

RFID – Making It So...With Some Help From the University of Florida¹

Bruce A. Welt and Jean-Pierre Emond²

Introduction

Recent advances in passive radio frequency identification (RFID) technologies have inspired a revolution in thinking about supply chain and inventory management. Briefly, modern passive RFID involves “smart” labels, readers and associated transmitting and receiving antennas, and back-end computer control and database management systems. Figure 1 gives examples of typical RFID components.

Two important distinctions about the “smart” labels, or “tags,” are warranted. Firstly, the term “passive” refers to tags that are designed to harvest energy from a radio frequency (RF) energy field emitted by a reader’s transmitting antenna. Fully passive tags have no onboard power source and are therefore unable to operate outside of an energizing RF field. Secondly, initial RFID work has relied extensively on press-on label technology; however, packaging manufacturers are seeking to add value to packaging, while helping to cut overall implementation costs by incorporating RFID technologies into packaging materials, making press-on labels or tags no longer necessary. Faculty in the Agricultural & Biological Engineering Department's Packaging Science program and the University of Florida/IFAS Research Center for Food Distribution and Retailing are currently working with several leading companies on such projects.

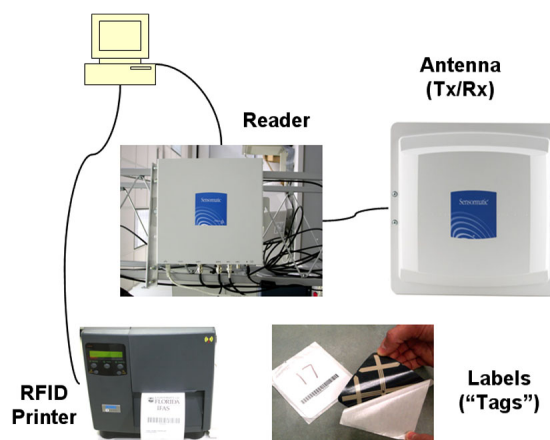


Figure 1. Examples of typical radio frequency identification hardware. Credits: UF Packaging Science Laboratory

Technological advances with RFID technologies combined with real-world experimentation have helped to define certain boundaries (or limitations) around current and future implementation schemes. Several major boundaries involve operating frequencies, data standardization and hardware interoperability. Much of the initial work in RFID focused on 13.56 MHz, however, a major limitation involving very short read-ranges, typically on the order of a few inches, has caused a shift in focus to UHF frequencies in the range of 860 MHz (Europe) to 915 MHz (USA). Differences in UHF frequency standards appear to have been overcome by antenna

¹ This document is Circular 1465, one of a series from the Department of Agricultural & Biological Engineering, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. First published: March 2005. Please visit the EDIS Web site at <http://edis.ifas.ufl.edu>.

² Bruce A. Welt, Assistant Professor, and Jean-Pierre Emond, Associate Professor, Department of Agricultural & Biological Engineering, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

designs capable of handling such variations. However, differences remain in permissible transmission power in various regions of the world, which directly impacts tag read ranges.

Data collection is central to the mission of RFID. Given the enormous global investment in barcode-based technologies, particularly EAN/UPC-based barcodes, it made sense to develop a coding system that can easily incorporate this system. The electronic product code, or EPC, aspires to supersede EAN/UPC and is in fact a superset of this system. The relatively new management body, EPCglobal, seeks to manage EPC coding, while providing value added data warehousing services. Currently, the emerging RFID-related data service industry is shaping up to be a very competitive space. Arriving at a standardized EPC data structure has been the focus of much effort over the past five years.

The current 96-bit data structure (Figure 2) is the result of competing forces related to ever-increasing desire to store more data and physical limitations of any RFID based system. While storing increasing amounts of data on tags is not a significant problem, it must be kept in mind that each bit of data requires a finite amount of precious communications time. Therefore, the overriding philosophy of the EPC coding system is to keep the EPC as small as possible, and to use it as a pointer to volumes of related data in networks of relational database management systems.

Header	EPC Manager No	Object Class	Serial Number
--------	----------------	--------------	---------------

Figure 2. Electronic Product Code (EPC) data structure. Credits: UF Packaging Science Laboratory

Lack of hardware interoperability has been a major limiting factor for RFID implementation. This has resulted in a confusing “class” based categorization system for RFID readers and tags. Passive RFID implementations generally deal with Class 0 (zero), Class 0+ (zero plus) and/or Class 1 tags. Functionally, the difference between Class 0 and Class 1 tags is programmability; where Class 1 tags are field programmable and Class 0 tags are programmed by the manufacturer. Similar to the difference between preprinted or field printed barcodes, field programmability offers users the

ability to limit inventories of label stock. However, the ability to program tags carries with it the important responsibility of managing EPC codes. The University of Florida is working with several corporate partners to develop such data management solutions. Additionally, Class 0 and Class 1 tags operate with different communications protocols, which means that Class 0 (or Class 0+, which are field programmable Class 0 tags) and Class 1 hardware are not interoperable.

