A Comparison of ISO 18000-6C and eGo for AVI Applications

White Paper
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Executive Summary

Two common RFID protocols for automatic vehicle identification (AVI) applications are ISO 18000-6C and Transcore’s eGo™. This paper will compare these two protocols as applied to AVI applications.

The eGo protocol was developed by Amtech in the mid-to-late 1990s and introduced to the market as “Intellitag™”. Amtech’s RFID business was acquired by Intermec in 1998 and shortly afterward the remaining portion of Amtech was acquired by Transcore. Intermec licensed the Intellitag technology back to Transcore, where it was rebranded as “eGo”. Intermec also sought standardization of the Intellitag protocol under ISO 18000-6 and some years later it was introduced as ISO 18000-6B (hereafter abbreviated to ISO-B). Philips made enhancements to ISO-B by increasing the tag-to-reader data rate, which is also part of the ISO 18000-6 standard and we will refer to simply as ISO-B 4x. Transcore uses this ISO-B 4x version but brands it “SuperEgo™”.

The ISO 18000-6C (hereafter abbreviated to ISO-C) was developed in 2004-2005 by a group of industry and academic experts to leverage advances in integrated circuit technology and to solve many of the inherent problems with the older protocols. It has since become widely adopted across many industries, including AVI, with multiple sources for chips, tags, and readers. ISO-C is an active standard and continues to expand with additions including sensors and semi-passive protocol extensions for extremely broad applications.
Communications Link

First we compare the communications link used by ISO-B and ISO-C. The communications link refers to the signaling used to transmit data wirelessly between the tag and reader. This is an important aspect in the design of an RFID system since it determines the basic reliability of the data transfer, i.e. how well it handles real world conditions.

Both ISO-B and ISO-C are reader talks first protocols, meaning that the tag only answers to reader commands. The tag never signals without being told to do so. In addition, both protocols are half duplex, meaning that the reader-to-tag signaling (forward link) and the tag-to-reader signaling (reverse link) never occur at the same time. The reader sends a command, then the tag replies while the reader listens, then the reader sends another command, and so on.

Figure 1 shows the forward and reverse link frequency spectrums for ISO-B. The ISO-B forward link uses 40K bit/second Manchester encoding which is modulated onto the RF carrier oscillator using large carrier amplitude modulation [Stremler, 1982]. The rise/fall times of the forward link waveform must be at least 18% of the bit interval. The 40K bit/second data rate, Manchester encoding, and rise/fall time specification of ISO-B together determine the spectral occupancy of the forward link. The spectral occupancy is typically defined as the amount of RF spectrum needed for 99% of the signal energy. Transcore’s eGo version of ISO-B uses 100% forward link modulation depth. While signaling this is nearly 320 KHz (RF carrier frequency Fc +/- 160 KHz). Figure 1 also shows the ISO-B reverse link which uses FM0 encoding, also known as bi-phase space, at 40K bit/second. Figure 2 shows the frequency spectrum for ISO-B 4x. The forward link is the same as ISO-B, but in this case the reverse link uses FM0 at 160K bits/second.

ISO-C has considerable flexibility in both the forward link and the reverse link. The forward link uses pulse interval encoding (PIE) which is modulated onto the RF carrier using either large carrier AM (as in ISO-B / 4x), or suppressed carrier AM, or single sideband AM. Both suppressed carrier and single sideband modulation formats offer vastly improved spectral occupancy over large carrier AM. In addition, the rise/fall times of the transmitter waveforms are allowed to be as much as 33% of the bit period. This combination of improved modulation and larger rise/fall times allows ISO-C to transmit 80K bits/second with the same spectral occupancy as 40K bits/second in ISO-B.

Using the same amount of frequency spectrum the ISO-C forward link is much faster.
The reverse link in ISO-C has even more flexibility. Every ISO-C tag supports FM0 encoding at data rates from 40 KHz to 640 KHz, under the control of the reader commands. In addition, three other encoding formats are supported by all ISO-C tags: Miller-2, Miller-4, and Miller-8. These encoding formats use a Miller line code phase modulated onto a subcarrier with 2, 4, or 8 subcarrier cycles per bit. The use of subcarriers is common in wireless communications systems and is used to provide frequency separation between bands to avoid interference. All ISO-C tags support subcarriers covering the range from 40 KHz to 640 KHz. Figure 3 shows one possible spectrum for ISO-C where a 320 KHz subcarrier and Miller-4 encoding is used to move the return link spectrum away from the forward link spectrum.

