Whitepaper

Common RFID Implementation Issues:

10 Considerations for Deployment

Introduction

Early RFID implementations were fundamentally driven by external mandates, but along with significant technological improvements, more readily available component options, cost reductions, and shared lessons learned, the technology has proven its value in driving significant operational efficiencies, and RFID has gained a broader adoption.

Today, industries are looking beyond the realm of compliance, as they seek competitive advantages and integrate RFID much earlier into their production processes. Innovative companies are expanding the use of RFID in their supply chain, logistics and asset tracking operations. As a result, they are achieving demonstrable improvements in supply chain visibility, forecast accuracy, reduced out-of-stock situations and reduced counterfeiting.

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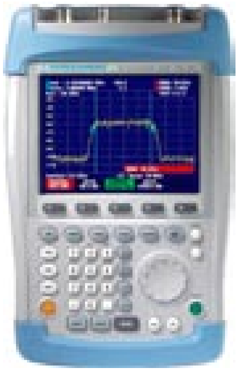
Many organizations encounter similar challenges as they embark on their individual RFID journeys. Leveraging industry lessons learned can assist in building your technical knowledgebase and help you appreciate the realistic expectations and physical limitations of the technology. By following industry best practices, you can overcome these hurdles, save valuable time, and more quickly reap the benefits of a successful initial implementation.

This whitepaper identifies a few common RFID implementation issues and presents practical lessons learned, based on Alien Technology®'s deep expertise, developed from numerous production deployments across many industries.

1. Develop the use case.

Start by defining the business objectives and metrics for success for your RFID project. What is the use case for RFID in your organization? Is the intent to track product movement from supply through distribution? Perhaps the application involves locating the right equipment at the right time? Do you wish to track materials in production and through manufacturing process so you can deliver finished products to customers sooner and at a lower defect rate? Or is your application targeted at containment, addressing market diversion, or even alleviating counterfeits? In developing the use case, you will identify the processes involved and determine which assets should be tagged, such as individual items, cases and/or pallets.



Conduct a site survey as part of your planning phase. A site survey will identify issues related to RF communications and potential electromagnetic interference in your facility, so you can design your RFID system accordingly. A site survey will help identify existing in-band RF sources that may present co-existence challenges, such as vintage 915MHz wireless access points and wireless alarms or monitoring systems. A proper site survey is also instrumental in mapping out the antenna RF coverage, power and network architecture.

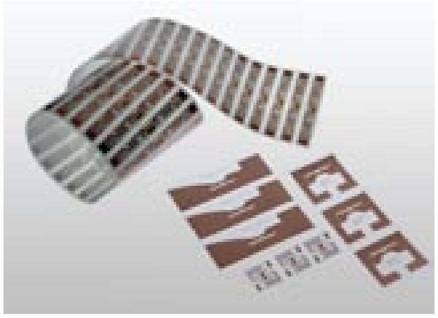
A site survey is vital to identify equipment requirements and as a vehicle to optimize component placement. Based upon your objectives, you can determine the most appropriate programming and read zones. The site survey is also a good point to determine the amount and content of data that you need in the tag. Some customers are comfortable with simply a short random number and a link to a central data base. Many customers need a fully programmed ID that has back-up both locally and to the network. Look at your data needs closely and globally.

Programming tags can be accomplished in a variety of ways, but are generally categorized in the following high-level buckets: 1) "slap-'n-ship", where desktop printers/label programmers dispense labels for manual application, typically at the end of the process. This is not the recommended solution, as it introduces significant variability in the tag placement process (see the tag placement discussion in #3, "Optimize Tag Placement and Orientation"), requires some degree of personnel training, and generally does not facilitate RFID visibility until the final stages of the production process. 2) Label applicators placed at the front end of the packaging line provide a more controlled tag placement, which alleviates variability, potentially enhances tag performance, provides visibility throughout the manufacturing process, and offers scalability.

Be cognizant of the tag commissioning (programming/application) location. Seek locations with inherent case isolation, such as the case erect/fill station, and if correctly deployed, you can take advantage of existing equipment, such as reject stations (where the cases are checked for case weight and proper tag ID, otherwise they are rejected). Be aware that some products may be imposed to further tag commissioning location restrictions if they are subjected to metal detection processes, as is often the case for such items as adhesive bandages.

Once you have identified your reader pinch points, you will be better positioned to determine the type, and quantity of RFID components, including applicators, handheld readers, fixed conveyor readers, integrated reader/antenna assemblies, turntable readers, and portals.

