

## GrandPrix™ Application Series

# RFID Communication and Interference

Interference is an often-misunderstood factor in the design of a successful RFID solution. While interference *is* a real concern and does affect system performance, there are many mitigation factors that enable robust system deployments even in noisy RF environments. This application note examines how UHF RFID communication presents unique interference challenges and how they are solved in practice.

### Unique aspects of UHF Gen 2 RFID Communication

The UHF Gen 2 RFID form of radio communication has three unique design challenges when considering interference mitigation:

- *UHF Gen 2 tags have limited “tuning” capability.* The integrated circuits (chips) embedded in RFID tags must be as small and as power-efficient as possible, and must work with all readers in every region of the world (each region has different allowed frequency ranges). These tradeoffs leave the chips more susceptible to interference from radio signals than most communication circuits. Although RFID tag chips vary widely in their ability to filter out unwanted transmissions, none have the tuning capability that you might find in a normal radio system.
- *UHF Gen 2 readers transmit at a far greater power level than required for communication alone.* RFID tags do not have their own power source, so the reader must provide sufficient energy via the communication link to power the tag, and the energy required to power the tag is much higher than the energy needed just to communicate. As a consequence, the physical space potentially affected by an operating reader is considerably larger than that which would be affected by two normal radios communicating over a similar distance.
- *UHF Gen 2 tags transmit their signal in such a way that it is centered in the same channel as the reader with which it is communicating (and possibly the same channel as other readers in the area as well).* UHF Gen 2 tags do not generate their own signal on a separate channel—they simply reflect the reader signal, adding modulation to represent their data. The signal reflected by the tag is many orders of magnitude weaker than the signals transmitted by the readers.

These factors create potential for interference that may not occur in more typical radio communications. Yet high-performance, dense-reader applications are practical with UHF Gen 2 systems, and this paper will show you why, from both the tag and reader points of view.

## Interference from a Tag's Point of View

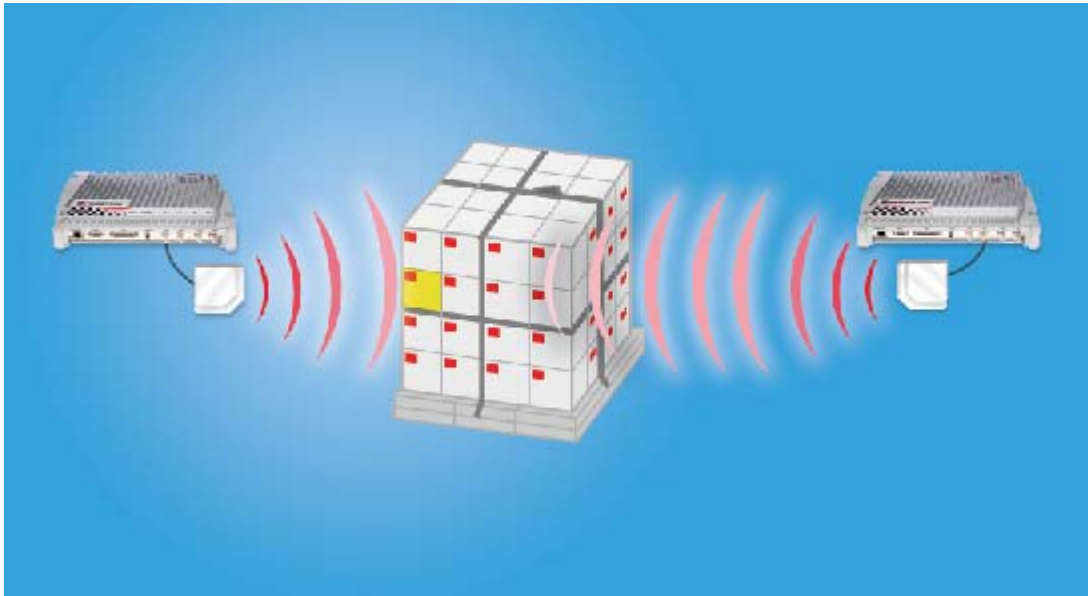
Although a tag can listen to any reader in its vicinity, it can communicate with only one reader at a time, and only if the signal arriving from that one reader is stronger than other signals. If a tag is close to one reader and far from another, it will have no trouble communicating with the nearby reader. But when the tag is roughly equidistant to both readers, interference becomes more likely. In other words, between any two readers, there is an area between them where a tag cannot communicate with either reader *if both readers are transmitting*. We refer to this form of interference as *tag jamming* and the regions where tags are jammed as *dead zones*. If the readers are far enough apart, the dead zone lies outside of the read range of the tag. But if they are close together, the dead zone can fall inside a read zone, especially when more than one reader serves a read zone. Tag jamming is primarily related to transmission power levels and the proximity of readers, and is only secondarily a function of transmitter frequency. Tag jamming's impact on system performance depends on a number of factors, including the design of the tag's chip, the presence of any RF-absorbing material in the communication path, the motion of the tag through the read zone, channel frequency selection, the sequencing of the reader antennas, and the type of tag antenna.