Fortunately, this “class warfare” is about to end with the widely anticipated adoption of the “generation two” or “Gen-2” standard. This new standard promises seamless hardware interoperability. It is expected that Gen-2 will be ratified by the end of 2004 and that Gen-2 hardware will be available by the middle of 2005.

RFID and the University of Florida

Faculty in the Agricultural & Biological Engineering Department's Packaging Science program and the University of Florida/IFAS Research Center for Food Distribution and Retailing are playing a key role in the study, development and implementation of new RFID technology. They have a strong history in the field of smart and intelligent packaging, and see RFID as an extension and new focal point of this work (Figure 3).



Figure 3. RFID studies at University of Florida's Packaging Science Pilot Plant. Credits: UF Packaging Science Laboratory

The uniqueness of this laboratory is its ability to deal with perishable items. The facility is equipped with eight temperature- and humidity-controlled, walk-in environmental chambers, as well as two walk-in freezers (Figure 4).



Figure 4. Programmable environmental chambers at the University of Florida's Packaging Science lab.
Credits: UF Packaging Science Laboratory

RFID Compliance Mandates

By nature, radio transmission can be finicky and problematic. Ultimately, every variable has some impact on the performance of the system. Two widely discussed challenges include products that absorb RF energy in the UHF region, such as water, as well as the inability of RF energy to penetrate through metals, which make up a significant portion of packaging materials and handling equipment such as forklifts. It is often too difficult to predict RFID system performance; therefore, actual experimentation is required to get a sense of anticipated performance. Additionally, there is a need to assemble operating prototypes in order to evaluate human and legacy system integration performance.

Currently, there are two priorities driving performance evaluations. The first and most immediate need is compliance with customer mandates. Once compliance issues are solved, companies need to learn how to leverage the power of RFID to improve their own operations to achieve improved returns on investment.

Wal-Mart, Inc. is now just one of many large scale companies and government institutions issuing RFID compliance mandates to its vendors.

The Wal-Mart compliance mandate reflects state-of-the-art RFID technology as well as current thinking as to best approaches for implementing RFID technology. In general, the mandate requires pallets and cases to be tagged. Wal-Mart expects to be able to read 100% of pallet tags moving through a portal configuration (Figure 5). Additionally, Wal-Mart expects to be able to read 100% of case tags on a conveyor moving at a speed of 600 ft/min.

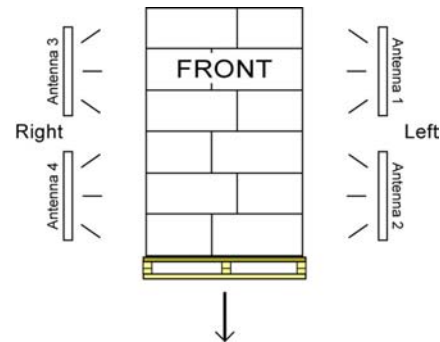


Figure 5. Typical portal configuration.

Credits: UF Packaging Science Laboratory

It is interesting to note that the Wal-Mart's compliance mandate effectively negates two of the most widely promoted benefits of RFID technology, namely, data collection rate and ability to read data without line-of-site. Clearly, the Wal-Mart compliance standard could be met with common barcode readers and/or machine vision systems. However, RFID may offer additional longer-term benefits to users who are able to push applications beyond simple compliance. Such benefits may include, reduced out-of-stocks on store shelves, reduced losses due to theft and/or spoilage, better warehouse management of inventory, greater awareness of consumer behavior and demands, etc.

RFID Evaluations

The UF/IFAS Research Center for Food Distribution and Retailing has combined its RFID equipment with the ones from the faculty in the Agricultural & Biological Engineering Department's Packaging Science program in order to offer the latest hardware and software currently on the market. Therefore, it is possible to compare results for each test between different hardware vendors. Ideally, results from such tests should help participating RFID vendors improve their hardware.

Evaluations focus on the two main compliance mandate configurations, namely pallets and cases. The following are examples of some common tests performed:

Pallets

- Tag location on pallet loaded with actual cases of product.
- Mapping readability of case tags in pallet/portal configuration as a function of pallet-to-carrier spacing and carrier speed.

