FIVE FACTORS FOR SUCCESS

UHF Gen 2 RFID Readers

Impinj Speedway reader: realizing the full potential of the UHF Gen 2 Standard

Not all RFID readers are created equal. In the case of UHF Gen 2, this maxim bears added significance. Why? Because standards compliance is only part of the story: meeting the standard says nothing, for example, about performance, let alone performance under demanding conditions. Fundamental to achieving your ROI goals—however you measure them—is the confidence that all the tags whose data you need to read actually make it into your business process. So the choice of components that make up your RFID system matters a great deal. Here then are five essential reader attributes that ultimately determine the quality and performance of your RFID implementation.

1. **STANDARDS COMPLIANCE**
   - EPCGLOBAL CERTIFICATION
   - BEYOND COMPLIANCE
2. **PERFORMANCE**
   - ROBUST OPERATION
   - HIGH RECEIVE SENSITIVITY
   - MONOSTATIC ANTENNA CONFIGURATION
3. **FLEXIBILITY**
   - APPLICATION PROGRAM INTERFACE
4. **QUALITY & RELIABILITY**
   - SINGLE BOARD SOLUTION
   - RUGGED ENCLOSURE
   - MANUFACTURING FOR QUALITY
5. **DELIVERY**
   - DEPENDABLE SUPPLY
   - SOURCING BY AN INDUSTRY LEADER

1 Standards Compliance

EPCGLOBAL CERTIFICATION:
Interoperability is essential

One of the keys to the proliferation of UHF Gen 2 products is EPCglobal testing, designed to ensure that readers and tags implement Gen 2 correctly. A first key aspect is compliance testing. Products that pass this testing earn the EPCglobal certification mark, a "seal of approval," indicating the products' adherence to the requirements of the Gen 2 specification. A second key aspect is interoperability testing, a suite of tests that evaluate interoperability among tags and readers from multiple vendors. The Speedway™ reader from Impinj® was the first reader to receive both certifications, and now serves as a reference platform for evaluating the interoperability of other suppliers' Gen 2 products.

BEYOND COMPLIANCE:
When a reader does more than the least it can do

It is important to note that the Gen 2 standard includes optional functions and not all readers support all the options. In particular, readers can be certified as Gen 2-compliant and Gen 2-interoperable even if they are not able to operate at high data rates or support the Gen 2 dense-reader mode. Impinj designed the Speedway reader from the ground up to support Gen 2 in its entirety. Moreover, as discussed below, Impinj designed into the Speedway reader certain features that have actually expanded the applicability of the Gen 2 standard itself.

2 Performance

ROBUST OPERATION:
Gen 2-only readers have significant advantage

Other "Gen 2" readers are adaptations of existing Gen 1 designs. When it comes to performance, readers based on legacy technologies are at an obvious disadvantage—a problem further exacerbated by their need to cycle through all the various protocols. As a result, because of the inherent time delays incurred by protocol switching, multi-protocol readers will miss many tags, resulting in unacceptable levels of read reliability. The "jack of all trades" is a master of none. Impinj designed the Speedway reader for users who demand the most robust read performance possible—a goal that can only be met by a Gen 2-only reader.

HIGH RECEIVE SENSITIVITY:
Link margins matter

Because tag signals have very low power levels, they effectively whisper their responses to interrogating readers. Consequently, a reader's sensitivity is paramount. Receive sensitivity must also take into account noise, interference, and other effects that conspire to increase the reader's bit error rate (BER)—that is, the ratio of the number of bits incorrectly received to the total number of bits sent in a specified period. A high-performance reader has a four-fold charge: 1) hear the tags' weak signals, 2) hear them accurately, 3) hear them with sensitivity margin, and 4) hear a large and potentially fast-moving population of them very quickly. Just how well a reader lives up to these objectives is a reflection of the engineering expertise that went into its development.

