

RFID WHITE PAPER

1.1 What Is RFID?

In general terms, RFID is a means of identifying a person or object using a radio frequency transmission. In basic terms, an RFID transponder will identify itself when it detects a signal from a compatible device, known as a reader or interrogator, in an RFID system.

In a typical RFID system, transponders, or tags, are attached to objects. Each tag carries with it information: a serial number, model number, color, place of assembly or any other imaginable data. When these tags pass through a field generated by a compatible reader, they transmit this information back to the reader, thereby identifying the object.

Radio frequency identification is hardly a new technology. The concept was first developed over 50 years ago as a method of identifying friendly aircraft during World War II. Recently, however, the technology has received great attention due to a confluence of events, including technology advancement, heightened security concerns and a greater emphasis on cost control.

1.2 Current State of RFID Technology

Tag technology generally dictates the operating parameters of an RFID system. Operating frequencies and tag power source are two of the many factors influencing performance. Some systems can only read tags one-by-one as they pass a reader on a conveyor belt, while others can identify 50 tags as a forklift exits a loading dock door. No single combination is best suited for all applications.

Performance characteristics are driven by several transponder attributes, as outlined in Table 1. Transponder operating frequency further defines the capabilities of an RFID system, as summarized in Table 2.

1.3 Current Alternatives

Typically the largest alternative to an RFID system is the status quo, which can be as simple as a human-readable, printed label to identify an object or person. More often, however, other auto-identification methods are already employed, such as barcodes or optical character recognition (OCR). Other emerging technologies can be used as an alternative to RFID. Bluetooth, for example, can be used to identify objects within a piconet.

Table 1
Transponder Characteristics of Various Types

Transponder Attribute	Performance Characteristics
Chip	The transponder contains an IC which provides the basic functionality of the transponder, including memory and anti-collision properties
Chipless	Chipless transponders do not contain an IC on the tag. Instead, these tags usually rely on reflected energy to produce a unique identification. While they lack many of the performance capabilities of a chip tag, they are far less expensive.
Passive	Passive tags do not require a battery for RF transmission. Generally, these tags are powered by the reader antenna through an antenna located on the tag. The reader's transmission is coupled to the specially designed antenna through induction or E-field capacitance which generates a small voltage potential. This power is then used by the IC to transmit a signal back to the reader or reflect back a modulated, encoded identification. Note that some passive tags do have a battery which is used for ancillary features, such as an LED or LCD display, not transmission.
Active	Active tags incorporate a battery to transmit a signal to a reader antenna. These tags either emit a signal at a predefined interval or transmit only when addressed by a reader. Either way, the battery provides the power for RF transmissions, not an inductive or capacitive coupling.
Read-only	Tags with read-only memory are pre-programmed at manufacture with a unique and/or randomly assigned identification code.
Write-once	These differ from read-only tags in that they allow the end-user to program the tags memory. Therefore, as an item progresses down a conveyor, for example, an end-user can encode a write-once tag with the item's serial number or part number which cannot be erased.
Read-write	These allow for full read-write capability, allowing a user to update information stored in a tag as often as possible. Information updates can include a temperature log in more sophisticated tags or simple binary information such as whether or not an item passed an inspection.
Anti-collision	Though there are many different approaches to anti-collision protocols, the goal is the same: to allow multiple tags to be read by a single reader simultaneously. Without anti-collision, multiple tags will interfere with each other preventing the reader from recognizing the tags.

