

**Maximizing RFID Performance on
Consumer Product Cases and Pallets**

Chris Cook, Field Application Specialist

Texas Instruments Radio Frequency Identification (TI-RFid™) Systems

Executive Summary

During the past two years, consumer packaged goods (CPG) suppliers have conducted pilots using Electronic Product Code™ (EPC) radio frequency identification (RFID) technology, and have come a long way in their understanding of the technology and its benefits. Compared with bar codes, RFID holds 30 times more information, does not require line of sight to be read, works in tough environmental conditions and can be embedded into a product or packaging. RFID improves productivity through automation: enabling unique stock keeping unit (SKU) serialization, and saves valuable time in reading products versus individual hand scanning. The newest RFID tags operating in the ultra-high frequency (UHF) band of the electromagnetic spectrum allow for fast tag-to-reader communication and can be read over moderate distances with low power consumption.

UHF tags in smart label form are moving into CPG supply chain. With all the benefits of RFID also come the challenges of implementing this technology due to the physical characteristics of radio frequency communication. RFID is sensitive to the product and packaging materials to which it is applied. Certain materials such as glass and cardboard have little effect on readability, while metal and liquids can quickly reduce the signal strength emitted from an RFID label.

This paper identifies the product and packaging variables that affect the performance of RFID smart labels, and provides advice on the appropriate measures to take to address difficult data reads. Knowing how to identify RF friendly and unfriendly materials and learning some techniques to minimize the effects of RF signal degradation can help users implement RFID successfully.

Quality

Protocol



SKU Properties

Antenna Design

Figure 1: Smart Label Performance Components

RFID Smart Label Performance Variables

A smart label is composed of an RFID chip, substrate, and antenna. The antenna communicates the digital information from the chip to the RFID reader. As illustrated by Figure 1, a smart label's performance is affected by the quality of its manufacturing, the protocol used, and its antenna design.

Antenna designers go to great lengths to tune their designs with just the right electrical properties, finely balancing capacitance, inductance, and resistance. In a perfect RFID world, each smart label manufacturer would supply one ideal tag that fits on any type of product and can be read on any box. Currently no one has an ideal tag which means that each manufacturer must carry a selection of different antenna designs for specific applications. Texas Instruments (TI) designs a minimal number of antennas that fit broad classes of products, making it easier for CPG suppliers to select the right label for the application.

Once the finished RFID label is placed on a box, some types of materials around the label have the potential to render the tag unreadable. Regardless of which antenna is being used, four properties of the product case can affect the label's readability:

1. Product contents: liquids, dry goods, textiles, plastic, metal
2. Primary packaging type (item level): metal, plastic, cardboard
3. Secondary packaging type (case level): full box, tray type box, shrink wrap

4. Available air gaps in the case packaging

Product contents such as dry goods, textiles, and plastics normally have little effect on the RF signal, so packages containing things like cereal or socks cause very little signal degradation. These types of products are considered “RF-friendly.” Products that are “RF-unfriendly” include absorptive (liquid) and reflective (metallic) materials. Product contents such as liquids tend to weaken the RF signal by absorbing much of the energy so the reader has no signal to receive. Other products, such as metal, reflect the RF signal so that too much energy comes back to the reader and the data signal is drowned out.

Just as the individual product can affect the RF signal, so can its primary packaging. Typically, packaging is not absorptive, so reflective materials such as metallic packaging are problematic in this instance. Metal cans cause major problems with readability. Even metallized plastic such as foils can render the signal unreadable. Nonmetallic cardboard, paper, and glass are good packaging materials to use for minimal signal attenuation. Secondary or case level packaging has similar issues, but is less of a concern because CPG suppliers typically use RF-friendly cardboard, shrink wrap, and reusable plastic boxes.

Proper Packaging Combinations to Maximize Smart Label Performance

When matching products to packaging, an effective way to ensure that RFID smart labels are readable is to be aware of how different materials affect the RF signal’s readability. The following chart illustrates several common product and packaging combinations and their relative RF-friendliness.