Consider the example shown in Figure 1, which illustrates a typical link budget in both reader-to-tag and tag-to-reader directions. Note that the FCC limits UHF reader transmission power to 1 watt (which equates to 30 dBm), measured at the antenna connection port. The antenna contributes additional gain on the order of 6 dBi for a linearly polarized antenna or 9 dBi for a circularly polarized antenna. Also note that, while the reader antenna may transmit as much as 4 watts when factoring in the antenna gain, a tag near its limit of range may receive and backscatter only microwatts of that energy.

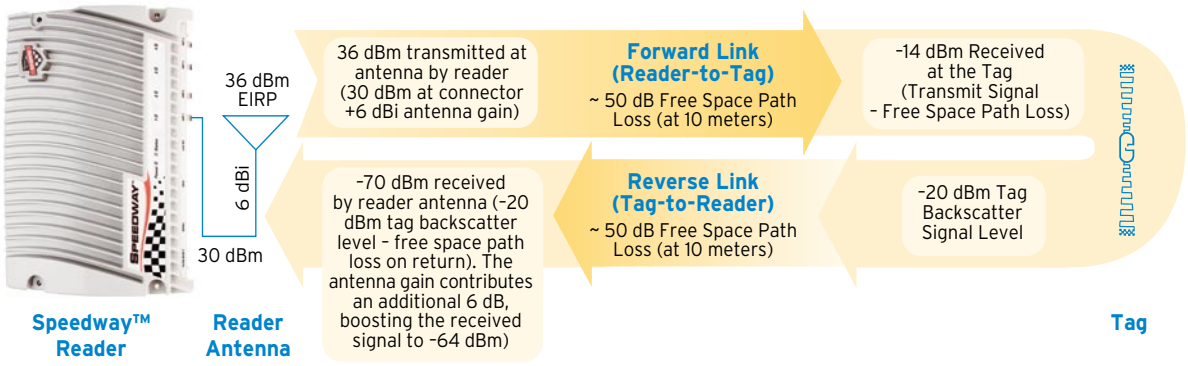

Figure 1. Evaluating Receive Sensitivity

Considering the magnitude of the losses, you can see how receive sensitivity matters. The Speedway reader, with –77 dBm sensitivity, typically has more than 10 dB link margin. Impinj engineers believe that if a reader can provide enough power to activate a tag buried inside a pallet of stacked cases, then it should have enough sensitivity to be able to hear the tag's response, with margin. By contrast, the typical RFID reader, with a receive sensitivity of –65 dBm, has only 1 dB of margin and experiences bit errors when listening to replies from weak tags.

Receive link margin also allows a reader to tolerate the interference coming from other readers operating in the area, as well as the polarization and phase effects of antenna orientation, and the losses caused by multi-path effects or the presence of RF-absorbing material that might be blocking a tag. Another benefit of the Speedway reader sensitivity margin is that it anticipates future improvements in tag sensitivity. It might be counter-intuitive at first blush, but as tag sensitivity improves, path losses increase (the tag is able to receive power from a greater distance) and the signal received at the reader becomes weaker. In fact, because of the increased range, every dB of increased tag sensitivity requires an additional 2 dB of reader sensitivity (because there is 1 dB of loss in each link direction). More sensitive tags make it increasingly important that readers have more receive sensitivity margin, not less. The Speedway reader has that margin designed-in today.

Limits to sensitivity relate back to bit error rate. BER quantifies the reliability of the entire RFID system from "bits in" to "bits out." Its definition is:

BER = Bit Errors/Total Number of Bits

It's a fact of life that the extraction of information from an RF signal (demodulation) incurs a certain BER. We care about transmission errors (which the Speedway reader's error-checking algorithms catch) because they impact system throughput. If a reader sees a bit error, it must re-read the tag to obtain a clean, error-free transmission. So the greater the receive sensitivity, the lower the BER, the fewer retries required, and the higher the system throughput. Stated simply, Speedway reader's sensitivity allows it to read faster.