### Tag Chip Design

The design of the tag chip influences its ability to reliably receive signals. Well-designed chips include interference rejection to decrease the size of dead zones. Smaller dead zones means less time that tags will be inaccessible when they move through a multiple-reader portal. Tags designed to have good interference rejection, such as those using Impinj<sup>®</sup>'s Monza<sup>™</sup> and Monaco<sup>™</sup> tag silicon, can receive power from more than one reader and still communicate effectively with the reader of interest.

### RF Absorbing Material in Path

Because path-loss through dense materials is greater than through free air, a tag within a pallet of RF-absorbing material is less likely to receive enough power from a reader on the far side of the pallet to cause interference. The existence of the material on the pallet increases the effective distance between the two readers, which results in smaller dead zones (see Figure 1).



**Figure 1 Material in Communication Path Increases Path-loss**

## **Motion**

As a tag on an item or pallet moves through a portal, it can move into and out of dead zones. The motion of the tag provides a reader with more opportunities to communicate with that tag. Dead zones and weak areas in the reader's RF field are of greater concern in static applications where either the tag is not moving or the RF environment is not changing.

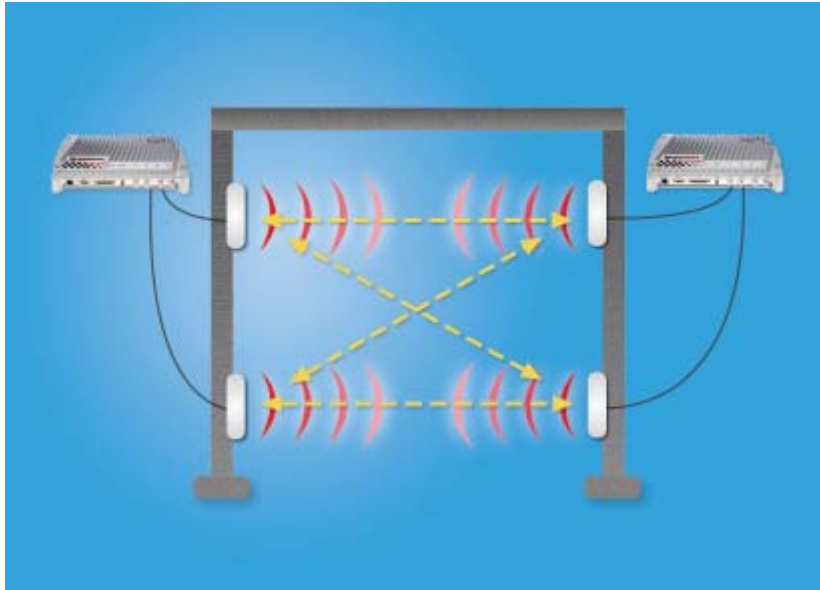
## **Frequency Selection**

Selection of an operational frequency is not as important as the overall RF noise level in the UHF Gen 2 frequency range. However, some RFID tags can be more sensitive to noise from adjacent or same-channel interferers. In regions covered by FCC regulations, the large number of channels available for RFID communication, as well as channel frequency hopping, decreases the likelihood of co-channel or adjacent channel interferers. In other areas, (for example, regions covered by ETSI regulations where fewer channels are available for RFID communication), readers serving a single portal should be set to operate in channels as widely spaced as possible.

