Effect of Unitization and Product Types on Readability of Tagged Packages of Consumer Goods

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ABSTRACT: Proper implementation of radio frequency identification (RFID) has the potential to revolutionize supply chain management. This technology provides simultaneous indirect scanning of multiple packages and palletized loads equipped with a RFID tag, transmitting substantially more information than a bar code. Also, stored information on the tag can be updated according to inventory status, thus, eliminating key limitations of barcode technology. This study was designed to address some of the currently known shortcomings of the RFID technology. One of the commonly occurring drawbacks is transmitted signal from RFID antennae is reflected from metal objects or absorbed by water contained in a product. These limitation of effective reads can be easily shown using EPC Hotspot, which is capable of creating a profile map for product cases based on the correct reads of RFID tags. This study included three types of packaged products that were palletized. These were filled beverage in metal cans, filled water in plastic bottles and plastic wrapped paper towels. The objective of the study was to assess overall tag readability of three newly developed Gen 2 RFID tags as a function of tag location and orientation, product composition, case location on a pallet load and speed of material handling equipment. The results indicated that overall readability was highest for 'paper towels' followed by 'water filled bottles' and 'soda filled cans' across all RFID tags. Also, it was established that normal forklift speeds barely affect overall tag readability with the exception of very poor tag "visibility" for filled beverage in metal cans. In summary a better understanding of tag placement on products at the case level was achieved at the completion of this study along with effective speeds of material handling equipment that allow for high read rates.

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1557-7244/08/03 179-11
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1.0 INTRODUCTION

Numerous studies have shown varying conclusions with regards to RFID readability. The following is a summary of findings from previous research involving industry testing. It has been assumed that a warehouse shipping mixed loads of RFID-tagged shipping containers, could automatically verify the order accuracy and update inventory status by driving each pallet load through a portal equipped with readers. This was made possible by connecting readers to the transaction and warehouse information systems. All the packages simultaneously transmitted embedded information on the tags to the host computer. Similarly, these tags could be re-programmed with new information to reflect the inventory status change. Such systems can increase transparency in manufacturing and retail supply chain system. RFID tags on each consumer package could offer other potential benefits. For instance, reductions in grocery check-out lanes to a doorway. In the presence of such RFID technology it is not far when a refrigerator can identify products within its storage area or provides instructions to a microwave to cook a meal. Similarly, a patient can be reminded to take his prescription medication at a specified time. There are many possible applications for this seemingly magical new packaging technology in the future. However, the potential of RFID can be truly exploited if RFID tags are consistently and reliably read. Unfortunately past research is indicating that the reliability of such technologies and tag read rates is dramatically less than what the leading proponents claim.

One of the key research studies published in 2006 by Clarke et-al [1], showed major limitations with read capability of RFID tags. Among the key findings the study concluded that only 25% of the tags on shipping containers containing water-filled bottles could be read. Rice filled jars (dry products) had a 74–79% read rate. Furthermore, even empty boxes did not provide a 100% read rate. However this study was done when both the type of tags used (Gen 1) and portal designs were still in infancy. In the past year tag design and portals have been improved and the industry has shifted to a Gen 2 tag.

Additional research and testing has been presented on readability of tagged packages of apparel, produce and consumer goods by Singh et-al [2] and on packages of water bottles by Brofman and Aguilar [3]. In the water bottle study only 25% of the tagged packages could be effectively read. Singh et-al presented various factors that influence readability and
provided effective tag location that could permit better read rates. These studies showed the initial limitations of Gen 1 tags on readability through products containing water and packages having a metal component in the read field.

Currently one of the debatable concerns in the RFID industry is the relative orientation of a tag’s antenna and those of the interrogator. Most manufacturers say that tag orientation has little effect on read range and tag readability. As the white paper produced by one supplier, Intermec [4] explains:

“Because no line of sight is required, RFID-tagged objects can be read in different orientations at very high speeds. Orientation sensitivity depends on the antenna design and the amount of interference that is present. In some environments tags may be read in any orientation. This gives product and package designers’ tremendous flexibility in tag placement options, and eliminates the need for human intervention to scan labels or to ensure items are placed properly for reading in conveyor belt or retail applications.”

One of the few published studies is by a manufacturer/supplier of RFID equipment, Alien Technologies, who evaluated readability for a variety of possible conditions, including location of tagged cases, antenna type and position, tag orientation, proximity of the tag to the reader, relative orientation of the antennae, number of tags in field, movement speed through portal, product variables and interference [1]. The results were optimistic, with a high percentage of tags read in spite of the variables. The study concluded that the tag and case orientations had very modest effect on readability. Liquid and metal products had some effect when tags faced away from the antenna but ‘could be worked around’ [1]. The Alien Technology research and Intermec claims, however, may be biased since the number of tests for each variable was not completely disclosed, and so their significance is uncertain. The testing was done on Alien Technology’s products using hardware that was a prototype. The test was set up to give constructive results, with no tags embedded at the centre of problematic materials. Intermec’s implication, that there are also some environments where orientation does matter, has not been developed. At least one research centre has found problems with tags in some orientations. A study performed by Clarke et al. showed that the read rates are indeed affected by tag orientation [1].
This paper is a continuation of a recently concluded research which evaluated the variables affecting RFID tag readability in a conveyer belt environment [5]. The research presented in this paper accounts for effects of tag orientation, product and package type as well as using new Gen 2 RFID tags and readers.