MONOSTATIC ANTENNA CONFIGURATION: When less is more

The configuration of the reader antennas (driven by tradeoffs in cost and performance) also greatly affects system performance. Two common schemes are monostatic and bistatic. A monostatic system uses the same antenna to both transmit and receive, while a bistatic system uses separate, dedicated antennas for the transmit and receive operations. A four-port monostatic reader requires four antennas; a four-port bistatic reader requires eight antennas. Deployment costs and complications notwithstanding, some reader suppliers have opted for the bistatic scheme because they have not developed the technology to maintain high receive sensitivity with a monostatic antenna. Because both transmit and receive signals share the same antenna in a monostatic system, if not properly designed, this arrangement is subject to signal reflections back into the receiver path, raising the noise floor and lowering reader sensitivity. Impinj, recognizing that a monostatic system is inexpensive, simple to deploy, and exhibits better data collection and processing efficiency over bistatic solutions, engineered a series of patent pending innovations that culminated in INR™ (Impinj Noise Reduction) to enable the benefits of monostatic antennas without compromising sensitivity. INR not only lowers the noise floor by as much as 20 dB, it has the added benefit of rejecting interference from readers operating in adjacent channels.

As previously noted, the Speedway reader can recover a –77 dBm signal. It does this while handling an interfering signal as high as +5 dBm. Interference rejection is important because in a typical dock door scenario, an interfering reader will be just 3 meters away—and transmitting as much as 36 dBm. At 3 meters the path loss is –41 dB, resulting in a –5 dBm signal at our reader antenna (+36 – 41). The receive antenna boosts the interfering signal by +6 dBm (remember the linearly polarized antenna gain discussed earlier), netting a total of +1 dBm received interference (–5 + 6), well within the Speedway reader's +5 dBm interference budget. It's nothing short of a breakthrough that the Speedway reader, using monostatic antennas buffered by INR, exhibits such high sensitivity in the presence of strong interference.

What's more, the monostatic antenna configuration enables the extension of the Speedway reader to item-level tagging (ILT). ILT is difficult for bistatic systems, because the transmit and receive antennas must be positioned so closely together that the signal from the transmit antenna couples strongly back into the receive antenna. The primary reason that some readers use bistatic antennas is to provide isolation between the transmit and receive signals, a condition not typically available in ILT environments. Readers equipped with monostatic antennas work better for ILT. Impinj is a pioneer in applying UHF to ILT applications, in no small part because of the Speedway reader's monostatic antenna solution.

3 Flexibility

APPLICATION PROGRAM INTERFACE:
Low-level access and high-level control

The Speedway reader provides powerful interfaces that are as robust and efficient as the hardware itself. These include the Mach1™ application program interface (API), the reader command line interface (CLI), and the Web-based graphical user interface.

- Providing operations and management command sets, the Mach1 interface delivers the best of both worlds: low-level data access and high-level control for all RFID related operations. The Mach1 API allows for transparent and immediate streaming of complete EPC data (with time stamps and received signal strength for every read) yet programming it does not require detailed Gen 2 expertise or understanding.
- The reader CLI, meant as a machine interface, is the engine behind such reader operations as network connectivity control, logging, and firmware upgrade.
- The especially user-friendly, Web-based, graphical user interface provides the user with yet another means of observing and configuring the network connectivity of the reader. In addition, it provides an RFID functionality demonstration that allows the user to specify many details, from the selection of active antennas and modes of operation to the specifics of data filtering and RFID command execution.

Impinj is also an active participant in EPCglobal's development of the standard called Low Level Reader Protocol (LLRP) for reader-to-network communications, control, and management. LLRP, which the Speedway reader will fully support, allows the technical user to fine tune the settings on the reader to further optimize performance.

Finally, 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.

Ultimately, the reader you choose should not only satisfy your current requirements but anticipate your future needs as well. A powerful API based on a hardware design with plenty of available processing cycles ensures the long-term viability of your RFID solution.

