Available online at www.sciencedirect.com
ScienceDirect
Technovation 26 (2006) 1317–1323
technovation
www.elsevier.com/locate/technovation

Challenges to global RFID adoption

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Abstract

Because of its potential to revolutionize global supply chain management (SCM) systems, ultra high-frequency (UHF) radio frequency identification (RFID) was recently the cause of much optimism. Wal-Mart mandated its top 100 suppliers to begin using RFID on 1 January 2005; this day was viewed as a watershed day in the industry. However, that date has come and gone, and the expected rapid industry adoption of RFID has not taken place. This paper explores the existing challenges and obstacles to RFID's quick adoption, the potential resolutions and approaches to the challenges, and the migration strategies to expand the RFID industry.

Keywords: Supply chain management (SCM); Radio frequency identification (RFID); Industry analysis

1. Background: the promises of RFID

Radio frequency identification (RFID) is a small tag containing an integrated circuit chip and an antenna, and has the ability to respond to radio waves transmitted from the RFID reader in order to send, process, and store information. The RFID system consists of three basic components: a tag, a reader, and back office data-processing equipment. The tag contains unique identification information of the item to which it is attached; the reader emits and receives radio waves to read the information stored in the tag, and the data-processing equipment processes all the collected data. This equipment can be as simple as a personal computer or as complex as an entire networked enterprise management information system.

Low-frequency (LF) and high-frequency (HF) active RFIDs operating with battery power and a moderate sized antenna can transmit over long distances. Thus, they can be used for livestock tracking, access control, point of sale (POS), etc. RFID has also been used for public transportation payment by embedding RFID into prepaid cards. In this example, the reader reads the amount left in the card; then, the data-processing equipment deducts the amount; and finally, the remaining amount of money will be recorded in the prepaid card.

Nonetheless, the biggest potential lies in ultra high-frequency (UHF) passive RFIDs which operate without battery and a very small-sized antenna can be used for item tracking, especially useful for global supply chain management (SCM). Once all goods are attached with RFID tags, their whereabouts can be tracked automatically by radio readers, which give complete inventory visibility and supply chain management efficiency.

Wal-Mart, the world's largest retailer, is expected to handle about four billion cartons in 2004 and five billion cartons in 2005 (Nogee, 2004). Any small increase in the efficiency of tracking goods in its global supply chain could generate tremendous benefits. Wal-Mart not only believes that the RFID system can reduce its labor and inventory costs but also thinks that its revenues will be increased by limiting the out-of stock items throughout its chain stores around the world. The US Department of Defense (DOD) and Wal-Mart both mandated their largest suppliers to begin tagging all goods delivered to their warehouses starting from 1 January 2005, while the remaining suppliers should follow within 1 year. Given Wal-Mart's enormous purchasing power and influence on its global suppliers, it has the potential to become the driving force to push for worldwide adoption of RFID systems.

In the past few years, RFID technology has led to much hope and optimism. The mainstream press hails RFID as

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0166-4972/$ - see front matter
doi:10.1016/j.technovation.2005.08.012

the avant-garde in technology and business. For example, CNN identified RFID as one of the "Ten Technologies to Watch" in 2004, and ZDNet named RFID as one of the 10 most strategic technologies in 2005. However, RFID vendors are complaining that the business is not growing as fast as expected.

Studies of barcode history (T & W Enterprises) showed that it took approximately 25 years from the development of the first barcode by the Drexel Institute of Technology in Philadelphia in 1949 to the first commercial barcode scanner installation at a Marsh's Supermarket in Ohio in 1974. The developmental timeframe of RFID is similar. Approximately 25 years have passed between the first RFID technology developed by the Los Alamos Scientific Laboratories in 1977 and EPCglobal's announcement of the EPC Generation 1 RFID standard in 2003 (Laran RFID, 2004). What would be a reasonable timeframe expectation for RFID to replace barcode on merchandise label?

The purpose of this paper is to examine the existing challenges that RFID technology is facing, its future development directions and obstacle resolution approaches, and the likely migration path to realize its promises.

Section 2 summarizes the present hurdles and challenges that hinder global RFID adoption. Section 3 describes promising development directions toward facing the challenges. Section 4 recommends strategic perspectives for the growth of the RFID industry.

2. Present realities: challenges to RFID adoption

Despite the promising applications of RFID in SCM, a number of challenges have hampered the adoption of RFID. This paper will address the attitudes needed to face these challenges and reasonable directions to commercialize this technology. The major issues can be broken down into technology challenges, standard challenges, patent challenges, cost challenges, infrastructure challenges, return on investment (ROI) challenges, and barcode to RFID migration challenges.

