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Forest Service

**Technology &
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Program**

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Transponder Technology—
Resource Identification and Tracking

Transponder Technology—
Resource Identification and Tracking

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Contents

This publication describes Transponders and radio frequency identification, and discusses their use in identifying boundary trees in a timber sale and boom sticks used to secure log rafts. Hopefully this report will stimulate discussion on your Forest to review applications which might benefit your unit.

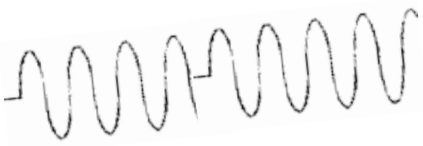
Work continues at the San Dimas Technology and Development Center (SDTDC) to test new technology that can be used in forest product identification. Projects to test new technology are initiated by the Forest Management/Sales Technology Committee. This committee meets annually to discuss field needs ranging from initial sale layout to the transportation of products. Work is prioritized and future projects are developed to address needs that appear to be multi-regional in scope.

Field personnel are encouraged to contact their regional representative on the committee if they see a need for the distribution of information, the application of new technology, or have ideas for new product development.

The current Forest Management/Sales Technology Committee representatives are:

Representative	*DG Address*	*IBM Address*
Dan Castillo		R1
Don Martinez		R2
Alan Lucas		R3
Gerry Thompson		R4
Rick Toupin	R06C	
Alan Quan	R05F15A	
Jim Sherar	R08F11A	
Tom Peterson		R9
Don Golnick		R10
Rod Sallee		WO

Bob Simonson/wo,sdtdc
Program Leader, Forest Mangement



EXECUTIVE SUMMARY

Transponders are the main component of a technology called radio frequency identification (RF/ID). This technology provides a reliable and flexible method to positively identify objects, such as trees or logs, automatically. Unlike magnetic strip or bar code methods, transponders do not require contact or direct line-of-sight between the identification tag and the reader device and this makes them ideal for harsh outdoor environments. Transponders can be read when embedded in wood (or when the wood grows over the transponder). Passive transponders should last virtually forever since there is no battery to replace. A reader device reads transponder tags automatically with no need for operator entry and can interface directly with computer data bases. This technology can provide an effective way to facilitate identifying, tracking, and recording significant information about specific trees and forest products.

Field trials, conducted by the Technology and Development Center, showed that transponder technology can be used to identify boom sticks and boundary, leave, and wildlife trees. Researchers and nursery personnel have used them to identify and track superior or research-study trees and seedlings. Law Enforcement personnel have evaluated transponders for use in boundary trees and blown-down logs to deter and detect timber theft and provide evidence for prosecution.

Potential Forest Service uses for transponders in addition to those noted previously include: use by timber cruisers and purchasers to locate and positively identify cruise trees and plot centers; for more permanent identification needs such as inventory plot centers that are remeasured every 5 to 10 years or land-line corners; and transponders could someday replace branding and painting to improve log accountability. Forest Service or purchaser scalers could use hand-held readers and data recorders to establish log-specific data bases, provide a means for after-the-fact check scaling, and keep accurate inventories. As transponder technology expands and utilization grows, new ideas for ways to use them will evolve.

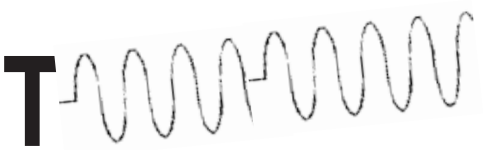
BACKGROUND

The USDA Forest Service uses various methods to identify and keep track of forest products, as well as items used in managing the resources of our National Forests. These methods are essential to provide a means of conducting business and complying with Federal laws and regulations. Recently, the need to positively identify ownership and origin of commodities sold, such as saw logs, has increased dramatically. This is due to several factors including reduced timber supply, greater product values, increased transport distance, and export restrictions.

The technology of identifying and tracking logs from the harvesting area to the log yard has not changed for decades. This traditional method uses hammer brands and paint spots to designate the log as coming from a particular timber sale on Federal land. However, this method has not been satisfactory in many situations due to the fact that branding and painting are difficult to control and often produce marks that are illegible, especially when applied to frozen, muddy, or mechanically-harvested log ends.

The Forest Service is responsible for taking all reasonable precautions and actions to provide for proper accountability and to avoid unauthorized cutting or illegal export of timber from National Forests. Recognizing that there have been significant advances in product identification and tracking technologies, the Director of Timber Management organized a team to investigate opportunities for improving forest-product accountability. One of the recommendations from this team was to evaluate the use of transponders to identify boundary, leave, wildlife and environmentally-superior trees, and harvested logs.

The Technology and Development Center in San Dimas, California was assigned to investigate the use of transponder systems as an alternative identification and tracking method. This work included gathering information from transponder manufacturers and other industries using tracking technology and conducting field trials of the most



promising approaches. The purpose of this report is to provide information on transponder technology with the goal being to give Forest Service personnel the knowledge needed to improve accountability of forest products and to visualize the use of this technology for other important identification and tracking needs.

INTRODUCTION

Identification and tracking of things is one of the most important activities done in the workplace. The accuracy and timeliness of data collection are crucial to productivity. Automated identification-and-tracking technology and systems play a major role in today's global business arena. Increasing capability of computers and the explosive growth of the Internet are moving businesses towards paperless systems and electronic commerce.

Automated identification-and-tracking technology providers have become a huge industry that is continuing to grow. Numerous acronyms have been coined and some are widely used, including: ADC (automated data collection), EDI (electronic data interchange), and RF/ID (radio frequency identification). Transponders are the main component of RF/ID systems.