4 Quality & Reliability

SINGLE BOARD SOLUTION:
Reliability is not an option

Impinj engineered the Speedway reader not only for high performance, but for high reliability as well. A single printed circuit board (PCB) contains all of the Speedway reader circuitry with no added jumpers, wires, or cables. Other readers use as many as five separate PCBs connected via numerous jumpers and ribbon cables. Such arrangements present significant reliability, servicing, and upgrading challenges—to say nothing of potential compromises to performance.

RUGGED ENCLOSURE:
Designed for harsh environments

While some manufacturers house their readers in stamped steel enclosures, Impinj encased the Speedway reader within a rugged die-cast enclosure of A380 aluminum, enabling a wide operating temperature range and full IEC IP54 liquid and dust protection. In short, Impinj designed the Speedway reader to deliver the highest level of performance and reliability, and to take the kind of abuse expected in warehouse and distribution center deployments.

MANUFACTURING FOR QUALITY:
Ensuring defect-free performance

Speedway reader circuit boards progress through a series of thorough in-line inspections and tests to ensure that each unit meets the highest quality levels:

- In addition to 100% visual inspection, every Speedway reader board goes through automatic optical inspection to verify that every component is mounted properly and is in the correct location and orientation.
- For hidden solder joints that technicians cannot visually inspect, 100% X-ray inspection sees through the printed circuit board to verify solder joint integrity.
- A bed-of-nails test fixture verifies correct electrical operation. Tester pins make direct contact with a great many test points on the board, providing the highest test coverage possible.
- Links to integrated quality software monitor our high quality standards, with statistical process controls analyzing the results in real time.
- Once assembled, the Speedway reader undergoes a complete functional test that exercises all connections and proves its outstanding RF performance.
- Finally, every Speedway reader goes through full, continuous operation for 24 hours in a high-temperature burn-in procedure, eliminating infant mortality failures and ensuring the Speedway reader's consistent performance and robust reliability in the field.

This 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

DEPENDABLE SUPPLY:
Scalable capacity, global availability, on-time delivery

Plexus, the world-class contract manufacturer that builds the Speedway reader, uses state-of-the-art manufacturing practices to ensure a high quality product. Plexus builds thousands of Speedway readers each week in a facility that ramps rapidly to meet demand in the many thousands of units per week.

SOURCING BY AN INDUSTRY LEADER:
Standards-driving expertise sets the bar

Impinj played a leading role in the effort to develop the UHF Gen 2 standard. Impinj actually performed much of the systems engineering and analysis that proved the essential technological elements of the standard as it was being created. Leveraging this intimate understanding of the standard and comprehending its many nuances, Impinj was also the first to market a true Gen 2 reader. Together with being the first company to market UHF Gen 2 tag chips, Impinj is indeed the company that made UHF Gen 2 real, while continuing to deliver the industry's most innovative tag and reader products.

Conclusion

The Speedway reader, for good reason—make that five good reasons—is the UHF Gen 2 reader of choice for all RFID applications, from the reading and writing of pallet tags in warehouses and distribution centers, to individual items on store shelves and in pharmaceutical filling lines. 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.

About Impinj

Impinj, Inc. is a semiconductor and RFID company whose patented Self-Adaptive Silicon® technology enables two synergistic business lines: high-performance RFID products and semiconductor intellectual property (IP). A leading contributor to the RFID standards for high-volume supply-chain applications worldwide, Impinj leverages technical expertise and industry partnerships to deliver the GrandPrix™ solution, comprising tags, readers, software and systems integration to offer RFID that just works™. Impinj licenses innovative IP products, core to the company's RFID tags, to leading semiconductor companies worldwide, allowing them to seamlessly integrate crucial nonvolatile memory (NVM) alongside analog and digital functionality on a single chip. Impinj's IP products include the popular AEON® family of embeddable cores, which provide rewriteable NVM technology in logic CMOS manufacturing.

For more information, visit www.impinj.com.

Impinj, Inc. 701 N. 34th Street, Suite 300 Seattle, WA 98103 www.impinj.com
rfid_info@impinj.com Tel: 206.517.5300 Fax: 206.517.5262