European RFID Reader Benchmark™
By
ODIN technologies, Inc.

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Thank you for participating in Sirit's Webinar on August 16. Sirit is pleased to provide you with this complimentary copy of the *European RFID Reader Benchmark*™ as prepared by ODIN technologies, the industry's leading independent research lab.

The benchmark was developed to provide end users with objective insight into the RFID reader performance from a European perspective. The report is the first handbook to guide European end users in the optimal technology choice for their RFID program comparing seven manufacturers' readers including Sirit's INfinity 510.

Scoring in the top 2 in 6 out of the 7 tests conducted in the Benchmark, the INfinity 510 was the first worldwide reader on the market to have obtained EPCglobal Gen 2 compliance, interoperability and dense reader mode (DRM) certification; making it the ideal solution whether for national and global installations.

We trust the information contained in the report will help you navigate the decision process in choosing a reader vendor that can meet your operational needs and we hope that you will consider Sirit's INfinity 510 in your evaluation.

Finally, we would like to draw your attention to the Enterprise License statement on the following report cover. This Enterprise License also encompasses the information contained in the appended presentation slides. We would be happy to provide additional electronic copies and access to the replay Webinar to your colleagues, partners or customers, and would ask that you provide their contact details so that we may provide an authorized copy and access directly to them.

Sincerely,

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Trusted RFID Experts

Scientific Research
from ODIN Labs

European RFID Reader Benchmark™

An Evaluation of ETSI Compliant Readers

June 2007

ODIN technologies Labs

The European RFID Reader Benchmark

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1 EXECUTIVE SUMMARY

Europe is on the cusp of an RFID transformation. Retailers, manufacturers, aerospace, defence, pharmaceutical and healthcare companies have found competitive advantage by intelligently moving the technology beyond the IT sandbox and into the business strategy playing field. This clear trend in the EU, combined with improving technical performance and specifications has led many potential end users to wonder which technology to invest in. ODIN technologies has focused its latest RFID Benchmark research on the leading UHF RFID readers available for the European market. Reader performance is compared in a series of scientific and use case tests to identify which readers are best suited for various applications throughout the supply chain. The purpose of this report is to provide an objective, trusted opinion to help guide your purchase decisions.

As you read this report keep in mind that a holistic approach to any RFID project is a must for success - a proven approach which includes business process planning, physics assessment and then choosing the correct hardware and software all come before integrating hardware to the network. This European RFID Reader Benchmark™ should be used in conjunction with your planning and physics activities, to assist you in determining which UHF reader is optimal for your requirements or simply which short list of vendors you should consider from the start.

ODIN technologies has deployed hundreds of RFID readers in more than 125 paid projects, including the largest global RFID deployments in the world. A core vein running through the RFID body is the fact that no one size fits all. The engineers at ODIN have seen passive RFID, Active RFID, UHF, HF, LF, SAW, UWB and other technologies work for the right applications. And, active RFID technologies will be part of a forthcoming benchmark from ODIN. This report focuses on ESTI compliant UHF passive RFID, which is being used today by European leaders such as Airbus, Marks & Spencer, METRO and many others to enable supply chain visibility and fulfillment efficiency.

The quick take

North American vendors are clearly leveraging an early lead in the R&D of RFID to outperform the European-based manufacturers. Italian company CAEN has produced an offering that shows considerable promise. However, CAEN still needs to refine its performance in field use cases and provide a revised user interface. This trend of North American vendors leading in performance over European vendors correlates to the European deployment demand. Unlike the United States, where the Department of Defense, Wal-Mart, Shaw Industries and others have deployed aggressively, Europe is just now seeing large-scale production RFID capabilities in deployment.

The readers trail in performance because the European market has trailed in adoption and North American reader manufacturers simply have more field experience and customers, which has provided input into performance improvements.

Why readers matter

Reader performance is one critical key to a successful RFID implementation for four reasons:

1) ***Accuracy in Data Collection is essential –*** An RFID solution is only as accurate as the data gathered at the network edge. If the reader fails to capture tag data, no amount of middleware, integration elegance or process efficiency can retrieve it. RFID read rate accuracy is the top goal and requires physics expertise – 100% read rates should be the objective and fact-based reader selection based on performance is essential.

2) ***Most complex system component –*** The wireless system that retrieves RFID tag data is enormously complex. Success is achieved by balancing hundreds of variables managed by the reader.

3) ***Reader maintenance is expensive –*** Long-term solution cost will be driven by reader maintenance. Frequent firmware upgrades, configuration optimization and performance diagnosis will be issues for the foreseeable future. In the next ten years most manufacturing or distribution-centric enterprises will have more RFID readers than telephones. This will evolve into a CIO's nightmare as sophisticated readers proliferate on the edge of the network unless they work consistently and support the use of software tools that make support and maintenance more efficient.

4) ***Deployment decisions are expensive to reverse –*** A reader implementation is a business decision that affects budgets, processes and systems. Many large organizations, particularly in the United States have spent millions of dollars on technology that is now inadequate or obsolete.

1.1 The Value of This Report

Simply put, RFID readers should just work. End-users should not need a PhD in physics to cut through the marketing hype of today's RFID environment to find the best reader for an application. By purchasing this study you've made an investment, in helping protect your capital budget. Leave the physics to ODIN technologies and spend your time realizing the business value associated with deploying RFID. Taking this approach dramatically reduces the amount of time and effort required to scale the learning curve associated with reader testing and evaluation.

1.2 Using Science to Realize Business Value

Working with UHF RFID readers since 2002, ODIN technologies has identified six scientific tests to characterize and compare RFID reader performance. All RFID use cases are dependent on a blend of the following performance characteristics – power output, occupied channel power, receive sensitivity, interference rejection, tag acquisition speed and read distance. Understanding how they relate to the use cases valuable in your operation and how each reader performs will help guide you to the best reader selection decision for your business.

The six scientific tests that ODIN evaluates to get to the heart of reader performance are:

1.2.1. Power Output Analysis

Most modern readers, and certainly the top level readers, provide a means of controlling RF output power. Power should be level across the reader frequency range and should measure the same on every port. The ODIN Power Output Analysis measures the behavior of the readers along this axis using the software and firmware provided by the manufacturer.

1.2.2. Occupied Channel Power

All readers must conform to the regulatory environment where they are to be operated. The ODIN Occupied Channel Power test examines whether a reader meets the requirements of the ETSI EN 302-208 emission mask.

1.2.3. Receive Sensitivity

Readers should be sensitive enough to read all of today's ISO 18000-6C tags (EPC Class1 Gen2) to the furthest extent to which they can be powered. Tag signals can also be degraded by multi-path and by the material to which the tag is applied. The ODIN Receive Sensitivity test controls all of the variables that affect receiving a tag signal and allows an accurate and repeatable comparison among readers.

1.2.4. Interference Rejection

The ODIN Interference Rejection protocol is designed to provide a comparison among the readers as regards their ability to reject RF signals from adjacent sources.

1.2.5. Tag Acquisition Speed

One of the core attributes of a reader is its ability to handle large tag populations. The ODIN Tag Acquisition Speed test exposes the reader to an impossibly large population that extends beyond the field of the test antenna. The test measures how many tags can be identified in a controlled time period.

1.2.6. Read Distance

The ODIN Read Distance test provides a window into each reader's ability to read a medium population of tags at increasing distances.

In addition to devising metrics for the scientific tests above, we augmented our testing with real world use case scenarios:

1.2.7. Conveyor Testing

The ODIN Conveyor test provides metrics around one of the less challenging but widely deployed use-cases; the ability to read a case level tag as it passes a given point on a conveyor system. ODIN sets high velocities to stress the readers' capabilities.

1.2.8. Stretch Wrapper Testing

Many end-users are finding that aggregating case level tags as cases are assembled on a pallet adds to the value of using RFID in business processes. The ODIN Stretch Wrapper Reading test compares the readers in their ability to collect all of the data in a Stretch Wrapper interrogation zone.

1.2.9. Adjacent Dock Door Portals with Listen Before Talk

The ODIN Adjacent Dock Door Portal test provides a harsh test of a reader's capability. The test identifies a large population of tags in an environment where nearby readers are also operating. The current ETSI EN 302-208 regulation requires readers to listen for channel occupancy before radiating in that channel, known as

the Listen Before Talk protocol (LBT). This test provides insight into the difficulty reader manufacturers have had meeting the very strict requirements of this protocol.

1.2.10. Adjacent Dock Door Portals with Proposed ETSI EN 302-208

ODIN technologies repeats the Adjacent Dock Door Portal test, disabling the LBT functionality and substituting the channel scheme under consideration and expected to be adopted by the European Telecommunications Standards Institute (ETSI).

Results from these use-case tests, coupled with the scientific performance results, allow the RFID end user to make informed decisions about reader selection.

1.3 Managing Risk

Managing the risk associated with selecting an RFID reader is critical to good service and support. Risk can be assessed on characteristics such as the established infrastructure for support, returns and maintenance in Europe. Choose a reader manufacturer with the stability, infrastructure and resources to keep up with production and ongoing support demands if you are going to a full production system. If your risk tolerance is higher, you can pick an upstart that may have better performance but less stability. Often the upstart ends up being the long-term winner in the space, as they are focusing only on one technology.

1.4 How did the Readers Compare – The ODIN Reader Evaluation

Selecting the right RFID reader for your business operation is analogous to selecting the right wine for a dinner – some meals require a simple table wine while others deserve nothing less than a vintage Bordeaux. Choosing your optimal reader requires scientific evaluation with an eye towards business realities. The key criteria for selecting the right vintage are reader performance in the areas that matter to your application.

As you can see from the chart on the following page, four reader vendors were ranked as strong performers – Sirit, Impinj, Motorola and Intermec. These companies either exhibited exceptional technical performance such as Sirit and Impinj or very good performance such as Motorola and Intermec. For the majority of users, any one of these readers will perform successfully provided there is a strong understanding of the configuration and optimization.

Readers in the lower portion of the chart are all capable products with strong distinguishing features such as Caen's receive sensitivity, interference rejection and long distance read ability, Alien's ability to read large populations of tags and good receive sensitivity, and Feig's unique approach to managing the LBT challenge, but overall they performed less well on the scientific and use case tests than their top-performing peers.

The data in the following pages will arm you with solid knowledge on the major players.

European Reader Performance Summary										
Vendors/Models	Power Output	Occupied Channel	Receive Sensitivity	Interference Rejection	Tag Acquisition	Distance Testing	Conveyor Testing	Stretch Wrapper	Adjacent LBT	Dock Door Channel
Sirit IN510	High	Yes	6 (M)	2	★1	★1	Yes	2	2	★1
Impinj Speedway	High	Yes	2 (H)	4	2	3	Yes	★1	4	2
Motorola XR480EU	High	Yes	4 (M)	3	3	2	Yes	4	3	3
Intermec IF61	High	Yes	3 (M)	6	6	6	Yes	3	5	4
Alien ALR8800	High	Yes	5 (M)	5	4	5	Yes	5	6	5
Caen A948EU	Low	Yes	★1	★1	5	4	Yes	7	7	7
Feig LRU2000	High	Yes	7 (L)	7	7	7	Yes	6	★1	6

Figure 1: European RFID Reader Performance Summary

A Note About Readers Tested:

ODIN technologies invited all the major reader manufacturers active in Europe today to participate in this head-to-head Benchmark. Those who had confidence in their equipment, and who were looking to improve their technology based on objective testing participated. One manufacturer did not choose to have their readers evaluated, and likely were concerned with the performance outcome vis-à-vis their peers. We applaud all the participants and their willingness to lead the industry through improved performance and the lens of public scrutiny.

1.5 Scientific Objectivity

ODIN technologies does not manufacture RFID readers, tags or printers and maintains strict independence in our testing and selection processes. However, we do take RFID equipment out of the lab and into the field to deploy it for large and medium-sized companies worldwide. The analysis included in this benchmark is based on the critical issues that make a difference in real-life RFID deployments, whether its 90 facilities or one, readers should just work and scientific objectivity can help you narrow your selection decision.

2 PURPOSE OF STUDY

2.1 Background

Europe is undergoing an RFID revolution. Large retailers are planning major deployments, and new applications are reported almost daily. Aerospace and other manufacturers are saving costs and improving accuracy, and pharmaceutical companies are preventing theft and fraud through the use of RFID.

Complementing the increased European interest in RFID are an improving standards and regulatory environment. ISO has adopted the ISO 18000-6C protocol, which is the highly successful EPC Class1 Gen2 air protocol for tag-reader communication. The European Telecommunications Standards Institute (ETSI) has recognized the difficulties in applying Listen Before Talk (LBT) to RFID. It is now nearing the adoption of a revised ETSI EN 302-208 standard, allowing four channels of RFID operation without LBT.

As these vines begin to bear fruit, ODIN technologies determined that the timing is ripe to focus its analytical test protocols on the RFID readers that serve the European market. Three leading European and five North American reader manufacturers were invited to participate in the process; one European manufacturer, Siemens, declined the invitation, which is typically an indication that the vendor is not confident in its current reader performance compared to its peers.

ODIN technologies has published the RFID Benchmark Series since 2004. These benchmark reports provide RFID adopters an independent and impartial set of performance tests to complement the marketing and sales efforts of RFID vendors.

2.2 Objectives

The 2007 European RFID Reader Benchmark has several objectives:

First, as with all the ODIN technologies benchmarks, this study will inform the end user in deliberations regarding RFID equipment purchases. RFID equipment varies in pricing and in value; just as you might choose an expensive wine for an important or special purpose, one might need the most capable equipment for a particularly difficult installation. On the other hand, you might select a more prosaic (and less costly) vintage for some less demanding requirement.

Second, the ODIN technologies benchmarks also drive debate and have led to equipment performance improvements. Manufacturers by nature believe their product is superior to all others; independent observations can lead to internal re-examination and from there to product enhancements.

Third, this Benchmark includes independent testing and validation of the proposed amendment to the ETSI EN 302-208 standard. The amendment is expected to materially improve the capabilities of passive UHF RFID in the European market by removing the constraining Listen Before Talk requirements for frequency channel occupation.

Finally, the European RFID Reader Benchmark should serve as a document to which end users with new and emerging applications requirements can turn to find objective, scientific information about RFID technology. In a market saturated with inflated claims and non-standardized data, the technology can be misapplied, leading to costly mistakes and

abandonment of promising processes. ODIN technologies has from its start developed RFID solutions based on complete understanding of the needs of its customers and in-depth understanding of the physics underlying RFID. We leverage this expertise throughout the European Reader Benchmark™.

2.3 Fixed RFID UHF Readers – Practical Uses

Fixed UHF readers enable hands-off data capture requiring no human intervention. They represent an unobtrusive way to capture data for visibility, event documentation, quality assurance and security. This data capture can occur transparently throughout the supply chain, manufacturing plant or at customer touch points. This is in stark contrast to most data capture methods, which require human intervention or closely followed processes.

Fixed UHF (ultra high frequency) readers are becoming the most ubiquitous RFID equipment available on the market and at between €1,000 to €3,000 a unit (not including peripherals), represent a significant upfront capital cost for each deployment. Combine this cost with the fact that along with tags, RFID readers represent the most critical element of read rate success, a correct reader decision has both financial and performance impact.

The challenge for end users is to differentiate between the hype promoted by each reader manufacturer's marketing department and actual expected performance. Not surprisingly, there is a difference. In order to maximize your chance for a successful RFID implementation, it is critical that you properly select and tune your reader. This ETSI Reader Benchmark is the first to offer end users objective, scientific evidence of which readers work the best, which may work sufficiently, and which pose the biggest risk.

2.3.1. UHF at the Pallet, Case and Item Level, and Others

The research in this report addresses key performance characteristics that are relevant to supply chain tracking in the aerospace industry, retail industry and many other verticals. The performance characteristics of UHF RFID readers are germane at several packaging levels. Typically, there are one or more characteristics that are most important for a specific use case. For example, for pallet tracking, read range, tag volume and speed are critical, but for low speed conveyors, read range tends to be most important.

2.3.2. Common UHF Use Cases in the Field

The most common uses for fixed UHF RFID today include reads at dock doors, on conveyors, at stretch wrappers, and in specific storage locations. These uses can be broken down further into read types such as pallet, case, item or asset. Combine the use and type with requirements such as speed, number of items, transport method and proximity to other readers and you have the critical elements of a use case. The "use case" includes the where, what and how variables of your process and system.

Each use case places stress on RFID capabilities in different ways. Some of the critical performance characteristics that drive use case success include: read distance, read speed, interference rejection, ability to read large populations of tags, and others. Reader selection and configuration can have a large impact on your read success depending on your use case requirements. Some readers are simply stronger at specific performance elements than others. Just like selecting the wrong wine with an entrée, if you do not choose the right tool for the job at hand, you risk low read rates and an under-performing system.

The reason reader selection and configuration is so critical is simple. If the tag and reader do not communicate efficiently and consistently, the entire system will be flawed. Your data will be inconsistent and unpredictable no matter how elegant your backend software processing. ODIN technologies addressed the tough question of choosing the right Gen 2 UHF tags in the *RFID Global Tag Benchmark* in November 2006 (www.ODINtechnologies.com/store). The Global Tag Benchmark, your use case requirements, and the performance of the ETSI readers tested in this report will help you be best informed for a reader selection that meets your needs and maximizes your probability of high read rate success.