2. Choose the tag.



Your use case will help define the tag performance criteria and ultimately drive the tag selection process, but with so many tag options to chose from, the selection process may be daunting. Ultimately, the choice often boils down to 1) cost, 2) size and 3) performance. Fortunately, technological and production trends have afforded solutions which fundamentally meet all three requirements. But differentiations remain, though more subtle than in the past.

Considerations for passive tags include:

Tag price.

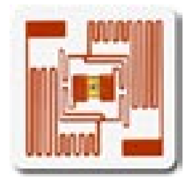
Tag prices have been reduced very significantly over the past few years, primarily because of technology improvements, production efficiencies, standardization, and most importantly, volume. Previously, tags were often optimized for various material types and SKUs (stock keeping units), which often resulted in a plethora of custom tags. Needless to say, in addition to development and production ramp-up costs, this approach was not economically viable and tag designs were vulnerable to obsolescence, depending upon their particular volumes. But today, with tags available in smaller footprints, providing better performance and substantially less affected by the materials for which they are applied, the industry has responded in a more narrowly focused tag offering and customers benefit from volume. Your tag selection should initiate with a classic, mainstream tag offering, which will allow you to reap the benefits of volume production.

Tag size.

Consider the geometry of the tag that's appropriate for the asset. Different assets require different size and type tags, based on physical restrictions and material properties. As a rule of thumb, smaller tags are less sensitive, resulting in lower read range properties, but for applicable use cases, this is not an impediment and it is often a desired feature. For instance, for item-level, and pharmaceutical applications, tag geometries are often restricted by the product, but by the same token, long range is generally not desired.

Today, the majority of the available UHF tags are rather narrow, and typically slightly less than 4 inches long, which provides a viable option for standard 2x4-inch label stock. But a portion of the market requires labels confined to 3 inches in length. In many of these case-level applications, range remains paramount. Newer, more sensitive RFID silicon and efficient tag antenna developments now facilitate these yet smaller, high performance requirements.

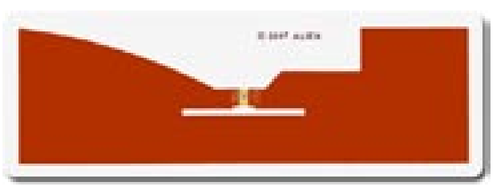
Consider applications where tag orientation is of concern (more about this topic in Issue #3, "Optimize Tag Placement and Orientation"). Some tag offerings provide yet smaller geometries (e.g., 2x2 inch) whereby the symmetry facilitates a vertically oriented RF-field (the nominal preference) on narrow height form factors, such as conventional corrugate trays.



Don't assume that smaller tag geometries result in lower cost. Consider high volume, general purpose mainstream options first, and then migrate to high-end or custom options if necessary.

Tag performance requirements.

Consider the performance requirements, defined by your use case. Some challenging applications, such as tagged vehicles in tollway applications, require very long read distances.



Here, larger tags with high sensitivity and high backscatter properties are best suited. Standard high volume tag offerings typically address applications where the requirements may remain somewhat stringent, but are confined to more reasonable read ranges (such as for a dock egress).

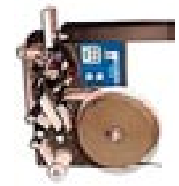
Beyond read range requirements, consider the material for which the tag is applied. More demanding applications, such as those requiring relatively long read distances of aqueous materials within cases on a pallet, may confine tag selection to only the most sensitive, highest performance tag options.

For certain challenging applications where the material properties have a tendency to alter the resonant tag antenna properties (e.g., potentially detuning the antenna, resulting in a frequency shift and hence lowering performance), a suggestion is to use a world tag with a relatively flat frequency response and broad bandwidth. World tags typically encompass a very wide frequency band, from 860MHz to 960MHz, which generally results in less performance degradation as result of challenging material application. Using world tags is critically important if your product is likely to be read in environments where different reader frequencies will be used. Quite often, world tags are needed for items of export so that guaranteed reads can take place in both the country of origin and at the point of sale.

Again, today's mainstream tag offerings address the more common use-cases, including case reads on conveyance systems, and placard tags on pallets.

Label application technique.

Pilots often initiate with manual "slap-'n-ship" tag commissioning techniques. This process is generalized by use of a desktop RFID label printer/programmer in which the tag is manually applied to the product. Caution should be exercised with this process. It is true that the initial capital investment is low, but this is often at the expense of non-repetitive, non-optimized and actually high-labor processing costs. It also generally takes place at the end of the packaging process, and offers very little, if any, internal ROI potential through the manufacturing assembly. By contrast, an automated label applicator may result in a higher initial capital investment, but the benefits can be significant, including reduced labor and training, more accurate and repetitive tag placement, which often results in higher performance and more consistent reads. Using an automated label applicator also offers a scalable solution that will likely be required anyway as volumes increase.



