The Intelleflex XC3 Technology Platform

An Implementation of The New ISO Class 3 Standard

intelleflex®

Extended Capability RFID

OVERVIEW

With the recent approval of the ISO 18000-6C Class 3 standard, a new category of RFID technology has been launched; providing new levels of visibility, enabling new applications and opening new markets. This newly standardized category of RFID is called Battery Assisted Passive (BAP) RFID. In a nutshell, BAP RFID combines the best features of both passive and active RFID. Building on the successful EPC C1G2 passive RFID standard's relatively simple, low power communications protocol, the new BAP Class 3 standard enables capabilities previously only available with active RFID; long read ranges in excess of 100 meters, reliable performance in RF challenging environments and support for sensors - all at a compelling price point.

Intelleflex has led the development of BAP RFID technology and the development of the ISO 18000-6C Class 3 standard. Intelleflex continues its market leadership in releasing its new XC3 BAP technology platform, the first dual protocol product set supporting the new ISO 18000-6C Class 3 standard and the existing EPCglobal Class 1 Gen 2 Standard. Intelleflex's new XC3 technology platform consists of chips, tags, reader modules, fixed readers and mobile readers. This white paper explores the benefits of Intelleflex's new XC3 technology followed by a technical discussion of the new ISO 18000-6C BAP Class 3 standard on which it is based.

EVOLUTION OF BAP RFID

The successful adoption of the C1G2 passive RFID standard led many to look for ways RFID could be used to gain better visibility into their supply chains and business operations. This quest for better visibility pushed passive RFID into many markets and applications and, in some cases, beyond its limits, into applications for which it was not originally designed or intended. These applications typically required robust performance in RF challenging environments (on and around metal or high water content product) or long read ranges. Passive RFID's performance suffered in these applications, limiting its success and leaving the customer to look elsewhere. Customers also saw an opportunity for increased supply chain and operational visibility by leveraging passive RFID's relatively simple communications protocol to transfer not only item identity information, but also environmental information coming from sensors incorporated in the RFID tags. However, passive RFID, by its nature, does not support sensing and logging data, again requiring the customer to look for alternate technology solutions.

For these applications, focus shifted to active RFID which performs well in RF challenging conditions and offers the ability to add sensors. However, the improved performance provided by active RFID comes with some notable drawbacks. For instance, active RFID does not adhere to a single interface Standard, often has greater tag size and complexity, and is significantly more expensive than passive RFID solutions.

With the introduction of Intelleflex's XC3 BAP technology, customers now have a cost effective option that provides the performance benefits of active RFID, delivering the visibility required in these challenging applications. Based on the ISO 18000-6C Class 3 Standard, the XC3 technology combines the best features of the EPC C1G2 passive RFID standard with the wireless performance typical of active RFID technologies.

Intelleflex's XC3 BAP Technology: Combining the Best of Passive and Active

PASSIVE RFID	Intelleflex XC3 BAP "Extended Capability RFID"	ACTIVE RFID
PROS • Reader talks first communications. • Low power passive backscatter • Low overhead, simple communications protocol • Low cost **CONS** • Shorter read range • Unreliable in RF challenging environments	***Combines the best of Passive & Active to deliver…*** • Long read/write range (>100m) • Reliable in RF challenging environments • Ability to add sensors and store data • Reader talks first communications • Low power passive backscatter • Low overhead, simple communications protocol • Significantly lower cost than active tags	**PROS** • Long read range (>100m) • Reliable in RF challenging environments • Ability to add sensors and store data. **CONS** • Tag talks first (beacons) communications. • Higher power requirements • More complex communications protocol • Relatively high cost

XC3 TECHNOLOGY BENEFITS

There are several compelling capabilities provided by Intelleflex's new XC3 technology, the most notable being the extended read/write proficiency.