3 READERS USED IN TESTING

3.1 Readers Tested

Figure 2: Readers tested in European RFID Reader Benchmark

Seven readers were tested in the European RFID reader benchmark. These included the Alien ALR8800, the Caen A948EU, the Feig ID ISC.LRU2000, the Impinj URP1000-ETSI (also known as the Speedway), the Intermec IF61, the Motorola XR480EU, and the Sirit IN510. All the vendors should be applauded for their willingness to subject themselves to the rigors of independent, scientific testing. We had hoped to include in our analysis the Siemens Simatic RS600R, but Siemens declined to participate in the benchmark.

4 EUROPEAN READERS – MARKET OBSERVATIONS

Conventional wisdom holds that European adoption of RFID has been hampered by tight frequency regulations. However, the European Telecommunications Standards Institute (ETSI) has proposed changes to RFID transmission regulations that should drive more rapid RFID deployment in Europe. These include the reallocation of spectrum to support four high power 200 kHz channels for reader transmission and the removal of the Listen Before Talk (LBT) requirement.

Spectrum reallocation will lead to improved performance by ensuring that readers do not transmit on the same channel as tag backscatter. It also means that dense-reader deployments are now practical in Europe. Without the requirement for LBT, readers will be permitted to re-use frequency channels. Because reader transmissions are spaced at a minimum of 0.6 MHz and in most cases 1.2 MHz apart, reader-to-tag and reader-to-reader interference will be virtually eliminated. Moreover, higher reader transmission and tag backscatter rates are made possible, improving tag singulation throughput and increasing tag read reliability.

The removal of the Listen Before Talk requirement also means the likelihood of a tag being missed by a reader greatly diminishes. For time-critical applications, such as items moving on a conveyor, the transmission channel must be immediately available—a condition not always possible when a reader must listen for a free channel before initiating transmission.

These changes, plus a growing number of RFID deployments throughout Europe, are encouraging European retailers and manufacturers to adopt RFID to achieve supply chain efficiencies. The high concentration of countries and borders in Europe makes the shipment of goods more complicated than in the US, also driving a focus on supply chain efficiency. This contrasts with US manufacturers who have ranked mandate compliance and federal regulation as primary reasons for adopting RFID, and Asian manufacturers who are interested in supply chain visibility, as surveyed in the 2nd Annual Global RFID Report by Manufacturing Insights.

4.1 The impact of major European companies driving RFID adoption

How will major retailers and industrial manufacturers' reader selections impact the market? Marks & Spencer and METRO Stores have made their decisions and Karstadt is not far behind. The reader industry in Europe is moving from the pilot and trial stage to early deployments, and certain vendors are getting a head start through participation in these programs. End-users can be confident that suppliers such as Sirit and Intermec are here for the long term, and it is likely a few other winners will emerge over the long term.

Metro Stores Makes the Call – the Metro mandate

"Now, it is time for a broadscale rollout of RFID" – Gerd Wolfram, managing director of Metro Group Information Technology, announced the retailer will require its top suppliers to tag pallets shipped to 180 METRO locations within Germany starting October 1, 2007. Suppliers not in compliance will be charged a fee per pallet. If successful, case-level initiatives will begin in 2008. METRO has shared with its suppliers that RFID is the key to more transparency and efficiency in its operations.

Airbus takes RFID into Aerospace - Enabling Value Chain Visibility

At the 2007 Paris Air Show, Airbus formally acknowledged a far-reaching RFID initiative and its selection of ODIN technologies as its exclusive worldwide RFID hardware integration partner. This program in phase one will create value chain visibility from suppliers through aircraft assembly. Future phases include asset tracking and flyable part tagging, enabling item lifecycle track and trace. Airbus' announcement signals that another major vertical industry in Europe beyond retailing has a coordinated effort to utilize RFID across its operations and supply base. As with the United State Department of Defense RFID rollout in the United States in 2006, the Airbus program is expected to catalyze an entire sector of industrial goods manufacturers to begin utilizing RFID.

4.2 European footprint is more important than business address

The importance of European in-market experience and resource presence should not be under-estimated by RFID vendors, many of whom are based in North America. The regulatory and operating policies and common business practices are different in Europe. However, the perceived end user risk of buying equipment from North American vendors should not be based on where their headquarters are located, but rather on the scope and scale of their business in Europe.

Intermec and Motorola are not European companies, but their European operations are extensive and readily available for support. Similarly, there are European reader manufacturers who have headquarters in region, but are not very large and do not have substantial resources to support production RFID operations.

These dynamics are having an impact on the RFID landscape in Europe. Here is a breakdown of ODIN technologies' market observations, developed through direct interaction with its European client base and a number of reader evaluation cycles:

Alien – Based in North America, Alien has a smaller client base in Europe than in the United States where it has a large client base of Wal-Mart suppliers. In some selection decisions, they were not considered due to its withdrawn IPO attempt in 2006.

Caen – Based in Italy, Caen is not top-of-mind for most RFID end-users beyond the boundaries of its homeland. However, their financial and support presence position them well for serious consideration.

Feig – Based in Germany, Feig is perhaps the best-established RFID company on the continent. Selling a broad portfolio of LF, HF and UHF technology, they are financially secure, claiming a reader footprint of greater than one million devices. They are considered in any serious reader evaluation process, although to be fair their reputation and skill base is rooted in their substantial market share in HF passive RFID. Feig's UHF offerings are less mature.

Impinj – Based in North America, Impinj has aggressively pursued a number of large-scale buyers and advertised its performance in tests at a METRO distribution center. However, among small to medium sized buyers, who do not justify the same time and attention, the company is viewed as a higher-risk option with little on-continent presence.

Intermec – Based in North America, Intermec is the most-established non-EU RFID company in Europe. As one of two vendors selected by METRO Stores for a 150-store deployment later this year, Intermec is well positioned to capture a significant portion of the European market and leverages a support infrastructure already in place to service their bar code hardware.

Motorola – Based in the North America, Motorola has a massive distribution channel in Europe, but its RFID product line is not as well known in the EU. Motorola has key deployments, such as with SONY Europe, but the company must leverage its channel to build greater mind share across Europe.

Sirit – Based in North America, Sirit has been deployed by several high profile retailers, including Marks & Spencer, and is one of two companies slated for deployment by METRO Stores later this year. Unlike Intermec, Sirit does not enjoy the same level of mind share and acceptance among small to medium sized buyers.

Siemens – Based in Germany, the company is generally well regarded for a broad range of reliable products. Its RFID reader, although uniquely ruggedized and thoughtfully constructed, has not performed as well as other readers in testing conducted by ODIN technologies outside this benchmark. In trials conducted by ODIN technologies, the RF660R was found to have significantly lower receive sensitivity. This likely explains why Siemens elected not to participate in this Benchmark.

5 SCIENTIFIC TESTS

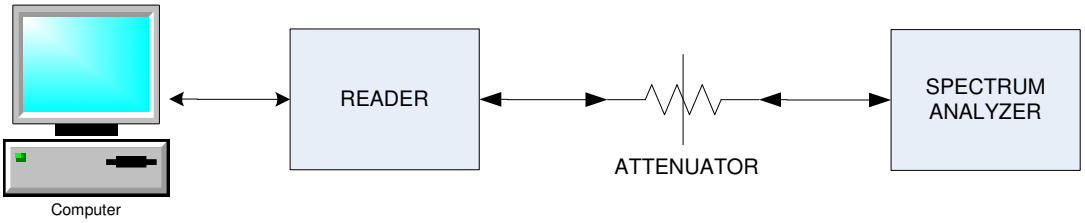
ODIN technologies has applied its industry-leading team of physicists and RF engineers to answer the question of best (and worst) European ETSI compliant RFID readers on the market today. Efforts were taken to isolate and control the test variables to ensure relevance and repeatability within the testing. ODIN technologies investigates only production readers configured with production firmware. These are readers available for purchase today.

5.1 Power Output Analysis

Effective power management is critical to RFID reader performance because it determines the range and consistency of tag capture. Overdriving reader transmit power is tempting for reader vendors because extra power often achieves better results in a single portal situation; however, in multiple portal installations (such as distribution centers), extra power can lead to extra interference, not to mention regulatory issues. Installers need to know that when they set a power level in software that the reader responds appropriately. They are also interested in whether there is extra power available to compensate for attenuation in long cable lengths.

Purpose. To investigate the maximum power capability, linearity, accuracy and port-to-port variability of the tested readers.

Apparatus. Reader power measurements were conducted using a Rohde and Schwarz spectrum analyzer. Because different readers have different connectors for RF ports, ODIN technologies created standard length cabling terminated with the appropriate connector for each reader. This removed the influence of cable length and adapter variations as uncontrolled variables. Conducted power measurements at each reader port were taken.



Power output analysis test setup

Procedure. Three subtests are conducted in this procedure.

First, the first RF port of the reader under test (RUT) was connected to a Rohde and Schwarz FSH3 Spectrum Analyzer. The RUT was tuned by means of software control to 866.3 MHz, and power was varied under software control across its entire range. At each point, power was measured on the R&S Analyzer and recorded.

Second, the RUT was returned to its maximum power setting, and the power was measured and recorded for each of the four RF ports.

Finally, the RUT was reconnected to the first RF port and the frequency of the RUT was varied in 200 kHz steps that match the ETSI EN 302-208 Short Range Device (SRD) channels. At each frequency, the reader was set to full power. A measurement was taken and recorded of that power level.

Results.

A well-behaved reader will exhibit close correlation across the frequencies and across its RF ports. All the readers tested by ODIN technologies for this Benchmark exhibited close correlation. The largest variance was 12% across antennas exhibited by the Feig LRU 2000 reader. The median variance across antennas and frequencies was 5%.

In addition to the variance across ports and antennas, the maximum power available from the reader, and the linearity and accuracy of controls are important.

Power measurement focused on peak RF power output at the reader port. Each reader was configured using the manufacturer supplied Web interface or software to reflect maximum power at the port and varied in steps allowed by the manufacturer's interface. The results were generally accurate and linear, with one notable exception.

The power from one of the reader models measured significantly differently than the power assigned by its controlling application. The Caen A948EU reader is advertised to provide 35 dBm. However, the software controls would not provide a setting beyond 32.7 dBm, and the output power actually leveled out at about 31.4 dBm. The power decreased linearly and read about 3 dB below the software setting from there. It is likely that the reader cannot actually radiate a power level beyond 31.4 dBm. However, the error in power finds its source in the applications software rather than the reader hardware provided. Figure 3 reports the results.

The power output from the Motorola XR480EU reader was at significant variance from the power assigned by the Motorola *Showcase* software. The Web interface did allow accurate control of the power. The variance highlighted an issue with the *Showcase* software that the manufacturer will rectify with the next software release.

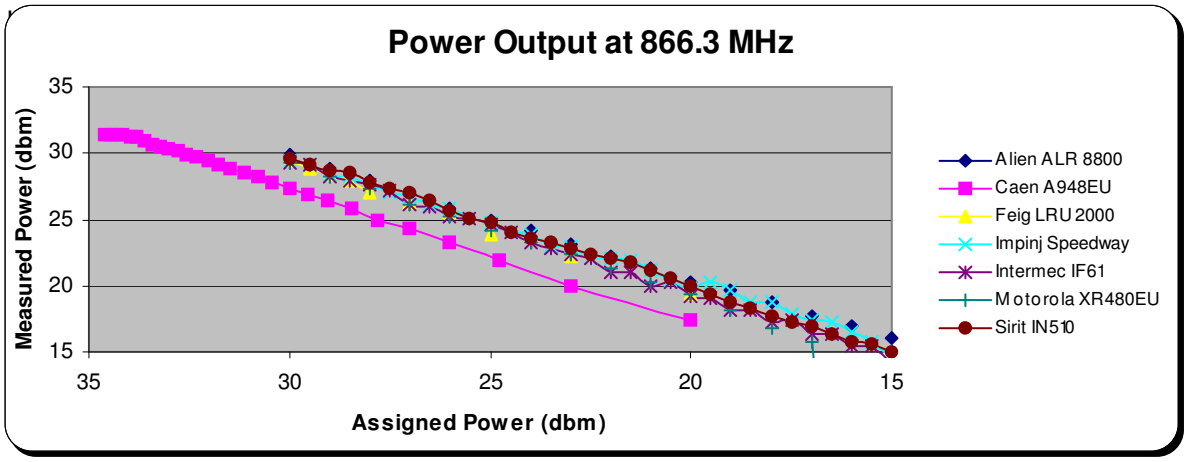


Figure 3: Power output analysis

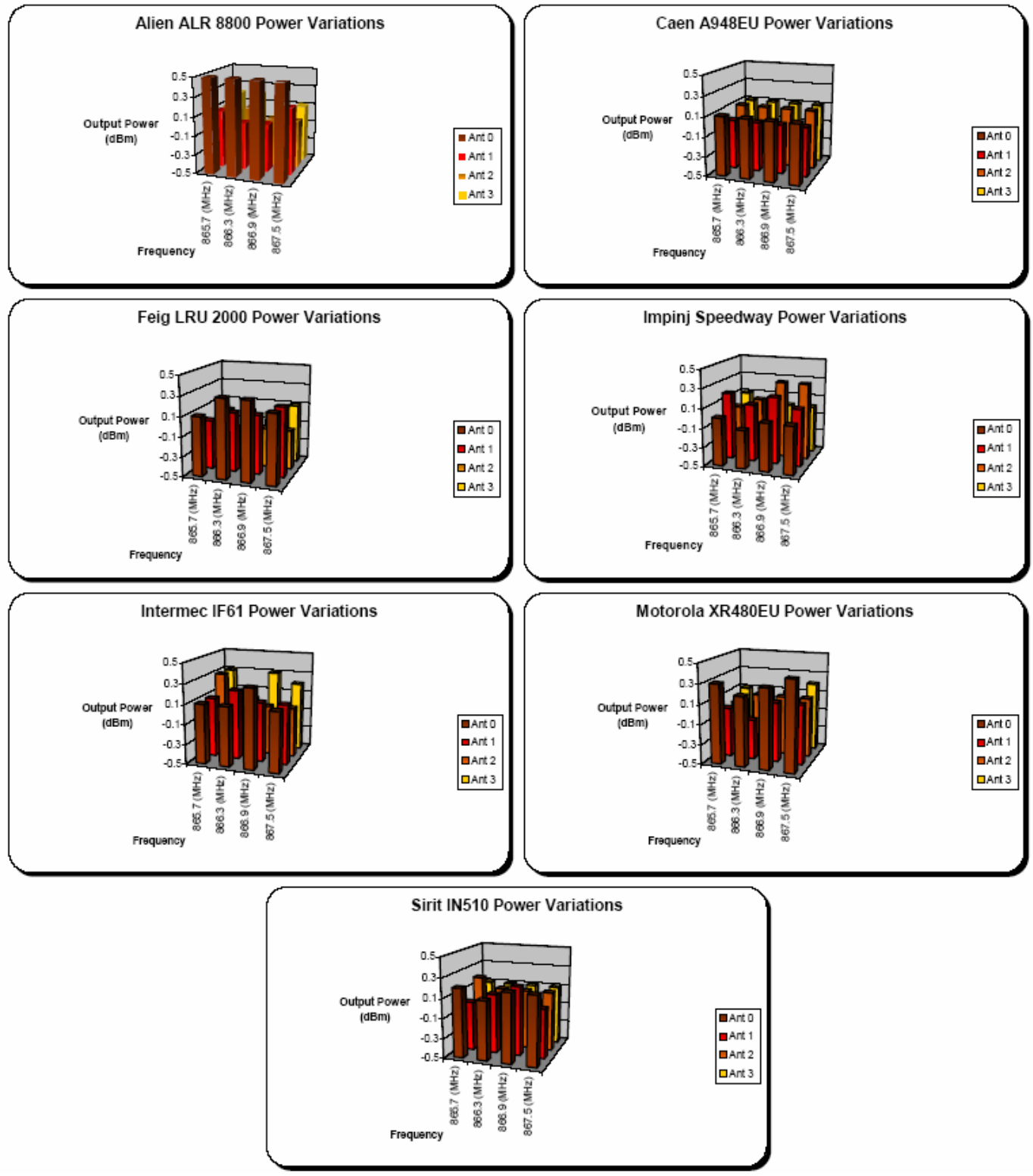


Figure 4: Frequency and port power variations

Applying the Results. Power output is one of the basic configuration requirements for any RFID reader installation. Installing a reader which is "too hot" can result in degraded performance from unwanted tag reads, can cause additional interference among readers and may result in regulatory action. On the other hand, a reader that has a reduced power output can result in missed reads. The end user, generally lacking the test equipment required to confirm power output, relies on the system software to establish the correct and legal power for the application. Software that reports a power level setting must set the correct level.

Some reader manufacturers provide software calculators to establish power levels. We have not yet seen such a calculator that is superior to or replaces a firm understanding of the physics and regulatory environment involved.