Product and packaging characteristics.

Properties of the tagged materials and packaging can impact tag performance. It's important to understand the general characteristics of the material under consideration. Aqueous products, such as water-based drinks, liquid detergents, green wood, moist wipes and cosmetics, can be very challenging due to the physical properties of water, which absorbs the available RF energy (like a sponge) and robs it from the tag. Metals and metallized/foil-lined packaging are especially interesting. Tagged properly, the product properties may actually enhance the tag's performance. However, improperly tagged, the results may be dismal.

As if that were not enough, there are those products that have both absorptive and conductive properties. Such applications need special consideration. Spacers are generally used to isolate the tag from the material (as with most products containing metal). A key identifier is the color black. Sometimes carbon or graphite-impregnated plastics, which are typically used for the black coloring, can seriously impede the tag performance. ESD plastic boxes are a prime example (e.g., static resistant materials designed to protect sensitive electronics). Plastic totes used in the electronics industry often have these characteristics.

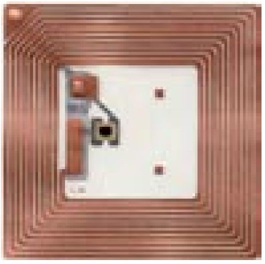
Consider near field vs. far field.

All antennas emit a magnetic field and an electric field component, but typically one field is emphasized while the other is minimized. Generally speaking, magnetic fields are considered "near field" as their RF radiation field falls off more rapidly (e.g., inversely proportional to the distance cubed) than their "far field" (electric field) counterparts which decay more slowly (e.g., inversely proportional to the distance squared).

$$E_\theta = \frac{I * l * \beta^3}{4 * \pi * \omega * \varepsilon_0}\left[\frac{j * 1}{\beta * r} + \frac{1}{(\beta * r)^2} + \frac{-j}{(\beta * r)^3}\right] * \sin(\theta) * e^{-j * \beta * r} \text{ V/m}$$

Near fields are typically used in applications where short read distances are desired, such as with smart cards or access control where 1 to 4 inch read ranges are acceptable. Magnetic fields are typically associated with inductively coupled loop antennas, which are traditionally not affected by aqueous materials. As a rule of thumb, the read range is limited to approximately 1 wavelength. (At UHF frequencies, 1 wavelength is approximately 13 inches.)

Far fields (aka E-Fields) are typically used for longer range applications, such as reading cases or pallets through a conveyor or dock portal, but they are not precluded from reading tags in very close proximity. E-fields can be easily reduced by attenuating (decreasing) power (much like a dimmer for an incandescent light). Recent technology advancements have demonstrated the feasibility of achieving read distances up to 1 or 2 meters with some standard UHF tags on, or in some cases, in aqueous materials.



Some have been led to believe that inductively coupled loop reader antennas and near-field magnetic loop tag antennas are required to read tags on aqueous materials, or for short, confined read ranges where singulation is required. This can be confusing. Near-field antennas in short range applications are probably best described as "close-coupled" antennas, which means that the electric far-field is simply confined to a very short, controlled read zone. Fortunately for those wishing to minimize their tag variety inventory, tags exist today which couple well to both near-field and far-field signals, and system designs facilitate both "close-coupled" and distant read requirements.

3. Optimize tag placement and orientation.

Tagging is not black magic, but technique helps. Ideal RFID tag placement is not the same as for bar code labels, which are traditionally placed in the lower section of a case.

Movement helps alleviate RF "nulls" or dead spots. Much like a cell phone whereby an RF dead spot may result at a particular location, dead spots typically are not as noticeable while the phone is in motion. It's generally easiest to read a tag when there is direct line of sight between the tag and the reader antenna (this is referred to as the "near-side"), but unlike bar codes, line of sight is not necessarily a requirement. RFID performance benefits from air gaps, generally at the top of a typical case, furthest from the conveyor metal, and above aqueous material. If you are tagging products with foil or metal, you can sometimes take advantage of the reflective or waveguide properties and actually channel the RF "through" the product to enhance the tag's performance.

Tag orientation also impacts read range. Whenever possible, try to vertically orient dipole tag antennas. Horizontal orientations are prone to miss-reads due to "perpendicular" or "cross"-presentation.

Avoid placing tags symmetrically on cases (for example, avoid the center of the case) to help alleviate "shadowing" or "shading" at the pallet level, which occurs when cases are adjacent to one another. Shadowing occurs when multiple tags are placed very close to one another and the tag antennas "hide" or detune each other, thereby reducing the chance of reading "buried" tags by minimizing their chance to be activated. So in general, tags placed too close to one another can detrimentally affect performance. But here too, new technological advancements in certain RFID tag silicon and tag antenna designs have greatly alleviated this problem.