2.1. Technology challenges

2.1.1. Material effects on antenna power pattern

A passive RFID tag has no power source of its own; it relies on its antenna to receive radio waves emitted by the reader and converts these radio waves into electrical power. The data stored in the chip can be transmitted back to the reader via the tag antenna. Therefore, the antenna plays a key role in the radio communication between the tag and the reader. Radio waves will be reflected and refracted differently by the different materials to which a tag is attached. If UHF radio waves propagate toward liquid, a large portion of the radio energy will become refracted into the liquid. If UHF radio waves pass onto metal, a large portion of the radio energy will become reflected. In both cases, there will be signal strength degradation and interference in the reception quality of the tag antenna (Nogee, 2004; Accenture White Paper, 2001). Consumer products with a high percentage of water such as shampoo or juice, and canned goods with metal cases refract and reflect RF waves, respectively (Mullen, 2004a; AIM, 2000). Radio waves reflected from multiple objects may cause multi-path interference to the receiving antenna.

Fig. 1 shows the difference between the normal antenna power pattern of a stand-alone RFID tag and that of an RFID tag attached to certain radio-absorbing material. A major tire manufacturer once reported that it was difficult to read tags placed on tires because tires are made of reinforced carbon, which absorbs RF energy (RFID Journal News, 2004d).

2.1.2. Tag antenna orientation affects radio wave reception

RFID technology allows non-line-of-sight, non-contact, and multiple-tag simultaneous-reading capabilities, which is more efficient than scanning barcodes for product tracking. However, RFID readability can be affected by the relative position and orientation of the tag antenna and the reader antenna, because antenna orientation affects its power pattern (Finkenzeller, 2003). As a result, if a tag antenna is perpendicular to a reader antenna, the former cannot receive the latter's radio signal. Fig. 2 illustrates that Tags A and B cannot be read by reader antenna C. In addition, if obstacles exist between two antennas, the radio signal strength will be attenuated so the reading range will also be reduced (Accenture White Paper, 2001). In real-world goods-tracking applications, RFID tags attached on variety products will have random antenna orientations, while some tag antennas may happen to be perpendicular to a reader antenna by chance. This will cause such tags to be unreadable as they travel through the portal with just one uni-directional reader antenna (Alien, 2002). As shown in Fig. 2, an additional reader antenna D with a different orientation to that of antenna C could resolve this problem.

2.1.3. Collision caused by simultaneous radio transmission

If an RFID system is designed so that tags are read one at a time by a reader, the chances of successful reading are

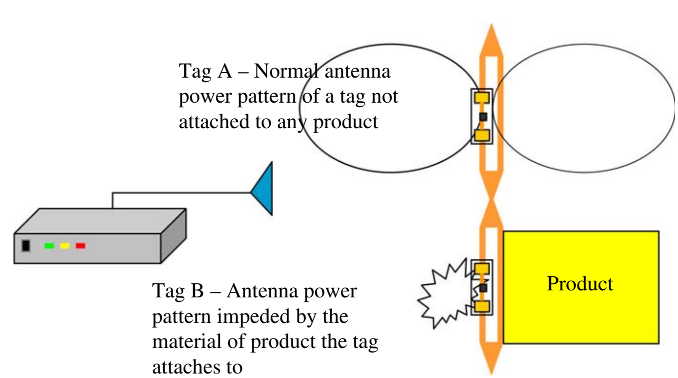

Fig. 1. Antenna power patterns of RFID tags.

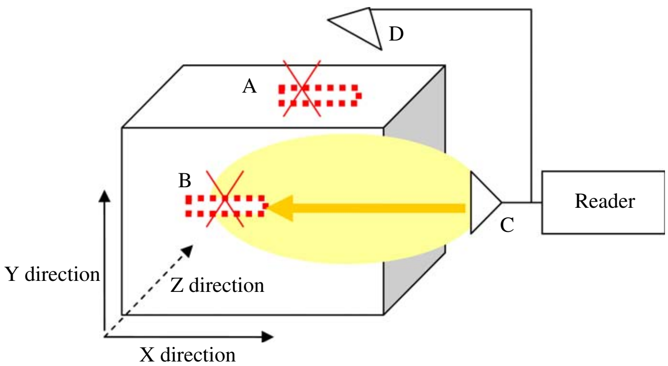

Fig. 2. Tag antenna orientation issue.

high. However, it is time-consuming, especially with a large number of tags. In UHF RFID applications, hundreds of tags may respond simultaneously to a reader's signal. Simultaneous transmitted radio signals may cause collision interference to the receiver. In order for a reader to communicate with multiple tags, some techniques of collision-resolution protocol must be employed.