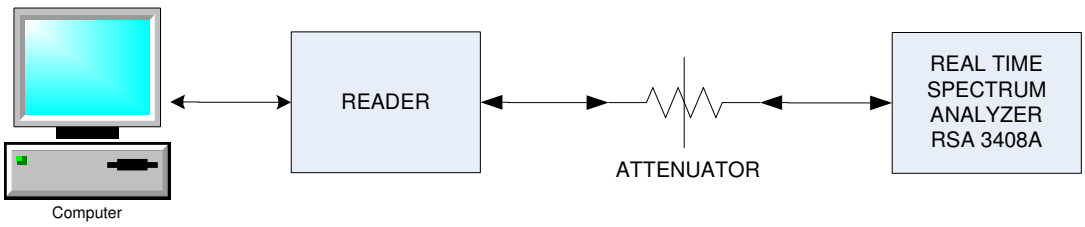
All of the tested readers exhibited good power consistency across the frequencies tested and their antenna ports. Such readers are simpler to install and tune for best results.

5.2 Occupied Channel Power

Among RFID manufacturers, European regulators have the reputation of being stricter than the Federal Communications Commission in the United States. ETSI EN 302-208 is very specific regarding the emission mask allowed by Short Range Devices (SRDs), including RFID readers. A reader that exceeds the limits imposed could cause excessive interference with adjacent readers and degrade system performance.

Purpose. ODIN technologies conducted an Occupied Channel Power test using the limits adopted by ETSI in the EN 302-208 standard to confirm that all of the readers in fact were within specification.

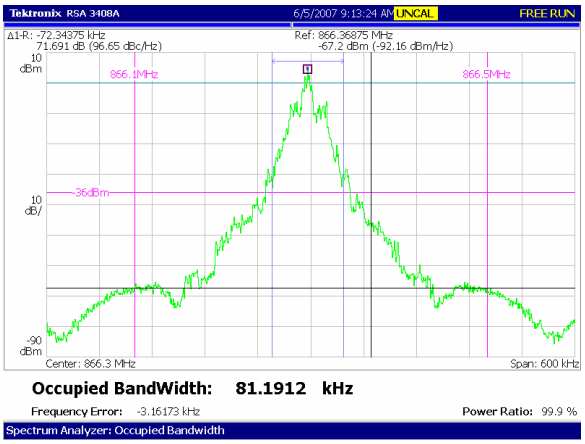
Apparatus. The basic apparatus used for the Occupied Channel Power test is the Tektronix RSA 3408A Real Time Spectrum Analyzer. The RTSA provides highly precise measurements and spectral triggering not common to other less sophisticated instruments. Standard cabling fabricated for this testing was used.



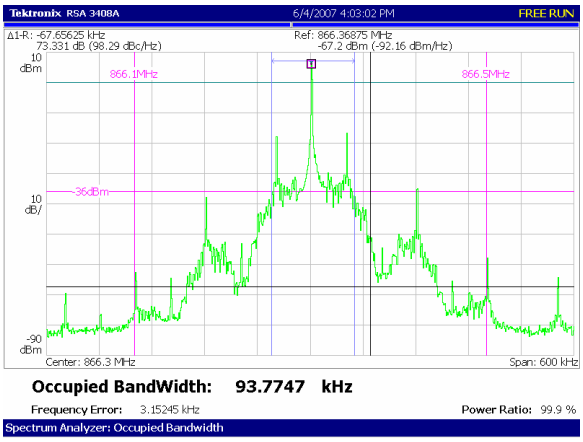
Occupied channel test setup

Procedure. The RUT was connected to the RSA through a 10dB attenuator (to prevent possible overload or damage to the test equipment). The RSA was set to report Occupied Channel Power at the 99.9% level (30 dBm). Using the manufacturer's software or Web interface, the RUT was started and conducted full power into the RSA.

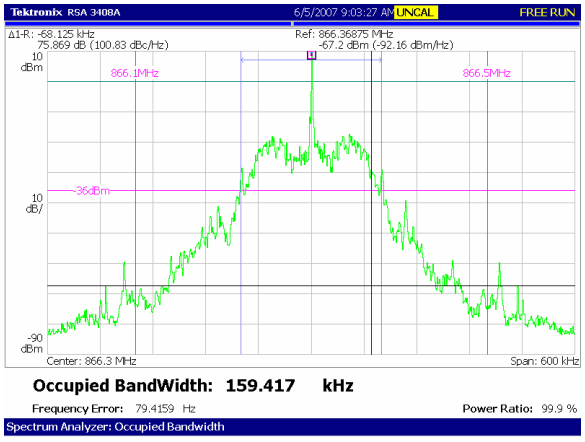
Results. Figures 5a and 5b display the RSA display for each of the tested readers. The Alien ALR 8800 demonstrated the narrowest Occupied Channel, the Impinj Speedway the widest. All of the readers were in compliance with the ETSI EN 302-208 specification.



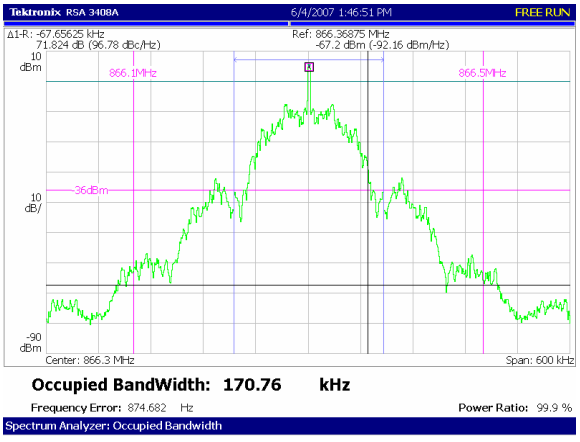
Alien ALR 8800



Caen A948EU

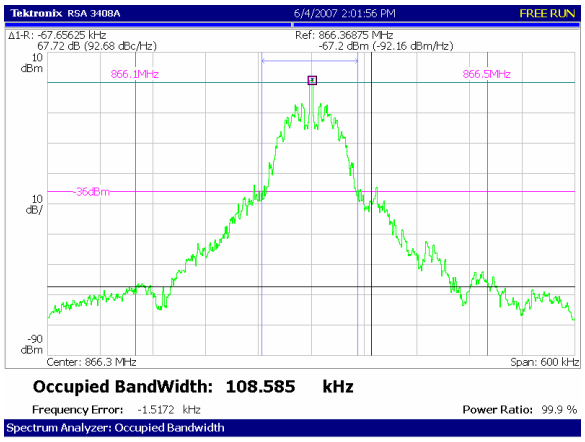


Feig LRU2000

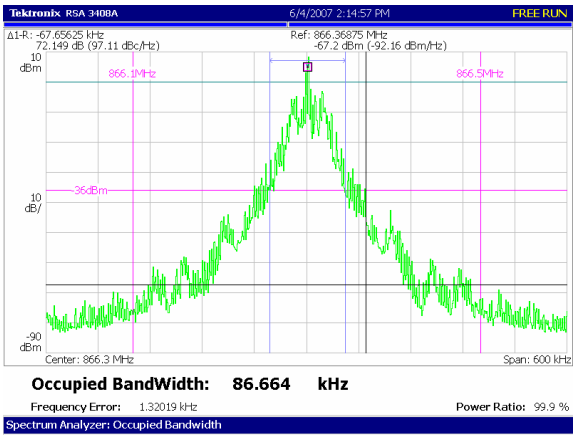


Impinj Speedway

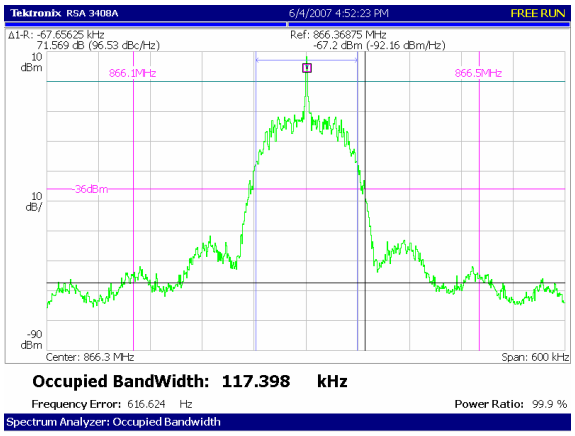
Figure 5a: Occupied Power Setting Results



Intermec IF61



Motorola XR480EU



Sirit IN510

Figure 5b: Occupied Power Setting Results

Applying the Results. Since the Occupied Channel Power is not under end user or installer control, the manufacturer must ensure that the readers comply with the regulations. The organization that is considering which system to procure and deploy can be assured that all of the readers tested for this Benchmark comply with the ETSI specification. End users planning to deploy RFID systems may wish to seek similar assurance about readers not included in this Benchmark.

5.3 Receive Sensitivity

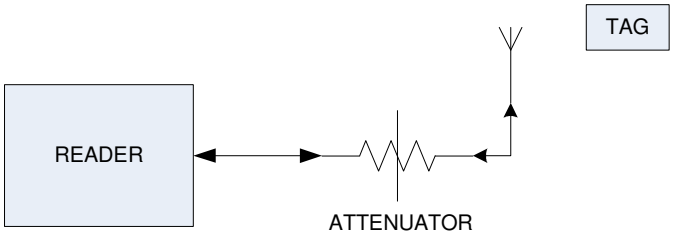
Every reader design team faces the formidable challenge of designing a system that transmits 2 Watts Effective Radiated Power (ERP) while simultaneously listening for a faint tag response that is one millionth as strong. Success is driven by the ability to carefully filter the tag response from the transmission signal so that these two signals do not interact destructively within the reader.

Conducting receive sensitivity measurements is non-trivial. Absolute sensitivity measurements are conducted during the engineering development of a reader with

tight controls on the level of injected signal. Fortunately, to compare among readers, relative reader sensitivity is sufficient, as long as the test setup remains consistent for tested readers. ODIN technologies has developed a test setup that achieves this end, while ensuring that experimental insertion losses are held constant for each reader.

Purpose. This test is conducted to determine the relative receive sensitivity of each reader and provide a comparison among the tested readers.

Apparatus. The test requires a fixed reader antenna/tag geometry; in this case, a tag 1 meter from a standard RFID antenna. RF transmission line circuitry created separate pathways for the transmitted and received signals. Adjustable attenuators were inserted in the receive pathway.



Receive sensitivity test setup

Procedure. The test was conducted by calibrating the output power level of each reader so that each generated equivalent transmission power to within a 5% tolerance. The RUT was set to radiate at 866.3 MHz. Attenuation was added to the receive pathway in 0.1 dB resolution until the tag was no longer displaying as being read by the reader. The total attenuation value was recorded and reported for each reader.

Results. A 20 dB difference in receive sensitivity is identical to saying that one reader is 100 times more sensitive than another. The Caen A948EU narrowly edged the Impinj Speedway as the most sensitive reader tested. The Intermec IF61, Motorola XR480EU, Sirit IN510 and Alien ALR8800 all performed within 6dB of each other. The Feig LRU 2000, at 12.5 dB, demonstrated less sensitivity than other readers.

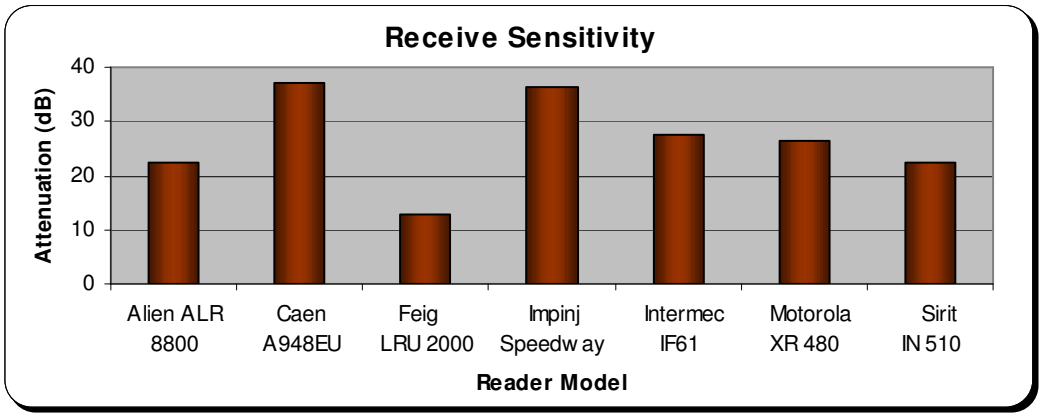


Figure 6: Receive Sensitivity

Applying the Results. Superficially, a more sensitive reader may be considered a superior reader. This generalization, however, fails to consider an important characteristic of UHF passive RFID communications. For communication with an RFID tag to be established, the tag must first be in an RF field that provides sufficient energy to power up the tag silicon. Most passive RFID communications today are constrained by that field. The design goal for a UHF passive reader must be to be sensitive enough to detect the tag whenever it is powered up.

Manufacturers of tags and of tag silicon are working to reduce the field strength necessary to power a tag. Extra sensitivity provides a margin for the future and for less than optimal receive conditions today, but can also add to stray reads and degraded performance due to interference. The varying levels of sensitivity among the tested readers represent the result of how each manufacturer optimized the balance between these considerations.

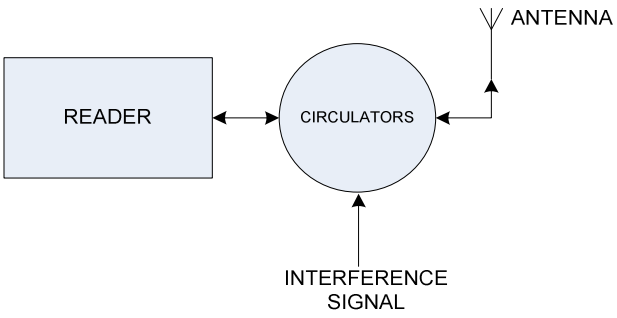
5.4 Interference Rejection

RFID deployments in Europe are increasing as 2007 unfolds. Enterprises are beginning to deploy RFID throughout the enterprise, migrating implementations beyond the warehouse into manufacturing and raw materials tracking. Other firms are adding readers as their volume of tagged products and assets grows.

When additional read points are brought online, existing RFID reader infrastructure faces growing interference pressure. Many end-users overlook an important question as they select RFID technology components, “Are the readers I’m deploying today sufficiently robust to reject the interference generated by my planned and unplanned RFID infrastructure 2-5 years from now?” ODIN technologies advises end-users to consider this impact early on when designing and deploying RFID solutions. You do not want to be forced to replace your RFID network because it cannot scale to meet your needs over time.

Purpose. Interference rejection testing is designed to study the effects that an interfering signal will have on the performance of the RUT.

Apparatus. The test apparatus separated transmit and receive paths of the RF signal between the reader antenna and the reader, and allowed an interfering RF signal to be injected into the receive path of the RUT. An RF signal generator injected the interfering signal. A fixed reader/ antenna geometry, in this case 1 meter, was established to minimize uncontrolled variables.



Interference rejection test setup

Procedure. The reader was operated at 866.3 MHz using the manufacturer provided software or Web interface. Initially, with no interfering signal injected into the receive path, the tag read was confirmed. The signal generator was started at 866.3 MHz and the amplitude was set to the point where reporting of the tag by the software ceased. The setting was varied around that amplitude to ensure that the minimum RF signal that prevents the reading was in fact discovered. That amplitude

value and RF frequency were recorded. The frequency was varied in 200 kHz steps and the procedure was repeated in the frequency range of 865.3 MHz to 867.3 MHz.

