White Paper

On

The Technical aspects that support the PJM HF Unique 100% Reliability Level

Document Number : 00000-00-01

Last Changed : 16 July 2010

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1. Introduction

PJM HF achieves 100% reliability whereas UHF only achieves reliability levels of between 85% and 92%. The reasons for the unique reliability of PJM HF are explained below.

Unlike its competitors, Magellan's PJM HF technology offers 100% reliability. This is particularly important as PJM HF technology is used in medical applications, where anything less than 100% reliability is unacceptable.

There are two principle causes of less than 100% reliability:

- tags not being read and
- tags being incorrectly read (false reads or ghost tags)

We will now consider these two causes of unreliability and the means by which Magellan's PJM HF technology avoids them.

2. Tags Not Being Read

Tags not being read usually indicate that tags are either; not replying due to poor coupling between the tag and reader, tag replies are being lost due to interference from adjacent readers or that there are too many tags in the reader resulting in a failure of the multiple tag anti-collision protocol.

These issues are addressed by the PJM HF combination of the choice of frequency, modulation methods, data rates and anti-collision protocol.

2.1 Excellent Reader to Tag Coupling at 13.56MHz

UHF uses the electric Far Field which is a radiating field that can reflect and destructively (or constructively) interfere to produce null and hot spots. Null spots cause poor coupling between a UHF tag and the reader antenna and will result in the tag not receiving enough power to operate. At the HF frequency of 13.56MHz the RFID field is a magnetic Near Field which does not radiate nor reflect and cannot destructively (or constructively) interfere to produce null (or hot) spots. At 13.56 MHz the magnetic Near Field is very well controlled in its extent and it provides a highly predictable field pattern and orientation. The magnetic field provides HF PJM with excellent Reader to Tag coupling.

With the correct antennas a properly designed HF PJM system will always provide adequate power to tags in the working volume so that they to operate correctly. Magellan has extensive experience at designing reader antenna for 1D, 2D and full 3D operation and can provide the correct antenna configuration for each application to ensure adequate Reader to Tag coupling.

2.2 Minimum Adjacent Reader Interference

A major issue with UHF Far Field radiation is that it is uncontrolled and adjacent readers will interfere with each other. There have been various attempts to resolve this issue by

synchronizing UHF readers so that when one UHF reader is transmitting adjacent UHF readers are not but the phenomenon of multi pathing means that UHF readers often some hundreds of yards apart will still interfere with each other and produce erroneous reads and even worse, fictitious reads in the form of a problem that is so ubiquitous it is known as the “Ghost Tag” phenomenon.

Conversely, the HF 13.56 MHz Near Field has the property that it attenuates rapidly with distance (typically as a cube of distance beyond the read range). Close to a Reader’s antenna the field is strong and couples strongly to tags. Beyond the antennas’ desired read range the magnetic field diminishes rapidly and consequently for, adjacent HF readers, the RFID signal coupled between HF reader antennas is inherently small. This characteristic prevents tags on adjacent readers being unintentionally and erroneously read.

It still is however possible, even for an HF reader, for the commands transmitted by a reader to interfere with the replies of tags on an adjacent reader. This occurs because tag replies are always very much weaker than the reader’s transmission. In all RFID systems except PJM HF, commands occupy the same frequency spectrum space as tag replies. If the commands transmitted by a reader coincide with the replies of a tag on an adjacent reader then even an HF tag reply can be corrupted. So, while HF has a much smaller problem than UHF, standard HF is also affected by adjacent readers and is unreliable.

Only in a PJM HF system do commands and replies occupy distinctly different frequency spectrum spaces. .Commands are transmitted as Phase Jitter Modulation (PJM) centered on the 13.56MHz RFID signal where as tags reply on a choice of multiple frequencies in a different frequency band either side of 13.56MHz RFID signal. Because of this frequency spectrum separation commands transmitted by a reader do not interfere with replies from tags on an adjacent reader. This frequency spectrum separation of the commands and replies is unique to PJM HF and ensures unlike all other RFID systems and uniquely to PJM systems that interference between readers is removed.

2.3 Highest Command and Reply Data Rates

PJM HF tags (both ItemTag® and StackTag®) have a command data rate of 424 kbits per second and a maximum effective reply data rate of 848 kbits per second. All replies are at 106 kbits a second but, as these are across eight different reply channels, the effective reply rate when all channels are in use is 848 kbits per second. This is very much faster than other technologies. The speed at which PJM communicates is so fast that it can communicate with many hundreds of tags practically simultaneously. Apart from the major benefit of raw speed this also means that PJM tags can access much more memory than other RFID tags in the same time. Very importantly, because of its high speed data rates PJM can also use a robust and sophisticated anti-collision method using both frequency and time parameters and a full 32 bit CRC (the minimum standard for security) and does not have to fall back on unacceptable 8 bit or 16 bit CRC as do other RFID systems.