One way to enhance RF readability is to pack a case shipment with air gaps between products. Even if a product and its packaging are very RF-unfriendly, an air gap between the label and product can make an otherwise unreadable product readable. For example, liquids like salad dressing or motor oil are usually RF-unfriendly, but when they are packaged in bottles with thin necks, air gaps are present in the case packaging and the RF signal is readable.

As a secondary packaging, shrink wrap on its own is RF-friendly; however, it does little to counter the RF-unfriendly properties of liquid and metal such as those in a case of juice packets which are liquid in metallized plastic pouches. Styrofoam material is very RF-friendly and creates the same effect as an air gap in case packaging.

SKU PACKAGING AFFECTS FRIENDLINESS OF RFID READABILITY

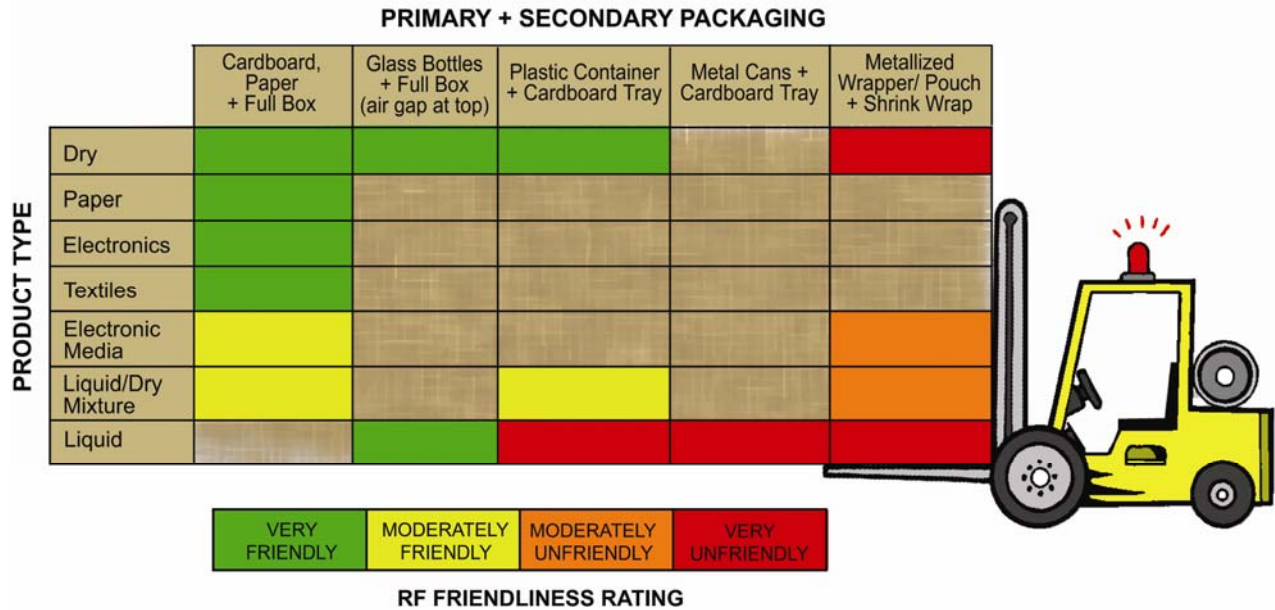


Figure 2: Product-Packaging Combinations

Smart Label Placement

Proper label placement is another adjustment that will help ensure RF signal readability. For some products it is easy to find the best label position, but for others it is much more difficult. Many companies perform “sweet spot” testing to find the optimum location on the product case. It is hard to determine a single sweet spot on some cases because the products inside often shift in transport which upsets the amount of air gaps created in the initial packing stage. For example, a typical package of macaroni and cheese is mostly dry pasta and a foil pouch with cheese. The pasta is very RF-friendly, and there is plenty of free air in the box. However, depending on vibration, gravity, and box orientation, the foil pouch can disrupt the signal by shifting positions in the box during transport. In this situation a case may be easily readable when packed, but after shipping it may be unreadable if the pouch shifts directly behind the smart label. Multiple cases and multiple orientations should be tested with such items.