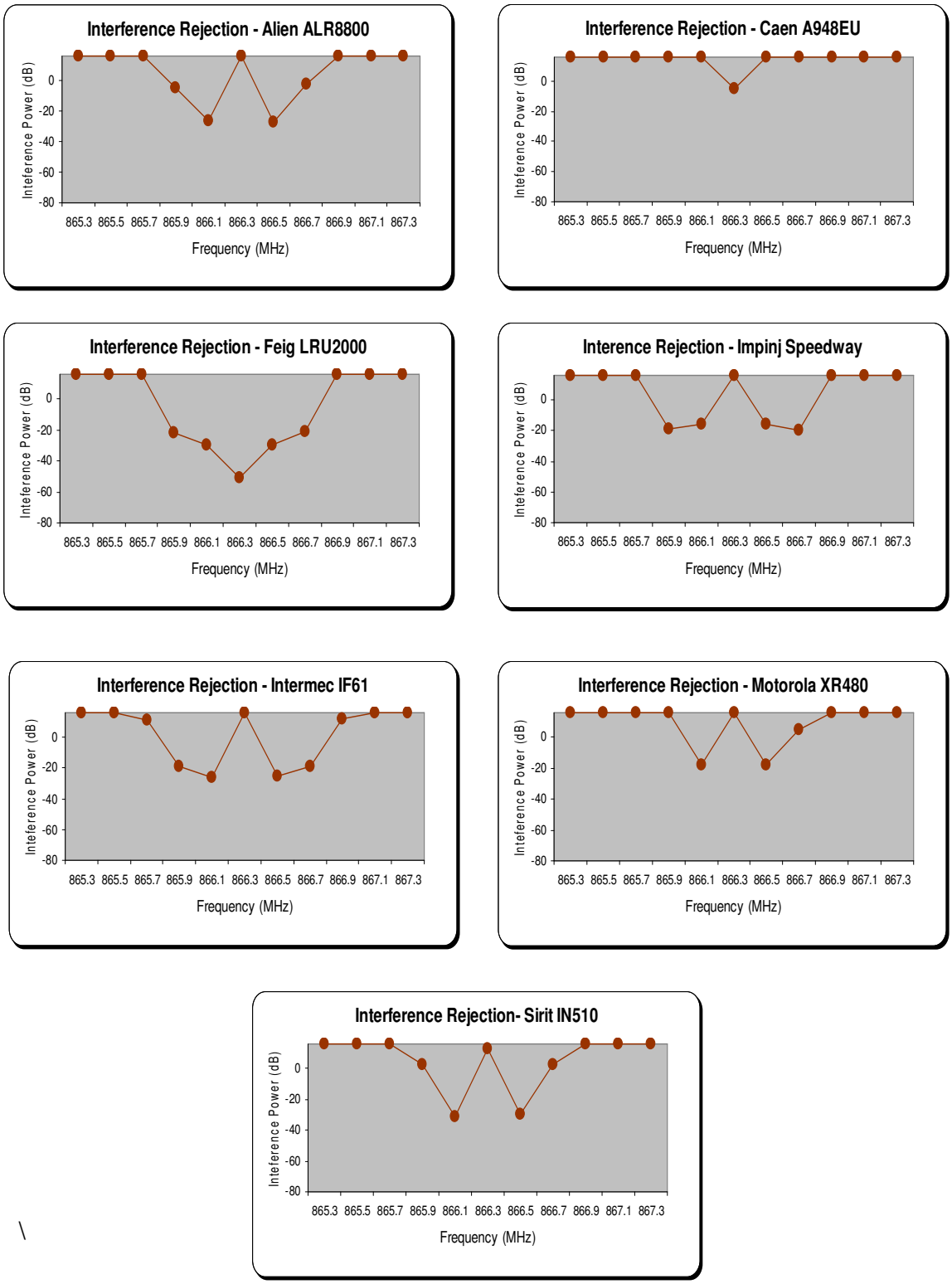


Figure 7 – Interference Rejection Results

Results. Signals levels above the graphed lines in the charts caused the reader to stop reporting tags. ODIN technologies did not inject a signal above +15dBm. From an inspection of the charts, the Caen A948EU reader showed the best interference rejection; the Caen reader currently does not support Dense Reader Mode so it uses very narrow filtering.

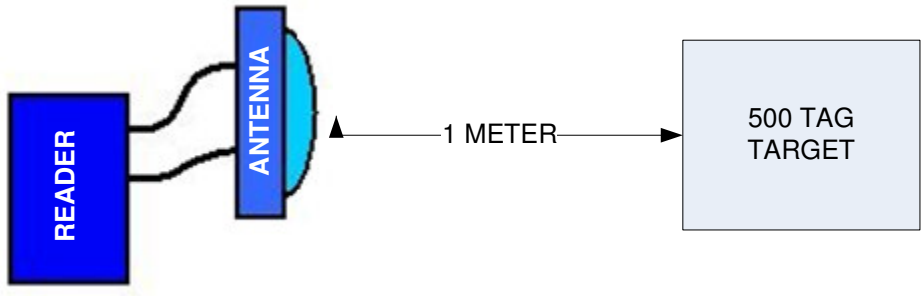
Applying the Results The ability of a reader to read a tag in the presence of interfering signals is critical in the narrow ETSI band. Readers that reject interference well at least 600 kHz away from their transmit frequency will have a better chance of reading tags in the new ETSI EN 302-208 channelization plan when it is adopted.

5.5 Tag Acquisition Ability in Large Populations

The ability to interrogate large tag populations is critical to many use cases. Each reader manufacturer has developed a proprietary algorithm for handling collisions, and the results of large population reading will vary widely among readers. The ODIN technologies test is designed to provide a level comparison among readers in their ability to rapidly handle large tag populations.

Purpose. To determine the relative ability of each tested reader to handle a large tag population.

Apparatus. A fixed geometry is established between a standard reader antenna and a population of 500 tags laid out in a plane parallel to the face of the reader antenna. The field of tags exceeds the beam width of the reader antenna. To eliminate the antenna and field intensity as variables, the same antenna is connected to all the RUTs and the power output is controlled to conduct the same power level from each RUT to the antenna.



Tag acquisition test setup

Procedure. The reader is set to a fixed frequency. Power is measured and adjusted to standard power using the software or Web interface provided by the manufacturer. The reader is placed in continuous read mode for a period of ten seconds and the results examined. Generation 2 control parameters are adjusted by repeated trials to achieve a maximum number of unique tag reads for the reader.

Once set for these parameters, the test was conducted by repeating data collection five times for each reader to ensure repeatability and accuracy.

Results.

The Sirit IN510 shows a clear superiority in this test. Not only did it capture the most tags overall, edging out the Motorola XR480EU and the Impinj Speedway, but it far outstrips all of the other readers in unique tags captured, as illustrated below.

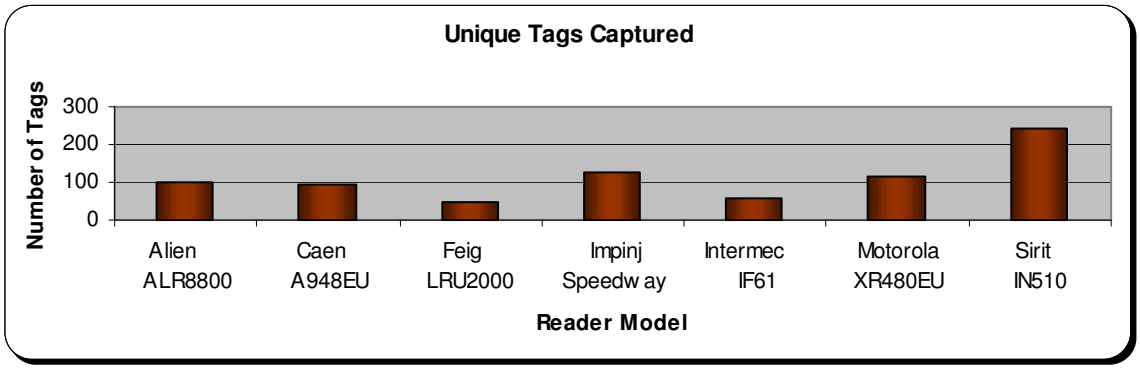


Figure 8: Acquisition in Large Tag Populations

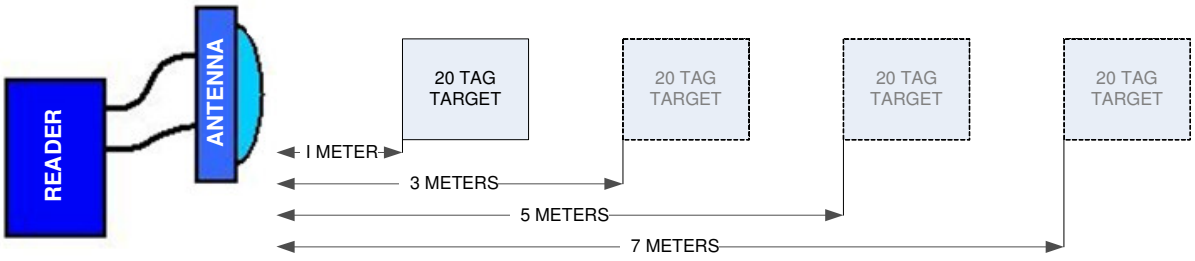
Applying the Results. These results should be weighted in a reader selection process based upon individual requirements. Are you a consumer goods manufacturer seeking to capture large tag populations on a pallet or an equipment manufacturer only capturing case level information in a conveyor portal? The former requires high performance in tag read speed, while the latter is more concerned about establishing a tight and consistent read zone. These questions should be considered in the process of designing an end-to-end RFID solution.

5.6 Distance Testing

Distance testing is a simple metric of comparison that end-users have used for years to compare reader performance. This test is linked to other performance characteristics, since it is impossible to decouple the core drivers of performance over distance (transmit power accuracy and receive sensitivity) from distance tests.

Purpose. This test determines read performance at various distances. Distance testing provides an easy to understand method of discussing reader performance

Apparatus. Testing was conducted by using a grid of twenty tags on a corrugate substrate. The grid was held by a tall tripod more than three meters above the floor. The reader antenna was situated over three meters above the floor as well.



Distance test setup

Procedure. The grid was placed at four distances – 1, 3, 5 and 7 meters from the interrogation antenna of the RUT. The total number of tags read and the number of times each tag was read during a 30-second time interval at each distance was recorded. No other readers were active during the test.

Results.

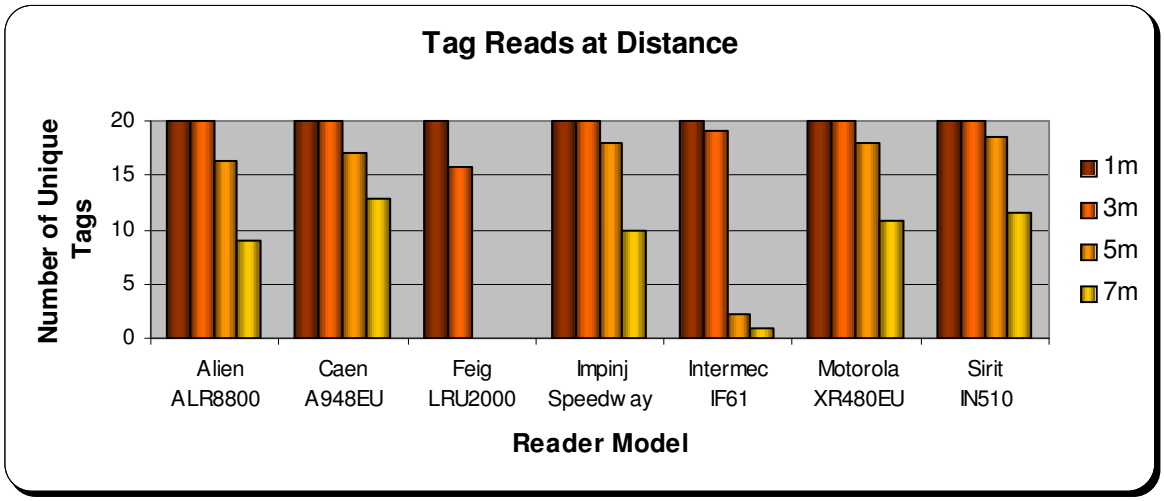


Figure 9: Tag Distance Reading Results

This chart shows that the readers vary in their ability to capture all of the tags in the twenty-tag target at longer distances. Five of the readers read all of the tags at 1 and 3 meters, none were able to read them all at 5 or 7 meters. Five of the readers showed good performance at 5 meters and moderate performance at 7 meters, with the Caen edging out the other models at the longest distance. Two readers were considerably less capable at greater distances.

Applying the Results. Distance testing can lead to misleading results. ODIN technologies developed this test to remove as many extraneous variables as possible to make this a truly significant test. Most use cases require that RFID tags be read at ranges between 0 and 2 meters; any of the readers tested would provide adequate results with properly designed tags. For longer range applications, or applications where tags are constrained in size or performance, consider a reader that shows best at the greater distances.

You should keep in mind that the tag model will influence the distance at which the system will read. Also, read distances in the real world are affected by multi-path destructive interference.

6 USE CASE ANALYSIS

Each time ODIN technologies designs an RFID solution for its clients, we leverage scientific data similar to the results outlined above. This provides a scientific rationale to support technology selection decisions. The scientific tests are specifically designed to isolate a single variable (power output, receive sensitivity, etc.) for reader comparison purposes, which points to a shortlist of viable reader options. The next step is to test the top readers in the use case that will be deployed as a final proof of concept.

6.1 Conveyor Testing

The conveyor use case is widely deployed to automate internal sorting processes as well as to conduct inline verification of applied tag performance. Even more commonly, it is used in the process of capturing material receipt information, particularly among major retailers. Although not the most challenging use case, it is among the most important.

Below is a sample ODIN technologies' conveyor deployment with the rack cover removed to show a single antenna.

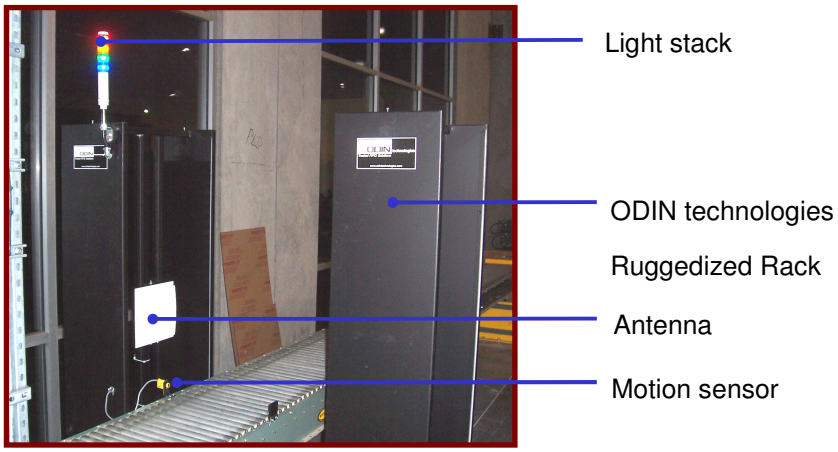


Figure 10: Conveyor Test

Purpose. To determine if the RUT will read a tag on a conveyor each time the tag is exposed to the reader antenna passing at high speed.

Apparatus. This testing was conducted using the ODIN technologies Cyclotron, which enables superior control over object orientation relative to the interrogation antenna to ensure scientific accuracy and makes it possible to test the upper threshold of speed performance at 360 meters per minute.

Procedure. A known tag is placed on the Cyclotron test fixture. The Cyclotron is started and calibrated to the test velocity. The reader read is enabled and the number of tags on a single pass of the test fixture by the antenna is noted. The test is repeated 10 times.

Results.

Conveyor Testing			
Speed at which tags were interrogated	**120 meters/min**	**180 meters/min**	**360 meters/min**
Reader Vendor	**Successful tag read**		
Alien ALR 9800	Yes	Yes	Yes
Caen A948EU	Yes	Yes	Yes
Feig LRU2000	Yes	Yes	Yes
Impinj Speedway	Yes	Yes	Yes
Intermec IF61	Yes	Yes	Yes
Motorola XR480	Yes	Yes	Yes
Sirit IN510	Yes	Yes	Yes

Figure 11: Conveyor Test Results

Every Reader Works

The most important finding in the Conveyor Use Test is that every reader tested captured the tag every time it passed the antenna. In this use case, that is the primary requirement and every reader was up to the challenge.

Applying the Results. In a conveyor use case, all that end users care about is the ability to capture 100% of the case tags passing on a conveyor 100% of the time. The conveyor speeds established for this test are very rapid, exceeding the fastest shipping conveyors by up to a factor of 2. All of the readers in this test performed to this level.

6.2 Stretch Wrapper Testing

The stretch wrapper use case has become important in manufacturing and warehouse operations to verify tagged cases and associate them to a specific pallet. An RFID interrogation zone at the stretch wrapper is often employed to save processing time and maintain throughput levels after RFID is introduced into operations. Pictured is the ODIN technologies' stretch wrapper test setup.

Figure 12: Stretch Wrap Interrogation Zone

Purpose. To determine the ability of the RUT to capture all of the tags presented in a representative stretch wrapping application

Apparatus. The test is conducted with the ODIN technologies Stretch Wrap machine, the RUT, two standard antennas and the reader manufacturer's software or Web interface. The test target is the ODIN technologies "standard pallet".

Procedure. This testing was conducted using the "standard pallet" shown in figure 12. Each side has a different tag type applied. The standard pallet is placed on the Stretch Wrap Machine. Antennas are situated one meter from the corner of the pallet. The standard pallet was rotated three times. The number of reads captured for each unique tag was recorded. The trial was conducted five times for accuracy.

Results. Each reader's performance is visualized using a color gradient. The scale is summarized on the following page. This analysis makes it easy to identify how each reader compares in this use case.

The Impinj Speedway showed best in this comparison, followed closely by the Intermec IF61 and the Sirit IN510. The Motorola XR480EU and the Alien ALR8800 are in the second tier, with adequate performance, while the Feig LRU2000 and the Caen A948EU displayed poor results in this test.

Applying the Results. Aggregating by reading the tags on cases or goods after a pallet is assembled can lead to significant return on investment, especially in mixed pallet situations or where shrinkage may be of concern. Stretch Wrapper Reading is one of the ideal RFID applications, because the relative motion between the tags and the reader antenna. Often, pallets are arranged chaotically and tags can be in less than optimal positions for good reads.

Properly installed, RFID readers at the stretch wrapper can provide a huge benefit in shipping visibility. All of the elements helpful to perfect read results are present – a well-defined read zone, relative motion between tags and reader, and orientation variation. RF need only be radiated when the stretch-wrapping machine is in motion, which is a benefit in the tight European frequency allocation.

In many stretch wrappers, the pallet is stationary and an arm rotates around the pallet. With such a device in particular, an effective choice of RFID reader and antennas is critical as those components will be mounted on the moving arm. In addition to the results of the ODIN testing, designers will want to consider mechanical ruggedness and electrical connectivity in their selection criteria.

