UHF GEN 2 RFID

Deep and Wide, Near and Far

Impinj's UHF Gen 2 RFID Wins the Great Frequency Debate

If you are considering HF RFID technologies over UHF Gen 2, the first question is… why?

By virtue of the innovative ways Impinj exploits the nuances of RF physics, UHF Gen 2 now performs equally well on small, individual items traveling along high-speed manufacturing lines as it does on pallets of cased goods rolling through distribution centers. In the bargain, UHF Gen 2 has rendered the older, slower, and more costly HF (13.56 MHz) RFID technologies obsolete.

The key to this development is Impinj's patented (and patents pending) technologies for harnessing UHF's *near field*—that aspect of the radio wave that is particularly well-suited to close range, item-level RFID operations. The result is a growing suite of application-optimized, near-field UHF Gen 2 solutions that comprise Impinj's Speedway reader, Monza tag chips, and a host of specialized tag and reader antenna products. A brief survey of UHF near-field RFID deployments in retail, textiles, and pharmaceuticals illustrates the many solutions that are already producing tremendous results from the manufacturing floor to the point of sale.

RFID and the Great Frequency Debate

In December 2004, EPCglobal ratified the UHF Gen 2 Protocol, creating the first world-wide standard for RFID. Since then, myriad products built to UHF Gen 2 have proliferated, proving their applicability in applications ranging from items to cases to pallets, for use with objects in the near field and far field, and on liquids, metals, tightly stacked and packed items, and more. And the performance levels and innovative applications of these products continue to advance.

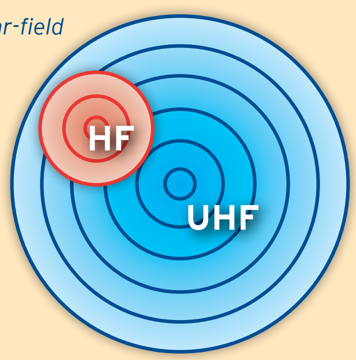
Three years later, the HF camp has yet to answer the UHF Gen 2 achievement with a ratified standard of their own. Instead, the latest HF candidate specification has left even its own authors disillusioned. According to Ken Laing, the editor of the proposed HF "V2" (the HF version of UHF Gen 2), their work thus far offers little if any improvement over existing standards and commercially available products. "Companies encoding an EPC on a Gen 2 HF tag," Laing says, "will get an improvement over encoding EPC in ISO 15693 [the current prevailing HF standard]. Will it be a significant improvement? I suggest not. You'll get something marginally better than [HF] products on the market now."[1] Perhaps the larger point is that even if ratified, the first qualified V2 products will follow by a year or more. That's a long time to wait for something that, even if available today, falls short of UHF Gen 2's current capability. And given the pace of UHF Gen 2 adoption and deployment innovation, imagine the advances that will occur in that timeframe. But let's step back and take the longer view of the frequency debate as it relates to actual deployments.

First, consider a few basic facts: UHF Gen 2 covers all supply chain applications, near and far, worldwide. Furthermore, UHF Gen 2 is effective on all product materials, including liquids and metals. As such, HF RFID technology is actually redundant to UHF Gen 2:

- There is *nothing* that HF can do that UHF can't do
- There are a great many things that HF can't do that UHF can
- HF addresses only a *small subset* of the UHF RFID universe

UHF Gen 2 - *Superior Technology*

UHF - *near-field and far-field*
HF - *near-field only*



UHF is RFID's "superset" for RFID applications. Products properly built to this standard address items, cases, pallets, all material and package types, and exhibit much higher throughput rates over HF.

A properly deployed near-field UHF Gen 2 system operates equally well on items large and small, liquid and metallic, as it does on cases and pallets, effectively erasing any item-level advantage HF enjoyed prior to the advent of near-field UHF Gen 2. While it is true that liquid absorbs RF and metal reflects it, these characteristics come into play only when considering its far-field performance; near-field UHF is quite another matter. In fact, because a properly designed UHF tag antenna is able to exploit the near and/or far fields, it can actually use to its advantage the metal to which it is attached, using it as an extension to the antenna! The same cannot be said of HF tags, which lack the means for electric field coupling. Notwithstanding, let's dig a little deeper and examine the practical implications of deploying HF-based RFID systems.