The most favorable position for the label is where there is likely to be air gaps. The type of the box is also a factor. Full boxes (those with 6 sides) allow the most area and flexibility to position the label to take advantage of the internal air gaps. Corrugated cardboard trays have far less area and provide little flexibility for label placement. There is typically only two to three inches of cardboard on the bottom of the case to place a label which limits its position, orientation, and size.

Of course finding the sweet spot on a product is not always as simple as finding an available air pocket. Product materials can effectively bend the electrical fields in an unpredictable manner. There are many companies that scientifically test products specifically to find the sweet spot.

The antenna design embedded in the smart label can also improve performance. By designing and tuning a custom antenna to a particular type of product, it is possible to partially counteract the effects of RF-unfriendly materials. However, most users are reluctant to stock several different labels, because it means increased cost and complexity. For this reason, it is important for CPG suppliers to work with label suppliers that offer the most flexible and selective antenna designs possible.

Pallets

Until this point the focus has been on reading individual cases moving through a conveyor portal reader or using a handheld. Once the cases are put together in a pallet, some of the labels may not be readable because other cases on the pallet are shielding them from being read. Also, a typical portal only has a few seconds to read incoming pallet shipments so the RFID reader has little time to differentiate among the many weakened signals. At this point, it is a challenge to read 100 percent of palletized cases 100 percent of the time unless they contain very RF-friendly products.

A well-designed system of readers and portals can work around this problem. It is important to realize that there is more than one opportunity to read a case or pallet in the supply chain. In addition to the supplier's dock door, there is the retailer's distribution center, the individual store's dock door, and even the box crusher in the store's back room. Suppliers and retailers can use the entire RFID data acquisition system to overcome incomplete reads at certain points and ensure more accurate inventory, billing, and order processing.

It is best to count cases individually as the pallet is being built and associate all the labels to that order. An extra master label can be applied to the completed pallet to verify the entire shipment's arrival. Any pallet of products should have at least a few labels on the outside face of the stack making those case tags readable. Any additional case tags that are read can be cross-referenced to the pallet's bill of materials and it can be assumed that the entire order has been received. This is referred to as a "virtual pallet label" and eliminates the need for the extra master labels. If a CPG supplier's processes allow it, the boxes on the pallet could be stacked in such a way as to maximize the number of tags on an outside face of the stack, further increasing the reliability of the system.

The Systems Approach

To manage the technological challenges inherent with UHF smart labels, a CPG supplier needs a well-designed IT infrastructure and data analysis system. When the systems of suppliers and retailers are linked together to cross-reference data reads and ensure that “virtual pallet labels” are created, many problems caused by missed reads can be solved. Figure three illustrates the entire RFID system and how the smart label, reader infrastructure, and data processing are interdependent pieces of the solution.

