A System to Test the Performance of RFID-Tagged Objects

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Abstract

A system is described which has been developed to assess how well RFID-tagged products can be read with various positionings of the tag on the product face. The system can search the entire product surface and provide a measure of tag performance in any location, allowing also for variation in the position of the reader antenna. Simulation of moving products is also possible. Results are shown.

1. Background

RFID tags show great promise for the supply chain, but even newer generations show sharp variations in performance [7]. To implement the technology reliably, its performance must be predictable. Work has been undertaken to test tag performance directly [7], and also to test products with attached tags. One approach to testing tagged products is to simulate a supply chain and send the products through it [3], comparing different tags in different positions on the item to find an optimal location. This technique is effective but time-consuming. In this paper we describe a system developed to automate this process. Automation brings advantages of both speed and accuracy, as well as great flexibility in configuration changes to the testing environment.

2. Overview

The system consists of two Fanuc M6i industrial robot arms which hold the RFID reader antenna and the product under test. The tag is supported on a radio-neutral stand made of wood and PVC piping. With this arrangement any relative position of tag, reader, and product can be simulated. By disregarding the product, the system can also be used to survey the range and other performance characteristics of RFID antennas and readers. The robots and reader are controlled by a custom VisualBasic program, which uses an ActiveX control to directly supply positional data to the robots during testing.

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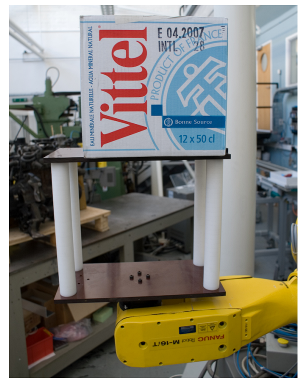

Figure 1. The product holder, shown with a product (a case of bottled water) ready for testing

2.1. The Product

The product under test is supported on a stand made of HDPE which stands .5m above the robot to reduce interference. Once attached to the stand the robot can rotate the item 360° around the vertical axis, allowing all vertical faces (for a cuboid object) to be tested. Other faces can be tested by changing the item's position on the stand. The robot which carries the product runs a simple program which takes a point movement request from the control software and moves the product to that new point, pressing it firmly up against the tag when it's positioned properly.

2.2. The Tag

To simulate the tag being physically attached to a product, the stand which supports it has a flexible mount which presses the tag against the face of the product and stretches it across the surface, ensuring that it lies flush, even along curves or around edges. It does this by gripping the tag at its edges, so there is minimal interference to its performance.

2.3. The Reader

The reader is connected to the PC where it is interfaced to the main VisualBasic program. Interrogation of the tags and internal reader settings are all handled by this program. The reader interface is abstracted to allow different readers to be easily used.

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The antenna from the reader is mounted on the second robot, facing the tag and product. This robot too is controlled by the main program, and it can be moved relative to the tag to simulate a tagged product being read while not directly in front of the reader. A series of such tests can be used to simulate the tagged product moving past the reader antenna.

Inline between the antenna and reader a digital attenuator is used to measure (indirectly) the power received at the tag. It ranges from 0 to 63dB in 1dB increments, with a 2dB insertion loss [6]. The attenuator can be in either the forward or back link; in the case of an Alien or other single-antenna reader it must be in both. It is controlled by a small microcontroller circuit which is also driven by the main PC.

Once the tag is positioned on the product, the attenuator is set to 0dB and the tag is interrogated (the number of interrogations can be set in the software, but the default is 40). The number of successes and the total time are recorded, and the attenuator is incremented and the process repeated. For some value of attenuation there will be no successful reads, and this is the value which is plotted in the final analysis. To increase the speed of the data gathering, it is possible to stop increasing the attenuation once there is no response back from the tag. We have found some cases, however, where a tag does not respond at a given attenuation for some reason, but then does again at a higher attenuation. This is taken to be an indication that the number of interrogations is not sufficiently high, and the reading is a false negative.

2.4. The Software

The system is controlled by a modular application which ties together the low-level communication with individual system components and provides a unified interface. Initial conditions for an experiment are set by manually positioning the product robot so that the tag is in two opposite corners of a face and storing these points in the program. The desired maximum interval between points is then set, and the software creates a set of points for the robot to move to. Once these have been generated, Sections can be deactivated to avoid portions of a face, if desired. The order in which the points are visited can also be randomized to reduce possible false spatial-temporal correlation. After the product movement has been determined, the antenna movements are set. For each desired antenna position, the product test will be repeated. The antenna positions are determined in the inverse fashion from the product: starting from the "home" position—directly in front of the reader—the antenna can be moved a set increment in any direction for any number of steps, for example 3 steps left and right, at 20cm intervals, for a total of 7 tests. The final component of the software is its interface with the reader. Settings such as the number of times a tag is to be interrogated, which frequency bands to use, or which EPC to interrogate can all be set. The actual data recorded is the attenuation required to make the tag unreadable. For each value of attenuation the read rate is also saved.

