHF (Ultra High Frequency) band tags used by the DOD (US Department of Defense) and WalMart.

It should be noted that the equipment for different frequency tags is, by and large, not interchangeable. The UHF tags are, however, interoperable at both the European 860 MHz band and the American 902–930 MHz band.

The EPC Global standards organization, the DOD and WalMart have chosen to adopt the UHF tags as the standard for their supply chains because of their longer interrogation ranges compared to the shorter range VHF band tags. With UHF tags ranges of up to 10 feet can be achieved. With VHF tags, ranges are limited to about 2 feet in the USA and about 4 feet in Europe. This is because the European Communications Commission (ECC) allows for a higher radiated power (800 mW) in the VHF band than does the US Federal Communications Commission (FCC), which only allows 200mW.

It is anticipated that all US Government agencies and big box retailers will adopt the passive UHF tags for supply chain applications due to their longer range and greater communications bandwidth.

A major issue with tags is how to sort out the responses from multiple tags when they are in range of a transmitting antenna. This situation occurs, for example, when a pallet load of boxes is driven between a pair of antennas on either side of a shipping bay door. If all the RFID tags responded to the interrogation at the same time and in a like manner their already weak transmitted reply signals would interfere with each other and cancel each other out.

There are several ways to handle this situation:

a) Have each tag wait a random time before transmitting its reply.

b) Have each tag pick a random frequency on which to reply.

c) Use spread spectrum technology with each tag using a unique encryption code.

Unfortunately these methods are not interchangeable and the method used by the interrogating electronics must match the method used by the tags.

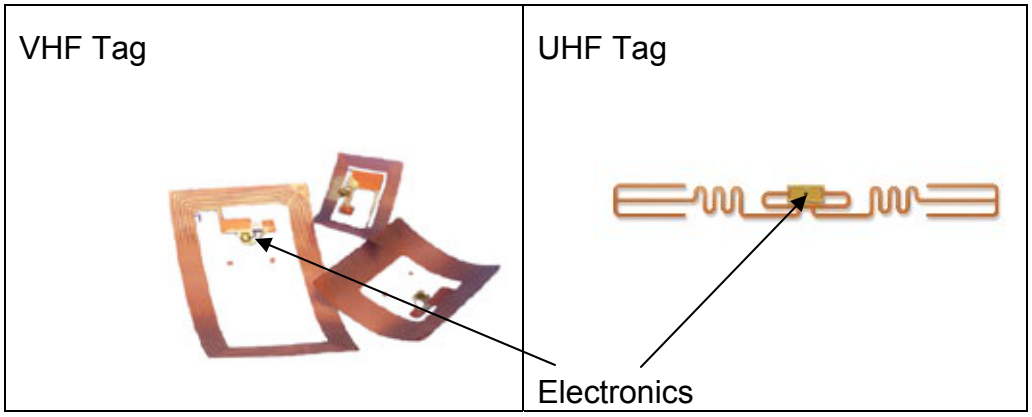
In the UHF band, tags have been classified as class 0, 1 or 2, which has been somewhat muddied by the appearance of class 0+ tags. Most equipment now available can read or write the class 0 or class 1 tags which are currently in use. These tags are expected to be supplanted by the class 2 or Gen 2 tags, which are incompatible with the equipment used to read and write class 0 or class 1 tags. So any current equipment will need to be upgraded or replaced.

Tags also have different memory sizes. Many currently available tags have a 64 bit memory which is not sufficient to hold a standard license plate tag. 96 bit tags are starting to become available, which have a memory big enough to hold a license plate tag but not big enough for any security information. The class 2 tags are expected to have 128 bit memories so the data can be encrypted. They will also have enough memory to store encryption keys so that the data in the tag can be unlocked for read or write with the appropriate encryption keys.

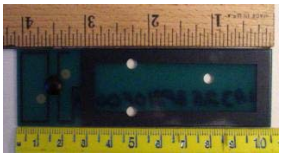
The lessons here are that the equipment and the tags have to be compatible in terms of frequency, air–interface protocols, encryption and security methods. Fortunately WalMart and the DOD have enough economic clout to make the new UHF class 2 tags the de–facto standard once they become readily available.

Tags

Tags start as an insert whose antenna is printed on a flexible plastic substrate. The electronics, which are the size of a pinhead are then bonded to the substrate.