There are three major anti-collision procedures (Finkenzeller, 2003) to achieve multiple tag reading. Because anti-collision procedures require additional communication sessions, the reading speed will be delayed. An alternate method known as binary search can prevent tag signal collisions (Wu, 2003; Roesner, 2004).

When a large number of tags are being read simultaneously, it is difficult to identify those tags which have failed to be read. It is a serious problem in any tracking system if 100% accuracy cannot be achieved.

2.2. Standard challenges

There are three major advantages of developing international standards for RFID systems. First of all, a common RFID standard will ensure interoperability among tags and readers manufactured by different vendors and allow for seamless interoperation across national boundaries (Finkenzeller, 2003). Secondly, due to compatibility and exchangeability, the demand for RFID components and equipment will be high which can bring the cost down (Pine et al., 2003). Finally, an internationally accepted RFID standard will facilitate the growth of the worldwide RFID market (Harrop and Das, 2002).

2.2.1. Lack of a unified RFID standard

Currently, there are two major organizations working to develop international standards for RFID technologies in the UHF spectrum. These two organizations are EPCglobal and International Standards Organization (ISO). EPCglobal released its EPC class 1 G2 protocol (EPCglobal Inc., 2005) for the UHF band at the end of 2004, and the ISO released its 18000-6 in August of 2004. Both standards are still evolving and are not completely compatible with each other (EPCglobal Press Release, 2005). A unified, globally interoperable RFID standard is ideal to realize the full benefits of RFID applications. The lack of a complete and unified RFID standard has caused many companies to hesitate in adopting the RFID systems; these companies were afraid of making a commitment that might render their entire RFID system investment worthless in the future.

2.2.2. Lack of consistent UHF spectrum allocation for RFID

Regulations on radio spectrum allocation for RFID use are not unified among nations. A large portion of the UHF spectrum has already been auctioned to cellular phone service providers for high license fees by a few countries. It would be difficult, if not impossible, to buy that portion of spectrum back for RFID use. This adds complexity to the adoption of RFID for global supply chain management applications where tagged goods must often travel across borders. RFID tags which respond only to a specific UHF frequency range cannot be read in countries where different spectrum bands are allocated for RFID use (Finkenzeller, 2003; Min et al., 2003; Mullen, 2004b).

The United States and Canada can allocate the frequency band from 902 to 928 MHz for UHF RFID systems because their GSM bandwidths are not located within this band. Outside North America, however, the frequency band around 915 MHz is almost exclusively used for wireless communications services such as GSM, PHS, GPRS or 3G (Finkenzeller, 2003; Mullen, 2004b; Sarma et al., 2002). The European Telecommunications Standards Institute (ETSI) has released a 2 MHz band ranging from 865.6 to 867.6 MHz for Europe's UHF RFID use in July 2004 (RFID Journal News, 2004b). Japan has allocated a 2 MHz UHF band ranging from 953 to 954 MHz for RFID use in May 2005 (ARIB, 2005). The diversity in national spectrum allocation for RFID adds more hurdles to the growth of RFID systems in the world market.

In addition to the unavailability of common spectrum bandwidths for RFID systems, power regulations and certification procedures are also incompatible from country to country (Mullen, 2004a).

2.3. Patent challenges

The purpose of developing international standards is to leverage existing intellectual properties (IPs) and technologies from all vendors in the industry. Under EPCglobal's IP policy, which all EPC subscribers must sign, companies holding IPs that adhere to EPC standards must declare their IPs and indicate whether they will make the IPs available to other vendors on a royalty-free basis or a RAND (reasonable and non-discriminatory) royalty-bearing basis (EPCglobal, 2003). Although the EPC G2 standard has already been formally released, the royalty payments for IPs involved in this standard are still unclear. One example of confusion is as follows: in June 2004, Intermac filed a patent-infringement lawsuit against Matrics (RFID Journal News, 2004a) and spelled out its licensing plan to vendors of EPC Gen 2 products. (RFID Journal News, 2004c). Potential vendors concerned about paying high royalty cost is another obstacle holding back the development of RFID systems.