Source: Allied Business Intelligence Inc

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Table 2
Transponder Performance at Various Transponder Frequencies

Frequency Range	LF 125 KHz	HF 13.56 MHz	UHF 868 - 915 MHz	Microwave 2.45 GHz & 5.8 GHz
Typical Max Read Range (Passive Tags)	< 0.5 m	~ 1 m	~ 3 m	~ 1 m
General Characteristics	Relatively expensive, even at high volumes. Low frequency requires a longer, more expensive copper antenna. Additionally, inductive tags are more expensive than a capacitive tag. Least susceptible to performance degradations from metal and liquids, though read range is very short.	Less expensive than inductive LF tags. Relatively short read range and slower data rates when compared to higher frequencies. Best suited for applications that do not require long range reading of multiple tags.	In large volumes, UHF tags have the potential for being cheaper than LF and HF tags due to recent advances in IC design. Offers good balance between range and performance - especially for reading multiple tags.	Similar characteristics to the UHF tag, but with faster read rates. A drawback to this band is that microwave transmissions are most susceptible to performance degradations due to metal and liquids, among other materials. Offers the most directional signal, ideal for certain applications.
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitive coupling	Active tags with integral battery or passive tags using capacitive, E-field coupling	Active tags with integral battery or passive tags using capacitive, E-field coupling
Typical Applications Today	Access control, animal tracking, vehicle immobilizers, POS applications including SpeedPass	"Smart Cards", Item-level tracking including baggage handling (non-US), libraries	Pallet tracking, electronic toll collection, baggage handling (US)	SCM, electronic toll collection
Notes	Largest install base due to the mature nature of low frequency, inductive transponders.	Currently the most widely available high frequency worldwide, due mainly to the relatively wide adoption of smart cards.	Japan does not allow transmissions in this band. Europe allows 868 MHz whereas the US permits operation at 915 MHz, but at higher power levels.	
Data Rate	Slower	←————→		Faster
Ability to read near metal or wet surfaces	Better	←————→		Worse
Passive Tag Size	Larger	←————→		Smaller

Source: Allied Business Intelligence Inc

While these alternatives all serve to identify an object, there is no universally superior approach. Human-readable labels lack automation. Bar codes require line-of-sight and cannot be deciphered without a compatible reader. OCR can be read by a human but requires sophisticated software to decipher the characters. And finally, Bluetooth is overkill for identification.

2. RFID Applications

2.1 Current Uses

In 2002, radio frequency identification (RFID) has emerged as the leading solution for many applications. Electronic toll collection, access control systems and vehicle immobilizers are all systems that would not be nearly as efficient or effective without RFID technology. See Table 3 for a listing of key application segments, including representative applications and competing technologies.

Given the current lack of standards and universal support for RFID in the marketplace, closed-loop systems will adopt the technology sooner than open systems, which require support from a variety of organizations. Without cohesive standards, open systems requiring close support among many partners will never prosper. Until standards are finalized, closed-loop systems, where there is no need to identify tags outside of one's own operating areas, will succeed.

The wildly successful RFID implementations today share these characteristics:

- Electronic toll collection applications are closed-loop systems within a well-defined geographic region.
- Asset management applications for companies to track their own internal assets have been incredibly successful for books, gas bottles, kegs and IT equipment.
- Access control systems provide campus-wide access to buildings and gates.

In these examples, there is a very well-defined scope to the project, requiring little or no cooperation from customers, suppliers or even end users.

2.2 Future Applications

Lurking around the corner are myriad other applications set to revolutionize everything from microwaving popcorn to international espionage. The major question is whether RFID will spawn a boom at the end of this decade as the Internet did at the end of the last. Companies will migrate to RFID applications; it is not a question of "if." However, before this revolutionary change occurs, the RFID market must undergo an evolutionary process to bring the market together on a common ground.

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Table 3
RFID Application Matrix

Application Segment	Representative Applications	Competitive Technologies	Current Penetration	Typical Tag Type
Access Control	Doorway entry	Other keyless entry technologies	High	Passive
Asset Tracking	Locating tractors within a freight yard	None	Low	Active
Asset Tagging	Tracking corporate computing systems	Bar Code	Low	Passive
Authentication	Luxury goods counterfeit prevention	Holograms	Low	Passive
Baggage Tracking	Positive bag matching	Bar Code, Optical Character Recognition	Low	Passive
POS Applications	SpeedPass	Credit Cards, Debit Cards, Smart Cards, Wireless Phones	Medium	Passive
SCM (Container Level)	Tracking containers in shipping terminals	GPS-based Systems	Low	Active
SCM (Pallet Level)	Tracking palletized shipments	Bar Code	Minimal	Active, Passive
SCM (Item Level)	Identifying individual items	Bar Code	Minimal	Passive
Vehicle Identification	Electronic toll collection	Bar Code, License plate reader systems	Medium	Active, Passive
Vehicle Immobilizers	Automotive ignition systems	Other theft prevention technologies	High	Passive