## **Randomization of Antenna Sequencing**

Speedway readers can connect with up to four monostatic antennas, and often more than one reader will control antennas on a single portal, which can increase the likelihood of dead-zones. For example, in a design that has four antennas per portal with antennas on opposite sides of the portal that are controlled by different readers, there are four possible dead-zones—one for each pair of antennas from the two readers, as indicated in Figure 2. If the readers randomly enable each of their four antenna ports, then each dead-zone exists for only 25% x 25% of the time, which is only 6.25% of the time. The benefits of increasing the parallelism of the portal by having multiple active antennas may outweigh the cost of occasional dead-zone appearances. Good reader

search algorithms that effectively randomize antenna sequencing, such as those offered by the Impinj Speedway® reader, can greatly enhance performance by ensuring that the dead zones are short-lived and move frequently.



**Figure 2 Antenna Sequencing Affects Dead Zone Location**

### **Selection of Tag Antenna**

Impinj designs tag antennas in a variety of form factors to address the varying needs of different applications. Some tag antennas have been optimized for near-field use (as in item-level tagging) and are specifically designed to reject far-field signals, while others are more general purpose to address both near- and far-field applications (item, case, or pallet). Some antennas are designed to work better when oriented in a particular way relative to the reader antenna as well. Working with your tag supplier to select a tag with the appropriate antenna for the desired application can also help to mitigate interference.

### **Synchronization**

Antennas *may* be synchronized to ensure that only one is powered at any given time in a multiple-reader portal. However, this option slows down operation because reduction in parallelism requires more expensive synchronization schemes, and is generally not necessary given the other interference mitigation factors already described.

Deterministic synchronization can also have the unwanted effect of repeating a sequence of dead-zones so that, in a static application, some tags may never be readable.

### **Interference from the Reader's Point of View**

Another important type of interference is *reader jamming*, which can occur in a UHF Gen 2 RFID environment between readers located in the same facility even if they are relatively far apart. If a co-located reader generates a signal at a power level high

enough to overpower the signal coming from the tag of interest, the local reader may not be able to discern the tag response (see Figure 3).



**Figure 3 Reader-to-Reader Interference**

As mentioned above, this circumstance can occur because readers and tags transmit on the same channels but at very different power levels. Unlike tag jamming, reader jamming is inherently more problematic, because it can involve readers that are quite far away relative to the tag. (Readers can transmit at a power level more than one million times higher than tag backscatter.)

Mitigating factors for reader jamming include using well-designed readers, proper selection of reader mode, channel-use randomization, shielding the reader, and the appropriate selection of reader antennas for the application.

### **Reader Design**

One way to mitigate interference problems on the reader side is to design interference rejection into the reader itself. The Speedway reader includes Impinj Noise Reduction (INR™), a series of patent-pending innovations designed to lower the perceived interference. INR decreases the error rate caused by reader interference, allowing readers to operate at higher data rates without increasing error rates—resulting in net higher performance.

Another key feature of the Speedway reader is that it is operationally aware—it senses the level of RF noise and the size of the tag population within its read zone, and using a patent-pending method, automatically selects the most appropriate data rate, modulation scheme, and other settings for the best performance under those operating conditions. Thus users need not alter settings every time the environment changes because the Speedway reader takes care of that function automatically. The Speedway reader also

uses the operating environment information it gathers to dynamically optimize its inventory operations.

## **Dense Reader Mode**

In radio communications, high data rates require wide frequency bandwidth usage. If the tag-to-reader and reader-to-tag communication data rates are very fast, then the tags and readers will use a lot of bandwidth. This situation increases the chances that reader transmissions will interfere with tag transmissions and reduce system performance.

When a single reader runs at a high data rate and thus broadcasts very widely in terms of bandwidth, a tag can respond within the same frequency space because the reader can filter out its own signal. In this scenario, the communication is successful. But if another reader operates on the same or nearby channel, or operates at a high data rate on a different channel, it can interfere with the desired reader's ability to receive a signal from the tag. By reducing the data rate and using correspondingly less frequency bandwidth, more readers can communicate in the same frequency spectrum without interference.

To overcome the constraints imposed by readers and tags sharing the same channel, the UHF Gen 2 specification includes dense reader mode, which is the key to scalable systems. Dense reader mode defines how the RF spectrum is shared in a way that allows many readers to operate in the same environment even when just a few channels are available. In effect, readers use the middle of the shared channel, and tags use the edges of it. A reader that implements dense reader mode and has high-quality interference rejection can tune into weak signals from tags while filtering out noise from other readers, even ones that are operating on the same or adjacent channels. Because this mode is optional within the specification, not all reader vendors have implemented it. When selecting a reader vendor, use diligence in understanding product capabilities. Within the Speedway reader, Impinj simplified the Gen 2 parameters into five modes, ranging from the very high data rate or high throughput mode, to the slower data rate, dense reader modes. These options offer varying points in the tradeoff between data rate and frequency bandwidth used, and the two dense reader modes offered by Impinj are very effective for managing many readers in environments with considerable RF interference.