2.4. Cost challenges

RFID holds much promise for increasing goods screening and monitoring efficiency, but costs still stand in the way. The cost elements can be broken down in the following ways.

2.4.1. Manufacturing costs

In November of 2001, Sanjay Sarma of the Auto ID Center, an influential industry promotion group, published a White Paper titled "Towards the Five-Cent Tag" (Sarma, 2001). This report envisioned a chip-based, passive, packaged 64-bit read-only RF tag that would be cheap enough to enable usage on a mass scale, all the way down to the individual item level. Sanjay predicted that a five-cent tag would be achievable in the near future. Today, prices for passive tags currently range from $0.15 to $1.10, depending upon the volume of tags produced and the complexity of tag functions (Nogee, 2004).

Based on industry marketing reports (Instat/MDR December, 2004), tag cost structure can be broken down as follows (Nogee, 2004):

1. *Chip*: Generally in the range of $0.25–$0.35 a piece in quantities of roughly 1–10 M.
2. *Inlay/Substate with antenna*: From $0.02 to $0.10 and beyond, depending on the size and the material used.
3. *Assembly*: Typically from $0.02 to $0.04.
4. *Licensing*: Referencing Intermec's licensing plan, 5–7.5% of the hardware value.

There are two major cost elements constituting the tag cost; one is the chip cost and the other is the assembly cost. Chip cost is related to the die size and fabrication yield. For example, one six-inch wafer can produce more than 15–20 thousand chips, but the wafer, mask, and chip preparation costs are shared among only the good chips. An RFID chip consists of analog logic, digital logic, and memory circuitry; thus, it is a challenge to keep error rates low in the chip fabrication process. The chip cost can decrease if the chip order volume becomes large.

Because RFID chips are very small in size (0.4–1.0 mm^2), and the antenna inlay material, such as PET, is very soft, it is also a challenge to perform RFID chip assembly at a very high throughput with a high accuracy.

As a result, the goal of a five-cent tag will require efforts from every participant in the value chain before it can be realized. Unless customers have an urgent need that can be solved by RFID, they tend to wait until RFID tag prices drop and standards are sorted out before making any investments. The high cost of the RFID tag is a major reason why the market penetration of RFID remains stagnant.

2.4.2. Customization costs

A UHF RFID system can collect data from hundreds or thousands of goods simultaneously. It can generate a large throughput of data, and requires considerable computing power and system integration to collect and process all the data. However, many users and system integrators (SI) assumed that installing an RFID system is a simple task and all tags will be accurately read by readers. As described in the previous sections, the presence of objects in the vicinity of the tags and readers will interfere with radio signal propagation. As a result, the RFID system's greatest challenge is to assure that all tags are read successfully.

An RFID system must be customized for its specific working environment and application purposes. For example: (1) the tags and readers need to operate in the radio spectrum band licensed by the country's regulations; (2) tag antenna design needs to consider the types of material they will be attached to beforehand; and (3) multiple readers must be installed at proper locations with serious consideration of the tags' and readers' antenna orientation, the RFID system's operations environment, and the client's mission and performance expectations of the RFID application. Therefore, the successful operation of an RFID system will have to incur considerable system design, customization and configuration costs.

2.5. Infrastructure challenges

The adoption of a UHF RFID system along an entire supply chain will benefit multiple companies. Industry supply chains can be quite long and can often cross international borders. For example, an industry supply chain may begin with a manufacturer who assembles goods from parts imported from around the world. The finished goods may be sent via trucks to a warehouse for distribution, then to an airport or seaport for international transport, then to an overseas distributor's warehouse, and then again to individual retail stores by trucks. Ideally, at every stage in the chain, RFID readers will track the flow of goods, thereby increasing the management efficiency in the entire chain.

But in order to achieve this goal, an entire RFID infrastructure must first be established (Ornauer et al., 2004). This will allow for the collection of real-time tag information from anywhere in the supply chain, including the manufacturer's factory, local logistic/warehouse, air cargo, foreign logistic/warehouse and the retailer or department stores.

The shipment of goods involves multiple manufacturing companies, multiple transportation companies, and multiple sea ports and airport authorities; therefore, the entire RFID infrastructure available to track every tagged item from the beginning to the end of the supply chain is really a challenge.