There has been a revolution in today's warehouses and distribution centers. Corporate reengineering and continuous improvement initiatives have focused on distribution and logistics. Many companies (Wal-Mart for instance) have gained market leadership largely through their excellence in distribution. ADC and related technologies have provided methods of improving asset management and logistics and are now seen as essential to operational savings, cost reduction, and competitive advantage.

The most familiar and user-friendly ADC technology in use today is the card. Most people are unaware that they are using ADC technology when they swipe their credit card through an ATM slot scanner or insert it into the gas pump prior to filling up. These magnetic stripe cards have transformed the way people handle cash transactions. "Smart" cards that contain an integrated circuit may be the next step in changing the process of financial transactions and could lead to a cashless society in the future.

Bar codes have become ubiquitous. They have been around for many years and can be found in supermarkets, at the library, and on our mail. Bar codes are easy to make and inexpensive to use. Bar codes systems usually consist of a coded tag that is attached to an object and a reader device that optically scans the bar code and decodes the information it contains. Often, a data logger or computer with software to manage the data is used. RF/ID or transponder systems also use tags, readers and data management software. Think of transponders as electronic bar codes.

BENEFITS OF RF/ID

The purpose of automatic identification technology is to speed up the collection of data and, eliminate the need for human operations in the process. The amount of data generated today is so overwhelming that the only practical way of collecting and processing this data is to do it automatically, with the help of computer-based identification-and-tracking systems. Automatic data acquisition improves the accuracy of the information in a system because human error in reading, recording, and transposing is eliminated. It makes taking data quick and easy, and makes data available sooner. RF/ID is an automatic identification technology that is similar to bar code technology but has some distinct differences.

RF/ID is ideal for harsh environments. It works well in dirty, wet, or harsh conditions often found in outdoor, commercial, or industrial settings. This is one of the main differences between RF/ID and bar code systems. Bar codes are visual, easy to produce, and inexpensive to use. They work well as long as the decoding (or scanning) equipment has a clear view of the bar code label. However, if the bar code is dirty, damaged, or hidden, it may not be readable. To successfully read a bar code, the decoding device must receive a high-contrast

signal between the bars and spaces that make up the symbol. It will not decode if the contrast falls below the threshold limits of the device due to variables such as dirt, viewing angle, or airborne interference.

RF/ID system manufacturers often describe their products by what they are not: RF/ID is a non-optical, non-contact, non-line-of-sight automatic data collection technique. Communication is accomplished using low-wattage radio frequency signals. Both readers and transponders (also referred to as RF or electronic tags or simply tags) are basically small radio stations, able to both transmit and receive radio waves. These broadcasted radio waves do not require a direct line-of-sight and can travel easily through non-metallic materials. Transponders do not have to be in contact with the reader to communicate data. RF/ID systems can work in environments where bar codes and other technologies fail. Transponder tags can be painted over, covered with grease, salt, dirt, moisture, or other obscuring materials without significantly affecting system performance. These features make RF/ID systems ideal for certain data collection situations.

Another advantageous feature of transponders is that they are extremely difficult to copy or counterfeit. This makes them ideal for confidential identification of people or assets. Also, RF/ID is fast; reader and tag can communicate in milliseconds. Some manufacturers offer systems that have extremely high data rates that allow reading of limited data even when the transponder is moving at more that 60 miles per hour.

Figure 1. Transponders are available in various sizes and shapes and have a wide range of costs and capabilities.

Transponders are available in read-only or read/write configurations. Read-only tags have a permanent identification sequence that is installed when it is manufactured. Read/write tags usually have a permanent ID number but also contain up to several kilobytes of addressable, rewritable memory. With bar codes, if the information contained needs to be changed, a new label is required. Read/write transponders act as reprogrammable "data carriers". They allow identification codes and other data to be programmed, read, and changed thousands of times. Users can create their own coding and numbering systems to easily integrate data with their computerized informations systems. Read/write transponders can be used to update build instructions or inspection results on an item going through a production process.

Readers and transponders have no moving parts, systems do not require much maintenance, and equipment can operate perfectly for extended periods of time. Passive (no battery) transponders have an extremely long life and will usually last longer than the object to which they are attached. Active (internal battery) transponders will last as long as their battery does, typically in the range of two to ten years. This means that when evaluated over time, RF/ID can be a cost effective method of automatic identification.

HOW IT WORKS

An RF/ID system consists of a transponder and a reader, and is often supported by data management software on a computer. These components work together to provide the user with a way to uniquely identify and keep track of people, animals, and objects.

The reader has an antenna and transmitter/receiver and decoder/control modules. The transmitter/receiver allows communication between the reader and transponder via the antenna, while the decoder/control modules process the data and communicate with the user's host computer system. (Most readers are equipped with computer interfaces such as RS-232 ports.) The reader produces a low-power,

radio-frequency magnetic field. This RF magnetic field emanates from the antenna and provides power to the (passive) transponder. Readers can be fixed or hand held. Most units have an LED display so data collected from the transponder can be viewed immediately, and is then stored for later uploading to a computer.

Transponders have an antenna and an integrated circuit (IC) that contains a memory and a transmitter/receiver component. Memories range from 1 bit up to several kilobytes. Read/write transponders usually have larger memories than read-only models. Transponders can be passive or active, depending on the source of power. Passive types obtain their power from the reader while active ones get it from an internal battery. (The presence of a battery in a transponder does not automatically make it an "active" tag since some systems use on board batteries only to maintain volatile memory.)