4. Configure the reader for the application.

The EPC Gen 2 protocol offers many opportunities for optimizing performance for any given application. Like a high-end camera, some readers offer predefined configurations (like automatic mode on a camera), and some facilitate fine tuning (like manual mode) for the application.

For general applications, it's typically acceptable to use the pre-defined or default configurations. You may wish to fine tune some parameters to enhance performance, but exercise care – without a solid understanding of their contributions, altering some parameters could adversely impact performance. Ensure you are well acquainted with the command attributes – advanced training is strongly advisable.

The reader you choose can be quite important. While many of the more recent vintage of readers work well, there can be significant performance and / or feature gaps between various makes and models. Seek the advice of reputable reader vendors, value added resellers, or service providers with a solid implementation history for additional recommendations.

Don't rely simply on "read rates" for quantitative benchmarking. Gen 2 settings are often optimized to minimize repetitive tag reads, and focus their attention on acquiring unique tag reads. This means that once a tag is read, it is placed in an "accounted" state (known as the B-State). Benchmarking read rates in your own environment will provide you with the most accurate measure.

Filtering tags can also minimize network data traffic and downstream decisions. Use of "added" or "removed" tag filters is an excellent way of making the system more efficient.

Some readers allow the user to tailor the EPC "Q" (Query) such that it initiates with the anticipated slot count, or is bound to an upper limit. This can be helpful if the anticipated tag inventory is well defined, but it is also advisable to use the reader's auto-Q adjustment feature if available. This helps alleviate tag contention, resulting in much more efficient tag inventories.

Modulation	Speed	Noise Immunity
FM	Wicked Fast	Noise Prone
M2	Fast	Good
M4	Medium	Better
M8	Slow	Best

Proper "Session" selection can also enhance performance. For larger tag populations, Sessions 2 and 3 may prove beneficial. For lower tag populations where redundant tag reads are required, Session 0 may be best suited, because it facilitates higher repetitive reads. Session 1 is a good, all-around choice.

In applications where tag read speed is paramount and where RF interference is minimal, choose reader modulation settings that use FM modulation with relatively short Tari values and high link frequencies. By contrast, in dense reader applications choose reader modulation settings which use higher Miller modulation schemes with relatively longer Tari values and lower link frequencies. For standard applications, choose reader options in between the two options – typically the default option is best suited for general applications.

5. Be environmentally RF responsible

Help reduce RF pollution by taking advantage of reader triggering options. Some readers facilitate autonomous modes of operation, facilitating automatic acquisitions only when necessary (vs. continuously on). Use of photoelectric eyes or motion detectors is a good practice, as it reduces potential RF interference between adjacent readers or with nearby in-band appliances. It also helps alleviate inadvertent reads.

During the site survey, look for potential interference sources, such as wireless alarm systems, environmental monitors such as baby monitors, and vintage wireless access points. Readers are generally not impacted by this interference but it's important to make sure that your RFID system is a good citizen and does not adversely affect the performance of other wireless devices. Conduct a baseline test without RF and assess the differential impact with RF enabled.

For densely populated reader environments, select a reader that offers Dense Reader Mode and ensure that all readers in the vicinity are set accordingly. This can have a very significant, favorable impact on the system performance.

6. Be cautious with system alterations.

RFID vendor offerings are often optimized and certified for compliance as a "system." Be cautious about deviating from the reader manufacturer's recommended settings or complementary components.

Readers are compliant with designated cables, antennas and reader settings. Most systems use 6dBi antennas. dBi units characterize Linearly Polarized antenna "gain." dBic units characterize Circularly Polarized antenna "gain" and take axial ratios into consideration. Note that dBic ratings are typically 3dB higher than dBi ratings. Be aware of alternate antennas with higher than the recommended gains. Be aware that use of any antenna not explicitly listed as compliant by the reader manufacturer technically violates regulatory compliance and such deviations are the liability of the installer.

Long RF cable extensions can result in power losses, which reduce the available RF transmit power available to the antenna. When necessary, use low-loss cables if power losses are not acceptable.

Where systems are designed to use designated cable lengths (such as 6 meter integrated antenna cables), be cautious about using alternate antennas with shorter cables, as this can increase RF power above compliant levels if the RF power is not adjusted appropriately. Be advised that power meters are generally thermally responsive, and the complexities of modulated reader output signals are not easily measured, as the RF output includes various constant wave, modulated signals, and null periods in each inventory cycle, and this often results in an averaged output. Again, it's often best to follow the manufacturers suggested system configurations.