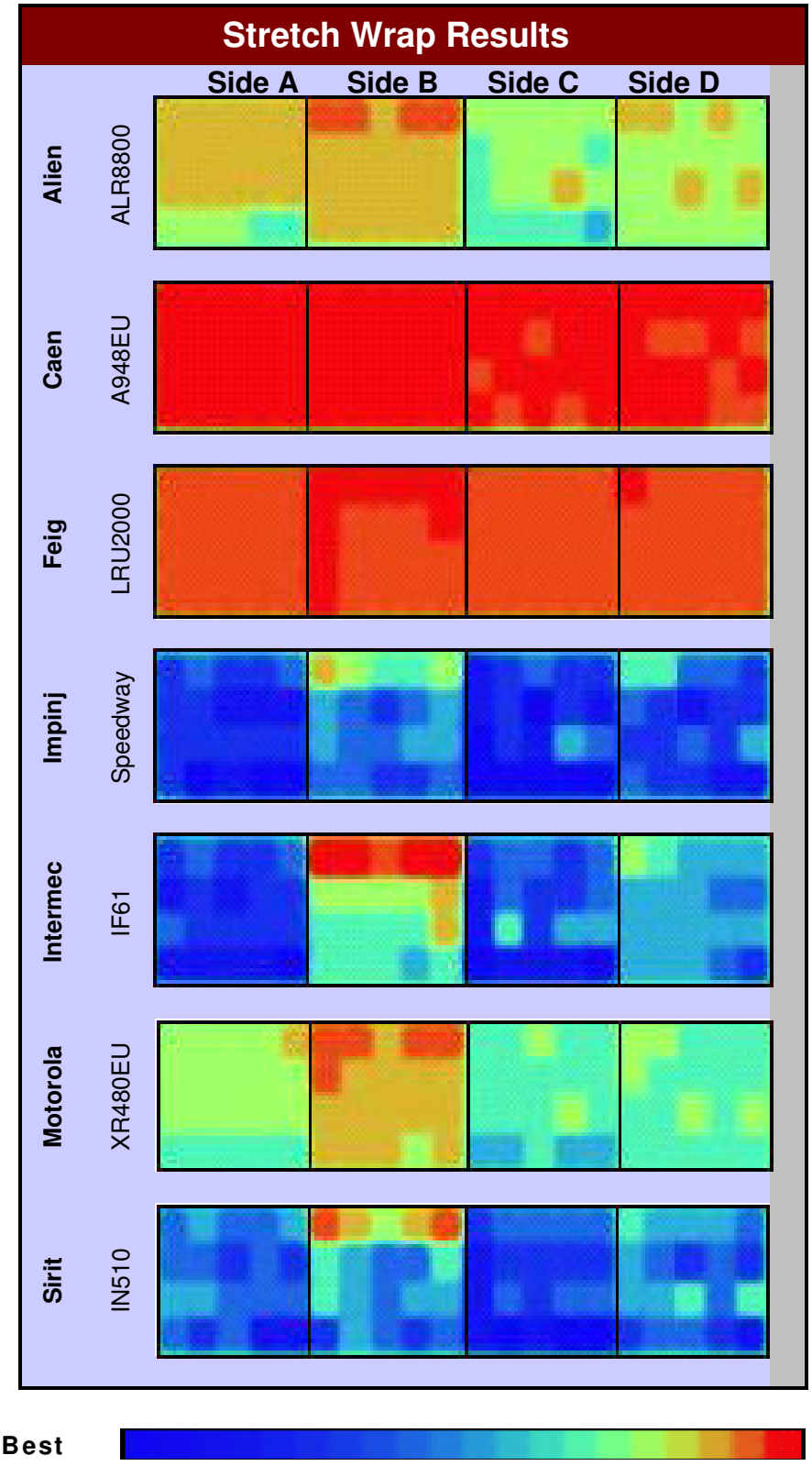


Figure 13: Stretch Wrapper Reading Results

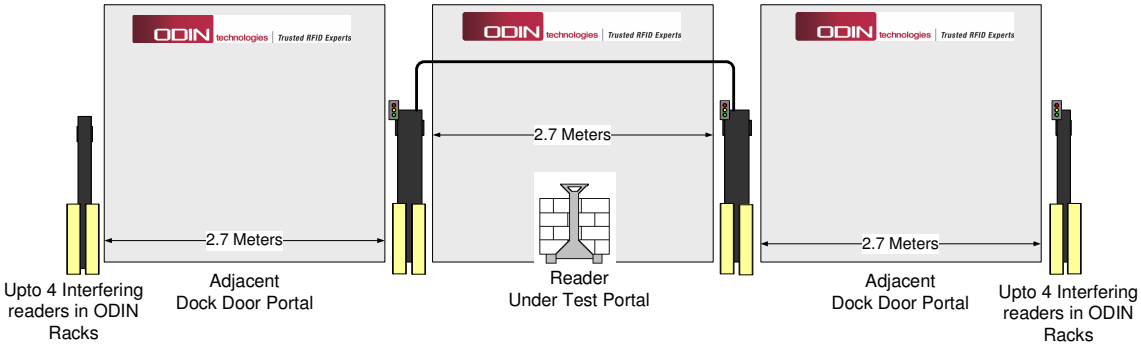
6.3 Adjacent Dock Door Portals with Listen Before Talk

The adjacent dock door use case is where end-users from many industry verticals are harvesting business value from RFID technology. The value proposition ranges from automated receiving to ship verification and more efficient put away processes. Yet with this value comes complexity. Distribution centers outfitting every dock door with RFID leads to a serious level of RF noise that leads to a high likelihood of two readers activating the same channel simultaneously and missing read opportunities. End-users need to understand that one size does not fit all when it comes to designing and deploying a dense reader environment.

In addition, adjacent dock doors lead to confusion of a different type called crosstalk. Crosstalk occurs when a reader in portal A reads case tags moving through portal B. Resolving this issue, while ensuring a robust use case, requires special tuning tools to optimize reader configuration, leading to the best performance possible.

Go to http://www.odintechnologies.com/page.php?t=2 for more information.

Below is a sample ODIN technologies' adjacent dock door installation.



Adjacent Dock Door Test Setup

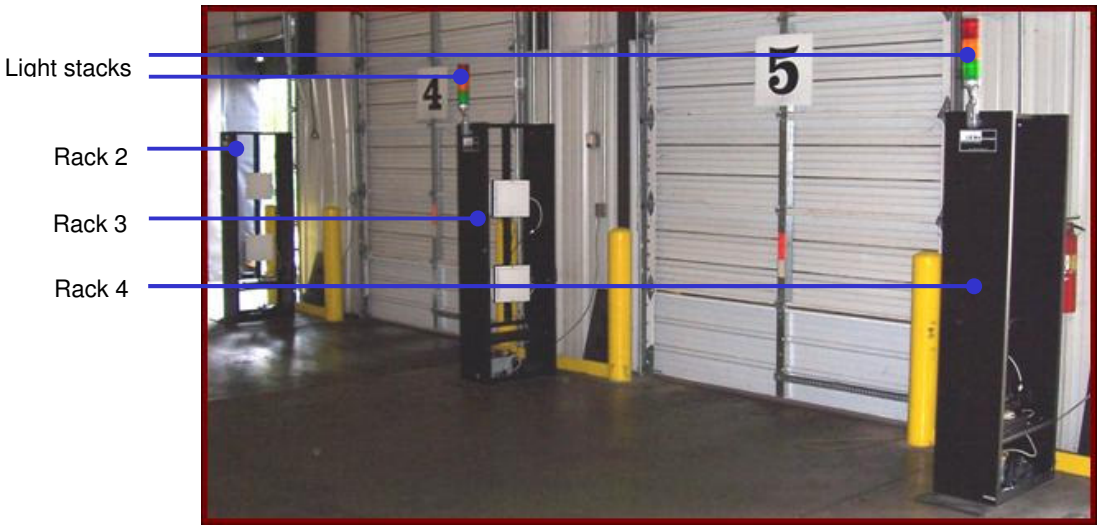


Figure 14: ODIN Dock Door illustration

Purpose. To measure the ability of each RUT to perform in the presence of interfering readers configured in adjacent dock doors within the current version of ETSI EN 302-208.

Apparatus. Standard ODIN technologies Dock Door Portal racks, one RUT configured with four antennas, eight interfering readers configured with one antenna each (four on each side of the test portal), ODIN Standard Pallet with eighty tags mounted (twenty to a side), pallet jack, controlling software, Rohde & Schwarz FSH3 Spectrum Analyzer.

Procedure. The test is a harsh simulation of dock door portals in adjacent configurations such as might be found in a distribution center. Data was captured from the RUT with 0, 2, 4, 6 and 8 interfering readers radiating as the tagged pallet was moved through the portal. In this test, the interferers are set on separate channels within the EN 302-208 band, and setup with LBT turned off. A spectrum analyzer monitors the band to ensure all of the interferers are radiating and to determine whether the reader under test finds an available channel with its LBT.

Results.

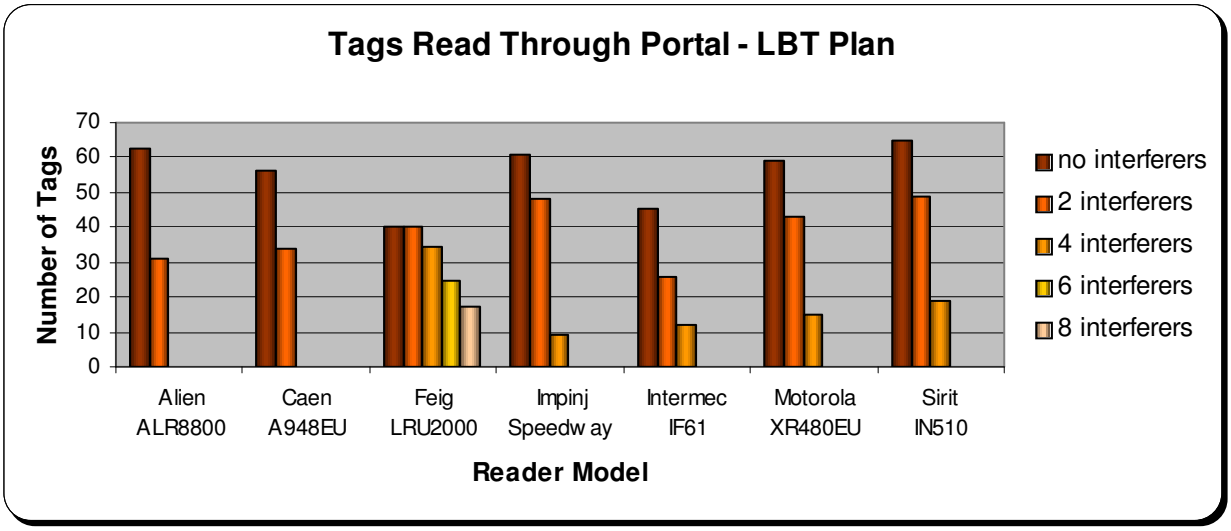


Figure 15: Adjacent Dock Door Results – LBT Plan

With the notable exception of the Feig LRU2000 reader, no reader was able to report tags with six or eight interferers radiating. However, the Feig LRU2000 reader did not capture as many tags as most readers with no or minimal interference. Five readers could find 55 to 65 tags on the square Standard Pallet with no interferers. Performance quickly degraded for all but the Feig LRU2000 as interferers were added. The Alien ALR8800 and Caen A948EU did not capture tags with four interferers radiating.

The Feig LRU2000 demonstrated a unique solution to the LBT problem; specifically, change frequencies and power setting out of the EN 302-208 band and into the EN 300-220 single frequency of 869.5 MHz. As tested by the ODIN technologies test protocol, this method proved extremely effective. This method works well for the

single Feig LRU2000 under test; however, it is probable that under real conditions with many Feig LRU2000 readers this technique would not work as well. Since there is no requirement for LBT in the 300-220 specification, any number of LRU 2000 readers could shift to that frequency; however, it is likely that more than one reader on that frequency would cause massive mutual interference. This is an open question not resolved in this test.

Applying the Results. The data confirms that adjacent dock doors are not practical applications within the current version of the ETSI EN 302-208. With any of the readers, large tag population reading becomes difficult as soon as there are two interfering channels occupied. This has been recognized by the ETSI, and revised standards are being developed. A channelization plan tested in September and October of 2006, which will allow four channels to operate RFID readers without LBT is in ratification.

6.4 Adjacent Dock Door Portals with Proposed ETSI EN 302-208

The proposed update to the ETSI EN 302-208 regulation will allow four channels to operate RFID readers without first checking for the presence of other signals. ODIN technologies has adapted the Adjacent Dock Door Portal test to test the channelization plan. The test here is a very harsh test with no synchronization of readers and no motion sensor control of power radiation.

Purpose. To measure the ability of each RUT to perform in the presence of interfering readers configured in adjacent dock doors within the proposed version of ETSI EN 302-208.

Apparatus. Standard ODIN technologies Dock Door Portal racks, one RUT configured with four antennas, eight interfering readers configured with one antenna each (four on each side of the test portal), ODIN Standard Pallet with eighty tags mounted (twenty to a side), pallet jack, controlling software, and Rohde & Schwarz FSH3 Spectrum Analyzer.

Procedure. Data was captured from the RUT with 0, 2, 4, 6 and 8 interfering readers radiating as the tagged pallet was moved through the portal. In this test, the interferers are set on the channels identified in the proposed ETSI EN 302-208 standard with LBT turned off. A spectrum analyzer monitors the band to ensure all of the interferers and that the reader under test radiates on command.

Results. The results of this version of the Adjacent Dock Door protocol are somewhat better among most of the readers than when LBT is used. The Caen showed the worst performance, despite its top ranking in the interference rejection test. This validates the benefit of Dense Reader Mode (which the Caen A948EU lacks). It should be noted that the test protocol used here is very harsh. Every interferer is transmitting continuously; there is no synchronization of readers or tag communications.

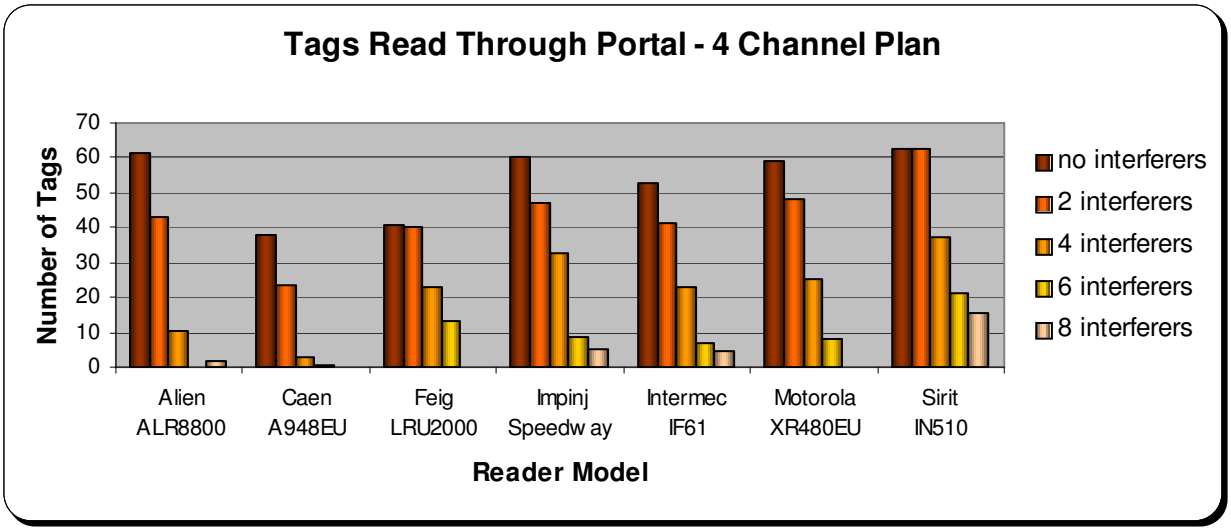


Figure 16: Adjacent Dock Door Results – 4 Channel Plan (proposed standard)

Applying the Results. These results demonstrate that the decision to eliminate LBT as a requirement is sound; but the narrow ETSI frequency band still will be a difficult environment in which to operate. The critical importance of careful design in deployments of more than a few dock doors becomes evident from these results. Readers must be controlled to radiate only when goods are passing into a portal. Careful calculation to optimize antenna fields to improve tag capture from difficult angles must be applied. Reader selection should be influenced by features allowing for system-wide synchronization.

7 CONCLUSIONS

7.1 Performance Summary Results

MASTER RANKING	Alien	Caen	Feig	Impinj	Intermec	Motorola	Sirit
	ALR 8800	A948EU	LRU2000	Speedway	IF61	XR480EU	IN510
Scientific Testing							
Power Output Analysis	High	Low	High	High	High	High	High
Occupied Channel Power	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Receive Sensitivity	5 (M)	1	7 (L)	2 (H)	3 (M)	4 (M)	6 (M)
Interference Rejection	5	1	7	4	6	3	2
Tag Acquisition Speed	4	5	7	2	6	3	1
Distance Testing	5	4	7	3	6	2	1
Use Case Testing							
Conveyor Testing	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stretch Wrapper Testing	5	7	6	1	3	4	2
Adjacent Dock Door Portals with LBT	6	7	1	4	5	3	2
Adjacent Dock Door Portals with Proposed ETSI EN 302-208	5	7	6	2	4	3	1

Figure 17: European RFID Readers Performance Summary Table

ODIN technologies knows that when it comes to reader selection, one size does not fit all. In the performance summary analysis, ODIN has illustrated the results of appropriate scientific tests and the three use cases highlighted throughout this study. Identify the use case that applies most directly to your situation and find the readers more likely to meet your needs. If your use case requires an especially sensitive reader or one able to read long distances, then lean toward a unit with high receive sensitivity or long distance read capability. If you are interrogating large populations of tags, then go with a unit that performs well on the "Tag Acquisition Speed" test. Temper your selection of a reader based on its technical performance merits with the vendor's investment in a support infrastructure for the European market.