The data is written out to a log file, which is processed in Mathematica to produce an image of the scanned product.

Optimization It is possible to speed up the collection of data in two ways. First by stopping the increase of attenuation once the tag is no longer read, and second by assuming that adjacent points will have similar attenuations. At sufficient resolution, the variation of an object's impact on the tag should be continuous, so it is sensible to assume that adjacent measurements would be similar. The system can optionally begin its test of a point with the attenuation from the adjacent one, check if that is too high or too low, and then proceed to lower or raise the attenuation respectively.

3. A Comparison with Existing Approaches

There are already many organizations engaged in testing RFID tags and products, either for themselves or for third parties. "RFID testing" is a very broad term, and it has come to encompass many different forms of testing, from confirming that equipment meets relevant standards [5] to looking at the behavior of products when they have tags attached and are shipping through a supply chain [3]. The early standardized tagged-product testing was based on the idea of building a small-scale simulation of the environment in which the products would be read and testing various configurations of tag and reader. This method can involve significant transition times between tests because the objects under test must be manipulated manually. The system described in this paper was developed to introduce industrial automation to the testing process, greatly increasing its speed and accuracy, and therefore allowing more extensive testing in a given amount of time. Performing the tests in a controlled environment also made possible the use of further diagnostic measurements of the equipment under test. These measurements, some of which are demonstrated in the following Section, allow for the prediction of a system's performance in a variety of scenarios without requiring the space to actually simulate them.

After the initial development of the system, we became aware of other systems which take a similarly analytical approach [1, 4, 2]. Our system falls between the empirical and analytical extremes of these two forms of testing.

3.1. Testing with Tags

This system differs from others [2] in the use of the actual tag to test products. It would be possible to measure the received field strength at points along a product, and to then combine these data with a profile of a tag's performance. The trade-off is in the possibility of not entirely accounting

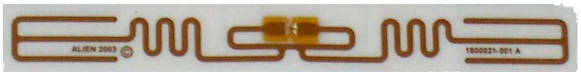

Figure 2. The Alien Technologies “Squiggle” tag

for a tag’s performance when making this profile, and so making inaccurate predictions about the tag’s performance when attached to the product. This system was designed to actually place a tag on a product and take as much simulation out of the process as possible. For some tag geometries a tag needs to be placed in what casual users might consider a counter-intuitive position.

3.2. Testing Without an Anechoic Chamber

To completely guarantee the electromagnetic isolation of an experiment, it is generally necessary to use an anechoic chamber. This will provide results which can be applied to any situation given the appropriate noise model. Using such a chamber provides barriers in terms of cost, setup time, and available space. Rather than isolate the tests from possible noise sources, the system keeps the components under test (the tag and antenna) and their surroundings stationary, moving only the product behind the tag. In this way the performance of the tag is only affected by the presence of a different part of the tested product. By measuring the performance of the tag with the product absent, it is possible to determine its effect on the tag and therefore its performance in a real-world situation.

In the near field of the tag antenna, the product should have the largest effect on the antenna’s performance and so that of the tag. The lack of an anechoic chamber could have potentially greater impact on far field effects. But since the range between tag and antenna is small (1m), the possible surfaces for reflection are relatively distant so any reflected waves would have less power, and therefore have a small effect. The only moving sources of reflection are those on the robot which holds the product, which is below and to the side of the product—any reflected wave would have to travel at least 1.5m.

4. Results

The system was tested with a cuboid case of bottled water and a non-cuboid shrink-wrapped 3-pack of coffee.

4.1. Testing Using the Tag

Figure 3 shows the top of a case of bottled water with the lid removed. Figure 4 indicates good tagging positions in white and bad in black. It is clear that the best locations for the tested tag (an Alien Squiggle, Figure 2) is actually straddling the bottle itself, so that the bulk of the antenna lies in the air gap. This result could have been obtained by measuring the field around the box and then finding the optimal fit of a model of the tag onto the resulting data, but testing directly with the tag was more efficient in this case.

Figure 3. The view inside a case of bottled water

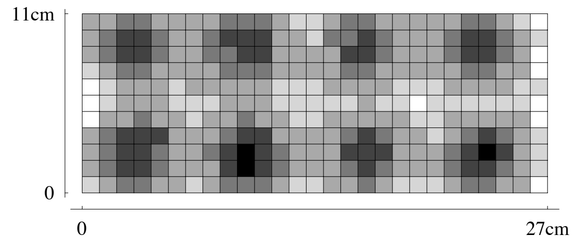

Figure 4. The graph produced by scanning the top of the case

A possible downside of testing with the tag is that it might prove difficult to hold flush to the product. Figure 5 shows an example of a potentially tricky surface: the curve of a heat-shrink wrapping between two cans of coffee. The system’s tag holder was able to position the tag flush along the surface of the shrink wrap over this entire package.