7. Understand multipath and reflections.

In the same way that you may experience interference listening to your car radio when approaching a stoplight in a large city, multipath signals can interfere with your RF reception. The reception is cancelled due to a "bounced" secondary (reflected) signal that is often out of phase with the primary incident signal. Just as you may move your vehicle a few feet to eliminate interference with a car radio, you can adjust the tag and antenna position, type, and orientation to improve performance (or adversely affect it).

Think of antennas as being halogen lamps, emitting an approximate 65 degree beam width. Think of metal surfaces as being mirrors which reflect the incident signals. Out-of-phase reflections can cause nulls as they cancel the incident signal. This effect is generally more pronounced with horizontally oriented tags.

A thorough site survey and environmental analysis can help identify troublesome areas. In extreme situations, lowering power, adjusting antenna orientations or adding absorptive material can help rectify the situation.

8. Choose the antenna best suited to the application.

Walls, buildings, floors and the surrounding environment will impact the antenna performance, as the antenna serves to focus and direct the RF energy. Common varieties include circularly polarized antennas, linearly polarized antennas, Yagi antennas and close coupled antennas.

Circularly polarized antennas are the most popular, as they are the most accommodating for various tag orientations. These antennas are often used where tag orientations cannot be controlled. Often, its RF penetration strength is approximately 3 dB less (half the power) in any given axis over that of a linearly polarized antenna if comparing the linear gain (e.g., 6dBi) to the same magnitude circular gain (e.g., 6dBic). Axial ratios come into consideration, but assuming a high performance circular antenna with an axial ratio of 1 was under consideration, a 6dBic circular gain would effectively result in a 3dBi linear gain.

Linearly polarized antennas focus the electric field in one axis. Because of this focused energy, the RF penetration is typically stronger in that axis than that of a circularly polarized antenna. This is an excellent choice for challenging applications but they must be used where tag orientation is controlled. For instance, linearly polarized antennas are typically used for tollway applications and reading tough cases within a pallet in a manufacturing site.

Yagi antennas, not readily offered by most reader manufacturers, are less common in RFID implementations. Yagi antennas offer a very focused and intense RF beam which generally results in narrower widths, but longer read distances. Their gains typically exceed those tested by most reader manufacturers, so exercise care to lower power or apply for site licenses if this is under consideration. Yagi antennas typically require professional installation.

"Close-coupled" antennas may be required for high density applications where tags are in close proximity and where conventional singulation techniques are not appropriate. "Close-coupled" antennas offer low gain and concentrate their energy close to the vicinity of the antenna. Examples include high density labels on a roll within an RFID desktop reader/writer printer, on an in-line label applicator, testing or programming individual labels on an RFID roll or singulation of small products on a conveyor.

9. Independently adjustable RF power levels.

Some applications require the ability to determine the relative distance from the antenna. Sometimes this task can be achieved easily by using readers that offer independent RF power adjustment for each antenna port.

Consider an application where you must determine whether the tag is 5, 15 or 25 feet from the antenna. After characterizing the system, you may find the following meet your objectives:

- Set Port 1 to operate at full power (e.g., 30 dBm). Assume that this will read all tags up to 30 feet.

- Set Port 2 to operate at a reduced power level (e.g., 25 dBm). Assume that this will read all tags up to 20 feet.

- Set Port 3 to operate at a further reduced power level (e.g., 21 dBm). Assume this will read all tags up to 10 feet.

Now, using simple math, you can determine the relative position of the assets. Those read by (Port 3) were within 10 feet of the antenna. Those read by (Port 2 – Port 3) were within 10 to 20 feet. And those read by (Port 3 – Port 2) were 30 feet and beyond.

10. Choose read points wisely.

Your use case will determine the read requirements and opportunities. A thorough understanding of the process and some creative solutions can often overcome a challenging use case.

For instance, case tags are generally easily read on conveyors but it may be challenging to read them within a pallet. Typically, cases are read and aggregated as a pallet is assembled. But it can be more challenging to read all of the cases within a pallet, especially if reading through portals.

In this instance, installing a reader on a stretch wrap turntable provides an excellent opportunity to read as many cases as possible as the pallet is rotated about the reader field. Consider an integrated reader/antenna combination for this application whereby the reader is attached to the stretch wrap dispense head. The read opportunities are dramatically enhanced as the stretch wrap is dispensed, the turntable rotates, and the dispense head is elevated and lowered. For most pallets, stretch wrappers are an integral process just prior to shipment, and so this can be easily integrated into the process.

We hope these considerations are found to be fruitful for your deployment.

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