When a transponder encounters the magnetic field produced by the reader, the recovered energy is used to power its IC, which transmits the contents of its memory through its antenna. Passive tags put out a signal that is an altered form of the magnetic field from the reader (see figure 2). Active tags use the on board battery to power the IC and when interrogated by the reader, broadcast

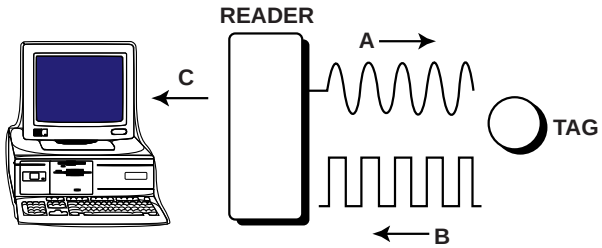


Figure 2—The reader sends a burst of energy (A) to the transponder tag. The tag responds with a coded signal (B) that is read by the reader. Data collected by the reader can be downloaded to a computer.

a signal that identifies itself to the reader. Active tags have a much longer read range (the maximum distance from the reader that a tag can be read) than passive ones. Read range is generally a function of the antenna that the reader and/or tag has for a given operating frequency. Higher operating frequencies provide longer read ranges and faster data transfer rates.

RF/ID systems operate in three basic frequency ranges, classified as low, medium, and high. These are relative designations and not a measure of their place in the electromagnetic spectrum. Low frequency systems operate between 50 and 500 kilohertz, close the the range of commercial AM radio. Medium frequency systems go from one to 30 megahertz. High frequency systems operate over a range between 300 megahertz and 9 gigahertz which is similar to television transmissions.

RF/ID manufacturers use various communication methods to transmit between the tag and reader. The tag modulates the carrier signal from the reader by varying the frequency, phase, or amplitude. This type of communication is subject to interference from unwanted signals—electromagnetic noise. Manufacturers use various techniques to protect against this noise such as encoding bits in the data to provide for error detection by the reader.

TYPICAL APPLICATIONS

RF/ID systems are currently being used for a wide range of identification and data collection purposes. Transponders come in variety of sizes, shapes, and read-range capabilities (see figure 3). They can be packaged to look like just about anything

Figure 3—Transponder shapes (shown with keys for scale).

including a button, a nail, a credit card, or a tube or cylinder as small as a grain of rice. Chances are that if you have not already encountered a transponder, you will soon.

Transportation

RF/ID is ideally suited for transportation applications. Most of the 4 million railroad cars in the United States are currently equipped with a transponder that has the car owner symbol and a unique car number encoded into it according to a national industry standard. Individual cars can be automatically identified and tracked. Ground transportation providers are using transponder technology in several applications for tractor/trailer identification. Intermodal containers, that are transported overseas by cargo ships and then hauled overland by rail or highway, are using transponders based on a standard developed by the maritime industry. This provides a means to identify not only the container, but also the truck or railcar it is on which greatly improves the ability of carriers to track shipments.

Commuters that use the Golden Gate Bridge can use a transponder to pay their toll. The idea is to reduce the long lines of motorists at toll booths during rush hour. It provides a way to collect tolls without requiring motorists to stop, or even slow down much, as they pass though the toll plaza. Many major highways and bridges, as well as smaller areas, such as the Dallas/Fort Worth airport, offer the option of transponder toll passes.

Customers enrolled in the new Mobil Speedpass program can fill their gas tanks without using cash or credit cards by simply waving a transponder (that is attached to their key chain) in front of designated pumps.

Security

Since transponders are difficult to counterfeit and readers can be placed behind walls and windows, RF/ID badges, tags, and key rings are being used as a tamper-proof means to access secure areas. Systems that have sufficient read ranges allow authorized employees to enter or leave an area - without even removing the transponder from the employees pocket or handbag. Another application is to place transponders on company vehicles so they "unlock" company gas pumps. This ensures that employees are not filling their own vehicles and provides a means of tracking and charging fuel to a particular car/driver, activity, or department. Electronic article surveillance tags are attached to merchandise in retail stores to provide a means of preventing and detecting theft. These are used in libraries, clothing and video stores, and other places where theft is a problem.

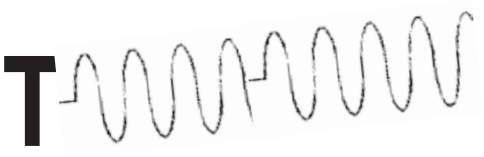
Animal Identification

Transponders on collars or attached to ears of livestock are used to activate automatic weighing and feeding stations so the best feed mix and quantities can be customized for each animal. Researchers have used implanted transponders to identify and track salmon as they returned upstream to spawn after a few years in the Pacific Ocean. Small glass-encapsulated transponders similar to those used in the salmon are being used to identify pets. In this way, if a family pet strays, the animal shelter is able to make a positive identification and notify the owners (see figure 4).

Figure 4—Glass-encapsulated transponders are inserted into animals for identification and tracking.

Factory Automation

Transponders are used to identify and track pallets, totes, and racks in factories and warehouses, particularly in environments where optically-based systems will not work. By using this technology and customized software systems, accurate, real-time work-in-process production data is available.



Read/write transponders are being used for quality control. Rather than store production details about a particular part, mechanism, or circuit board in a host computer, the information is stored in the attached transponder memory. This way each step in the production process and each inspection along the way are recorded on the transponder and can be read at any time. The data is used to control the machining, assembly, or test processes (for example, "I'm part number XXX of batch YYY—steps 1 and 2 are complete and check A was positive - perform operation Z.") In some cases, this data is stored in both the host computer system and the attached transponders. This way if the computer systems goes down, production can continue using hand held readers and the information stored on the transponders.

One other interesting example is the use of transponders in articles of clothing. Uniform rental companies identify, track, and sort laundry automatically using microcircuits embedded in a plastic strip that is sewn into a hem or cuff. Designer-clothing makers are considering using this technique to prevent counterfeiting of their products.