Extended Read/Write Range

> *Intelleflex's new XC3 chip has an unparalleled receive sensitivity of -40 dBm and the new XC3 reader has an equally impressive receive sensitivity of -120 dBm.*

With the new XC3 technology, free space read and write ranges in excess of 100 meters are realized. Recall, with this technology, the tag uses passive backscatter to communicate with the reader, it does not transmit the return signal like active tags. This requires industry leading, highly sensitive tags AND readers. In fact, Intelleflex's new XC3 chip has an unparalleled receive sensitivity of -40 dBm and the new XC3 reader has an equally impressive receive sensitivity of -120 dBm. To put this in perspective, the best C1G2 passive IC on the market has a receive sensitivity of -18 dBm and the best C1G2 reader has a receive sensitivity of -82 dBm.

IMPORTANT NOTE: Intelleflex's XC3 technology implements a balanced approach to the design of the tag and reader platform. Optimizing read range performance requires both a highly sensitive tag AND reader. Having only one or the other leads to significantly reduced read performance as the overall performance is determined by the "weakest link" in the chain. For more details on the long range capabilities afforded by the 18000-6C Class 3 Standard as implemented by Intelleflex's XC3 technology, see section (1) in the Technical Discussion section.

Robust Performance in RF Challenging Environments

In addition to the long range read/write performance, this industry leading system sensitivity delivers solid performance in RF challenging environments, providing extra margin required to design robust solutions.

XC3 Technology In Action
Placing a new XC3 temperature sensing tag inside a pharmaceutical container surrounded by gel and cold packs, or inserting the XC3 tag into a pallet of produce, still results in solid read/write performance. This direct, in-place tag data access capability, without the overhead associated with retrieving the tag from the package, enables real time decision making. With the Intelleflex XC3 technology, business processes are streamlined and more cold supply chain visibility is provided. These are real world examples of applications where better supply chain visibility can deliver real benefits, but for which there has been no cost effective solution to date.

Support For Sensors

These examples highlight another capability of Intelleflex's new XC3 technology – support for sensors. As the name implies, battery assisted passive tags contain a small battery to power the tag IC when there is not enough RF power present. With this battery on board, new applications are enabled through the integration of sensors. Intelleflex's XC3 technology supports the integration of multiple sensors on the tag, as well as simple controllers to manage and log sensor readings. One of the first new XC3 BAP tags available will be a temperature sensing / data logging tag. Other intelligent sensor based tags will follow.

Extended Memory

With the addition of sensors to a tag, a natural requirement follows – memory to store and log the sensor data. While not part of the new ISO 18000-6C Class 3 Standard, extended memory is an application requirement. Intelleflex's XC3 technology meets this requirement with an industry leading 60 kbits of on-chip extended memory. A critical feature of the memory is that it is integrated on the tag IC – a single chip – such that the stored data can be accessed at full protocol speeds for fast data reads, and the stored data can be retrieved in passive C1G2 mode when the battery has run out. The memory is organized into 60, 1Kbit blocks, each 1K block having its own unique and distinct read, write and permalock password. On the sensor based tags, this memory can be further configured as User Data, WayPoint Data and Sensor Data, giving the application full flexibility to not only log sensor data, but to also store critical process information and waypoint data.

Tag Security

Once a tag has the capacity to store sensor, user or waypoint data, it is essentially a mobile database holding critical data that requires security. The Intelleflex XC3 based ICs implement industry leading security features allowing users to manage and protect the data on the tag. The XC3 enhanced on-tag security features, include:

- Block Level Password Protection for Read, Write and Permalock,
- Encrypted (by cover-coding) over-the-air data transmission using an XC3 Security Exchange Protocol,
- Three levels of User Access security for accessing the data in extended memory,
- Tag Authentication (unique 256-bit factory locked key), providing the ability to confirm the tag is the original tag, not a cloned version.

XC3 Technology In Action

In the example of our new XC3 temperature sensor / data logger tag placed in a pharmaceutical container, the pharmaceutical company has the ability to record the import / export and customs information on the tag in the User Memory section. They can then secure that section of memory and only allow authorized users read-only access to the information. They can use additional User Memory for other data as well, securing it separately from the first block of memory, for access by another authorized party. This method of data security allows multiple trading partners to share data when authorized or keep data secure and only accessible by certain parties.