Cases

- Tag location on actual product case.
- Readability as a function of antenna power and conveyor speed.

Tag location on pallet

Typical results from tests involving tag locations on a pallet with and without the presence of a forklift emphasize the importance of testing with equipment used in real situations. Figure 6 shows typical readability results for tags attached to fully loaded pallets at various locations. The figure shows that readability of tags in close proximity to large metal objects such as a forklift is significantly reduced. Therefore, companies need to carefully consider where RFID tags will be placed on product cases.

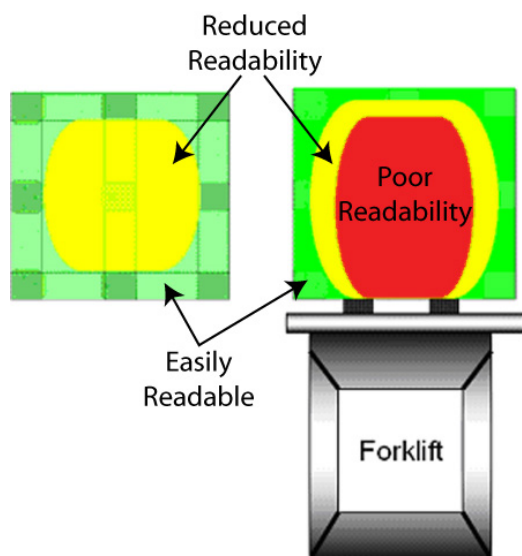


Figure 6. Results from pallet tag location study show significant differences in readability depending on whether a forklift is used (Green areas are easily readable; Yellow areas demonstrate reduced readability; Red areas offer poor readability).

Credits: UF Packaging Science Laboratory

Mapping case readability in pallet load/portal configuration

Mapping readability of cases on pallets is not essential for current compliance mandates; however, such tests provide some basis for understanding overall performance limits. Additionally, it is expected that reading cases on pallets may be useful for in-house inventory management.

Typically, cases are mapped by placing tags on intersections of a 6-inch grid, covering the pallet load. Standard tests involve moving the mapped pallet through a portal configuration at different speeds. Sample results of a typical speed test are shown in Figure 7.

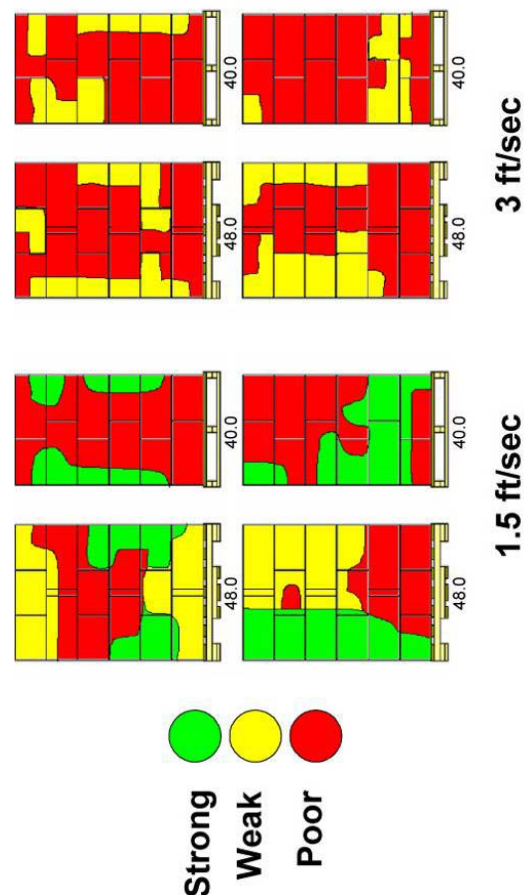


Figure 7. Pallet/Case readability mapping during speed tests through RFID portal at 1.5 and 3 feet per second (about 1 and 2 miles per hour, respectively). Note: Standard US-GMA pallets are 48 inches by 40 inches. Dimensions are provided in the figure to show pallet orientation. Credits: UF Packaging Science Laboratory

Case tag location readability

Operations involving case tags on conveyors have been found to be surprisingly challenging in real-world situations because it is often necessary to reduce transmission power in order to avoid spurious reads. Figure 8 shows actual read ranges for a particular RFID hardware arrangement determined in our laboratory:

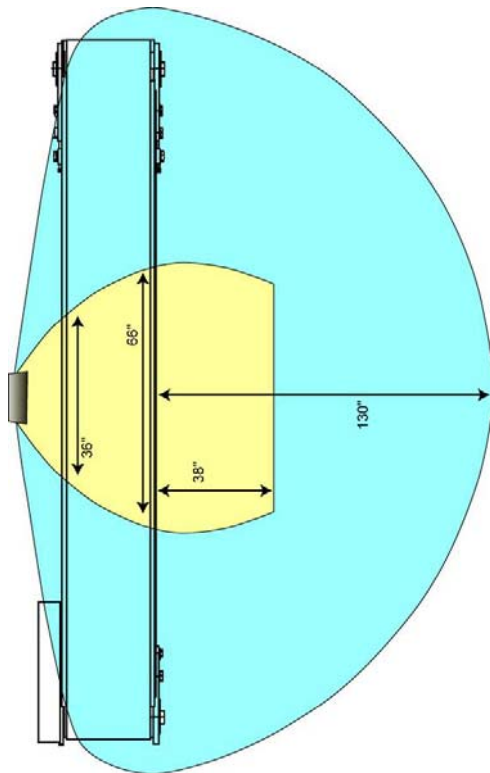


Figure 8. Read ranges across a length of conveyor for Vendor X (Blue = 500 MW, Yellow = 100 MW).
Credits: UF Packaging Science Laboratory

As with the proposed standardized pallet location specification, the University of Florida is proposing a standardized tag location scheme for cases. Since case sizes vary, this scheme is not presented here.

Typical results for case tag location studies are shown in Figure 9.

Figure 9 shows that the number of tag reads depends on conveyor speed and location on the case. This type of study helps to show not only best possible tag location, but also, by comparing results using different RFID hardware, insights into strengths and weaknesses of hardware. More

importantly, these studies are used to predict read rates at any specific conveyor speed such as 600 ft/min.

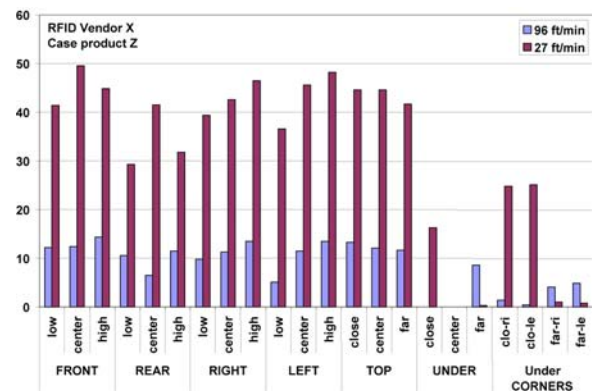


Figure 9. Case tag readability as a function of vendor and conveyor speed.

Credits: UF Packaging Science Laboratory

Prototyping Solutions

In the near future, many companies will be facing similar compliance mandate issues. The University of Florida is playing a key role in developing solutions to the challenges of accurate and economical standardized RFID technology. Central to the solution effort is the need to collect data on facility layouts, work-flow patterns and existing data management systems. After these data have been collected and analyzed, approaches for accomplishing these tasks with RFID can be created. Critical common tasks that need to be incorporated into the solution effort include the ability to manage the field programmable tag data, associating new tags with cases of products and pallets, associating case tags with pallet tags, integrating these data with legacy systems, and, finally, being able to communicate these data with customers.

Recently, the University of Florida developed an approach for the Case-2-Pallet™ prototype solution to help manage such tasks. Figure 10 depicts operations involved with building a new pallet.

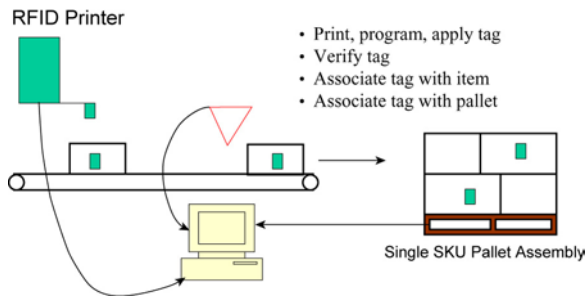


Figure 10. Scheme for building new, single SKU pallets.
Credits: UF Packaging Science Laboratory

The University of Florida welcomes opportunities to partner with companies to rapidly bring potential solutions out of the laboratory and into practice.

Conclusion

The University of Florida's Packaging Science program is playing a key role in developing new knowledge and solutions involving auto-identification technologies. Radio frequency identification offers a new frontier for innovation. Customer-driven RFID mandates are simply a first step toward improving supply-chain management. Each link in the supply chain has specific limitations and opportunities that must be identified and explored. Sound decision making requires knowledge and understanding that can only come from experimentation and experience. The University of Florida offers a forum for supply chain partners to work together to solve mutual problems.