In the European RFID reader market, among the readers tested, Sirit and Impinj are the top technical performers, and Motorola rounds out the Top 3 from a technical performance perspective. Sirit was rated the top in tag acquisition ability, distance reading and performance in the adjacent dock door testing under the proposed ETSI EN 302-208 standard. Impinj and Sirit performed the best of all the readers in the Stretch Wrapper use case tests. Impinj was a close second to Sirit in the Adjacent Dock Door tests under the proposed EN 302-208 standard, and was in the Top 3 in six of the tests and demonstrated high receive sensitivity. Motorola showed strong distance reading capability and was in the Top 3 for performance on tag acquisition ability and adjacent dock door performance under both LBT and EN 302-208.

Intermec showed solid performance, being in the Top 3 for receive sensitivity and in performance on the Stretch Wrapper use case tests and closely behind Motorola on performance in the adjacent dock door tests under the proposed ETSI EN 302-208 standard.

Caen showed the highest receive sensitivity, best interference rejection and longest distance read ability, but had an issue with accuracy of its power setting, and performed poorly in the adjacent dock door tests, likely due to not implementing a dense reader mode capability.

Alien was in the middle of the pack on tag acquisition ability(i.e., ability to read large populations of tags), and on receive sensitivity, distance reading and stretch wrapper read ability.

Feig ranked #1 in adjacent dock door testing under the current Listen Before Talk (LBT) standard, demonstrating a unique solution to the LBT challenge. Feig shifts frequencies and power settings out of the EN 302-208 band and into the EN 300-220 single frequency of 869.5 MHz. Although the test results point to strong Feig performance, the results may not reflect reality when several Feig readers are in close proximity. On adjacent dock door testing under the proposed EN 302-208 standard, Feig showed only middle of the pack performance, correlating to its poorer results on functions such as tag acquisition, distance reading and receive sensitivity.

As a general observation, the maturity of European RFID readers is lagging somewhat behind readers being produced by the North American manufacturers, but each European vendor has invested its considerable engineering talent in unique capabilities that outshine the competition – Caen's receive sensitivity and interference rejection and Feig's unique LBT management approach.

7.2 Conclusions

As of today, European reader manufacturers are behind North American manufacturers in the evolution of passive UHF RFID products.

The two European readers tested by ODIN technologies had fewer features, less computing power and less developed interfaces and applications than the North American products.

The Feig LRU2000 reader provided access to a host of configuration parameters in its software, but the software was cumbersome and unintuitive. The Caen A948EU is a well-designed radio that performed well in some of the scientific testing, but without Dense Reader Mode, it is effectively limited to single unit applications.

In contrast, the North American offerings demonstrated a theme of continuing evolution. Older companies offered improved, feature-packed readers, such as the Motorola XR480EU and the Intermec IF61. Newer entrants, such as the Impinj Speedway and the Sirit IN510 showed the results of well thought-out engineering efforts that demonstrated top performance.

One driver of reader improvements in North America has been the comparison by testing and the sharing of results among reader manufacturers. The cross-fertilization of ideas and research has lead to a healthy competition among those who solve the problems of deploying RFID in the real world. ODIN technologies' benchmarks have played a role in these comparisons and ODIN hopes that this Benchmark will have a similar effect in the developing markets of Europe.

Even under the proposed changes to ETSI EN 302-208, multiple loading dock doors remain a difficult problem in Europe.

With only four frequencies to use, mutual interference in multiple reader installations will remain a problem. Careful planning will be required in such installations to optimize power transmitted, to minimize the radiating time, and finally to synchronize across readers to allow the operation of many readers in close proximity.

Deployers in North America have had the luxury of a relatively wide UHF frequency range. The European frequency band constraints will have the practical results of increasing deployment expense and effort, and will require greater knowledge and experience from service providers.

The art and science of passive UHF RFID technology continues to advance.

Product offerings from Sirit and Impinj can almost be considered a new generation of readers. Both readers were built with a firm understanding of the EPC Class 1 Generation 2 air interface, and both execute that protocol better than the older readers that may have legacy technology not optimized for Gen2. Impinj was an integral part of the design of the Generation 2 technology and was the first to market with effective Generation 2 tag silicon. The Sirit IN510 reader started its development cycle as the SAMSys Saturn project, which was a bottom up Generation 2 reader design informed by the SAMSys MP9320 and MP9310 Generation 2 readers.

It is a reasonable conclusion that there is more that can be wrested from passive UHF RFID technology. End-users should not allow previous experiences to color their perceptions of the newest technologies.

Different engineering teams have solved challenges in different ways.

An examination of the scientific results indicates that the engineering teams from the various manufacturers have assigned different priorities to the various problems of building an RFID reader to read the Generation 2 tags. For example, the Caen A948EU team appears to have pursued excellent receiver hardware development while the Sirit team's anti-collision algorithms seem to be first rate.

This does not necessarily mean that one reader is better than another, anymore than red wine is superior to white wine. What it indicates is that each team has optimized its reader capabilities differently. The purpose of this independent testing is to provide an outsider's independent perspective of the readers.

7.3 Integrated View of the Market

By evaluating reader performance metrics on both the scientific and use case tests, the ODIN team was able to segment the reader manufacturers into two tiers. The first tier companies either exhibited very strong technical performance such as Sirit and Impinj or good across the board performance such as Motorola and Intermec. Readers in the second tier are all capable products with strong features such as Caen's receive sensitivity and interference rejection ability, Alien's ability to read large tag populations, and Feig's unique solution for managing the LBT challenge, but overall they performed less well on the critical use case tests than their top-performing peers under the ETSI standards.

European Reader Performance Summary

Vendors/Models	Power Output	Occupied Channel	Receive Sensitivity	Interference Rejection	Tag Acquisition	Distance Testing	Conveyor Testing	Stretch Wrapper	Adjacent LBT	Dock Door Channel
Sirit IN510	High	Yes	6 (M)	2	★1	★1	Yes	2	2	★1
Impinj Speedway	High	Yes	2 (H)	4	2	3	Yes	★1	4	2
Motorola XR480EU	High	Yes	4 (M)	3	3	2	Yes	4	3	3
Intermec IF61	High	Yes	3 (M)	6	6	6	Yes	3	5	4
Alien ALR8800	High	Yes	5 (M)	5	4	5	Yes	5	6	5
Caen A948EU	Low	Yes	★1	★1	5	4	Yes	7	7	7
Feig LRU2000	High	Yes	7 (L)	7	7	7	Yes	6	★1	6

Figure 18: European RFID Reader Performance Summary

8 ENGINEERING TEAM PERSPECTIVE

This section provides editorial insight from ODIN technologies' engineering team based on its deployment and test experience with each of the devices included in this evaluation. These comments highlight how each reader compares from an RF Engineering, firmware and demonstration test utility perspective. This helps end-users know what to expect in the reader evaluation and implementation process.

8.1 Tester's Notes and Observations

Alien ALR 8800:

Alien has made their interface easy to use. The Alien "Gateway," which resides on the reader, is a user-friendly interface for basic reader demonstrations. The manuals are also preloaded on the reader and can be accessed using the web interface. For more scientific control, the user must become familiar with the command line, which enables key testing features such as reading for a preset time interval, setting protocol features, controlling GPIO and enabling autonomous operation of the reader. This is not recommended for people who have not received formal training from Alien.

From a testing and deployment perspective, a challenge is that the ALR 8800 requires two antennas for operation. Alien's multi-static antenna sequencing, which transmits on antenna A while receiving on antenna B and then switches, theoretically enables some solutions to use fewer antennas. However, for applications where one antenna would be sufficient, either an external circulator and additional cabling is required, or a second antenna must be added, possibly leading to less than optimal read field control.

The unit requires a separate LBT antenna to be connected until the changes to ETSI EN 302 208 are ratified.

Caen A948EU:

The Caen A948EU seems to be a well-engineered radio that is not yet up to date with the latest advances in the RFID world. It was the only reader tested in this trial that did not implement Dense Reader Mode.

The Caen has a power on/power off switch; a feature that most other reader manufacturers have abandoned. It also has a built in AC power supply; only one of two readers tested to have one. It is the only reader tested with standard TNC connectors, which some European deployers would view as an advantage.

The Caen A948EU provided software gives a user friendly, but feature poor interface for the developer or installer to use. There is no Web interface. Power control settings were difficult to understand and changed value after being set. There is no apparent way to easily upgrade firmware versions.

All that being said, the Caen hardware seems to perform well, and ODIN technologies looks forward to testing the promised Dense Reader Mode version of the Caen equipment.

Feig LRU2000:

The Feig LRU2000 in some ways is incomplete. All connections are made inside a plastic housing. Cabling is attached through environmental fittings, which is inconvenient for testing and can be expected to be inconvenient for installation.

The ODIN engineering team was disappointed with the performance of the Feig LRU2000. The Feig LRU2000 does not provide a Web interface, and the Buffered Reader Mode demonstration software did not allow any settings. To make experimental changes, one has to return to the configuration software, which is somewhat cumbersome. Configuring the reader is a forced education in RFID and protocols. Many settings are not obvious, and settings that affect each other are not necessarily grouped together.

On the positive side, the firmware utility for upgrade was user-friendly and can use either RS232 or TCP/IP for upgrade. And once the software is understood, it allowed extremely fine grain setting of reader and tag parameters. Frequency control is excellent, allowing for a number of regions beyond Europe and also allowing for easy change between the current ETSI EN 302-208 standard and the proposed new one. The LRU2000 also allows for reader synchronization, a feature that will become necessary as the sizes of deployments increase.

The feature the ODIN team found most intriguing about the Feig LRU2000 was its ability to shift from the EN 302-208 frequencies to the EN 300-220 frequency in the presence of interference. This work-around for the LBT problem is effective tested against the ODIN test protocol. How effective this technique would be with a number of Feig readers in close proximity could not be tested with the equipment we had available. It probably becomes unnecessary once the proposed EN 302-208 changes take effect.

Impinj Speedway:

The ODIN engineering team was impressed with the Impinj Speedway. All connections are on the same side of the reader, which experience has shown to be efficient and convenient. The reader uses four monostatic antennas with reverse polarity TNC connectors.

The reader can be configured for Europe, either compliant with the current EN 302-208 (LBT) or for the new proposed changes. However, when configured for the current regulations, the unit allows for only four frequencies, rather than the 10 that are generally available. The ODIN engineering team does not view this as a disadvantage, and the Impinj engineers report that this allows for easier and better receiver filtering.

This unit only works with EPC Class1 Generation2 (ISO 18000-6C). The Web interface allows good control of the air interface parameters. Power can be controlled independently at each RF port.

Intermec IF61:

The IF61 is a more modern looking unit compared to its older sibling, the IF5. It is also somewhat heavier. It may be that the heavier weight is a heat sink to conduct heat off of the circuit boards. This unit gets very warm to the touch. The heat did not seem to affect performance, so one assumes the heat on the outside is by design.

The unit uses four monostatic antennas that are connected with standard SMA connectors. Unused ports are protected by SMA 50 ohm terminations, which ODIN technologies engineers view as good engineering practice. This is the other reader that has a built-in power supply.

This unit has the most programmable memory space, which can allow for embedded edgeware applications within the reader. It has a robust Web Interface, allowing easy configuration, and port by port controllable RF power.

Motorola XR480EU:

The Motorola XR480EU is an improvement on the XR400. The reader can be configured to use four read points bi-statically, or it can be set to provide eight monostatic ports. Independent power control is available for all the ports, and the settings were accurate using the Web control. All connections are on the same side of the reader.

The reader automatically configures parameters such as the Class 1 Generation 2 “Q”; parameters that are often exposed to user manipulation (sometimes mis-used by inexperienced installers) in other readers. On the other hand, it is generally agreed among ODIN engineers that the Web interface controls for the XR480EU are cumbersome and not user friendly.

ODIN engineers discovered a problem with the Showcase software provided by Motorola. Setting power within the tool is very inaccurate. This bug was reported to and acknowledged by the Motorola engineers, who will issue a fixed version soon. Showcase in general does not recognize the eight-port capability of the XR480EU.

Despite some annoying characteristics, the Motorola XR480EU is a highly effective reader.

Sirit IN510:

The Sirit IN510 is relatively new in the field. It started life as a new generation offering from SAMSys technologies, which went broke before the reader was ready for market. Sirit rescued the design team and the design. It was a good move by Sirit; this reader has matured and become a top performer.

The reader is configurable for both ETSI bands and anticipates the proposed change to ETSI EN 302-208. It has excellent frequency control and allows port-by-port RF power control. The Web interface is user-friendly and allows for fine grain parameter control. The reader startup tool (RST) is very user-friendly and has a wizard to configure the reader for different use-cases.

The IN510 shines in the area of large population tag reads. The algorithms used are proprietary and give the reader a huge speed advantage.

8.2 Reader Features Summary

Below is a summary of the important features employed by each reader platform.

EUROPEAN READER FEATURES							
Vendor	**Alien**	**Caen**	**Feig**	**Impinj**	**Intermec**	**Motorola**	**Sirit**
Model	ALR 8800	A948EU	LRU2000	Speedway	IF61	XR 480EU	IN 510
Dense reader mode	Yes	No	Yes	Yes	Yes	Yes	Yes
Multiple Gen2 data rates	Yes	No	Yes	Yes	Yes	Yes	Yes
Antenna Sequencing	Multistatic/ BiStatic	Monostatic	Monostatic	Monostatic	Monostatic	Monostatic/ BiStatic	Monostatic
Maximum power	32.5 dBm	32 dBm	34.77 dBm	30 dBm	30 dBm	30 dBm	31 dBm
Individual port power control	Yes	No	No	No	Yes	Yes	Yes
Protocol agility	EPC C1C2, EPC C1G1, ISO 18000-6c	ISO 18000-6B, Philips UCODE EPC 1.19, EPC C1G2	EPC C1G2, ISO 18000 6B/C	EPC C1G2	C1G1, ISO 18000-6b, ISO 18000-6c, Philips 1.19,EPC C1G2	EPC CO, 0+, C1G1, EPC C1G2	ISO 18000-6b, ISO 18000-6c, Philips 1.19,EPC C1G2
Connectivity options	RS-232 , LAN TCPI/IP	RS232, RS485, USB 2.0, LAN TCPI/IP	RS232/485,LAN TCPI/IP	RS-232 , LAN TCPI/IP	RS232, USB 2.0, LAN TCPI/IP	USB Type A; USB Type B; RS232, LAN TCPI/IP	RS-232 , LAN TCPI/IP
Connectors	RP-TNC	TNC	SMA	RP-TNC	SMA	RP-TNC	RP-TNC
Compliance Certification	ETSI EN 302 208, ETSI EN 300 220	ETSI EN 302 208, ETSI EN 300 220	ETSI EN 302 208, ETSI EN 300 220	ETSI EN 302 208, ETSI EN 300 220	ETSI EN 302 208, ETSI EN 300 220	ETSI EN 302 208	ETSI EN 302 208, ETSI EN 300 220
Operating temperature range	-20° C to 50° C	-20° C to 70° C	-20° C to 55° C	-20° C to 55° C	-25° C to 55° C	-10° C to 60° C	-20° C to 55° C

9 FORWARD LOOKING STATEMENTS

The following forward-looking statements were provided by reader vendors and provide insight into perspectives on the European market and future technology offerings. All manufacturers were offered the opportunity to submit material for this section of the report. The material does not necessarily reflect the view of ODIN technologies, but is provided directly by the manufacturers.

ALIEN – ALR-8800 Enterprise RFID Reader

High Performance, Easy to Deploy, Easy to Manage.

The Alien ALR-8800 Enterprise RFID Reader enables users to deploy manageable, robust, best-in-class RFID solutions for supply chain, manufacturing and asset management applications. The unit uses a Linux system for filtering and collection, and a powerful DSP processor for high-performance Gen 2 RFID protocol capability. The Linux operating system hosts the popular Alien Reader Protocol and a suite of configuration and remote management functions, enabling fast, scalable implementation. A highly programmable signal processing architecture delivers exceptional Gen 2 read rates in demanding applications.

Interoperable and Broadly Supported

Alien pioneered the network-ready EPC RFID reader with the widely supported Alien Reader Protocol™. The ALR-8800 is supported by key RFID platforms including Microsoft BizTalk RFID, IBM WebSphere 6.0, Oat Systems, Oracle, GlobeRanger, BEA and many others. Proven support for SAP through 3rd-party middleware is also available. A well-documented SDK featuring .NET and Java libraries enables easy, custom interfaces to control the reader if desired. The reader includes support for remote firmware management and remote monitoring via the Simple Network Management Protocol (SNMP), which enables the network to monitor real-time health, revision and status information from the reader.