Summary

The recently approved ISO 18000-6C Class 3 Standard provides new levels of RFID performance enabling better supply chain visibility and new RFID applications. As the leader of Extended Capability RFID, Intelleflex's implementation of the Class 3 Standard provides features and performance comparable to other active RFID solutions at a fraction of their cost.

TECHNICAL DISCUSSION OF THE NEWLY REVISED ISO 18000-6C STANDARD

(Publication expected late 2010)

The ISO 18000-6C RFID standard is the ISO version of the popular EPC Global C1G2 air interface specification. This standard provides a very efficient protocol to power and communicate with passive tags (no battery) using an RF signal. This enables a wide variety of applications that can use very small, extremely low power RFID tags, at very low cost and high volumes to improve the efficiency of supply chain as well as any application that requires "license plate" identification and small data storage.

This standard has been used in large volumes in the global retail supply chain to improve efficiency and reduce time and cost in nearly all links of the chain. The infrastructure to utilize the information has been extensively developed globally, with heavy investment in readers, middleware, and business software applications. There is significant value in being backward compatible with the systems that have been developed for this widespread standard. With this in mind, it was decided that any extensions to support BAP tags should be based on this widely adopted standard.

The Revision 1 of the ISO 18000-6 RFID standard received Final Committee Draft approval in March of 2010, and is now in the final stages of document editing and preparation for publication in late 2010. This Revision adds, among other new features, support for battery assisted passive (C3) tags in two forms: a simple-PIE mode battery assist extension for incrementally improving the range and reliability of 18000-6C (C1G2) tags, and a revolutionary Manchester forward link mode which adds many new mechanisms to enable significantly longer ranges (10X), maximize battery life, and to control the interference that results from such long ranges.

This compatibility enables readers and tags that support both passive C1G2 and battery assisted C3 modes to seamlessly operate in a mixed environment with minimal reduction in efficiency.

Both of these extensions build upon the foundation established by the EPC Global C1G2 standard. All data and memory formats are retained, as are the fundamental protocols to singulate tags and read from and write to the tag's memory. While the forward link has been extensively improved for long range applications, the reverse link protocol was already nearly optimal and only required minor extensions. This compatibility enables readers and tags that support both passive C1G2 and battery assisted C3 modes to seamlessly operate in a mixed environment with minimal reduction in efficiency.

The remaining section of the document describes the extensions required to implement the Manchester BAP C3 mode, the benefits of the Manchester BAP C3 mode, and a comparison of the Manchester forward link approach to the PIE mode approach.

The Revolutionary Manchester Forward Link Class 3 Mode Extensions

The Manchester C3 extensions in the ISO 18000-6C revision was initially proposed by Intelleflex in 2006 based on the research & development and real world implementation experience prior to that submission. In working with the ISO committee charged with developing the new standard, many improvements were made to the original proposal. While Intelleflex holds key patents in the new C3 portion, in an effort to foster faster adoption of this new standard the company has donated the essential patents on a royalty free with reciprocity basis.

The ISO C3 extensions to the C1G2 protocol include:

- a Manchester signal modulation format that enables tags to have a more sensitive forward link receiver;
- a new activation command and a hibernation state which allows tags to conserve more power;
- and new commands and parameters which enable better selectivity in both readers and tags to avoid unnecessary interference given the much longer ranges possible in the new C3 mode.

The relatively small additions to the reverse link include:

- higher M divide values which enable better reverse link sensitivity;
- and digital command parameters that control backscatter link frequencies and M values to combat the noise inherent in measuring TRcal pulse widths at low signal levels.