They may be encapsulated in plastic to form a very robust tag, such as the pallet tag shown here:



Alternately the RFID tag is laminated into a barcode label forming a combination RFID tag/barcode label. These can be encoded on a combination barcode printer/RFID tag encoder:

The benefits of this approach are:

a) The RFID tag can be encoded at the same time as the barcode label is printed.

b) Both the RFID tag and the barcode label can contain the same license plate tracking information. This means that the RFID tag can be read when this is the most cost effective method and the barcode can be scanned when RFID equipment is not available.

c) Using software such as LabelHawk–RFID™ and Bartender®, users do not have to worry about label and tag formats as these are produced to the correct standards automatically.

Combination UHF smart–tags are rapidly becoming the de–facto standard for shipping pallet and box labels in the commercial and military supply chains.

Tags that are not encoded as part of a barcode label have to be encoded with a separate encoding device. These typically integrate the electronics and the interrogating antenna into a single unit, which may be a fixed station or a hand–held portable unit.

Scanning RFID Tags

The most common way of scanning RFID tags is by means of a "portal".
A portal consists of antennas on either side of an opening such as a vehicle loading–bay door. These antennas are then connected to an electronics box and thence to the computer.

VHF Portal	Electronics Box
	

A typical VHF portal, complete with electronics box, will cost in the vicinity of $10,000 US. A UHF portal uses smaller antennas and a smaller electronics box, as shown at the right, and costs about $5,000. Typically a pair of transmit–receive antennas is placed on either side of each loading bay door and connect to a single electronics box which is connected to its controlling computer over a local area network.

UHF Antenna and Electronics Box

RFID Tags versus Barcodes

It has been suggested that RFID tags will replace barcodes. This is not true, at least for the foreseeable future.

Some of the points of comparison:

a) Barcode tags cost less than 1 cent each whereas RFID tags, even in high volumes, cost 50 cents a piece.

b) Barcodes can be used to locate materials exactly by scanning a bin location. Portals only know that an RFID tag was within 10 feet of a portal at a specific time. They also do not know whether the tag went through the portal or, if it did, in which direction.

c) RFID scanning and encoding equipment is more complex and much more expensive than comparable barcode scanning equipment.

d) There is no limit to the number of license plate barcodes you can have on boxes or items that are shipped as one entity. Only a few (less than a dozen at fork–lift movement speeds) RFID tags can be read from a single shipment unit when transiting a portal and the probability of a successful read decreases rapidly as the number of tags exceeds one.

Given all of these disadvantages relative to the proven barcode technology, why would anyone want to use RFID technology?

As we will discuss in the next section, one of the major uses of RFID tags is in recording the shipment and receipt of materials on pallets and in shipping cartons. Typically fork–lift drivers will stage materials to be loaded on a truck and will then proceed to rapidly load the truck as soon as it arrives. With barcodes, we require the loader to scan the pallet "license plate" barcode and a barcode located at the shipping bay door. Inevitably they make mistakes and forget to scan a pallet or carton as it goes onto the truck. This problem can be avoided if each pallet or carton has an RFID tag that can be scanned as it goes through the loading bay doors.

When each pallet or carton is shipped an Advanced Shipment Notice is sent from the originating organization to the receiving organization. This contains a complete description of all the materials and containers on the pallet or in the shipping carton, including their license plate tracking barcodes. When a pallet is offloaded, the license plate on the RFID tag is automatically matched with the number in the Advanced Shipment Notice. This enables the materials to be automatically received without any barcode scanning or manual data entry.

Highest reliability is achieved by using barcodes to identify products and their containers. RFID tags are reserved for pallets or shipping containers. This enables the RFID tags to be read reliably as there will be only a small number of RFID tags in the portal at any one time.

The benefit of using RFID tags to record shipment and receipt is that the materials are only going onto or off–of the truck. There is no dispute about direction. This is not true in other application, such as tracking the movement of materials within a factory or warehouse.

One vision for RFID is that an RFID tag will be placed on every part. Then a warehouse manager will be able to press a button and a scanning system will be able to tell him where every item is within the warehouse. Unfortunately, at present, the amount of radio energy needed to

perform this scanning in any reasonable time for a typical warehouse would probably ionize the air within the warehouse. There is extensive research being carried out in this arena and I am confident that it will eventually bear fruit but we have to get the energy required down to pico–watts per bit of information for this to be practical.

Market Forces

So what is driving the push to implement RFID? In my opinion, it is Advanced Shipment Notices (ASNs) with all their attendant savings.

Consider a distributor purchasing goods from a vendor using a paper based process. The steps are as follows:

1. Issue purchase order to vendor.
2. Give copy of purchase order to receiving
3. Vendor ships goods to distributor
4. Upon receipt, receiving clerk matches received goods against purchase order.
5. Receiving clerk or office person enters material receipt into computer.
6. Vendor issues invoice
7. Distributor checks invoice against receipt paperwork
8. Distributor pays vendor.