Powerful API for Effective RFID Implementations

The Alien Reader Protocol features Autonomous Mode, a programmable state machine that enables the reader to operate independently based on external triggers, timing or software inputs. This flexible system leads to best-in-class read rates by enabling users to precisely control the parameters for timing, protocols, antenna usage and other critical variables without network latency.

A flexible general-purpose input-output (GPIO) system enables tight integration with external sensors and actuators for effective integration with existing business processes. High capacity, optically isolated GPIO signals can drive many external devices directly, eliminating the need for costly digital I/O equipment and relays. Optical isolation ensures accurate reception of triggering signals in noisy, industrial environments. Middleware access to GPIO inputs and outputs enables direct control via software. Configurable notification modes, data routing options and data formats provide flexibility and ease-of-integration.

Top Performance

The ALR-8800 delivers exceptional read rates thanks to a highly sensitive receiver subsystem. Both analog and digital programmable signal processing blocks enable optimization of the radio for different environments. The reader's multi-static antenna topology enables transmission of full-power outbound signals without corrupting minute return signals from tags.

The ALR-8800 does not require separate and dedicated transmit and receive antennas to achieve top read rates, however. The *multi-static* antenna system achieves the performance of independent transmit and receive antennas with half as many antennas in most cases. Only four single-element antennas are required for four read points, unlike bi-static readers, which require 8 antennas.

Power and LAN Failsafe Mechanisms Protect Data

The loss of power or LAN connectivity does not lead to the loss of critical tag data. The ALR-8800 caches tag lists in non-volatile memory, preserving data even in the event of a power loss. When operating in Autonomous Mode, the reader will continue to collect tag data even if the LAN connection is interrupted. Upon recovery of the LAN connection, middleware can download accumulated tag data from the reader.

Interference Management

The ALR-8800 offers several methods for interference mitigation that provide a powerful solution to the challenge of noisy environments.

Strong Filtering for Interference Rejection -The powerful signal processing architecture of the ALR-8800 ensures strong interference rejection in the presence of other readers or devices.

Good Citizen - The reader is compliant with the low noise, spectral mask requirements of Dense Reader Mode as defined in the EPC Gen 2 specification, which reduces interference impact on other readers.

Event-triggered operation and Autonomous Mode - The Autonomous Mode functionality of the Alien Reader Protocol enables the reader to collect tag data when triggered by external events detected by magic eyes and other sensors. In this mode, readers are activated only when needed, thereby reducing the number of readers operating at any given moment, and the resulting ambient signal level. This simple, but powerful tool is a critical part of co-locating large numbers of readers in a single facility.

High Performance, Easy to Deploy, Easy to Manage

The Alien ALR-8800 Enterprise RFID Reader enables users to deploy manageable, robust, best-in-class RFID thanks to: a flexible API with broad software support; a high performance radio; data protection; and robust dense reader interference management

CAEN A948EU

CAEN RFID Company Overview

CAEN RFID is a privately owned Italian company, a leading supplier of UHF RFID readers and tags. The company was born recently as a spin-off of CAEN, a world-leading company with 27 years of experience in electronics for nuclear physics. Expertise and know-how on Radio Frequency electronics and related Software has allowed CAEN RFID to rapidly become a leader in Europe.

As an active participant of ETSI ERM-TG34 and EPCGlobal working groups, CAEN RFID is committed to provide customers with state-of-the-art readers and tags that meet ISO/EPC standards and ETSI requirements.

Thanks to our R&D skills, we can also design specific equipment on a custom basis, thus providing RFID readers and tags for special applications on demand.

CAEN RFID is a proud member the Oracle Partner Network (OPN) and participates actively in the Italian Oracle Mobile Solution Provider Community. This partnership with Oracle has led to the integration between Oracle middleware and the EASY2READ® family of Readers.

CAEN RFID is also a proud member of the Association for Automatic Identification and Mobility (AIM), sharing vision and technology opportunities with the AIM members in Italy and enhancing the visibility of RFID technology towards end users and all the technology providers in the RFID ecosystem.

Last but not least, Intel Corporation and CAEN RFID recently announced a collaboration to boost the adoption of RFID technology. CAEN RFID has chosen to integrate the Intel® UHF RFID Transceiver R1000 in its range of RFID Easy2Read® products.

The Keys to RFID Success in Europe

Synergy

The first key to success is to understand that in Europe, as in all other parts of the world, RFID is not a “products” business, but rather a “solutions” business. In other words, it is vital that the technology providers set up strong synergy to build complete functional solutions to the business process issues of their end customers. This includes an effort to develop true middleware compliance as part of the synergy process, together with an in-depth knowledge of the UHF technology by all the “ecosystem” players.

Support

The second key to success is to provide real-time support in Europe, in order to handle integration and run-time operation issues that may eventually arise. CAEN RFID is strongly committed to provide such support.

Pervasive RFID

The third key to success is to offer to the solution providers a broad range of products, not limited to a portal reader, but covering all the different needs that may arise today and in the near future in RFID installations. By the use of different sizes and performance of readers (such as the whole CAEN RFID EASY2READ® family), a true “pervasive RFID” environment can be achieved.

Technical reader features needed to optimize ETSI performance

Reader features with current ETSI EN 302-208:

Improved Reader sensitivity: By decreasing the output power, it is possible to read tags with less EM radiation, thus reducing the probability of interference issues.

Specialized antenna for LBT: Improvement of the interoperability of readers on adjacent sub-bands.

Full implementation of all EPC G2 features: By reducing the time needed to read all tags, the probability of interference issues is strongly decreased.

Most of CAEN RFID readers implement all of the above features.

Architectural features:

In real-life installations, other techniques or features can help the interoperability of readers, such as the use of Wired or Software synchronization, coupled with the use of Input/output lines for motion sensors/traffic light/events triggering, e.g. to switch the RF on only on readers requiring it for a specific process.

Future features that further enhance European performance

The working group ETSI ERM-TG34 recently submitted to the CEPT an amendment for the removal of "Listen before talk" from the present version of the ETSI standard EN 302-208. The document proposes that this should be achieved by the use of the dense interrogator mode and the adoption of 4 channels only for high power transmissions. Tags will respond in the adjacent low power channels. At this point, reader synchronization becomes a must for the interoperability of readers. This will be handled both with wired and wireless techniques, thus overcoming the present limitations of EN 302-208 and allowing installations of several adjacent readers with no interference issues. CAEN RFID is well aware of these amendments and will release new firmware versions for the existing readers once the amendments will be accepted by CEPT.

In the future, further spectrum requirements for RFID at UHF over the next 15 years may provide further space for performance improvement over a higher fraction of the UHF band.

FEIG LRU2000

The key to RFID success in Europe is to offer high quality and high performance products, which are in full compliance with the European Radio Regulations and are supporting ISO standards, as well as to offer compliance to EPC specifications.

FEIG is very much involved in the radio regulation processes within ETSI and is working to develop reliable standards, meeting the requirements of users and technology providers and to develop reliable products and technologies according to the official standards and regulations.

IMPINJ – Ensuring Successful UHF Gen 2 RFID Deployments in Europe

Impinj's high-performance UHF Gen 2 Speedway® reader is fully certified for operation under rules of the European Telecommunications Standard Institute (ETSI). The Speedway reader also complies with the European Union's stringent Reduction of Hazardous Substances (RoHS) guidelines and also carries the CE mark, indicating compliance with all relevant health, safety and environmental regulations in Europe.

Certified to the ETSI EN 302-208 standard governing interoperability and performance of RFID devices in Europe, the Speedway reader maintains the same high levels of performance when operating in Europe as it enjoys in large-scale distribution and supply chain deployments in North America. With Speedway, European RFID users now have access to the only UHF reader that performs equally well in pallet and case tagging to item-level tagging applications using far-field or near-field modes of operation.

Standards Development and Evolution

Looking forward, numerous developments are working together to make the Speedway reader's Gen 2 performance even better. For example, ETSI has already proposed changes to the RFID transmission regulations that will bring about more rapid RFID deployment in Europe. These regulations include the removal of the Listen Before Talk (LBT) requirement (effective September 2007) and the reallocation of frequency spectrum to support four high power 200 kHz channels for reader transmission. This spectrum reallocation will lead to improved performance by enabling faster inventory modes than those available in the US and ensuring that readers do not transmit on the same channel as that of the tag backscatter. It also means that dense-reader deployments are now practical in Europe because without the requirement for LBT, readers will be permitted to reuse frequency channels.

This development brings other benefits, as well. Because reader transmissions are spaced at a minimum of 0.6 MHz (and in most cases 1.2 MHz) apart, both reader-to-tag and reader-to-reader interference is virtually eliminated. Moreover, higher reader transmission and tag backscatter rates are possible; improving tag singulation throughput and increased tag read reliability. The removal of the LBT requirement also means that the likelihood of a tag being missed by a reader greatly diminishes. For time-critical applications, such as items moving swiftly on a conveyor, the transmission channel must be immediately available—a condition not always possible when a reader must listen for a free channel before commencing transmission. In short, the elimination of the LBT encumbrance means that the performance advantages of the Speedway reader will become even more apparent.

Finally, the deployment of Speedway readers will become even easier with the availability of native LLRP—the standardized reader network interface recently ratified by EPCglobal. LLRP defines a standard interface to common reader functionality, including reader configuration, tag inventory, and tag access operations including the full functionality of the EPCglobal Gen2 Air Protocol. LLRP allows a rich set of defaults for basic operation, yet still allows control over advanced settings on the reader. A well-defined vendor extension mechanism means you can get access to all of Speedway's advanced RFID features with simple extension. Impinj is a leading participant in the development of the LLRP standard.

Five Essential Factors in the Success of a European UHF Gen 2 Deployment

Beyond these important new developments, the following attributes are fundamental to a high-quality UHF Gen 2 deployment in Europe—or anywhere, for that matter:

1) Standards compliance, and more importantly, interoperability certification

Impinj is the first (and at the time of this writing, the only) RFID solution provider delivering both tag and reader products certified for interoperability by EPCglobal. Certified interoperability is key to driving worldwide proliferation of UHF Gen 2 technology.

2) Performance

Impinj's Speedway reader is a high-performance platform based on a software radio architecture that enables the easy loading of new enhancements via firmware upgrades. Our latest firmware release includes improvements to our tag singulation algorithm and further optimization of the Gen 2 modes, both of which result in significant performance improvements in ETSI operation. In short, the innovative capabilities designed into both the hardware and firmware make Speedway the best performing reader available.

3) Flexibility

The Speedway reader's combination of high-margin receive sensitivity with a monostatic antenna configuration not only enables outstanding read reliability, but also the extension of the Speedway reader to item-level tagging (ILT). Impinj is a pioneer in applying UHF to ILT applications, in no small part because of the Speedway monostatic antenna solution, which also reduces deployment costs. In addition, the feature-rich Speedway reader provides a host of network and I/O interface possibilities, including raw access to a general-purpose input/output (GPIO) port that users can program to trigger reader operations.

4) Quality & Reliability

The Speedway reader's single board solution, rugged enclosure designed for harsh environments, and manufacturing for quality practices combine to ensure the defect-free performance required in mission-critical applications. Our intensive testing and attention to quality has helped Impinj achieve an impressive actual field return rate of less than 0.1% to establish a new industry gold standard (compare that to typical UHF reader unit field return rates of 3.0% or more).

5) Delivery

Impinj builds thousands of Speedway readers each week in a facility that ramps rapidly to meet demand in the many thousands of units per week. The Speedway reader is a high-volume, production-proven device designed to deliver outstanding performance and is available through our European network of VARs.

Only Impinj has demonstrated the level of systems engineering expertise, design, and manufacturing capability required to deliver the best performing, most reliable reader available anywhere. Learn more by visiting www.impinj.com

INTERMEC – The Key to RFID Success in Europe

A significant factor enabling more widespread adoption of RFID in Europe will be to remove or reduce the stringent LBT requirements. This would greatly improve RFID reliability in congested environments and provide companies scalability going from small pilots to full roll out.

Additionally, we would have better performing handheld readers from reduced LBT requirements, along with antenna beam restrictions. The increased performance would facilitate greater utilization of handheld readers in asset tracking, asset management and other warehouse applications.

Also, every country in Europe moving to the ETSI 302-208 standard or a similar higher power 2 watts ERP 86x MHz band would further facilitate success in Europe. The increased power provides the extra read range for reading cases and pallets moving throughout the supply chain.

Technical Reader Features Needed to Optimize ETSI Performance

Part of real-world deployment challenges is scalability when multiple readers are used in close proximity and can interfere with each other. Dense Reader Mode is a key feature needed to help prevent interference in these types of environments, by providing a method of receiving data from a tag at a narrower spectral mask and increasing data integrity and reliability.

Part of this is the ability of the reader to reject interference in adjacent channels. These channels are adjacent to the channel that is used to receive the tag signal. So, excellent adjacent channel rejection is another feature required to optimize RFID performance.

Future Features that Further Enhance European Performance

In the future we see dynamic frequency agility built into RFID readers, where readers select frequency channels for optimum usage to minimize interference.

MOTOROLA XR480 EU

Industrial-class RFID reader delivers maximum functionality and benefits

The Motorola XR480 Gen 2 reader offers maximum functionality for large-scale RFID deployments. This strategic platform is designed to help enterprises achieve competitive advantage by increasing inventory visibility and process efficiency in order to effectively reduce costs and improve profitability. Reliable and efficient tag reading in dense RF environments eliminates interference issues associated with multiple RFID readers in close proximity. The standards-based XR480 enables seamless integration and interoperability with any existing IT infrastructure.

Robust RFID Functionality

The Motorola XR480 includes support for standard back-end platforms, direct application hosting, and the ability to interact with additional asset automation equipment — such as forklifts and conveyor belts. With support for the ETSI EN 302 208 standard, the XR480 is the only commercially available EPC-compliant reader in Europe based on the Windows® CE operating system and with support for up to eight read points, increasing the flexibility and reducing the complexity of RFID implementations.

The reader not only satisfies the requirement of the current ETSI EN302-208 specification with built-in Listen before talk detectors on multiple ports, but it has also demonstrated the capability of operating with requirements of synchronization, as well as the draft technical requirement of the newly proposed EN302-208 modifications with Firmware upgrades.

The XR Series readers also support IBM's WebSphere® RFID Device Infrastructure (WRDI) as an option, providing an embedded Java platform that enables robust integration with enterprise IT environments. The XR480 is a true platform to maximize the power of RFID in your enterprise.

Next Generation Performance and Manageability

The reader engine uses a combination of FPGA and TI TMS320C64X DSP engine to bring unparalleled signal processing capability to the platform. The XR480 ER RF front-end design not only provides for exceptional RF performance, but also is the only interrogator that provides 8 Mono-Static ports. The reader also incorporates a sophisticated adaptive Q algorithm that maximizes the rate of reading tags, particularly in dock-door applications.

The XR480 provides maximum flexibility in RFID deployments. Superior read rates and enhanced read ranges make the XR480 ideal for multiple RFID applications — from dock doors and conveyor belts to the warehouse floor or store front. Easy to deploy, application specific setup enables rapid and seamless integration into any IT environment, further reducing implementation time and costs. Advanced data collection features — such as filtering, reconciliation, user-defined association and selective visibility — deliver refined real-time information, delivering incremental benefits throughout the enterprise.

The ability to incorporate alarms, light sensors and more from other automated asset equipment enables users to leverage RFID to activate a wide range of business processes — from dynamic reconfiguration of build-to-order assembly lines based on products on the conveyor belt to real-time alerts to stop forklift drivers from placing inventory in the wrong location. And the ability to control and maintain all XR480 readers from a single central location dramatically simplifies and reduces the costs associated with day-to-day management.

Direct Application Hosting

The XR480 increases productivity through the ability to embed a wide array of software applications. For example, IBM's WRDI can be embedded in the XR480 to provide a

secure, reliable Java platform to streamline logistics, improve inventory management, and provide better visibility of products throughout the supply chain, creating an "intelligent" RFID reader to automate and manage the incoming RFID data. WRDI applications process and filter the incoming RFID data for integration with upstream IT systems, ensuring delivery of critical RFID events to enterprise IT systems. These events can provide sales trend analysis, providing management with the decision-making tools to optimize inventory management — and reduce inventory levels and associated costs. And the industry-standard Windows CE operating system reduces the complexity associated with implementing and managing multiple platforms.

SIRIT IN510

RFID in Europe – Progress Continues

In April 2005, Tesco's CTO John Clarke stated that European retailers deploying RFID in their supply chain and stores face far more challenges than their U.S. counterparts do[(1)]. Mr. Clarke accurately pointed to several aspects of the ETSI radio regulations that made UHF RFID particularly challenging in Europe. These included the requirements for Listen Before Talk (LBT), the lack of Frequency Hopping Spread Spectrum (FHSS) allowances, and a 2MHz wide band vs. the 26MHz wide band in the US. Lastly, Mr. Clarke noted that very few readers took advantage of the new EN302 208 standard with sufficient performance. While most of these regulatory challenges remain, there have been a series of improvements in the last 2 years in the areas of product development that can significantly impact the overall performance of UHF RFID systems in supply chain applications throughout Europe. In addition, there are regulatory changes proposed that would further simplify the use of UHF RFID in Europe.