Manchester Forward Link Class 3 Mode Compared to PIE Mode

When comparing the Manchester forward link extension to the PIE mode extension, there are 5 fundamental improvements that are enabled by the new Manchester forward link:

1) Long range extension (Manchester AC coupled vs PIE DC coupled)
2) High reliability from close up to edge of range (Manchester vs PIE preambles)
3) Improved battery life (Activation with selection controls)
4) Instant access (Constant activation monitoring vs duty cycling)
5) Reduced inter-reader interference (Specific tag group activation and reader locking)

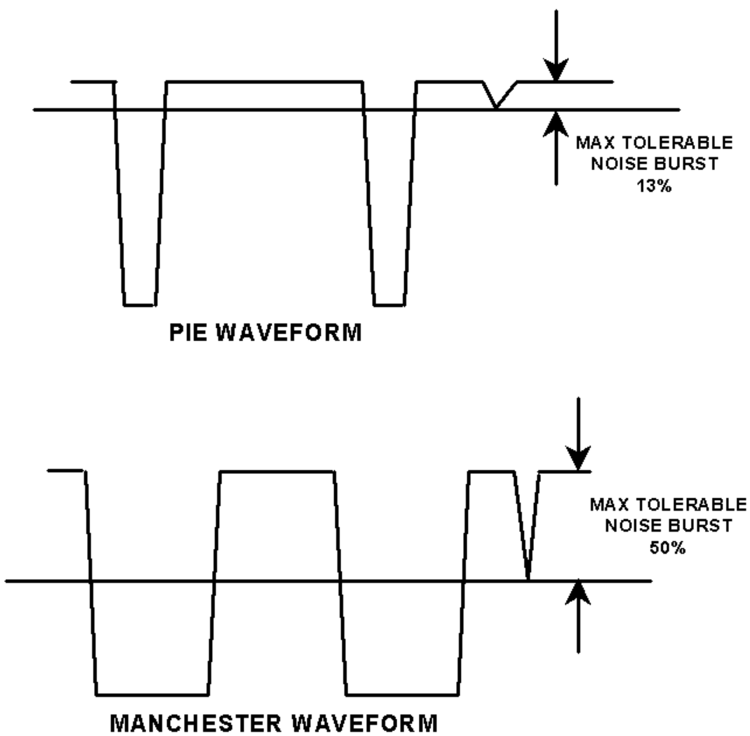
1.) Long Range Extension

The C1G2 protocol mandates Pulse-Interval Encoding (PIE) modulation for the interrogator-to-tag (forward) link. This modulation format transmits its information via the duty cycle of the waveform. Such a waveform is ideal for purely passive tags because it minimizes the amount of time that the carrier wave is reduced. However, this waveform is unsuitable for a battery-assisted tag.

The main point of battery-assistance is to enable receiving signals that are much lower in power at the antenna. This requires amplification of the detected AM signal, typically at the baseband portion of the circuit; this is where the expected sensitivity (range) improvement comes from. This amplification cannot be DC-coupled, because the amplifier's input offset voltage would exceed the detected signal voltage. So the amplifier must be AC-coupled, and that's where PIE modulation suffers. When the PIE waveform is AC-coupled, the average value of the waveform rides up and down with the duty cycle. The worst-case PIE waveform has a duty factor of about

