UHF Gen 2—Deep and Wide, Near and Far

Owing to technology breakthroughs from Impinj, the breakout standard now addresses the breadth and width of RFID applications from items to pallets. And reader antennas are a key part of the solution.

UHF Gen 2 was undersold. Originally conceived to address RFID applications in warehouse and distribution centers where the importance of long read range is underscored, it turns out that it can do much more. And by virtue of RF physics, the capability was there all along, meaning that UHF Gen 2 can be applied equally to items read at close range or pallets read at a distance. Here's how:

Simply stated, there are two components of the RF wave: *magnetic* and *electromagnetic*. Because the *inductive* aspect of the magnetic field diminishes greatly in strength over a relatively short distance, it can be exploited to good effect for "near field" application, most notably by HF (13.56 MHz) RFID systems.

UHF (860–960 MHz) RFID, on the other hand, is generally known to exploit "far-field" electromagnetic radiation (which, again, consists of both electric and magnetic field components), yielding the ability to read tags at ranges exceeding 10 meters. However, because both magnetic and electric fields are present in the radio wave regardless of the frequency of operation, antennas can be designed to emphasize response to one over the other. Accordingly, when using the right tag and reader antennas, UHF tags can just as easily harvest near-field energy—and actually do so more efficiently *and* cost-effectively than any HF solution. By using tag antennas featuring very simple geometries printed with conductive ink and reader antennas that generate a strong, well-controlled magnetic field, UHF has been demonstrated to be highly effective for all supply chain applications from items to pallets. What's more, by virtue of the UHF Gen 2 standard, a single RFID infrastructure is enabled for all of these applications worldwide. And that includes the applications that were previously thought to exclude UHF—applications that include the reading of tags on very small items placed in close proximity, as well as the reading of tags affixed to liquid- and metals-based products. The significance of this capability was best expressed by Rollin Ford, Wal-Mart's Executive Vice President and Chief Information Officer: "Many thought UHF tags could not be read around water or metal and that only HF tags could meet these tests. However our team and our technology partners proved that the new UHF Gen 2 tags could, in fact, be read in water and on metal. That's nothing short of a breakthrough."

With the groundwork thus established, we turn our attention to the specialized reader antennas designed for the reading and writing of tagged items in the near field.

The Essential Parameters

As previously discussed, RF transmissions contain both magnetic and electric wave components. The relative strength of each component, however, varies with antenna design. As it turns out, certain general-purpose UHF antennas are also capable of generating a reasonably strong magnetic field, making them well suited to a variety of generalized applications. But meeting more

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demanding performance objectives requires specialized antenna designs, the variables for which include the following:

- Near field range
- Far field range
- The degree of RF containment required
- The degree of orientation insensitivity required
- Form factor and size
- The mechanical requirements of the application

This spectrum of parameters can be addressed adequately with two general classes of reader antennas—*aperture* and *traveling wave*—each of which is supported by application-optimized designs. Aperture antennas are appropriate for point-of sale terminals where the field intensity and the dimensions of the read capture zone are optimized for totes, small cases, piles of loose merchandise, etc. Traveling wave antennas, on the other hand, are ideally suited for rack and shelving applications. The discussion that follows highlights the details of these two basic classes.

Aperture Antennas

Aperture antennas are defined by 1) the intensity of the magnetic field and 2) the square area of their coverage. Generally speaking, the larger the read capture area, the lower the field intensity—which brings us to the subject of important antenna specifications. In the far-field context, the specification of interest is *gain*. But this must ultimately be evaluated in terms of the sensitivity of the tag. For example, an aperture type reader antenna might have an effective range of ~2 meters when reading an Impinj Satellite™ tag (a hybrid near-field design that also exhibits a degree of far-field performance). Range in this case is more a function of the tag sensitivity than reader power, and in any case, is a useful metric only when considering true far-field performance. In the near-field context, however, gain has less meaning; here we're more interested in the magnetic field intensity measured at some distance.