Source: Allied Business Intelligence Inc

As the market congeals, through the creation of standards, better end-user understanding and more palatable costs, RFID will begin to proliferate into a wider array of functions, driven mainly by enhanced productivity.

For example, to fully realize the gains that RFID can enable for supply-chain management solutions, transponder costs must come down to a realistic level. Suppliers indicate that they require enormous volumes to bring the cost down to an acceptable level for widespread use of disposable smart labels. This struggle will continue over the next couple of years as suppliers wait for these big sales. However, as the technology slowly permeates different verticals and broad-based applications, the cost will eventually drop down to a level causing more than a few companies to bite. As soon as a few major companies shift to RFID, a network effect will ensue causing more companies eventually to adopt RFID for their auto-identification needs in supply-chain management.

While the penetration rate of RFID will likely increase across all application segments, it is projected that supply chain management and asset management applications will lead this growth. By 2007, these two segments will account for more than 70% of all transponder shipments, as seen in Chart 1.

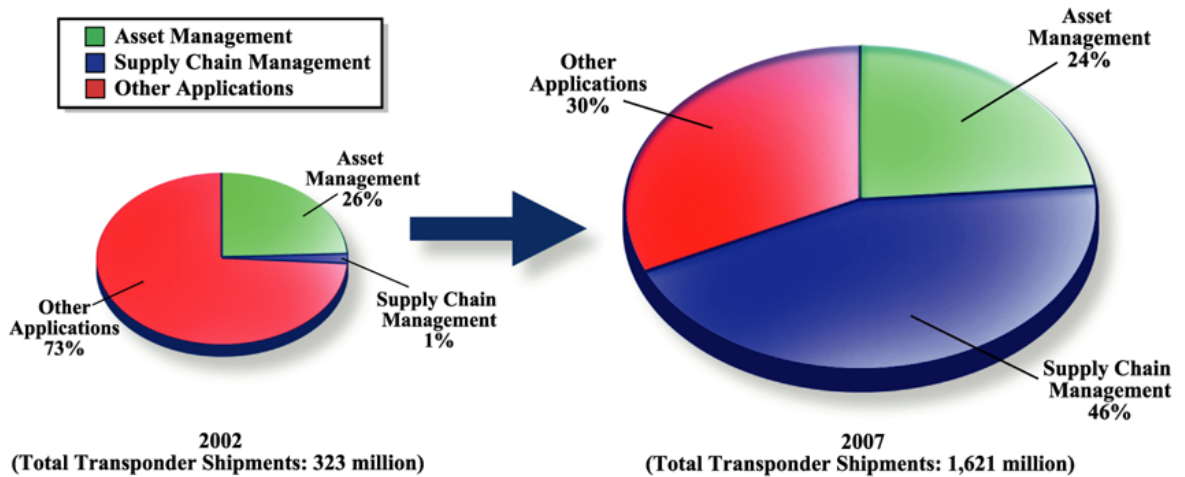
Many contend that security applications will be another driver behind RFID adoption.

With a renewed interest in security, the world is turning to RFID technology to guarantee the safety of its borders, airliners and merchandise. While RFID is only part of a multitiered approach, in most cases, the technology provides unparalleled benefits to an overall solution.

Consider border crossings where trustworthy companies ship goods frequently across the border in the same trucks. RFID products enable customs officials to readily identify the vehicle, its driver and the cargo. Furthermore, the technology can inform a border patrol agent if the contents have been tampered with. Myriad companies, from logistics providers to packaged goods companies, are investigating RFID cargo seals.