Military

Military logistics often involves the use of tremendous amounts of equipment and supplies. Following Desert Storm in the Persian Gulf, the Department of Defense (DoD) performed a logistics review and the found that a key deficiency was the lack of detailed source information on materials and supplies arriving at battlefield locations.

As a result, the DoD awarded a $70 million contract to Savi Technology to make RF/ID technology available for military use. Now, intermodal and other storage containers are equipped with very advanced, active, read/write transponders for asset and inventory tracking. These transponders have 128 kilobytes of memory and can store detailed information on all assets (water, food, medicine, munitions, guns, etc.) in the containers. Fixed or handheld readers (transceivers) can interrogate tags and find and identify assets up to 300 feet away. They can read, write, and activate the tag's beeper, making the tagged asset easy to locate. Using satellite communications and database integration, logistics officers can access supply and transportation information on any container and its location anywhere in the world. This system (which also uses bar codes and smart cards to complement the RF/ID) is obviously the most sophisticated and extensive identification-and-tracking system in use today.

RF/ID LIMITATIONS

The highly capable, and very expensive, RF/ID system used by the DoD is not the norm. One of the main limitations of transponders commonly used in business applications is read range. With a large, active transponder and powerful reader, as with a laser bar code scanner, it is possible to measure read distances in feet. This is not the case with most transponders, particularly passive ones. Many small transponder tags have a read range of less than one inch. With a distance this small, care is need to get proper alignment between the tag and reader ensure optimum performance. Slightly larger tags have read ranges of up to one foot. Larger transponder tags, such as those used for vehicles passing by readers, offer read ranges of over ten feet.

Another limitation is that, like bar code systems, most RF/ID systems are designed to read one transponder at a time. Therefore, the separation between the tags must be equal to the read distance. In other words, a tag with a one foot read range must be separated from the next tag by at least one foot. As mentioned previously, electromagnetic interference can also cause problems.

Another factor to consider is if the tag will be read while in motion. Passive tags take part of a second to charge up and respond, and reading and writing large amounts of data can take up to a few seconds. This can make dealing with a many tags at once difficult. However, RF/ID technology is advancing rapidly, as shown by a recent demonstration put on for the media where a grocery cart full of

supermarket items tagged with transponders was walked through a check stand equipped with a reader system. A receipt delineating the items and prices was produced instantly, and since the shopper was also equipped with a transponder for billing, the transaction was completed in a matter of seconds.

The biggest limitation for RF/ID at this time may be cost. While the prices of bar-code labels are measured in pennies, transponder prices are measured in dollars. Even though transponders might seem expensive, they are reusable and provide capabilities that bar codes do not have. And, the recurring cost of bar codes can make trans-ponders more cost effective in the long run.

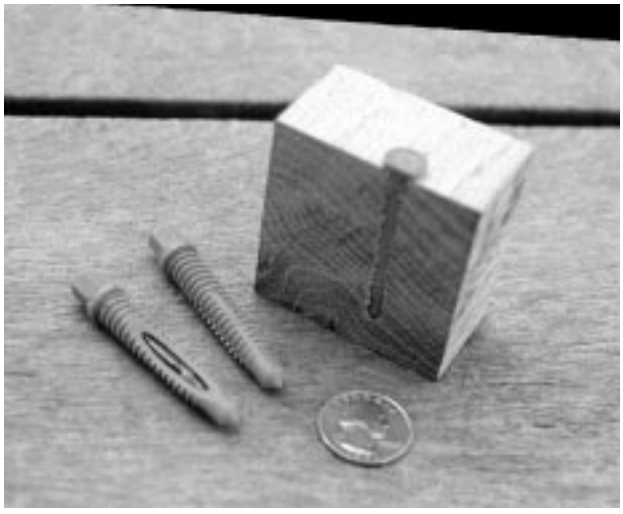
FOREST SERVICE RF/ID

Test Units

Project engi-neers at the Technology and Development Center in San Dimas, CA selected two systems for field trials (see figure 5). These use transponders that are de-signed for use in wood (for identifying and tracking pallets, telephone poles, railroad ties, etc.) The read-only transponders are encapsulated in rubber or plastic shapes that screw-in or press-fit into pre-drilled holes (3/8-inch or 9.5 mm in diameter and 2 inches or 51 mm deep) and have a read range of up to one foot (0.3 m).

Figure 5—The screw-in shape (made by Redex) and the press-in shape (made by EID) were tested on the Tongass NF.

The plastic, screw-in type purchased from Rydex ($14.60 each, part number PT-01261-41) contained a Texas Instruments transponder (see figures 6 and 7). It has a hex-shaped drive head to facilitate installation with a portable, battery-powered drill. This plastic head is designed so that it can be easily removed, making it very difficult to tamper with or remove the transponder. A Texas Instruments reader ($1350, model number RI-HHU-W3DG-00) was used to interrogate the transponder.



Figures 6 and 7 (together)—Portable, battery-powered drill is used to install the screw-in transponders. Cut-aways show transponder and installation.

The rubber-encapsulated, press-fit type transponder ($4.00 each, part number 100-A) and a reader ($1060, model number LID-502) were purchased from Electronic Identification Devices. These transponders were installed quickly and easily by simply pushing them into the hole.

(Another system was purchased, but was not available for the field trial, that uses transponders shaped like nails which are simply hammered into the wood. These transponders ($3.50 each, part number ST 101N) and the associated reader ($800, model number ST 302-2) are available from Microcom. This equipment worked well in backyard trials at the Technology and Development Center.)

All of the readers are hand-held devices that read and store the transponder information along with date/time information. They are equipped with RS-232 ports so data can be easily uploaded to a PC (see figure 8).

Figure 8—Reader interrogating transponder.