This is a very labor intensive process in which mistakes are easily made. It costs both the vendor and the distributor at least $50 each in labor handling the paperwork for each shipment. This may not seem like much until you consider the DOD or Walmart which each receive over a million shipments a month. They have a potential savings of over $50 Million a month if they can eliminate this paperwork processing.

So what is the alternative using RFID. The process goes something like this.

1. Vendor barcodes products and uses barcode tracking to record all the materials going onto shipping pallet. This can be performed using software such as LabelHawk–RFID from BellHawk Systems to record the packing operation and to generate a combination Shipping Label/RFID tag.
2. Vendor loads product onto delivery truck. The RFID tag on each pallet is read as it is loaded onto the truck.
3. The Advanced Shipment Notice is generated automatically as soon as loading is completed and is sent to distributor over the Internet.
4. The Advanced Shipment Notice is received by distributor and is verified for acceptance by the distributor while the material is in transit.

5. When the material is received and unloaded by a fork–lift truck driver, the RFID tag on each pallet is read. The tracking license plate on the pallet is compared to that in the ASN and the fork–lift truck driver is informed of where to put the material on the wireless mobile computer on his fork–lift truck. This may be a warehouse location, it may be a quarantine location, or it may be a cross–dock location.
6. Payment to the vendor is automatically made upon verification of the receipt against the ASN.

The savings from this can be considerable:

1. Eliminating the cost of issuing POs and processing for each shipment. A one–time blanket PO is negotiated and then releases are requested by Email or EDI (electronic data interchange).
2. Eliminating the cost of receiving the shipment. We have taken a lengthy process by the receiving clerk and automated the task so that it can be rapidly performed by a fork–lift truck driver.
3. Eliminating the cost of issuing and processing invoices.
4. Eliminating time to record materials into inventory and the delays in recognizing material has arrived.
5. Elimination of much vendor and distributor management time wasted in chasing mistakes.

In addition to which, payments are received much more quickly. For example, many DOD contractors are paid 10 days after approval of invoice. The problem was that it used to take at least 30 days to get their invoices (form DD250) approved. Now, using ASNs, many vendors are getting paid in 10 days from delivery against ASN's submitted through the DOD's Wide Area Work Flow system.

The problem with the ASN process is that vendors have to accurately record the data about the nested container structure of each pallet or shipping carton shipped to the customer. Then they have to accurately record what was shipped and received. Software such as LabelHawk–RFID enables organizations to use barcode scanning to accurately record the nested structure of what is in each shipping container or on each pallet. The problem is getting the fork–lift truck drivers to accurately record what is loaded and off–loaded from each truck, which is where RFID comes into the picture to automate the scanning of container license plates.

So we see that RFID, far from being a major technological revolution, is simply a technology component in eliminating the cost of handling paperwork in shipping and receiving by using ASNs. It is not even essential as we can use barcode scanning to perform the same function. But it is far more reliable if we wish to reduce the educational level (and therefore cost) of the people loading and unloading delivery trucks.

Does this mean that there will not be a major market for RFID tags and equipment and the software systems to support them? No, it simply means that RFID is quickly finding its place in the supply chain. I believe that RFID and ASNs will play a major role in the global supply chains girdling the planet. I believe that within a decade every shipping carton and pallet will soon have an RFID tag attached and that every shipping dock door will be equipped with an RFID portal.

The US Department of Defense Initiatives

The US DOD has mandated that all its suppliers attach RFID tracking barcodes to all domestic shipments within the USA by the end of 2005. It has also mandated a compatible set of barcode labels for serialized end use items, intermediate boxes, and shipping cartons and pallets. These are covered by Military Standards 129 and 130 augmented by the DOD's RFID and UID initiatives. In doing this, the DOD has become the key driving force in the development of RFID technology and standards, including the new class 2 or Gen 2 UHF tags.

Software such as LabelHawk–RFID™ from BellHawk Systems enables DOD suppliers to meet all the requirements of these DOD standards and initiatives.

Author

Dr Peter Green is President and Chief Systems Architect for BellHawk Systems Corporation. He is an expert in the use of software to track, identify, and schedule materials and industrial operations. He also has in–depth knowledge of RFID technology based on his training and his work for the DOD. Dr Green holds a BSEE and a Ph.D. in Computer Science from Leeds University in England. Prior to founding BellHawk Systems, Dr. Green was a Professor of Computer Engineering at WPI and a research staff member at MIT. Dr Green has over 30 years experience leading teams in the development of mission critical systems for Government, industrial, and commercial clients.

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