Security concerns have driven airports to deploy RFID tags to identify bags requiring further screening. Companies use RFID tags to identify employees and to grant access to buildings. Hazardous materials are labeled with an RFID tag to reliably indicate its contents. While all of these applications use RFID as part of a larger, overall security plan, RFID's primary benefit is efficiency.

**Contribution of Asset Management and Supply Chain Management Transponder Shipments
World Market, 2002 and 2007**
Source: Allied Business Intelligence



Security concerns will be the driver behind many new RFID applications. But while RFID can offer great benefits to a security plan, there is always another approach. RFID frees resources that these other methods require.

In the end, productivity, not security, will be the driver behind RFID-enabled processes, even if in the short-term, security is a primary force.

3. The RFID Industry

3.1 Suppliers

The heart of any RFID system is the transponder. The transponder dictates the performance characteristics of the system and is therefore the most critical component. Consequently, it is imperative to understand the structure of the transponder supplier market.

Generally, the larger, more entrenched companies offer a breadth of products in the low- and high-frequency bands. The technology to exploit RFID applications in these bands is mature, as are many of the markets for these frequencies. The larger companies, such as Philips and TI, have sold millions of ICs and transponders into these markets for devices, including vehicle immobilizers and smart cards.

In the last few years, advances in RF circuitry have enabled affordable transponders in the UHF and microwave bands. Smaller upstart companies are embracing these bands hoping to reap a portion of the pending growth expected in these bands. The larger manufacturers are taking a more cautious approach, focusing on their proven product offerings before fully embracing newer technologies.

While few, if any, would debate the enormous market potential for higher frequency RFID tags, they would all likely debate the best approach. Rival technologies, standards and data structures are key attributes currently under debate.

See Table 4 for a listing of select manufacturers' RFID product offering.

3.2 Customers

Up until 2002, the bulk of RFID sales were distributed among a few applications. Just like the early days of barcode, the technology has not spread widely outside of proven applications such as automotive immobilizers, access control and electronic toll applications. Allied Business Intelligence firmly believes that the progression of the market will mimic that of barcode. Today, barcode is ubiquitous. Desktop computers and printers can print barcodes for shipping applications and inventory control, whereas this capability did not exist a decade ago. Similarly, RFID applications today are limited to specialized applications, with the technology often far removed from the end user.

Slowly, however, the technology is permeating a second tier of applications and coming closer to the desktop computer. Zebra, a company known for its specialized barcode printers, now manufactures an RFID tag encoder/printer for desktop computers. The device prints information onto an RFID "smart label" and encodes the label with the pertinent information. Libraries and rental equipment vendors are ideal customers for this device. So while RFID technology is still far from ubiquitous, it is making its way closer to the end user.

The key to customer acceptance is proper education on RFID capabilities and limitations. Part of the education process is a slow evolution, as the technology percolates into society in different forms, including electronic toll collection and cash-replacement payment methods, for example. While tag cost will remain an issue for many applications, it is important for potential end users to understand that many applications will have a positive return on investment even with tag prices at current levels. Likely the most dominant factor driving tag cost is demand. Key to boosting demand is effective universal RFID standards.

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Table 4
RFID Player Matrix
A Comparison of Product and Service Offerings of Select Companies