Evaluations

Transponders, readers, and installation tools were evaluated for Forest Service use on the Thorne Bay Ranger District of the Tongass National Forest in Alaska. Boundary trees, along with some wildlife and leave trees (mostly spruce and hemlock), on two timber-sale units were marked with transponders. They were installed in the stump at ground level on the downhill side of the tree to make installation, and locating them later for reading, easier. All of the transponders functioned properly, before, during, and after harvesting operations. However, the screw-in type appeared to provide better attachment to the wood since the press-fit type could be pried out and, in one instance, the tree sap pushed out one of the press-fit transponders. Some RF/ID manufacturers recommend using a two-part epoxy rather than the encapsulation shapes (or in conjunction with them) to secure transponders to the trees.

In addition, for over a year all "boom sticks" (large logs that are chained together to contain ocean-going log rafts and are reused many times until they deteriorate) harvested on the Thorne Bay Ranger District were marked with the screw-in transponders (see figure 9). These were installed when the trees were felled and then tracked throughout their use. The transponders were installed in the same place on all boom sticks, four feet (1.2 m) from the large end, and marked with orange paint to facilitate locating and reading them. Transponders and readers performed well in this harsh, salt-water environment. Even when the transponders were under water, the readers were able to receive their signals. All systems tested used the reader to store data and then upload it to a PC. The data could then be displayed and printed in a table showing the transponder identification numbers and the date and time they were read. (Although not used in this field trial, readers are available that are equipped with internal GPS circuits so the precise reading location can also be recorded.)

Figure 9—Reading transponder installed in boom stick (Texas Instruments reader).

Potential Uses

Field trials showed that transponder technology can be used to identify boom sticks and boundary, leave, and wildlife trees. Researchers and nursery personnel have used them to identify and track superior or research-study trees and seedlings. Law Enforcement personnel have evaluated transponders for use in boundary trees and blown-down logs to deter and detect timber theft and provide evidence for prosecution.

Potential Forest Service uses for transponders in addition to those noted previously include: use by timber cruisers and purchasers to locate and positively identify cruise trees and plot centers; for more permanent identification needs such as inventory plot centers that are remeasured every 5 to 10 years or land-line corners; transponders could someday replace branding and painting to improve log accountability. Forest Service or purchaser scalers could use hand-held readers and data recorders to establish log-specific data bases, provide a means for after-the-fact check scaling, and keep accurate inventories. As transponder technology expands and utilization grows, new ideas for ways to use them will evolve.

FUTURE OF RF/ID

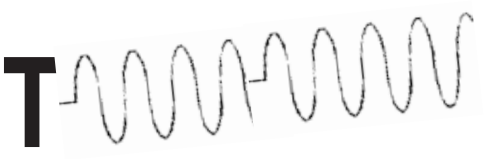
Transponders, like all electronic devices available today, come in various sizes, shapes, capabilities, and costs. Important trends in the RF/ID industry are appearing: systems are being developed where the reader can interact with more than one transponder at a time; integration of a variety of automatic identification technologies, such as bar codes and transponders; and the development of thin, flexible, disposable, and inexpensive transponder tags. The market for transponder systems is in its infancy and the state-of-the-art is changing rapidly as technology advances and applications develop. This means that capabilities are increasing while costs are going down.

While this is good news, there is a tremendous need in the RF/ID industry for established standards. The current trend is to create standards for each specific application. This is partially due to the fact that these varied applications require very different transponder systems. However, without standards, products are not interoperable - each manufacturer uses a distinct frequency and communications protocol. Consequently, transponders and readers have to be purchased from the same supplier to ensure reliable performance.

Figure 10—Reading nail-shaped transponder (made by Microcom).

The development of standards in the bar code industry fueled its explosive growth. Standards allow suppliers and users to store information in such a manner that allows others to retrieve and use that information. Sometimes, market forces provide a de facto standard. (Remember Beta versus VHS and Apple versus Microsoft?)

While there are drawbacks to standards, the advantages outweigh the disadvantages. New standards under development now would allow all systems to read the public segment of every transponder. Standards will create a more competitive market causing the price of RF/ID systems to be greatly reduced. This price reduction will increase applications and these two developments will generate widespread use of RF/ID systems.



FURTHER INFORMATION

The majority of information in this report was obtained from RF/ID manufacturers literature and sales brochures and ADC trade publications. Two of the best trade publications are *Automatic I.D. News* and *ID Systems*. There are a number of others. Trade shows on ADC technology can be found in most major cities on a yearly basis.

Because the state-of-the-art and the RF/ID industry are changing so rapidly, it is recommended that manufacturers be contacted directly to get the latest cost and capability information. A list of RF/ID suppliers can be found in the appendix.

Appendix

ELECTRONIC TAGS, RF/ID SYSTEMS OPERATING FREQUENCIES: LOW FREQUENCY

Aalstec Data Corp
Abraham Technical Services
ADC Technologies
AIM Systems
Alpha Software Inc.
Applied Integration Corp.
Architext Inc.
ASGI
Bar Code Supply Inc.
Barcode & Labeling Consultants Inc.
Barcodes Inc.
Brady USA Inc.
Business Computer Connections Inc.
CardCom Inc.
Data Automation Systems Inc.
Datalogic Inc.
Datamars SA
Deister Electronics USA Inc.
Dimensional Technology Int'l Inc.
Eger Int'l
Electronic Identification Devices Ltd.
Hibbard Information Technologies
HID Corp.
I-Tech Automation Inc.
ID Solutions
ID Technologies Inc.
Idesco Oy
Innovision Corp.
Intelligent Instrumentation
Kearney Systems Inc.
Motorola's Indala Corp.
Omron Electronics Inc.
Peacock Bros. Pty. Ltd.
Pepperl + Fuchs Inc.
Positive ID Wholesale
Productivity Enhancement Products
Provisioner Data Systems Inc
Racom Systems Inc.
SNL Solutions Inc.
SSE Technologies Inc.
Statec Technologies Inc.
Stratman Software Int'l Inc.
Summit Group, The
Sunx Sensors
Symbol Technologies Inc.
System Resources Corp.
Systems Technical Sales Corp.
Telsor Corp.
Texas Instruments
USData
Veridex BV
Wagner Bar Code Products
Whole Solutions
WPI Oyster Termiflex USA
Zetes Electronics