2.0 MATERIALS AND METHOD

2.1 Test Materials and Description

2.1.1 Pallets

A total of three palletized loads using Grocery Manufacturers’ Association recommended wood pallets measuring 1.02 m x 1.22 m (40” x 48”) were used for this study.

2.1.2 Product

Cases of products used and their pallet configurations for the study were:

- Carbonated beverage in metal cans—144 cases per pallet, 18 per tier (Figure 1)
- Drinking water in plastic bottles—35 cases per pallet, 7 per tier (Figure 1)
- Plastic wrapped paper towels—24 cases per pallet, 6 per tier (Figure 1)

In order to cover the variables of the packaging and product type that in the past have been an issue for effective readability of RFID tags, the palletized configuration of packaged products were selected and are shown in Figure 2.

![Figure 1. Cases of Product used in the Study.](image-url)
2.1.3 RFID Hardware

Alien Technology Corporation’s (Morgan Hill, CA, USA) ALR 9780 RFID reader and ALR-9610 circular polarized antennae were used for this study. The ALR-9780 provides both EPC Class 1 Gen 1 and Gen 2 support and was connected to a computer using RS-232 computer interconnection. It provides up to four ultrahigh frequency (UHF) antennae. Alien Gateway V2.15.08 middleware was used to collect all data. Four ALR-9610 circular polarized antennae were used, since they were less sensitive to the tag orientation and sufficed the read distance requirements for this project.

2.1.4 RFID Tags

Three types of Class 1—Gen 2 tags used (Figure 3):

- Raflatac G2 Short Dipole (UPM Raflatac, Fletcher, NC, USA)
- Avery AD-222 (Avery Dennison RFID, Clinton, SC, USA)
- Alien “Higgs” (Alien Technology Corporation, Morgan Hill, CA, USA)

They all measured approximately 10.16 cm × 1.27 cm (4 in × 1/2 in)
and were mounted with the horizontal tag orientations after experimentation was conducted using the EPC Hotspot Software.

2.1.5 Portal and Fork Lift Truck

A counterbalanced fork truck was used to carry and transfer the above palletized loads of product through a portal at three different speeds to simulate various driving conditions. These were 2.4 kph (1.5 mph), 8.1 kph (5.0 mph), and 16.1 kph (10.0 mph). A standard portal was used as described and shown with in Figure 4.

2.1.6 Instant EPC Hotspot v2.5 software

Instant EPC Hotspot software (Integral RFID, Richland, WA, USA) contains several tools to map out the RF-performance around a case of packaged-product [6]. The software was used for this research to conduct an in-depth analysis at every 2.54 cm (1 in) of the three product-package combinations. Easy to comprehend visual results were created to instantly identify the best location for tag placement and tag orientation on cases of each of the three products studied.

This, the first stage of testing, was done using one Alien ALR-9780 circular polarized antenna mounted on a stand, 91.44 cm (36 in) from the center of the antenna to the floor. Each of the products tested was placed on top of a 76.2 cm (30 in) high plastic stand located at 90 degrees and

![Figure 4. Portal Setup.](image-url)
91.44 cm away from the antenna. With each product tested, the face of the case and the front of the antenna were kept 91.44 cm apart. For each product, two sides of the case were selected to determine an optimal tag location, the front face and back face with respect to the antenna [7].

Each face to be tested was equipped with a 2.54 cm x 2.54 cm (1 in x 1 in) grid drawn on a piece of paper that was taped to the face of the case to be tested. The center of the tag was placed at the intersection of each horizontal and vertical line. The tag was moved from intersection to intersection for each read. Once the case and antenna were set up, the dimensions of the case were entered in the software’s Case Setup page [6]. The Hotspot test option, which brings up a 3-dimensional version of the product, was selected. The software creates a 2.54 cm x 2.54 cm grid on each face of the case. The face representing the face of the case to be tested and the closest size tag were selected from the on screen options. On the 3-dimensional on-screen image, an intersection was selected that allowed the tag to fit completely on the case without overhang, and the actual tag was placed in the same location on the product to be tested (Figure 5).

The tag was placed on the front of the package, the antenna activated, and results were recorded at each grid intersection. When each intersection had been tested, a still image of the face tested was saved, and the tag was moved to the back of the package, and the test was repeated. Again, once all intersections had been tested on the back side of the package, a still image of the face tested was saved. Once both sides had been completed with the tag in the vertical orientation, the tag was repositioned horizontally on the case, and both the front and back side of the case were tested again. This testing procedure was done for all four tags on all three packages.
Figure 6 shows a comparison of the RF performance of the Alien "Higgs" tag placed on bottled water cases in horizontal and vertical orientations. Figure 7 shows a comparison of the RF performance map for the same tag used horizontally on the three cases of products used for the study.