Company Name	URL	IC	Finished			Finished Readers	Frequency Bands Supported				Standalone Software	Integration Services
			Tags	Passive	Active		LF	HF	UHF	Micro		
Accu-Sort Systems Inc	www.accusort.com		X	X		X		X				X
ActiveWave Inc	www.activewaveinc.com		X		X	X			X		X	X
Alien Technology	www.alientechnology.com	X	X	X	X	X			X	X		
Allflex USA	www.allflexusa.com		X	X		X	X					
AmaTech USA	www.amatechusa.com		X	X		X	X					
AMSKAN Ltd	www.amskan.com		X	X		X	X				X	
Applied Digital Solutions	www.adsx.com		X				X					
Applied Wireless Identifications Group In	www.awid.com		X	X		X	X	X	X	X		
Athena Integration	www.athenaintegration.com											X
Atmel Corporation	www.atmel.com	X	X	X			X	X				
AVID Identification Systems Inc	www.avidid.com		X	X		X	X					
AXCESS Inc	www.axsi.com		X		X	X			X		X	X
BISTAR	www.bistartech.com		X	X		X			X		X	
BlueTags	www.bluetags.com		X		X	X				X		
C.W. Over Solutions Inc	www.cwosrfid.com		X	X				X				
Checkpoint Systems Inc	www.checkpointsystems.com		X	X		X		X			X	X
Cross Point B.V.	www.crosspoint.nl	X	X			X	X	X				
CrossLink Inc	www.crosslinkinc.com		X	X	X	X			X		X	X
DATAMARS SA	www.datamars.com		X				X					
Deister Electronic GmbH	www.deister.com		X	X		X		X				
Destron Fearing Corporation	www.destronfearing.com	X	X	X		X	X					
Dynasys Technologies Inc	www.dyna-sys.com		X	X		X	X	X			X	

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			Tags	Passive	Active	Readers	LF	HF	UHF	Micro		
ELGAB AB	www.elgab.se		X	X		X	X				X	
ELPAS Ltd	www.elpas.com		X	X		X					X	
EM Microelectronic	www.emmicroelectronic.com	X		X	X	X	X	X				
Escort Memory Systems	www.ens-rfid.com		X	X	X	X		X			X	
Farther Synergies Pte Ltd	www.far.com.sg		X	X	X	X	X	X				X
FlexChip AG	www.flexchip.de		X	X		X		X				
Franken Plastik GmbH	www.frankenplastik.com		X	X		X	X				X	
FreedomPay Inc	www.freedompay.com		X	X		X	X					
GLOBAL ID Holding AG	www.globalid-technologies.com		X	X		X	X				X	X
HID Corporation	www.hidcorp.com		X	X	X	X					X	
IAS	www.interasset.com											X
IDmicro, Inc	www.idmicro.com		X	X		X				X	X	X
ID Systems Inc	www.id-systems.com		X		X	X					X	
Identec Solutions	www.identec.com		X		X	X			X		X	X
Infineon Technologies AG	www.infineon.com	X	X					X				
INKODE USA	www.inkode.com		X	X		X				X		
Innovision R&T	www.innovision-group.com		X					X				
Intellident Limited	www.intellident.co.uk		X	X		X		X			X	X
Intermec	www.intermec.com		X	X		X			X	X	X	X
iPIN, Inc	www.ipin.com											X
KSW-Microtec GmbH	www.ksw-microtec.de	X	X	X	X	X		X		X		

Source: Allied Business Intelligence Inc

Table 4 - Continued
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Company Name	URL	IC	Finished			Finished Readers	Frequency Bands Supported				Standalone Software	Integration Services
			Tags	Passive	Active		LF	HF	UHF	Micro		
KTP Ltd	www.ktp.co.uk		X			X					X	X
Magellan Technology Pty Ltd	www.magtech.com.au	X	X	X		X		X			X	
Mark IV Industries Ltd	www.ivhs.com		X		X	X			X	X	X	X
Matrics Inc	www.matricsrfid.com		X	X		X			X		X	
Microchip Technology Inc	www.microchip.com	X					X	X				
Minec AB	www.minec.com					X	X	X				
Miyake Inc	www.miyake-inc.com		X	X		X		X		X		
MOBA Mobile Automation GmbH	www.moba.de		X	X		X	X	X			X	X
OmniTek	www.omnitek.com		X			X		X				
Omron	www.omron.com		X	X		X	X	X				
Phase IV Engineering Inc	www.phaseivengr.com		X	X	X	X	X					
Philips NV	www.philips.com	X		X		X	X	X	X	X		
Precision Dynamics Corp	www.pdcorp.com		X	X				X				
QueTel Corp	www.quetel.com					X					X	X
Rafsec	www.rafsec.com							X	X	X		
RCD Technology Corp	www.rcdtechnology.com							X	X	X		
RF Code Inc	www.rfcode.com		X		X	X			X		X	
RFID Inc	www.rfidinc.com		X	X		X	X	X				
SAMSys Technologies Inc	www.samsys.com					X	X	X	X	X	X	
Savi Technology	www.savi.com		X		X	X			X		X	X
Scanpak	www.scanpak.com		X	X		X		X				X