ELECTRONIC TAGS, RF/ID SYSTEMS-OPERATING FREQUENCIES: MICROWAVE

Architext Inc.
Barcode & Labeling Consultants Inc.
Hibbard Information Technologies
Integrated Silicon Design
Omron Electronics Inc.
Pepperl + Fuchs Inc.
Statec Technologies Inc.
Stratman Software Int'l Inc.
System Resources Corp.
TEK Industries Inc.
Texas Instruments
Vidya Data Systems
WareNet Inc.

ELECTRONIC TAGS—RF/ID READERS:FIXED STATION

Abraham Technical Services
Accu-Time Systems Inc.
AccuScan Inc.
AIDEA Inc.
Alpha Software Inc.
Amtech Transportation Systems Group
Architext Inc.
ASC Systems
ASGI
Asset Trading Corp.

Appendix

Aurora Bar Code Technologies Ltd.
Barcode Service Source
Blen-Cal Electronics
Brady USA Inc.
Business Computer Connections Inc.
CIM Vision Int'l
Data Automation Systems Inc.
Data Hunter
Datalogic Inc.
Datamars SA
Deister Electronics USA Inc.
Eaglesoft Corp.
Eger Int'l
Elcom Industries Inc.
G.S.D. Associates Inc.
Hibbard Information Technologies
HID Corp.
HK Systems Inc.
ID Technologies Inc.
Idesco Oy
Integrated Silicon Design
Intelligent Instrumentation
Intermec Corp.
Keyence Corp. of America
Logistic Data Systems Inc.
Lowry Computer Products Inc.
Millennium Software Inc.
Motorola's Indala Corp.
Norland Corp.
Nutech Systems Inc.
Omron Electronics Inc.
Optum Software
Parish Automation Inc.
Peacock Bros. Pty. Ltd.
Peak Technologies Group Inc.
Pepperl + Fuchs Inc.
Positive ID Wholesale
Printelogy
Productivity Enhancement Products
Racom Systems Inc.
Sensor Search and Recruiting
SmarTerminal Computer Co. Ltd.
SSE Technologies
Statec Technologies Inc.
Stratman Software Int'l Inc.
Summit Group, The
Sunx Sensors
System Resources Corp.
Systems Technical Sales Corp.
TEK Industries Inc.
Telsor Corp.
Texas Instruments
USData
Winco Identification Corp.

ELECTRONIC TAGS —RF/ID READERS: HANDHELD

Abraham Technical Services
AccuScan Inc.
ADC Technologies
AIM Systems
ALC Technologies PTE Ltd.
Alpha Software Inc.
AmeriCode Technologies Inc.
Applied Integration Corp.
Architext Inc.
ASC Systems
ASGI
Asset Trading Corp.
Aurora Bar Code Technologies Ltd.
Bar Code Applications Inc.
Bar Code Resources, A Div. of Allen Mgt. Inc.
Bar Code Supply Inc.
Barcode & Labeling Consultants Inc.
Barcode Int'l Solutions
Barcode Service Source
BCSI Inc.
Brady USA Inc.
Business Computer Connections Inc.
CardCom Inc.
Chafin, Goetz & Williams Inc.
Corvallis Microtechnology
Current Directions Inc.
Data Hunter
Datalogic Inc.
Datamars SA
Datex Inc.
Deister Electronics USA Inc.
Dimensional Technology Int'l Inc.
Dott Computer Systems Inc.
Dynasys Technologies Inc.
Eaglesoft Corp.
Eger Int'l

G.S.D. Associates Inc.
Glen Road Systems Inc.
Hans Systems Co. Ltd.
Heartland Computers Inc.
Hibbard Information Technologies
HID Corp.
HK Systems Inc.
I-Tech Automation Inc.
I.O. Solutions Inc.
ID Technologies Inc.
Idesco Oy
Innovision Corp.
Integrated Silicon Design
Intermec Corp.
Lowry-Marprint
Metanetics Corp.
Metropolitan Sales Co.
Millennium Software Inc.
Mission Critical Software Inc.
Motorola's Indala Corp.
NER Data Products Inc.
Nichiei Intec (USA) Corp.
Nimax Inc.
Norand Corp.
Omron Electronics Inc.
Optical Polymers Int'l
Optum Software
Orchid Systems Inc.
PAR Microsystems Corp.
PAR Supply Co.
Paradise Information & Communication Co. Ltd.
Parish Automation Inc.
Peacock Bros. Pty. Ltd.
Peak Techologies Group Inc.
Pepperl + Fuchs Inc.
Percon Inc.
Portable Products Inc.
Positive ID Wholesale
Printelogy
Product Identification & Processing Systems Inc.
Productivity Enhancement Products
Progressive Microtechnology Inc.
Provisioner Data Systems Inc.
Racom Systems Inc.
Scan Technology Inc.
Sensor Search and Recruiting
SNL Solutions Inc.
Stratix
Stratman Software Int'l Inc.
Summit Group, The
Systacom Bar Code Systems Inc,
System Resources Corp.
Systems Technical Sales Corp.
Telsor Corp.
Texas Instruments
Time Keeping Systems Inc.
USData
Vector USA Inc.
Veridex BV
Vidya Data Systems
Wagner Bar Code Products
Winco Identification Corp.
World Information Systems Inc.