The Key to RFID Success in Europe

Under the current RF regulations within Europe, the power levels allowed under ETSI have been shown to be sufficient, with several retailers reporting excellent reading rates for case-level tagging in portal readers. However, the limited number of channels and the requirement for Listen-Before-Talk (LBT) mean that special care needs to be taken when installing more than just a few UHF readers in a single location.

Currently, ETSI is evaluating a modification of its current 10 channel regulation (EN302-208) to a new "4 Channel Plan". The benefit would be to enable lower power devices to have dedicated "quiet" channels, while the higher power portals operate on their own dedicated channels. Of course, this exacerbates the LBT requirement, but testing has shown that standard synchronization techniques have very effective at operating under these guidelines.

Network Synchronization is a method whereby a network device manages timeslots in which each reader can operate. When this is employed, it has been shown that dozens of readers can operate successfully in a single location.

Wireless Synchronization is a method whereby each reader monitors signals from other readers to self-assign timeslots for their reading sequences. While this system can be more complex to design, it allows for a simpler installation solution. Preliminary testing on Wireless Synchronization under ETSI regulations has been very promising.

The ability for a reader to be modified through a simple firmware upgrade to address these dynamic regulatory environments is critical. The Sirit INfinity 510 has demonstrated this level of adaptability in several major supply chain tests in Europe.

Technical Features to Optimize Performance in Europe

Lastly, there are certain technical reader features that can optimize ETSI performance, regardless of LBT or 10 vs. 4 channels. As said before, the ETSI regulations have a much more difficult RF mask and emissions limits as compared to FCC markets. In order to meet these requirements, many UHF RFID readers use a slower data rate (e.g. tari = 25usec). But, in order to achieve the highest levels of performance in moderate to challenging applications, forward and reverse link speeds need to be maximized. Due to its comprehensive digital wave form generation, and filtering, the Sirit INfinity IN510 is able to have a tari down to 12.5 microseconds, allowing for the fastest data rate speeds in both directions.

(1) “Tesco CTO Describes Europe's Hurdles”, RFID Journal, by Jonathan Collins, April 12, 2005, http://www.rfidjournal.com/article/articleview/1502/1/9/

APPENDIX A: OTHER BENCHMARK RESEARCH

The European RFID Reader Benchmark builds on a long legacy of Benchmark research produced by ODIN technologies. Previous benchmarks helpful as you continue to research RFID technology performance include:

The 2006 Global Tag Benchmark

The Global RFID Tag Benchmark is a scientific evaluation of the top 18 UHF RFID tags for performance in Asian, European and North and South American frequencies. Tag performance is rank ordered for power effectiveness, orientation sensitivity, distance, interference rejection and material dependence for corrugate, water and metallic items. Both general purpose and "jumbo" oversized tags are evaluated. The Global RFID Tag Benchmark is the only published study that evaluates which tags can perform well across geographic boundaries. It is designed to help end users make better tag selection decisions that improve overall RFID system performance.

The Gen 2 RFID Reader Benchmark

The Gen 2 RFID Reader Benchmark presents analysis of seven of the leading EPC compliant Gen 2 reader vendors. The benchmark was developed to provide end users with objective insight into how well readers actually work in the field and what criteria should be evaluated when making reader selection decisions. The Benchmark is the first scientific and objective comparison of how Gen 2 RFID readers work in common use cases such as dock doors, conveyors and stretch wrappers and provides detailed insight into which readers simply work the best. In addition to scientific performance analysis, the report also includes sections on: mitigating the risks of selecting a Gen 2 reader, reader selection tools based on used case, and editorial user comments from the ODIN engineering team.

Pharmaceutical Item Level RFID: Battle of the Frequencies

Pharmaceutical Item Level RFID: Battle of the Frequencies is the first scientific evaluation pitting high frequency (HF) against ultra high frequency (UHF) for the most common and most challenging item level pharmaceutical use cases. Developed in conjunction with Unisys and leading pharmaceutical manufacturers and distributors, the benchmark represents the most comprehensive, objective and scientific analysis of RFID for use in the drug supply chain. The FDA, state regulators, industry associations and manufacturers all agree that RFID is the best available technology to efficiently and effectively improve the authenticity and safety of the nation's drug supply. This research provides a scientific basis for thoughtful regulatory action on the best implementation approach for RFID in the

pharmaceutical industry. The research also sheds light on the most important RFID design issues facing end users in their first pilot and production systems.

The 2006 Gen 2 Tag Benchmark

The report presents an analysis of eleven of the leading EPC (electronic product code) compliant Gen 2 RFID tags. The benchmark was developed to provide end users with objective insight into how well tags actually work in the field and what criteria should be evaluated when making tag selection, placement and orientation decisions. The Benchmark is the first scientific and objective comparison of how Gen 2 RFID tags work with various standard materials such as corrugate packaging, water and metal. Some of the results are surprising and will help end users make better tag selection decisions.

In addition to the scientific analysis, the report also includes sections on: the physics of RFID tag performance, how to select an RFID tag converter, an overview of what end users need to know about the Gen 2 standard, and recent changes in the RFID market.

RFID Handheld Reader Benchmark

The ODIN technologies 2005 RFID Handheld Reader Benchmark represents a groundbreaking step forward in the evaluation of the latest generation of RFID handheld readers.

APPENDIX B: BENCHMARK PARTNERS

TEKTRONIX

A Tektronix Real-Time spectrum analyzer was used in the *European RFID Reader Benchmark* test protocol and provides a comprehensive RFID solution.

Tektronix, an industry leader for test and measurement solutions for more than 55 years, meets the emerging test and measurement challenges for RFID. The award-winning Real-Time Spectrum Analyzer provides the most comprehensive support for RFID physical layer analysis. The Real-Time Spectrum Analyzer enables RFID designers to meet the measurement challenges today and for the next generation of RFID technologies.

The next generation of RFID standards uses complex modulation techniques, frequency hopping and new encoding methods that require a new measurement approach to characterize the RF, modulation and timing requirements. The amplitude, frequency and time varying characteristics of the next generation of RFID signals require a new solution. To successfully comply with the new RFID standards and measurement challenge, a designer needs a comprehensive, flexible solution that characterizes the physical layer performance of their Interrogator and Tag. With the patented Frequency Mask Trigger, the Real-Time Spectrum Analyzer is the only solution that allows RFID users to capture a seamless time record of the entire interaction between the Interrogator and Tag. Once a specific burst is captured, the user has the capability to analyze the RFID signal in multiple domains simultaneously without reacquiring the signal!

With the Real-Time Spectrum Analyzer and the new Option 21 Advanced Measurement Suite software, RFID designers now have a comprehensive solution with dedicated measurement buttons that allow quick and easy configuration. This enables RFID users to meet the new measurement challenges with a simple and easy to use measurement solution.

- Trigger on a specific RFID burst or a frequency hopping signal with the unique Frequency Mask Trigger feature to isolate interfering signals
- Capture a seamless time record of the RFID signal into deep memory once and perform frequency, modulation and time correlated multi-domain analysis without the need to reacquire the signal
- Quickly analyze RFID signals with dedicated buttons that support the ISO/IEC 18000 Part 4, Part 6 standards and EPC Gen 2. A manual mode provides the user with a comprehensive set of modulation and decoding formats to analyze existing RFID standards or proprietary RFID signals.
- Provides time-correlated multi-domain views. Quickly and easily characterize all of your RFID RF, timing and modulation measurements with one comprehensive solution.

For more information on the Real-Time Spectrum Analyzer RFID solution and support from Tektronix, please visit: http://www.tek.com/rfid .

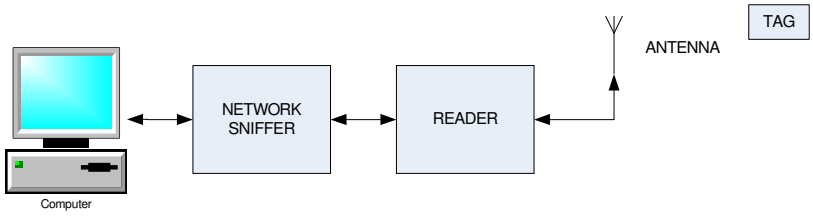
APPENDIX C: NETWORK LOADING

RFID PLANNING:
Resolving network bandwidth concerns

As RFID moves from pilot to production, more and more readers will be connecting to company networks. There is a concern that RFID readers will consume large amounts of network bandwidth with redundant tag data. Many contemporary RFID implementations rely on centrally located middleware to filter the data, which requires that redundant data to flow over the network. Filtration functionality is now beginning to move to the edge of the network, aboard the reader itself. This line of trials was conducted to identify which readers are the best network citizens.

Purpose. This test is conducted to explore the network loading of each reader and attempt a comparison among the tested readers.

Apparatus. ODIN technologies used a fixed antenna/tag geometry. Two different tests were conducted, one with a target of a single tag and one with a twenty tag target. A host PC with Network Monitoring software / Network Sniffer utility was used to capture the data. It is important to note that each reader used its own software or interface for control.

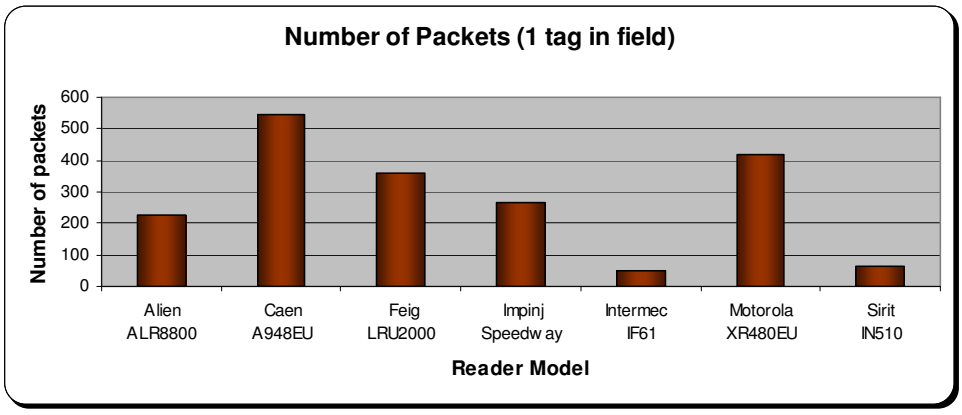


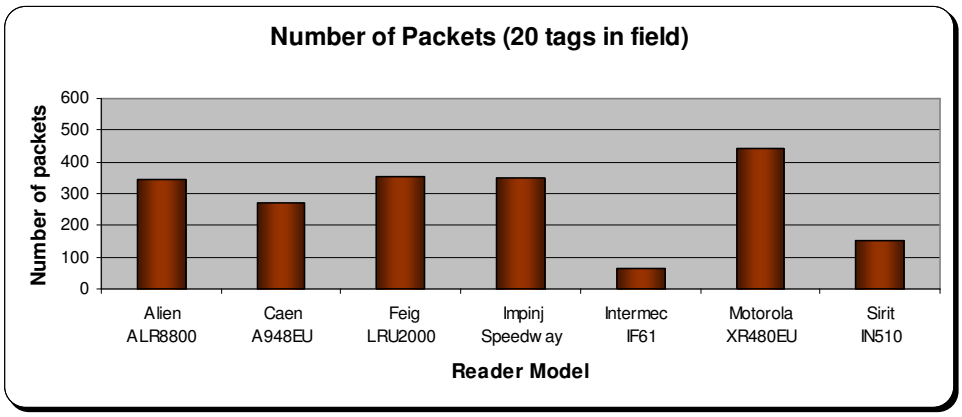
Network loading test

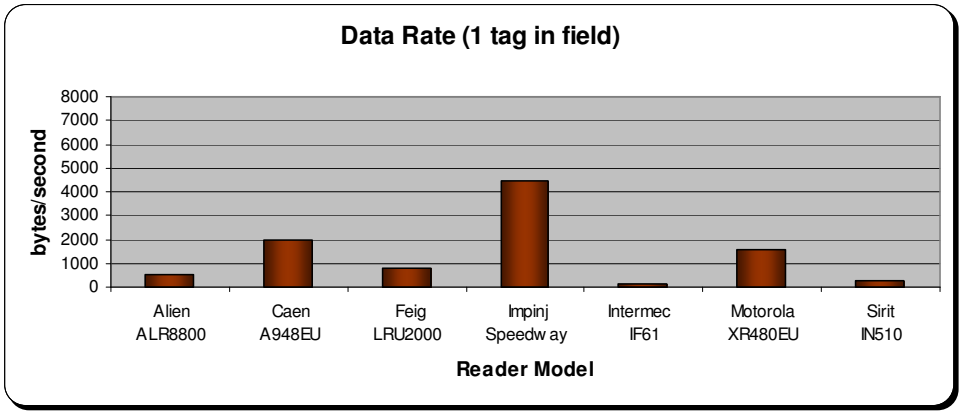
Procedure. Filters were set up in the network monitoring software which identified packets flowing between the host PC and RUT. Packets from the reader under test (RUT) to the PC were identified using software filters built into the Network Monitoring Utilities.

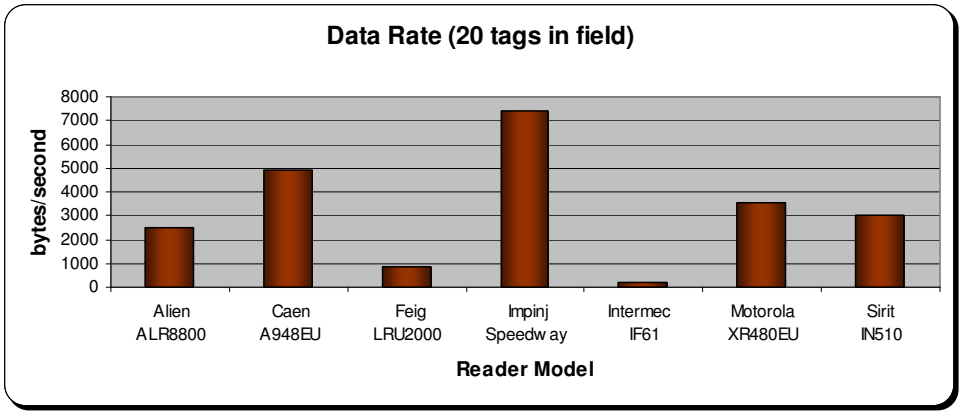
ODIN technologies tested two scenarios. In the first scenario the RUT was configured to read continuously with one tag in the field at a distance of 1 meter. Data was captured for thirty seconds by the network snuffer. The second scenario was similar, except that a twenty tag target was used.

Results.









The Caen A948EU reader sent the largest number of packets when one tag was in the field, with fewer when twenty tags were captured. This seems to indicate that the Caen A948EU processor assembles all of its reads into a group of packets before transmitting them. The Motorola sent approximately the same number of packets, possibly it time schedules its packets

It is interesting to note that the two readers which performed best in other testing showed opposing results in this test.

Applying the Results.

This data is provided for illustrative purposes only. ODIN technologies cannot make a judgment regarding the ranking of the readers on this measurement axis. Further study of the network traffic load is required before an accurate analysis can be achieved. In particular, a common interface among all of the reader and the host would be necessary to accurately determine a ranking among readers with respect to how much traffic each reader loads onto the network.

One observation can be made; even the reader with the largest report in this test is providing only a miniscule load to a normal network. A huge number of readers working simultaneously would be necessary to impact network performance. While further studies should be undertaken, it is at least a reasonable preliminary conclusion that RFID readers do not represent a significant drain on network resources.

About ODIN technologies

ODIN technologies is the leader in the physics of RFID for solution design, deployment services and optimization software. RFID is all we do. Global corporations on five continents leverage ODIN technologies' expert engineers and patented RFID optimization tools to achieve accuracy, speed and visibility for their RFID deployments. In addition to consulting services, ODIN technologies is also the publisher of the RFID Benchmark Series, the industry's first and most referenced head to head performance analysis of RFID equipment. ODIN's RFID optimization software suite EasyRFID has been successfully used at dozens of companies across more than 100 sites to ensure accurate RFID implementations. ODIN's President and CEO, Patrick J. Sweeney, II, is the author of RFID for Dummies and CompTIA RFID+ study guide, both published by John Wiley & Sons. ODIN serves clients from offices in Dulles, Virginia, USA, Tokyo, Japan, and Budapest, Hungary. www.ODINtechnologies.com.

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ABOUT ODIN TECHNOLOGIES

ODIN technologies is the leader in the physics of RFID for solution design, deployment services and optimization software. RFID is all we do. Global corporations on five continents leverage ODIN technologies' expert engineers and patented RFID optimization tools to achieve accuracy, speed and visibility for their RFID deployments. In addition to consulting services, ODIN technologies is also the publisher of the RFID Benchmark Series™, the industry's first and most referenced head to head performance analysis of RFID equipment. ODIN's RFID optimization software suite EasyRFID™ has been successfully used at dozens of companies across more than 100 sites to ensure accurate RFID implementations. ODIN's President and CEO, Patrick J. Sweeney II, is the author of RFID for Dummies and CompTIA RFID+ study guide, both published by John Wiley & Sons. ODIN serves clients from offices in Dulles, Virginia, USA, Tokyo, Japan and Budapest, Hungary. www.ODINtechnologies.com.