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Company Name	URL	IC	Finished			Finished Readers	Frequency Bands Supported				Standalone Software	Integration Services
			Tags	Passive	Active		LF	HF	UHF	Micro		
SCEMTEC	www.scemtec.com		X	X		X	X				X	X
SCS Corporation	www.scs-corp.com		X	X		X			X	X		
SIRIT	www.sirit.com		X	X		X		X	X	X		
Softrónica S.A.	www.softronica.es		X	X		X		X				
Sokymat SA	www.sokymat.com		X	X		X	X	X				
Sovereign Tracking Systems LLC	www.sovtechcorp.com		X		X	X			X		X	
ST LogiTrack Pte Ltd	www.stlogitrack.com										X	X
Stella Electronics	www.stella-sa.fr		X	X		X		X				
Symbol Technologies	www.symbol.com					X		X			X	X
TagMaster AB	www.tagmaster.com		X	X		X				X	X	
TagMaster Inc.	www.tagmasterinc.com		X	X		X				X	X	
TAGSYS	www.tagsys.net		X	X		X		X	X	X	X	X
TEK Industries	www.tekind.com					X	X	X				
Texas Instruments	www.ti.com		X	X		X	X	X	X		X	
ThingMagic LLC	www.thingmagic.com											X
TransCore	www.transcore.com		X	X	X	X			X	X	X	X
Trolley Scan (Pty) Ltd	trolleyscan.co.za		X	X		X			X	X		
TydenTek	www.tydentek.com		X	X		X		X			X	
USA Technologies	www.usatech.com											X
WhereNet	www.wherenet.com		X		X	X				X	X	X
X-ident GmbH	www.x-ident.de		X	X				X	X			
Zebra Technologies	www.zebra.com					X		X			X	X

Source: Allied Business Intelligence Inc

3.4 Standards

The standards landscape for the RFID industry has progressed slowly over the years. Many organizations are bringing together different parties to develop standards in a somewhat confusing, disjointed process. The International Standards Organization (ISO), the Uniform Code Council (UCC) and even the Massachusetts Institute of Technology (MIT) are developing standards.

The most widely referenced standard in the RFID market in 2002 is ISO 15693. Ironically, this standard was not developed for the item-level capabilities to which it is often applied. Originally developed for “contactless vicinity cards,” manufacturers have clung to the standard to provide end users with some sense of security regarding the longevity of their RFID investment. While this is not an ideal solution, it does provide some insurance against technical obsolescence. Moving forward, the new ISO 18000 standard for item-level tracking at 13.56 MHz will include backward capability for this standard.

In early 2002, the UCC and ISO agreed to merge their respective efforts concerning UHF tags for supply-chain applications. Moving forward, the UCC’s GTAG effort and ISO 18000-6 will now be a cooperative effort. Allied Business Intelligence applauds this effort to expedite the release of a final standard, expected in early 2003.

In addition to the above white paper, Allied Business Intelligence Inc has produced two research studies on the RFID industry. The first study, “RFID: Technology Evolution, Market Segmentation Analysis and Player Profiles” is a comprehensive analysis of the industry, including detailed market forecasts and segmentation analysis for several different application segments. The second study is geared to end-users of the technology. The report “RFID for End Users: Vendor Profiles, Technology Assessment and Industry Overview” provides a review of the technology, its many applications and select vendors in the market. The study does not provide market forecasts, though transponder average selling price information is provided for select application segments.

Allied Business Intelligence Inc is an Oyster Bay, NY-based technology research think tank that publishes research and technology intelligence on the wireless, broadband, electronics, networking and energy industries. Details can be found at www.alliedworld.com or by calling 516-624-3113.