ELECTRONIC TAGS—RF/ID TAGS/ TRANSPONDERS: ACTIVE

Alpha Software Inc.
Amtech Transportation Systems Group
ASGI
Aurora Bar Code Technologies Ltd.
Bar Code Applications Inc.
Barcode Int'l Solutions
Brady USA Lin.
Data Automation Systems Inc.
Hibbard Information Technologyies
Interfacers Workshop Inc.
Motorola's Indala Corp.
Pepperl + Fuchs Inc.
Sensor Search and Recruiting
Statec Technologies Inc.
TEK Industries Inc.
Texas Instruments
WarNet Inc.

ELECTRONIC TAGS—RF/ID TAGS/ TRANSPONDERS: ACTIVE, REPLACEABLE BATTERY

Alpha Software Inc.
Amtech Transportation Systems Group

Appendix

Datalogic Inc.
Deister Electronics USA Inc.
Hibbard Information Technologies
Interfacers Workshop Inc.
WareNet Inc.

ELECTRONIC TAGS—RF/ID TAGS/ TRANSPONDERS: PASSIVE

A.C.C. Systems Inc.
Alpha Software Inc.
Amtech Transportation Systems Group
ASGI
Aurora Bar Code Technologies Ltd.
Bar Code Applications Inc.
Barcode Int'l Solutions
Brady USA Inc.
CIM Vision Int'l
Datalogic Inc.
Datamars SA
Deister Electronics USA Inc.
Dimensional Technology Int'l Inc.
Eger Int'l
Electronic Identification Devices Ltd.
G.S.D. Associates Inc.
Hibbard Information Technologies
HID Corp.
ID Solutions
ID Technologies Inc.
Idesco Oy
Infoscan Inc.
Integrated Silicon Design
Intelligent Controls Inc.
Interfacers Workshop Inc.
Mitsubishi Cable America Inc.
Motorola's Indala Corp.
Omron Electronics Inc.
Pepperl + Fuchs Inc.
Productivity Enhancement Products
Racom Systems Inc.
Sensor Search and Recruiting
Southern Micro Systems Inc.
Statec Technologies Inc.
Telsor Corp.
Texas Instruments
WareNet Inc.
Zetes Electronics

ELECTRONIC TAGS—RF/ID TAGS/ TRANSPONDERS:READ-ONLY TAGS

A.C.C Systems Inc.
Alpha SoftwareAmtech
Transportation Systems Group
Brady USA Inc.
Datalogic Inc.
Datamars SA
Deister Electronics USA Inc.
Electronic Identification Devices Ltd.
Glen Road Systems Inc.\
Hibbard Information Technologies
HID Corp.
ID Technologies Inc.
Idesco Oy
Intelligent Controls Inc.
Interfacers Workshop Inc.
Motorola's Indala Corp.
Omron Electronics Inc.
Pearl Worldwide Industries Inc.
Pepperl + Fuchs Inc.
Printelogy
Productivity Enhancement Products
Racom Systems Inc.
Security Printing Corp.
Statec Technologies Inc.
TEK Industries Inc.
Telsor Corp.
Texas Instruments
WareNet Inc.
Winco Identification Corp.

ELECTRONIC TAGS —RF/ID TAGS/ TRANSPONDERS:READ/WRITE TAGS

Alpha Ssoftware Inc.
Amtech Transportation Systems Group
ASGI
Datalogic Inc.
Deister Electronics USA Inc.
Dimensional Technology Int'l Inc.
Hibbard Information Technologies
HID Corp.
Idesco Oy
Integrated Silicon Design

Appendix

Interfacers Workshop Inc.
Motorola's Indala Corp.
Omron Electronics Inc.
Paradise Information & Communication Co. Ltd.
Pepperl + Fuchs Inc.
Printelogy
Product Identification & Processing Systems Inc.
Productivity Enhancement Products
Racom Systems
Statec Technologies Inc.
Sunx Sensors
TEK Industries Inc.
Telsor Corp.
Texas Instruments
Uarco
WareNet Inc.