## **Randomization**

The signal from a reader may not always be on the same channel because of frequency hopping or active channel switching, depending on region. In regulatory regions that provide a large number of channels, such as the FCC for North America, a handful of readers can operate at relatively high data rates in the same physical environment. As the number of readers increases, it becomes necessary to switch to true dense-reader operation. Selecting a reader that automatically senses its environment and makes adjustments while in operation can help make more effective use of available channels.

## **Power and Path-Loss**

Intentionally increasing path loss by shielding or lowering the reader transmit level decreases the strength of interfering signals from adjacent readers. This approach is

especially useful in situations where the read zone never changes, such as in RFID for item-level applications using conveyor belts.

### **Reader Antenna Selection**

Inherent in all radio wave communication is the presence of both magnetic and electric fields. If antennas are designed to emphasize their response to one field over the other, they can be designed to respond better to transmission in the near field than to that in the far field, or vice versa. In addition, high-gain antennas focus their transmission more effectively and are less susceptible to interference from sources that are not in the area of focus. Knowing the environment where your readers will be placed, and the application for which they will be used, can help define the read distance requirements for the reader. These requirements can then guide the appropriate selection of reader antenna for the task.

### **Synchronization**

Readers across an entire facility can be synchronized so that potential interferers are never powered on at the same time. However, this option reduces performance by severely limiting parallelism, it is more expensive, and is generally not necessary given the other interference mitigating options described above.

### **Summary**

Robust RFID systems are possible despite the various forms of interference that can arise in real-world situations. When designing and testing solutions, it is important to consider the effects of interference in full-scale operating environments, and to investigate how well the infrastructure might improve automatically with improved tag receptivity.

## Glossary of Terms

**Backscatter**—This term refers to the tag-to-reader communication method of modulating data onto a reflected signal. This direction of communication is also known as the reverse link.

**Bandwidth**—The width of the signal (range of frequencies on either side of the carrier) that the signal requires; this width depends on how the carrier wave has been modulated by the data, with higher data rates equating to wider frequency band usage

**Broadband**—Indicates a wide range of frequencies

**Channel**—Set range of frequencies

**Dead Zone**— A location where a tag would normally be able to communicate with either one of two readers unless both readers are trying to communicate at the same time.

**Demodulation**—Process of separating the data from the carrier wave

**ETSI**—European Telecommunications Standards Institute

**FCC**—Federal Communication Commission

**Forward link**—Refers to direction of communication, in this case from reader to tag. During the forward link, a UHF Gen 2 reader sends power and commands to a UHF Gen tag.

**Interference rejection**—Measure of the ability of a receiver to determine the signal of interest correctly in the presence of interfering signals

**Modulation**—Refers to the process of transmitters mixing their variable data onto a constant carrier wave, which is usually designed to fit into the center of the channel.

**Passive tag**—UHF Gen 2 tags have no internal source of power. During the reverse link, the reader supplies pure power to the tag in the form of the carrier wave, which the tag then uses to modulate data for its reflected response.

**Path loss**—The amount of signal strength decrease as the signal travels along the forward or reverse link, which is not necessarily a straight line. Path-loss can be influenced by distance between the transmitter and receiver, and the presence of RF absorbing or reflecting materials in the environment.

**Range**—How far apart the tag and reader may be and still operate correctly. The range of an RFID system is limited by either forward- or reverse-link path-loss. In a well-

designed RFID system, range is limited by the forward link so that the overall system will naturally improve as tag sensitivity improves. A forward-link-limited RFID system always works as long as the tag can harvest enough power from the reader.

**Reader Jamming**—Reverse-link interference from other readers

**Reverse link**—Refers to direction of communication, in this case from tag to reader. A UHF Gen 2 reader sends power and commands to a tag during the forward link. During the reverse link, the reader sends power only and the UHF Gen 2 tag responds by modulating its data onto the reflected signal. This process is also known as backscatter.

**Tag Jamming**—Forward-link interference from other readers