Attribute	HF	UHF
Near-field sensitivity *(short range)*	✓	✓
Far-field sensitivity *(long range)*		✓
Worldwide frequency band	✓	✓
Single worldwide protocol standard		✓
Low manufacturing cost		✓
Works on liquids and metals	✓	✓
Single infrastructure for item to pallet		✓
High data rate		✓

First, HF cannot perform in the far field; this means it cannot be used on cases and pallets, where longer range read capability is required by warehouse and distribution center logistics. Consequently, enterprises that opt for HF for item-level tagging must also implement UHF Gen 2 for case and pallet operations. Now, once you cross the border into the land of multiple data carrier infrastructures, cost, complexity, efficiency, and maintenance—to say nothing of data logistics—take major hits. Which leads us to a few economic considerations.

UHF Gen 2 tags will always be less expensive than HF tags. In fact, two to three times less expensive. Why? Because UHF tags are so much easier to manufacture. Unlike HF tags, UHF Gen 2 tags lend themselves to simple, high-speed manufacturing techniques that scale exceptionally well. By virtue of UHF Gen 2's uncomplicated, single layer antenna geometries that can be manufactured using inexpensive conductive ink processes, UHF is a far more practical and economical band on which to base a standard. In fact, the same UHF Gen 2 chip used in a large pallet tag designed for long range operation can also be used with a near-field antenna as small as 6 mm round—considerably smaller and

[1] RFID Update, December 11, 2007

less expensive than the vast majority of HF tag offerings, and yet exhibiting better performance. Another benefit of the simpler antenna geometries afforded by UHF is that for items stacked or otherwise packed in close proximity, UHF tags don't cast an RF shadow on adjacent items. Because HF tag antennas are composed of dense metallic coils, they can magnetically shield adjacent tags, blocking their visibility to the reader. This is in contrast to UHF's "open" geometries that yield greater RF visibility for tightly packed items.

Continuing advances in the application of UHF Gen 2 further widen the cost-performance-capability gulf that already exists between it and HF technologies—a gap that HF will never be able to close. This is a fundamental point, as the economics of UHF Gen 2 actually benefit from UHF physics. In short, the UHF band is 60 times more efficient for RFID operations than the HF band (see Understanding UHF's Near Field). Therefore, if the objective is to couple communications between a tag and a reader, the UHF band is vastly superior to the comparatively weaker HF scheme. And that translates to UHF Gen 2's greater speed, reliability, and flexibility of operation. It's also why Blue Vector CEO Nancy Anderson concludes, "We're not doing a lot with HF right now; it's just not as flexible as UHF."[2]

For another case in point, Cardinal Health's Julie Kuhn, Director of Pedigree, explains, "You can't read an HF RFID tag as fast as you can read a UHF tag. That means our conveyor can't run any faster than the slowest read rates at the reader." And this is a limitation that could actually affect distributors' order throughput. "Right now," she continues, "we take orders up to 8 PM and orders are delivered as early as 5:30 in the morning. This complicated HF/UHF infrastructure could inhibit our ability to maintain those cut-off times."

This point raises the issue of multi-protocol infrastructures generally. Unfortunately, addressing these problems with multi-protocol RFID readers—devices that read both HF and UHF tags—only creates more problems. These include higher reader complexity and cost, and more critically, lower read rates and less overall read reliability, because read opportunities are always compromised when an interrogator must cycle through multiple protocols. And when multiple data carrier technologies are in use, the supply chain suffers.

While Gen 2 solved the problem of competing and incompatible UHF standards, the problem still persists in the HF space, where standards including ISO 14443, ISO 15693, and EPCglobal HF Class 1 are all in play. In terms of what it takes to select, deploy, maintain, and upgrade a mixed infrastructure system—to say nothing of managing disparate data formats—the support of separate UHF and HF infrastructures makes little economic or logistical sense. This situation amplifies the fact that decisions about data carrier solutions should not be made in a vacuum; the serialization strategy the manufacturer ultimately adopts has significant consequences for downstream trading partners, trickling down through the entire supply chain. The consequences of such a scenario are being played out in the pharma space today, where the use of a mixed protocol system impedes throughput and compromises reliability.