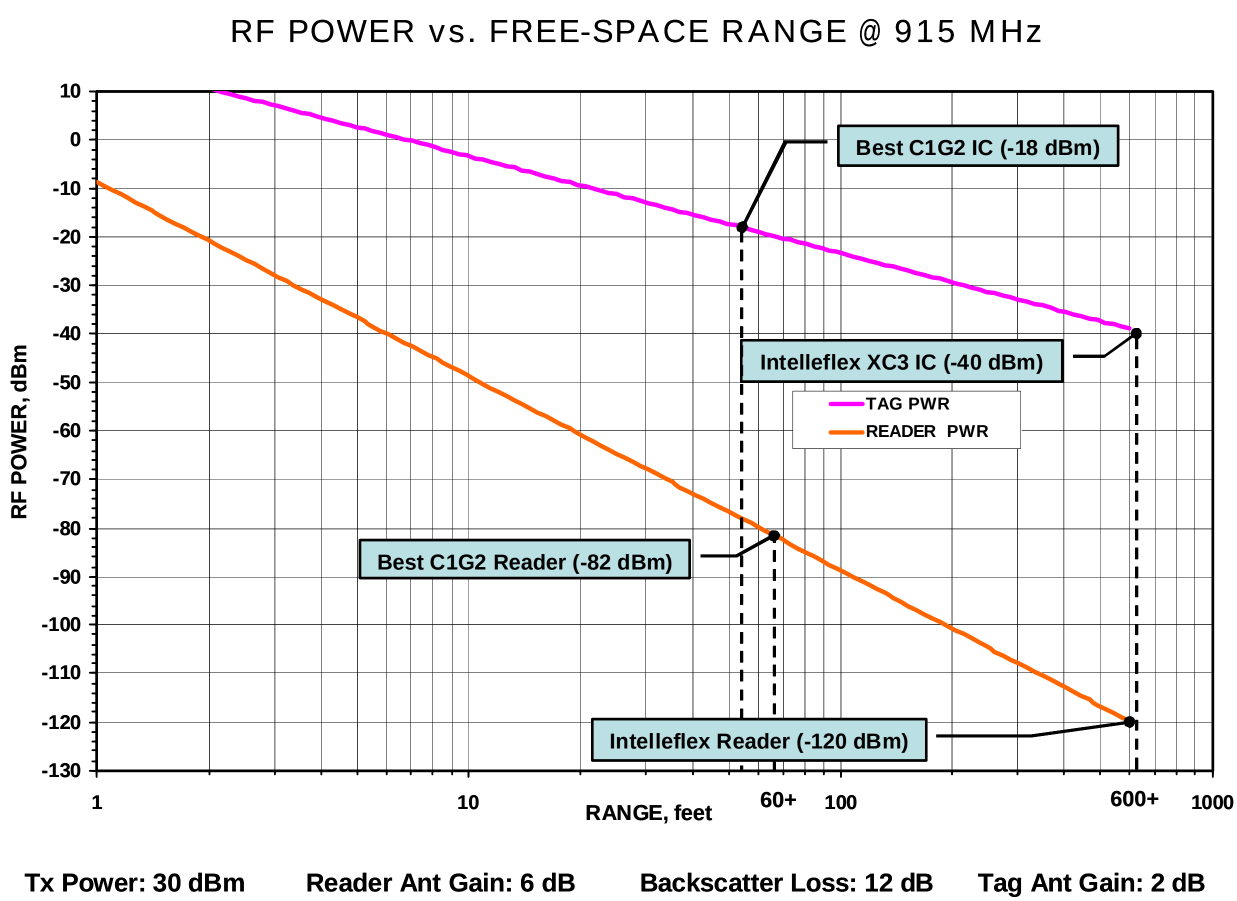
87%. As shown in the figure, this waveform slides so far down that a noise burst of a mere 13% of the waveform amplitude is sufficient to cause the following data slicer to err.

The ISO C3 protocol allows for Manchester modulation, chosen specifically because of its constant 50% duty cycle. AC coupling will not degrade such a signal, since it has no DC component. As shown in the figure, a noise burst must exceed 50% of the waveform amplitude before the slicer will err. Thus, Manchester encoding enjoys an intrinsic signal-to-noise advantage of 11.5 dB relative to PIE, which translates directly to a free-space range advantage of almost 4 to 1. Manchester encoding was incorporated into the C3 protocol specifically to utilize this advantage.