4.2. Testing Without an Anechoic Chamber

Despite not performing the tests in an anechoic chamber, the resulting plots bear out the results of non-automated testing. Figure 6 shows the result of scanning the face of the case of bottled water, and it shows the forms of the bottles distinctly, indicating that there is most interference at the points where the bottles are closest to the tag, and least where there is the largest air gap between bottle and tag.

Figure 5. A tag attached in the air gap created by the heat-shrink wrap between two coffee cans

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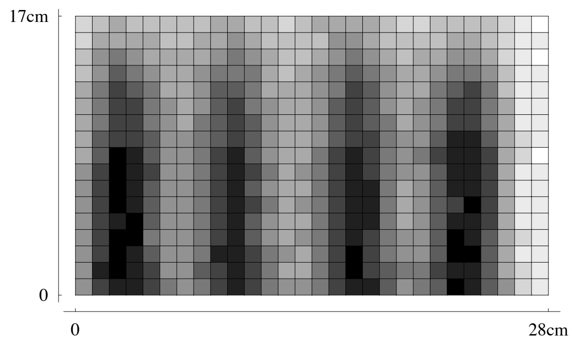

Figure 6. A plot of the front face of the case of bottled water

4.3. Speed

The time taken to measure a point depends on the number of interrogations, but is generally under 1s/attenuation value. Depending on the optimizations used the times for measuring the case of bottled water ranged from 40 to 60 minutes for the largest face, measuring 400 points.

4.4. More Complex Testing: Movement

As a demonstration of the system's ability to manipulate tag, product, and reader, an experiment was performed to simulate a product's movement along a conveyor. The face of the case was scanned 7 times, starting with the reader antenna 30cm to the right of the case and moving in 10cm increments up to and then past it to finish 30cm to its left. This series of graphs is effectively a series of "snapshots" of how the case appears as it moves past the reader on a conveyor. Usually the only read requirement for a system is that the tagged product be read; it does not matter at what point during its time within range of the reader this happens. Therefore the graphic which is truly important is not a measurement of a single moment, but a combination of all of the possible scenarios. Figure 7 shows plots which are the collected best- and worst-case scenario points for each tag location on the case, i.e. in the best-case plot, each point is indicates the best performance that will be seen at that point as the product moves past the reader.

5. Conclusions

This paper has detailed the design and implementation of a flexible RFID testing system. It can be configured to test many permutations of RFID equipment and potential tagged products to gather data useful for predicting the performance of these systems in industrial and commercial environments. By using industrial automation equipment the system can perform repeatably to very high (sub-mm) tolerances and remove many potential sources of error from the experimental process, while also delivering large speed gains over manual tests.

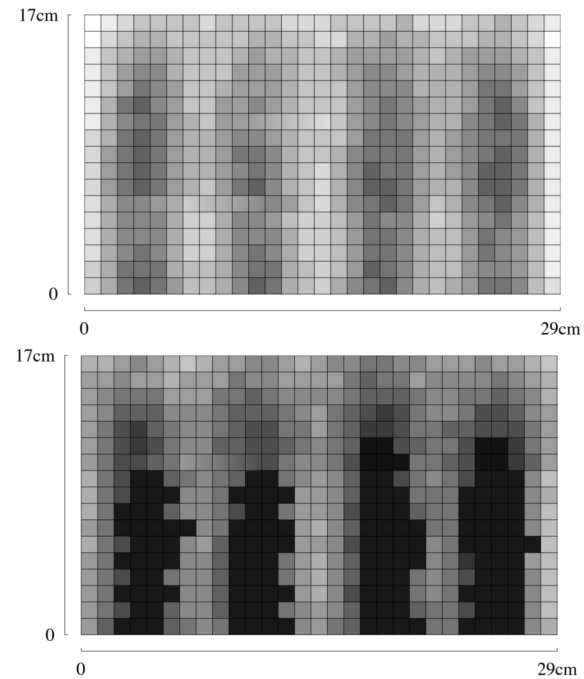

Figure 7. The best-case scenario (top) and the worst case (bottom) for a case of bottled water moving past the reader

6. Future Work

The current system has proven able to handle cuboid items and many irregularly-shaped packages as well. There are improvements to be made in the manipulation of the tag, which currently only fits flat or convex objects, and in the connection method to allow faster changes. There is the possibility of employing more automation to make the changing of tags or antennas automatic and allow for more extensive testing without operator intervention.

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