Using the RF performance maps for the three product cases and the three tags used, an optimal tag location and orientation was selected for all combinations. For the case with beverage metal cans, the ideal tag location was on the widest side, centered 2 inches from the bottom of the case. The bottled water and wrapped paper towel cases benefited from tag placement on the narrow end centered 4 inches from the bottom of the case. The main reason for these placements was due to case configuration and positioning on the pallet. In an attempt to promote tags towards the outer edges of the pallet, exterior sides were chosen to increase readability. Once tag location and case location were chosen, HotSpot was configured to "know" where each case is on a pallet. This was done by programming each tag with a number, and corresponding that with a specific location on the pallet for each case. As the palletized loads

Figure 6. RF Performance Comparison of Alien "Higgs" Tags Placed on Bottled Water Cases.

Figure 7. RF Performance Comparison of Alien "Higgs" Tags Placed Horizontally for Products.
Effect of Unitization and Product Types on Readability

Table 1. Results for Carbonated Beverage in Metal Cans.

<table>
<thead>
<tr>
<th>Tag</th>
<th>Fork Lift Speed (kph)</th>
<th>Number of Tags Read per Trial (Total = 144)</th>
<th>Average</th>
<th>Readability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raflatac G2</td>
<td>2.41 8.05 16.09</td>
<td>68 66 54 68 64 54 68 65 56 68 68 56 68 65 58</td>
<td>68</td>
<td>47.22%</td>
</tr>
<tr>
<td>Short Dipole</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avery AD-222</td>
<td>2.41 8.05 16.09</td>
<td>67 66 54 68 66 54 68 67 56 66 67 56 68 65 56</td>
<td>67</td>
<td>46.53%</td>
</tr>
<tr>
<td>Alien &quot;Higgs&quot;</td>
<td>2.41 8.05 16.09</td>
<td>60 60 54 61 60 54 62 60 56 55 60 55 60 56 55</td>
<td>61</td>
<td>42.36%</td>
</tr>
</tbody>
</table>

Passed through the portal, HotSpot software identified each accurate tag read (3 or more reads) to a specific pallet location. Any tags not read were displayed and noted.

3.0 DATA AND RESULTS

The results for all tests conducted are represented in Tables 1–3.

The following are the key findings from this study:

- Of the three types of palletized products, paper towels performed the best, followed by water in plastic bottles and then metal cans

<table>
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<td>35 35 35 35 35 35 35 35 35 35 35 35 35 35</td>
<td>35</td>
<td>100%</td>
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</tbody>
</table>
Table 3. Results for Paper Towels in Plastic Wraps.

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<thead>
<tr>
<th>Tag</th>
<th>Fork Lift Speed (kph)</th>
<th>Number of Tags Read per Trial (Total = 24)</th>
<th>Average</th>
<th>Readability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raflatac G2</td>
<td>2.41</td>
<td>24 24 24 24 24 24 24 24</td>
<td>24</td>
<td>100%</td>
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<tr>
<td>Short Dipole</td>
<td>8.05</td>
<td>24 24 24 24 24 24 24 24</td>
<td>24</td>
<td>100%</td>
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<td>16.09</td>
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<td>16.09</td>
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- Drinking Water in Plastic Bottles:
  - Pallet patterns greatly effect read rates. There were no center cases on the pallet. All cases touched the outer edges of the pallet and were tagged accordingly.
  - As all tags were exposed directly to the antenna, read rates were extremely consistent (Tables 2).
  - All three tags performed well and average reads were nearly 100%.
  - Speed of the fork lift truck had negligible effect on the read rates

- Carbonated Beverage in Metal Cans:
  - The overall read rate for metal cans for all speeds and tag types was a little over 42%.
  - Tag type 1 and 2 (44 %) performed better than tag type 3 (39 %) for readability with metal cans.
  - Speed of the fork lift truck had an inverse effect on the read rates for all tag types. The average read rate for 2.41 kph was the highest (45.37%) followed by that for 8.05 kph (43.06%) and 16.09 kph (37.96%)

4.0 CONCLUSIONS

In conclusion, three products were used to determine effect of pallet speeds through a portal on read rates using three different types of Gen 2 tags. After analyzing the data from this study the following conclusions were reached:

1. Fork truck operating speeds have very little effect on read rates.
Higher speeds over 15 kph reduced tag read rates by about 10% as compared to slower speeds around 2 kph.

2. The read rates for Gen 2 tags are significantly better for all package types as compared to previously reported data and findings for Class 1 Gen 1 tags.

3. Presence of air gaps created in secondary packaging (trays and shippers) configurations between the locations and positioning of RFID tags and primary packages or products (bottles and cans) allows RFID readers to get more effective reads and reduce interferences and reflectance or blockage by water and metal as previously reported.

4. All three types of Gen 2 tags studied showed similar performance in terms of read rates.

5. The type of pallet pattern (presence of air gaps) affects the read rates of packages lying within the palletized structure.

REFERENCES