Customer Benefits

The XC3 technology range extension enables new applications that require reading tags reliably at much longer distances than is now possible with pure passive tags. Alternatively, it also enables reading tags that are buried deep within RF absorbing products such as produce and cold temperature packing materials. As reflected in the chart below, the best C1G2 tag IC currently available has a receive sensitivity of -18 dBm which translates to a maximum read distance of a little more than 50 feet in free space. The best C1G2 reader currently available has a receive sensitivity of -82 dBm, equating to a maximum read distance of a little over 60 feet. The new Intelleflex XC3 BAP IC, implementing the new ISO 1800-6C extension, has a receive sensitivity of -40 dBm, equating to a read distance in excess of 600 feet! Reading a tag at this distance requires a balanced reader/tag solution, which is why the Intelleflex XC3 reader technology has a receive sensitivity of -120 dBm (close to a 40 dBm improvement over any reader currently on the market!). This balanced reader/tag approach is critical for robust Battery Assisted Passive solution deployment. Other Battery Assisted Passive tags have typical receive sensitivity between -20 to -25 dBm which requires a reader with a corresponding receive sensitivity of at least -95 dBm. Even the best C1G2 readers currently on the market don't come close to this and so the solution is not balanced, thus the effective read range is still limited by the receive sensitivity of the reader. As a matter of fact, no matter how much other tags improve their sensitivity above -20 dBm, they will still be limited by the current C1G2 readers' receive sensitivity. It should be noted that you can demonstrate read distances with some tags in excess of what is implied from this chart by varying tag or reader receive antenna gain or by leveraging the multi-path characteristics of RF. But this approach yields limited improvements that are often very directional/orientation sensitive and only enables operation at the margins, leading to unreliable real world performance. You will not achieve the read range performance or solution robustness that the Intelleflex XC3 technology platform offers.



2.) **High Reliability from Close Up to Edge of Range**

The C1G2 R->T preamble is very short since the expected signal level required to power a passive tag is very strong. This short preamble makes it difficult for a battery assisted C1G2 tag to be able to receive signals that vary from very strong to very weak. On the other hand, the longer Manchester R->T preamble is designed to train the tag's analog circuitry to the full range of signals from very strong when the tag is close to the interrogator, to very weak when the tag is at the edge of the C3 reading range.