Julie Kuhn continues: "We are concerned about how we're going to make all of these technologies work in a single, highly automated environment to get the pedigree information at the unit and case level and maintain the high level of throughput that we have now."

> "UHF Gen 2 garment tags are now priced significantly lower than comparable HF tags, and UHF readers offer both near- and far-field interrogation options for the most dynamic set of read ranges."[3]
>
> **Goetz Pfeifferling**
> **CIO, Lemmi Fashion**

Pharma is not the only industry to grapple with this issue and arrive at the same conclusion. Consider, for example, a major item-level deployment by the apparel manufacturer, Lemmi. Ashley Stephenson of Reva, one of Lemmi's RFID solution providers, explained his company's switch from HF technology to the more flexible, higher speed, lower cost, and

[2] Scan—The Data Capture Report, December 14, 2007

better performing UHF this way. "If you were trying to read 100 garments, UHF could read them all ten times faster than HF. The cost of UHF tags has come down markedly, a trend that is only expected to continue. UHF vendors like Impinj have invested in and advocated a flavor of UHF technology called 'near field,' thereby expanding the range of UHF infrastructure options. Fashion and retail RFID tagging did start with HF, but now everything is migrating to the UHF Gen 2 standard in the retail and fashion world."[3]

Mike Celantano, Associate Director of Supply Chain Systems at Purdue Pharma, concurs. "We have seen major improvements to our program on every level with our conversion to UHF Gen 2 technology: reliability, performance, tag availability, multi-sourcing, interoperability amongst vendors—it's across the board. These are the very baseline requirements we needed to evidence before making the decision to tag our entire domestic OxyContin production. UHF Gen 2 has enabled us to do our case- and item-level tagging on a single technology platform. All of our major downstream trading partners who have issued guidance on package serialization have indicated a preference for, or at minimum, an acceptance of the UHF Gen 2 platform. We see this as a strong affirmation of the technology."

Louis Bianchin, Senior RFID Analyst and Program Manager for Venture Development Corporation, sums things up: "UHF Gen 2 RFID is the premiere technology for supply chain applications in today's market. Deployments in the pharmaceutical supply chain, for example, have demonstrated that Gen 2 RFID technology is able to provide reliable, high-speed tracking throughout the entire supply chain—even under harsh conditions. Successful deployments in the pharmaceutical industry are expected to pioneer similar applications within other large markets."

Understanding UHF "Near Field"

There are two components of the RF wave: magnetic and electric. Generally speaking, HF RFID (13.56 MHz) relies on the "near-field" magnetic aspect of the field, while long range UHF RFID (860–960 MHz) exploits "far-field" radiation (which consists of both electric and magnetic components). But just which part of the RF wave a UHF tag responds to depends on two things: the tag antenna and its distance from the reader.

Because the magnetic component of the wave diminishes greatly in strength over a relatively short distance, it is characterized as *near field;* that is, its effective range is limited by antenna geometry to about one or two wavelengths. And because HF tags rely on inductive coupling to this magnetic field in order to receive power, the HF tag antenna is made up of an inductive, coil-like structure that requires more conductive material and more complex manufacturing processes than the equivalent UHF tag antenna. Fortunately HF tags have no corner on the near-field magnetic field; with the right antenna, UHF tags can just as easily harvest the same near-field energy—and do so more efficiently and cost-effectively. How? By virtue of the physics.

Maxwell's four equations are the basis of electromagnetic analysis and design. Faraday's law is one of these equations: "Voltage induced on a coil in a magnetic field is proportional to the intensity and frequency of the field." This translates to a very simple concept: higher frequency = greater efficiency. UHF is ~60X the frequency of HF, meaning that UHF is ~60X more efficient in coupling its energy between tag and reader antennas. You can't argue with the physics!

The conventional wisdom is that UHF is not suitable for item-level tagging—UHF tags are too big, UHF won't work on liquids, metals, or small items packed in close proximity to one another, UHF has too great a range—ignores the fact that Gen 2 can exploit UHF's near field just as easily and much more effectively than HF. That means anything that can be read by an HF system can also be read by a UHF system—and that includes items high in liquid or metallic content. More importantly this means that item-level applications can now leverage all the benefits that the UHF Gen 2 standard brings to the supply chain at large.

[3] RFID Update, August 08, 2007

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