2.6. ROI challenges

ROI is an important consideration in assessing RFID investments. Expectations of RFID benefits can be broken down into two parts: the first is cost reduction (e.g. labor cost reduction, inventory cost reduction, process automation, and efficiency improvements, etc.), and the second is value creation (e.g. increase in revenue, increase in customer satisfaction due to responsiveness, and anti-counterfeiting, etc.). As discussed, no comprehensive RFID infrastructure exists as yet. It is difficult to calculate the true returns based on limited benefit information from pilot projects in segmented RFID system installations. More realistic returns on investment could be achieved in the future, when an RFID infrastructure is built across the entire supply chain and economy of scale effect brings down costs of the RFID components and equipment.

2.7. Barcode to RFID migration challenges

To date, RFID technology is still developing, standards are still converging, and costs are still being brought down in order to attach tags to individual consumer products. However, the barcode system is deeply entrenched and will not be replaced any time soon. This means that both barcodes and RFID systems have to co-exist in parallel for a long time to come. The migration from barcodes to the RFID system will not only increase demands on system capabilities and compatibilities but also increase costs on maintenance and operation of both systems.

3. Future development directions

While the challenges to worldwide adoption of RFID are significant, they are not insurmountable. As with many other emerging new technologies, it will simply take time for reality to meet ends with the ideals. As more efforts are put in for RFID research and development, more pilots will be run and more data will be collected; these can be used to solve problems that stand in the way of widespread adoption. This is an ongoing process. The following describes some recommendations to meet the challenges of successful global RFID systems' deployment.

3.1. Resolutions to technology issues

It is imperative that RFID systems eventually approach 100% reliability. This could be achieved in a number of ways: customizing the tag antenna design for each material type of goods, installing multiple antennas with different orientations per reader, and installing multiple readers to increase tag readability. The binary search technique is emerging as a viable solution for reading numerous tags simultaneously. Tags that have been read will be put to "sleep" in order to prevent them from transmitting repeatedly. Ongoing research on tag placement and orientation will help maximize antenna power pattern and probability of successful reading.

3.2. Resolutions to standards and regulatory issues

Government organizations must work out regulations and standards for spectrum allocation and compatible technical specifications. However, to some extent technology itself can compensate for the differences in regulations and standards. For example, broadband RFID chips that can deal with a broad spectrum of UHF frequencies and broadband antennas that can transmit and receive radio frequencies in a broad spectrum band have both been developed. Hence, such RFID tags can be read by readers emitting radio wave in different spectrum bands allocated by different countries. Finally, multiple-protocol readers that could work with different RFID standards are being developed.

3.3. Resolutions to cost issues

Costs remain the largest impediment for the widespread adoption of RFID. A key to reducing costs is to increase the volume of demand; this can be facilitated if a unified global RFID standard exists. A universal RFID chip, which can be used by different applications in different countries, is an ideal to pursue; this ideal universal RFID chip would have a frequency-independent capability and would be integrated with read/write memory. Furthermore, for an RFID chip to satisfy the requirements of multiple applications, a minimum set of commands must be designed so that it can be customized by software for a variety of applications.

Other than the chip costs, the costs of packaging an antenna to a chip to become a module and attaching a module to a merchandise also need to be minimized. Right now, barcodes appear on labels of almost all merchandises. They are printed with all other information on the label in the print shop. If RFID tags are expected to appear on the labels of all products one day, they definitely cannot be attached by manual labor. Therefore, print shop automation machines that can print antennas and automatically paste RFID chips on merchandise labels are also critical research topics.

4. Deployment recommendations

4.1. Stand-alone applications first

RFID spectrum allocation and regulations will not easily be made unified and globally interoperable across different countries. RFID-friendly infrastructure throughout a supply chain is also not something to expect any time soon. Companies adopting RFID systems should start with a specific application for an internal organizational mission; the decisions to purchase RFID tags and readers could be made autonomously. Initially, this is necessary for the tracking of relatively expensive goods. An increase in efficiency or a reduction of loss of such goods will more easily justify the investment of RFID tags and systems. Once RFID systems prove to be effective and economical within companies, interoperable RFID systems across companies may proliferate. Interoperable RFID systems across country boarders will require negotiations among governments. RFID systems will obviously involve more than just economical considerations of businesses. Because the supply chain and logistics management cost could range from 6% to 13% of a company's revenue, reducing logistics cost and enhancing the visibility of SCM will benefit not only manufacturers but also retailers and consumers as well. RFID will undoubtedly be pushed and adopted in the SCM market gradually.