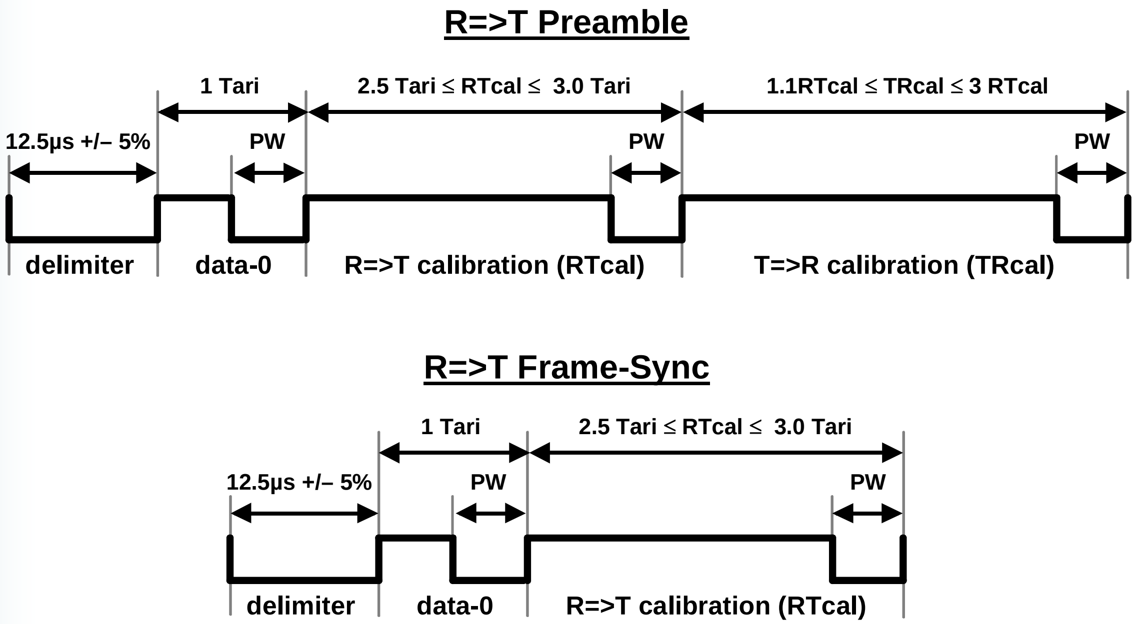


Figure 1 – C1G2 PIE R->T preamble and frame sync

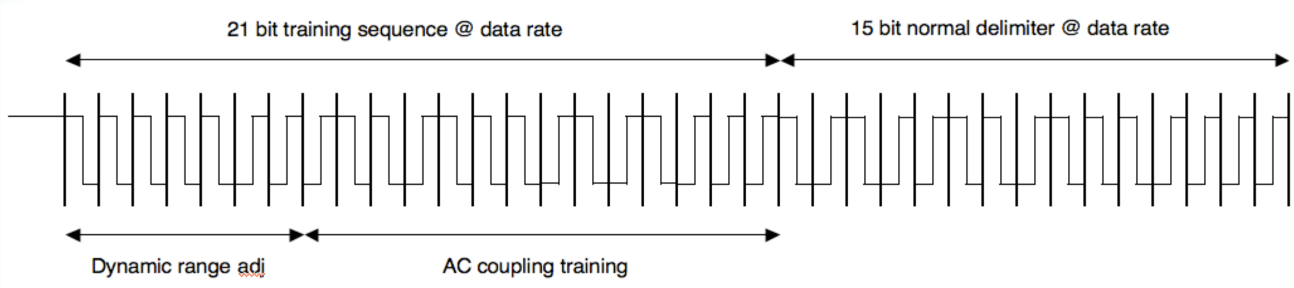


Figure 2 – ISO C3 Manchester R->T preamble and frame sync

A tag must receive an interrogator command signal and recognize a valid start of a command so that it can correctly receive the first through the last bit of the command data. This starts with the R->T preamble which is shown below for the PIE forward link. This short R->T preamble is very efficient for high power levels that are required to power purely passive tags. With such strong signals and DC coupling on the tag receiver input, a single PW dip is easily recognized, and the RTcal used to determine the threshold length of determining a data 0 from data 1 can be accurately measured.

However, with high sensitivity battery assisted tags, the input signal is much smaller and the tag receiver can be perturbed by internal circuit noise such as flicker or shot noise, or by external noise such as interference. AC coupling provides much better receiver sensitivity, but it also amplifies the input perturbations and causes random high/low transitions with no signal and with constant CW input until the actual signal modulation starts. These random transitions can fool the tag digital circuits into thinking that a command preamble has been received.

The Manchester mode R->T preamble is designed for noisy environments and AC coupling with high receiver baseband gain. The equivalent delimiter for Manchester is 15 bits long compared to the 4 bits long frame sync preamble. That would make the likely hood of a false alarm roughly 2^{11} times less, or about 1/2000. This can make a large difference for reliability of communication by keeping the tag from falsely starting the state machine and potentially missing the real command. This can also cause the chip to stay in the battery assisted state much more than necessary and thereby reduce battery life.

There is one more key difference in the reliability of the Manchester mode. The data rate of the commands to be transmitted is indicated in the activation command which is sent at the most reliable and lowest data rate. Therefore, the tag does not have to use a potentially noisy PIE RTcal measurement to determine the threshold point of a data 0 and data 1. While appropriate for strong C1G2 signal levels, that measurement at C3 sensitivity levels could be noisy enough to cause errors in the reception of the command. A single bit error is enough to invalidate the whole command, or in some cases, cause the tag to stay out of an entire singulation round. Finally, that prior knowledge of data rate allows the tags to configure the optimal filter bandwidths to get the maximum signal to noise ratio at any given rate. That would not be possible using the RTcal method which is embedded within the same command.

Customer Benefits
Manchester C3 tags can be read reliably out to the edge of range, but are well designed to operate seamlessly at any distance from up close to the reader antenna to the edge of range. Battery assisted C1G2 tags can be designed to have better sensitivity than standard passive tags, but the lack of training portion in the signal means they will not be able to work close up as well as at their edge of range. This means C1G2 tags will need to be configured to work at certain expected distances and if the tag is not within the expected distance to the reader, its performance will suffer. Deploying real world solutions trying to take this limitation into account, with numerous C1G2 BAP tags in the environment will prove enormously challenging, if not impossible.