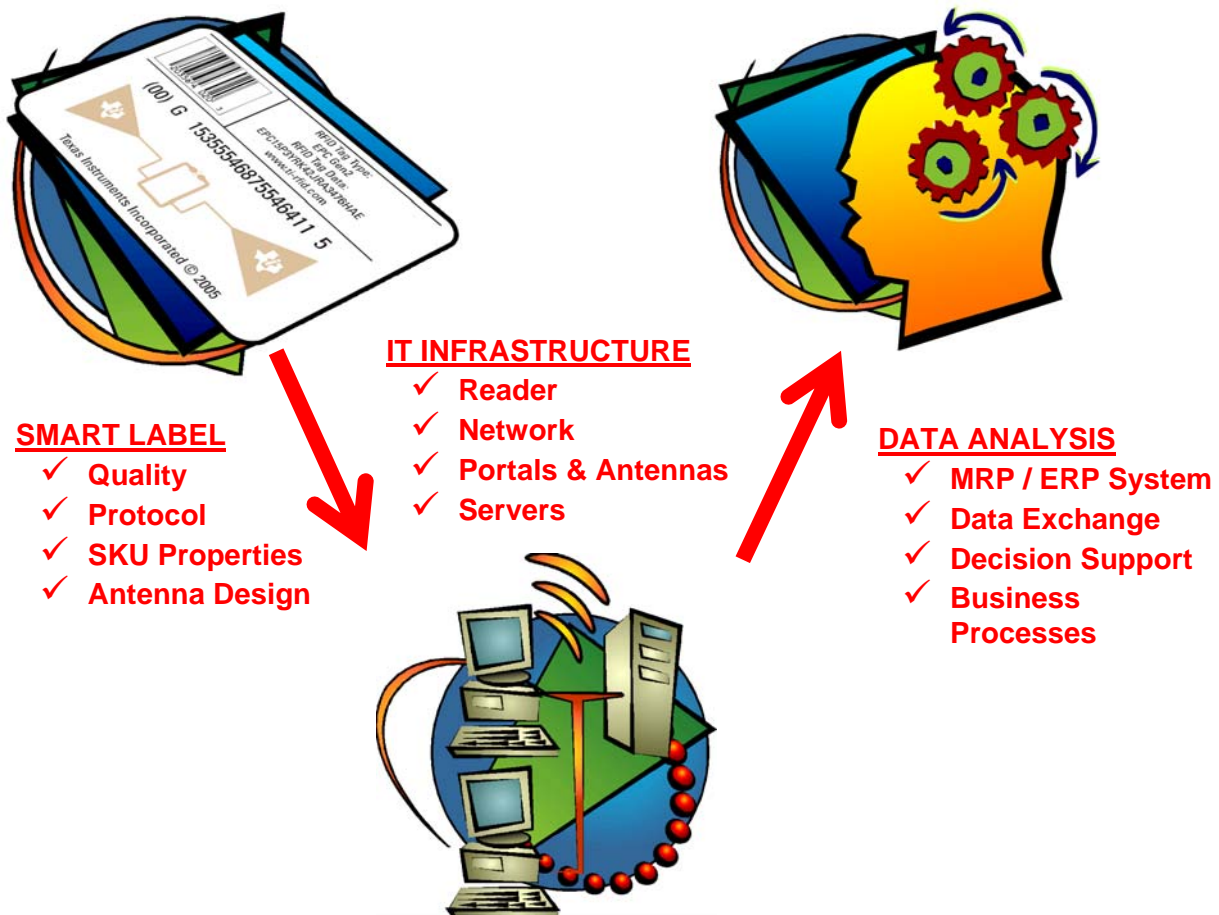


Figure 3: RFID Support System: Smart Label, IT Infrastructure, and Data Analysis

RFID solutions providers such as TI understand the critical link between the label and the rest of the system to ensure products fit and interact together within the system to support CPG suppliers.

Conclusion

Many of the issues discussed in this paper are not unique to the new EPC Gen 2 labels. Product and packaging materials affect RF signals according to the laws of physics that no standards-based protocol can address. As manufacturers with mature RFID tag assembly processes enter the market, quality issues associated with “dead” or “quiet” labels should be greatly improved. In addition, the Gen 2 protocol is poised to improve RFID systems through better hardware interoperability, faster data rates, and a dense reader mode.

CPG suppliers should have an appreciation for the physical characteristics of different types of products and packaging and their effects on RFID technology. Many of the issues associated with RF unfriendly materials can be overcome with correct packaging and product combinations, proper label placement at both the case and pallet level, and a well-designed reader and data-processing system to support efficient data reads throughout the supply chain process. The smoothest and most cost effective way for CPG suppliers to implement an effective RFID system is to use components from vendors who understand not only their piece of the system, but how the whole system functions within a networked data infrastructure. RFID solutions providers such as TI understand that its technology is part of an RFID system, and we work diligently to ensure our products are interoperable with as many readers, printers and label applicators, and in as many different operating conditions as possible.

About the Author

Chris Cook is an application specialist with Texas Instruments™ RFid Systems, a business unit of Texas Instruments Inc located in Plano, Texas. In this role, he works with UHF customers to provide real world application advice and testing as well as technical assistance. With more than ten years of experience, Chris has extensive expertise in designing and managing electronics packaging solutions.

About Texas Instruments RFid Systems

Texas Instruments is the world's largest integrated manufacturer of radio frequency identification (RFID) transponders and reader systems. Capitalizing on its competencies in high-volume semiconductor manufacturing and microelectronics packaging, TI is a visionary leader and at the forefront of establishing new markets and international standards for RFID applications.

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