2.4 FTDMA Anti Collision Method

PJM HF tags use a unique anti-collision method called Frequency & Time Division Multiple Access (FTDMA).

With FTDMA there is no loss of reader performance for up to 32,000 tags simultaneously present within the operating range of a reader. Other RFID systems are always limited by the fact that the reader can only communicate with a single tag at a time using a single RFID frequency or channel. PJM StackTag® and PJM ItemTag® are quite different in that each tag replies on any one of 8 different reply frequencies (channels). This means that where one channel is blocked, for whatever reason, there are seven other channels a tag can use to reply. For each reply tags select a specific reply channel and choose when to reply or not reply. This unique method of random frequency hopping and reply muting provides the benefits of frequency division with the added major advantage of time multiplexed operation. This means, particularly when multiple tags are simultaneously within the operating range of a reader, that they will be correctly identified and their several identifying messages individually and correctly received. Other RFID systems cannot do this as they have to use slot based protocols to achieve multiple tag reading. Using slot protocols for anti collision means these systems are both slow and limited in the number of separate tags they can read in the same time.

3. Tags Being Incorrectly Read

Whilst tags not being read are annoying a far more serious problem are tags being incorrectly read. Incorrectly read tags are known as 'ghost tags' as they falsely show tags being present which are not present. Ghost tags are mostly caused by noise corrupted, or colliding, tag replies decoding as good messages. This will occur if an RFID system does not have adequate methods of detecting and eliminating such messages.

In a UHF system ghost tags can also be caused by the phenomenon of multi pathing. UHF readers often read tags well outside the read area (sometimes hundreds of yards away). While these distant tags are correctly identified they are ghost tags as they are not properly associated with the tags being read. This type of ‘ghost’ tag cannot be eliminated by error checking and is impossible to eliminate from a UHF system without extensive shielding of the reader’s antenna.

Ghost tags are unacceptable and the PJM HF protocol and compliant readers have been specifically designed to eliminate ghost tags. For a 'ghost tag' to be received the following RFID system failures must occur:

- a noise corrupted tag reply or colliding tags replies are detected as a 'valid reply'
- the erroneous 'valid reply' is then decoded as a 'correct message'
- the data contained in the so called 'correct message' is then interpreted as being within the correct bounds of valid data

We will now consider the three different methods Magellan uses for eliminating false reads and ghost tags. With three independent levels of error checking Magellan can guarantee 100% accuracy for all tag replies.

3.1 Bit by Bit Encoding Check

All data is transmitted MFM encoded and the bit by bit timing is checked against precise templates to ensure that a valid reply is being received. If noise or another tag message is interfering with the reply false timing transitions will occur and if even one false timing transition is detected the whole message is rejected.

3.2 32 bit CRC Error Checking

The very high communication speeds used by PJM HF (424 kbit/sec command and 8 x 106 kbit/sec reply) allow for high redundancy error checking to be used without compromising performance. A full 32 bit CRC is used for all tag replies and guarantees that only correct messages are decoded as correct and incorrect messages are rejected. Other RFID systems with much slower communication speeds have sought to improve read speed by reducing message lengths and in particular reducing error checking to a minimum. For example 5 bit, 8 bit and 16 bit CRC checking are commonly used. Only PJM HF uses a full 32 bit CRC checking.

The advantages of a full 32 bit CRC and the disadvantages of using a less robust error checking code can be simply demonstrated as follows. With 16 bit CRC checking there is a $1/2^{16}$ = 1/65,536 chance that random noise or randomly colliding tags messages will erroneously decode with a correct CRC. This gives a 99.999% accuracy however, for a reader transmitting 100 identification requests per second there is an even probability (50% chance) that random noise will generate a ghost tag after 8 minutes of operation. On average 8 ghost tag replies will be generated every hour. As a comparison with a 32 bit

CRC 56 years of time is required before there is an even probability that noise could mimic just one valid reply.

3.3 Data Validity Checking

Tag replies, in addition to the read data, have multiple 16 bit data fields containing tag configuration data each of which have a limited set of well defined values. If this configuration data, or the tag data, does not correspond to the set of allowed values then the reply is rejected.

4. Conclusion

Magellan's PJM HF technology offers 100% reliability. This unique level of reliability is achieved by a combination of the choice of frequency, modulation methods, data rates and anti-collision protocol combined with three independent levels of error checking.

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16 July 2010