3.) Improved Battery Life

There are some difficult tradeoffs to make when designing C1G2 PIE Mode based battery assisted passive tags. How often should the tag wake up? What should the response time of the tag be? The longer a tag is in full wake state, the shorter the battery life. However, turning the tag off with a “duty cycling” approach will reduce current consumption but could cause significant delay in communicating with the tag. Also, any carrier activity within receiving range of any C1G2 tag will unnecessarily keep the tag awake until the tag is removed from the vicinity of the readers.

The Class 3 Manchester mode solves these problems by using an innovative Activation signal which is a simple, unique signal at a fixed data rate that the tag can search for continuously but with very little digital current being consumed. The only power consumption comes from the low power baseband amplifiers and the Activation detection circuitry. The high speed clock on the chip is turned off and the digital gates do not consume any power.

The Activation signal is unique from all C1G2 signals, and the bit-stuff coding of all Manchester commands guarantee that the Activation delimiter pattern is unique in all Manchester signals. Once a tag is activated, the fields within the Activation command identifies the tag or group of tag that the interrogator wants to inventory. If the tag is not part of that group of tag, it can go back to lower power hibernation within milliseconds. Thus, the effective duty cycle of the tag will be very low while remaining instantly accessible.

Manchester Activation allows the application or reader to selectively activate tags by a variety of parameters. The main selection method is the Activation Code which can be flexibly used by any application to hierarchically grouping merchandise, asset classes, shipment group, perishable date, etc. Activation codes may also be dynamically configured to adjust to variable conditions. There are two activation codes that can be used to activate the tags with multiple methods. Other activation methods include by tag type, alarm indication, and if the tag is a sensor tag. There are also parameters to control the sensitivity of the tag dynamically to limit the range of interferers.

Once activated, the Manchester Activation allows locking the tag to a particular session ID or ReaderID for the duration of the Activation session. This prevents the tag from getting distracted by other distant readers and only process commands from the activating reader. Finally, there are two commands which put the tag to sleep when the interrogator is done communicating with it. One command individually puts tag to sleep after being inventoried, and the other puts a selected group of tags to sleep.

Customer Benefits

Manchester Activation provides an enormously powerful tool to help manage tag populations. Each tag has two 96 bit activation codes. These codes can be used at the application level to determine which tags should be activated and read or written to. Imagine using one of the activation codes to map your set of business processes to so that only tags at certain stages of the business process get activated; all other tags stay in hibernation awaiting their turn at their relevant process stage. This significantly reduces issues related to stray tag reads, a feature even C1G2 tags could use. Next, imagine using the second activation code on a sensor based tag as a “dynamic” activation code where the activation code is set dynamically by the tag when alarm conditions are present. Readers can then activate tags that have alarm conditions present and won’t need to read any other tags.

4.) Instant Access

As described in the previous battery savings section, the “duty cycling” can be used to reduce power consumption by turning off the tag clock for most of the time. However, while the tag is in low power sleep, it will not be able to respond immediately. And activity detection used to turn on the tag or keep it on may end up keeping the tag constantly on if it is within range of a C1G2 reader.

The Activation command solves this tradeoff to get good battery savings and constant immediate access. It enables tags to implement a very low power analog detection circuit that can run in continuous mode with high sensitivity and low probability of false alarm. It also has specific commands to put tags to sleep deterministically and with minimum excess time in awake mode. It will not falsely wake up for more than a few milliseconds at a time even though the interrogator may be sending valid activation commands to other tags.

5.) Reduced Inter-Reader Interference

With such high sensitivity, the range of the tags can exceed 200 meters. With such large range, the likelihood of tags seeing multiple readers is very high. There will also be many tags visible to a single reader, sometimes up to many thousand. In such an environment, there will be a high likelihood of interference. One reader may confuse tags already is a session with another reader. The Manchester mode protocol has many new features that address these issues.

The first is Activation which makes it possible to wake up only a specific subset of tags, perform all necessary inventory and read/write operations, then finish up the operation and stop transmitting RF as quickly as possible. Another feature is the ability to lock a tag to talk only to the specific reader ID that activated the tag for the session.

In addition, the tag’s higher sensitivity allows for the reduction of the reader transmit power, decreasing the RF power levels and any potential interference they may cause.