For the highest levels of performance, it is important to consider the application when selecting the reader antenna. An antenna with a small aperture and a tight, intense field—Impinj's Brickyard™ Near-Field Reader Antenna, for example—is particularly well suited for reading small tags, such as those based on Impinj's Button™ and PaperClip™ tag antennas. The small aperture antenna will also perform well when reading Satellite tag antennas, provided they're read within the fairly tight read zone emanating from front of the antenna. An antenna with a broader aperture, like Impinj's POS Horn™, is ideal for reading the Satellite, and other similarly sized tags, spread over a wider surface area or placed in a tote. However, due to the tradeoffs previously discussed, the POS Horn, while covering a wide area, exhibits commensurately lower field intensity.

Field containment also comes into play in antenna selection—especially for aperture applications like point-of-sale terminals—where the read capture zone must be well controlled such that reads occur only within the immediate or otherwise desired area. This aspect requires careful design consideration, and involves tradeoffs between field containment and effective range.

Finally, unlike HF reader antennas, UHF near-field reader antennas are easily made to be orientation insensitive. That is, a tagged item can be read reliably without respect to how it is positioned within the reader's field. In the UHF aperture configuration, multiple antenna elements (two to four per reader) can be positioned within the read zone such that items are read from multiple directions, yielding very robust near-field performance.

Traveling Wave Antennas

Antennas for Shelving Systems

Traveling wave antennas, practical for RFID application only in the UHF band (and higher), are defined by 1) the intensity of the magnetic field and 2) nature of the field's distribution and diffusion. For example, a traveling wave antenna designed for retail shelving (Impinj's Bonneville™, for example) emits a low intensity field that is well diffused and evenly distributed to provide uniform coverage for the reading of tagged items placed on the shelf. A significant effect of this arrangement is orientation insensitivity. A DVD, for example, can be placed on the shelf in any manner: whether lying down, set on edge, facing out, or placed upside down, if it's on the shelf, it will be read. Furthermore, the shelf antenna can be configured to read very small, tightly grouped items such as vials, lipstick, and other small products. Likewise, it can be made to read larger tags on items such as pill bottles that might be spread out over an entire shelf or even down an aisle across many shelves.

Antennas for Rack Systems

Another application of the traveling wave antenna is the garment rack. In this configuration it exhibits a higher intensity field that is distributed in a linear fashion. Because the traveling wave loses power as it radiates along its length, the total antenna length is ultimately limited by the tag sensitivity at the end of the line (where available power is the least; at some point the tag will no longer be readable), the distance of the tag from the antenna, and the amount of power margin required for the desired read performance. As such, it's a fairly simple exercise to determine the optimal length.

Other attractive properties of the traveling wave antenna include the following:

- By virtue of its wideband operation, the same antenna can be used at all UHF frequencies, whereas aperture antennas tend to be resonant and must, therefore, be tuned for a particular region of operation.

- The traveling wave antenna can be made with two ports such that its energy can be made available to another antenna that might be connected to it. This allows the daisy-chaining of several traveling wave antennas—even those of different types. For example, a garment rack antenna can be connected to a shelf antenna; a POS wand can be connected to a checkout table, and so forth. And of course, they can be daisy-chained rack-to-rack or shelf-to-shelf.

- Traveling wave antennas exhibit limited read range that can be easily controlled and optimized for the application at hand.

Summary

By exploiting the inherent power of the UHF Gen 2 protocol—using the same Gen 2 reader and Gen 2 tag chip—the single worldwide standard can be applied to all supply chain applications, including those operating at the item level. The continuum of possibilities running from range, size and shape of the read zone, as well as specific performance requirements are readily available simply by managing the tradeoffs in tag and reader antenna design. These simple low-cost accessories not only enable a single RFID infrastructure, they also provide a high-performance solution unmatched by any other technology.

Recommended Reading (available at www.Impinj.com)

UHF Gen 2 for Item-Level Tagging: The Seven Things They Said You Couldn't Do
UHF Gen 2: The Perfect Storm
The Gen 2 Story

See UHF Gen 2 In Action

Watch the video demonstrations at www.impinj.com

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