Company Directory

A.C.C. Systems Inc.
(516) 674-0191

Aalstec Data
(313) 962-7790

Abraham Technical Services
(800) 478-8644

Accu-Time Systems Inc.
(860) 870-5000

AccuScan Inc.
(770) 457-3310

ADC Technologies
(714) 752-2328

AIDEA Inc.
(317) 842-3036

AIM Systems
(805) 238-4567

ALC Technologies PTE Ltd.
+65 354-1650

Alpha Software Inc.
(804) 272-1266

AmeriCode Technologies Inc.
(888) 400-7226

Amtech Transportation Systems Group
(800) 923-4824

Applied Integration Corp.
(520) 743-3095

Applied Systems Technologies
(402) 292-1144

Architext Inc.
(210) 490-2240

ASC Systems
(313) 882-1133

ASGI
(703) 733-0480

Asset Trading Corp.
(303) 989-4416

Aurora Bar Code Technologies Ltd.
(403) 483-6025

Bar Code Applications Inc.
(604) 451-7878

Bar Code Resources
(414) 760-2300

Bar Code Supply Inc.
(800) 775-5581

Barcode & Labeling Consultants Inc.
(770) 889-9568

Barcode Int'l Solutions
(909) 270-0016

Barcode Service Source
(616) 591-0455

Barcodes Inc.
(773) 381-3500

BCSI Inc.
(602) 788-4755

Blen-Cal Electronics
(516) 242-6243

Brady USA Inc.
(800) 368-3374

Business Computer Connections Inc.
(810) 615-1500

CardCom Inc.
(714) 833-8243

Chafin, Goetz & Williams Inc.
(423) 892-2902

Company Directory

CIM Vision Int'l
(310) 792-9099

Corvallis Microtechnology (CMT)
(541) 752-5456

Current Directions Inc.
(216) 354-5655

Data Automation Systems Inc.
(408) 983-0449

Data Hunter
(714) 892-5461

Datalogic Inc.
(606) 689-7000

Datamars SA
+46 (0) 91 968 2701

Datex Inc.
(813) 891-6464

Deister Electronics USA Inc.
(703) 368-2739

Dimensional Technology Int'l Inc.
(612) 784-2994

Dott Computer Systems Inc.
(810) 767-7070

Dynasys Technologies Inc.
(813) 443-6600

Eaglesoft Corp.
(206) 682-4830

Eger Int'l
(800) 343-7773

Elcom Industries Inc.
(800) 353-5266

Electronic Identification Devices Ltd.
(805) 565-1288

G.S.D. Associates Inc.
(541) 342-2052

Glen Road Systems Inc.
(215) 576-7756

Hans Systems Co., Ltd.
+82 2-539-0690

Heartland Computers Inc.
(800) 708-7226

Hibbard Information Technologies
(714) 733-2323

HID Coorp.
(714) 573-7297

HK Systems Inc.
(414) 860-6676

I-Tech Automation Inc.
(847) 726-9340

I.O. Solutions Inc.
(503) 646-3333

ID Solutions
(206) 775-2320

ID Technologies Inc.
(303) 546-9546

Idesco Oy
+358 8 557 4365

Infoscan Inc.
(612) 639-0301

Innovision Corp.
(770) 643-1118

Integrated Silicon Design
+61 08-8223-5802

Intelligent Controls Inc,
(206) 771-8107

Company Directory

Intelligent Instrumentation
(800) 685-9911

Interfacers Workshop Inc.
(800) 443-9747

Intermec Corp.
(800) 347-2636

Kearney Systems Inc.
(407) 740-5220

Keyence Corp. of America
(201) 930-1400

Logistic Data Systems Inc.
(414) 549-5600

Lowry Computer Products Inc.
(810) 229-7200

Lowry-Marprint
(800) 429-7722

Metanetics Corp.
(941) 939-4415

Metropolitan Sales Co.
(800) 638-3478

Millennium Ssoftware Inc.
(813) 736-6616

Mission Critical Software Inc.
(810) 247-0394

Mitsubishi Cable America
(201) 343-1818

Motorola's Indala Corp.
(408) 383-4000

NER Data Products Inc.
(609) 881-5524

Nichiel Intec (USA) Corp.
(813) 791-9805

Nimax Inc.
(619) 452-2220

Norand Corp.
(319) 369-3100

Nutech Systems Inc.
(905) 238-0575

Omron Electronics Inc.
(847) 843-7900

Optical Polymers Int'l
(203) 882-9093

Optum Software
(714) 557-9050

Rochid Systems Inc.
(617) 431-7446

PAR Microsystems Corp.
(770) 448-6135

PAR Supply Co.
(314) 839-5533

Paradise Information Communication Co. Ltd.
+82 2-711-0085

Parish Automation Inc.
(908) 528-1300

Peacock Bros. Pty. Ltd.
+61 39-563-1900

Peak Technologies Group Inc.
(410) 312-6000

Pearl Worldwide Industries Inc.
(914) 232-5906

Pepperl + Fuchs Inc.
(330) 425-3555

Percon Inc.
(800) 929-7899

Company Directory

Portable Products Inc.
(800) 849-0985

Positive ID Wholesale
(716) 692-2008

Printelogy
(303) 757-1711

Producá»Identification & Processing Sys Inc.
(888) 722-6772

Productivity Enhancement Products
(714) 348-1011

Progressive Microtechnology Inc.
(513) 891-1554

Provisioner Data Systems Inc.
(954) 427-7007

Racom Systems Inc.
(303) 771-2077

Scan Technology Inc.
(352) 332-2093

Security Printing Corp.
(213) 838-8300

Sensor Search and Recruiting
(713) 658-9343

SmarTerminal Computer Co. Ltd.
(822) 790-5505

SNL Solutions Inc.
(914) 567-1765

Southern Micro Systems Inc.
(770) 984-2266

SSE Technologies
(516) 872-9001

Statec Technologies Inc.
(704) 895-1199

Stratix
(770) 399-5921

Stratman Software Int'l Inc.
(860) 677-2898

Summit Group, The
(219) 272-8500

Sunx Sensors
(515) 225-6933

Symbol Technologies Inc.
(800) 722-6234

Systacom Bar Code Systems Inc.
(800) 544-5303

System Resources Corp.
(617) 270-9228

Systems Technical Sales Corp.
(206) 462-8088

TEK Industries Inc.
(860) 647-8738

Telsor Corp.
(303) 790-8877

Texas Instruments
(972) 917-1462

Time Keeping Systems In.
(216) 595-0890

Uarco
(847) 381-7000

USData
(972) 680-9700

Vector USA Inc.
(813) 817-0966

Veridex BV
+31 (0)46 457 2285

Company Directory

Veritec Inc.
(818) 880-5112

Vidya Data Systems
(415) 661-7780

Wagner Bar Code Products
(810) 360-0243

WareNet Inc.
(770) 753-3150

Whole Solutions
(610) 718-0856

Winco Identification Corp.
(603) 590-1553

World Information Systems Inc.
(910) 333-2580

WPI Oyster Termiflex USA
(603) 424-3700

Zetes Electronics
+32 (0)2 728 37 11