4.2. *Pallet or carton-level tracking first*

Retailers wish to use RFID readers to read price tags of purchased merchandises at checkout counters. RFID technology is limited due to the following facts: different merchandises are packaged by different materials and manufactured in different countries; most importantly, other merchandises in a shopping cart may obstruct radio waves from reaching some RFID tags. At the merchandise level, 100% reading accuracy for RFID tags is still difficult to achieve. However, tracking RFID tags at the pallet or carton level is already technically feasible and will begin to take off very soon.

4.3. *What to expect*

RFID technology is still becoming mature and the industry is still young. Its full impact is not yet foreseeable and there is still much promise for the future. It will simply take some time to realize its full potential.

References

Accenture White Paper, 2001. Radio Frequency Identification (RFID) White Paper.

AIM, 2000. Draft Paper on the Characteristics of RFID System, AIM Frequency Forums. AIM FF 2000:001.

Alien, 2002. RFID Primer. Rev A.

ARIB, 2005. Standard Regulation for 950 MHz band RFID device, ARIB Standard Meeting No. 58, ARIB STD-T89 1.0, http://www.arib.or.jp/tyosakenkyu/sakutei/sakutei02-2.html.

EPCglobal, 2003. EPCglobal Intellectual Property Policy. Working Group Declaration, Rev. 12/15/2003 A, 15 December 2003, http://www.epcglobalinc.org/action_groups/031223EPCglobalIPPolicy12152003A.html.

EPCglobal Press Release, 2005. EPCglobal AFI Committee Reaches Recommendation on Numbering Management—Resolution Clears Way for EPCglobal UHF Gen 2 Submission to ISO, 18 January 2005, http://www.epcglobalinc.org/news/pr_detail_epcinc.cfm?release_id=185.

EPCglobal Inc., 2005. EPC™ Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID Protocol for Communications at 860–960 MHz, Version 1.0.9, 31 January 2005.

Finkenzeller, K., 2003. RFID Handbook—Fundamentals and Applications in Contactless Smart Cards and Identification, second ed. Wiley, New York.

Harrop, P.J., Das, R., 2002. The Smart Label Revolution. ID TechEx Ltd.

Laran RFID, 2004. A Basic Introduction to RFID Technology and its uses in the Supply Chain, http://www.idii.com/wp/LaranRFID.pdf, January 2004, available: 01-05-2004.

Min, H., Zhou, F., Shang-ling, Jui, S.-L., Wang, T., Chen, X., 2003. RFID in China, Auto-ID Center White Paper.

Mullen, D., 2004a. RFID Technology Overview. Global Aviation Forum, AIM.

Mullen, D., 2004b. RFID Technology Overview. Global Aviation Forum, 9 June 2004. Atlanta, GA.

Nogee, A., 2004. RFID Tags and Chip: Changing the World for Less Than the Price of a Cup of Coffee. In-Stat/MDR.

Ornauer, J., Michielsen, E., Rerisi, E., 2004. RFID Integration Services Markets, 2004 Q1. Allied Business Intelligence.

Pine, H.B., Michielsen, E., Rerisi, E., 2003. RFID-Emerging Application Driving R&D Investment and End-User Demand, 2003 Q3. Allied Business Intelligence Inc.

RFID Journal News, 2004a. Intermec Sues Matrics. 8 June 2004, http://www.rfidjournal.com/article/articleview/979/1/1/.

RFID Journal News, 2004b. New UHF Regulations Move Forward in Europe. RFID News Roundup, 2 July 2004, http://www.rfidjournal.com/article/articleview/1012/1/1/.

RFID Journal News, 2004c. Intermec Spells Out Licensing Plan. 16 August 2004, http://www.rfidjournal.com/article/articleview/1084/1/1/.

RFID Journal News, 2004d. Goodyear Copes With RFID Challenges. 5 November 2004, http://www.rfidjournal.com/article/articleview/1223/1/1/.

Roesner, B., 2004. RFID Technology Analysis. In: RFID Conference, 17 June 2004, Taipei, Optotech Magazine.

Sarma, S., 2001. White Paper—Toward the 5 ¢ Tag, AutoID center, 1 November 2001.

Sarma, S.E., Weis, S.A., Engels, D.W., 2002. RFID Systems, Security & Privacy Implications. Auto-ID Center White PAPER, November 2002.

T & W Enterprises, 2005. Bar Code History. 11 October 2005, http://www.twe-online.com/barcode_history.htm.

Wu, N.-C., 2003. RFID industry development and market trend. In: ITRI-RFID Industry Development Seminar, 22 October 2003.

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