**Co-channel Interference**

Frequency planning and reuse is a major consideration when many readers operate in close proximity, as in a vehicle tolling plaza. To avoid complex and expensive reader synchronization it is good to have the forward link and return link properly channelized so no interference between readers occurs. This is particularly a problem for co-channel operation, wherein two readers within the same toll plaza operate on the same RF carrier frequency. As seen in Figures 1 and 2, the ISO-B protocol does not provide good frequency separation between forward and reverse links for either regular or 4x modes. Because of this ISO-B is completely intolerant of co-channel interference.
The ISO-C protocol was designed to resolve the problem of co-channel interference which ISO-B and so many other older protocols suffer from. All ISO-C tags support the spectrally efficient Miller modes on a wide range of subcarrier frequencies. Figure 3 shows one possible spectrum with 80K bits/second forward link and 80K bits/second reverse link using Miller-4 on a 320 KHz subcarrier. This type of frequency duplex technique is commonly used in wireless communications systems. Older RFID protocols such as ISO-B were developed at a time when it was not practical to have passive tags generating higher frequency subcarriers. ISO-C represents the current state of the art in passive RFID technology, allowing frequency duplexing of forward and reverse links so that co-channel interference is not a problem. This completely eliminates the need for complex, expensive, and fault-prone reader synchronization in multi-lane AVI applications.

**Carrier Phase Noise**

All RF communications systems must deal with oscillator phase noise [Lee, 2000], but few wireless systems are affected by phase noise as profoundly as backscatter RFID systems. This is because the reader must supply the RF carrier signal for the tag to communicate with the reader, and this high power carrier signal couples into the receive circuitry [Zhang, 2004]. 3M readers such as the 5100 contain patented noise reduction circuitry to reduce the effects [Sanders, 2004] [Frederick, 2007], but performance can be improved even further by using the subcarrier capabilities of ISO-C.

Figures 4 and 5 illustrate the effects of phase noise on ISO-B and ISO-B 4x, respectively. Carrier phase noise is strongest near the RF carrier signal and tapers off as the frequency separation from the carrier increases. Thus, ISO-B using a 40 KHz reverse link frequency is deep in the carrier phase noise and its range will be limited by this impairment. Using the 4x version of ISO-B improves the frequency separation from the carrier. However, for best performance one should use the subcarrier feature available in the newer ISO-C protocol to minimize the effects of phase noise. This is illustrated in Figure 6.

**Bandwidth and Interference**

In many regions around the world RFID devices share the radio band with unlicensed devices in an Industrial, Scientific and Medical (ISM) band. There are many other users in the ISM band such as two way radios, cordless phones, Bluetooth devices, etc. These other radio devices transmit signals which can interfere with the reception of the tag signal, especially if the other devices use the same spectrum that the tag is signaling in. It is therefore advantageous for the RFID system to adapt its bandwidth as needed so that the likelihood of interference from other ISM band devices is minimized.

While ISO-B supports only two modes of operation, 40K bits/second FM0 and 160K bits/second FM0, the newer ISO-C protocol supports a virtually continuous range of reverse link frequencies from 40 KHz to 640 KHz, any of which can use FM0, Miller-2, Miller-4, or Miller-8. ISO-C allows automatic frequency changes from 40 KHz to 640 KHz to adapt to interference.

**Security**

Tag cloning has become a significant concern in AVI applications. Cloning refers to the unauthorized, usually criminal, activity of duplicating or copying tags. This section compares ISO-B and ISO-C on aspects of anti-cloning and authentication. Authentication is a term commonly used in computer and data security applications and refers to the process of validating that the data is legitimate.

The first line of defense against cloning is to prevent tag skimming. Tag skimming is when an unauthorized reader gets tag data. For example, someone could go into a parking lot with a handheld reader and attempt to read all the RFID tags off the cars in the lot to get a batch of valid tags from which to generate copies. The ISO-B protocol has no security in this respect. The ISO-B protocol freely gives ALL information to the rogue reader. There is no reader authentication in ISO-B.
ISO-B Reverse link

Figure 4

ISO-B 4x Reverse link

Figure 5

ISO-C Reverse link

Figure 6
The ISO-C access protocol is much more sophisticated and does allow for reader authentication. The ISO-C tags have secret passwords which are not readable by rogue readers in a skimming attempt. For secured ISO-C tags skimming is not possible.

If valid tag data is obtained, either by skimming or hacking into computer data bases, the next step for the counterfeiter is to create duplicate tags. The most straightforward way to accomplish this is to write the data onto actual tags. Both technologies, ISO-B and ISO-C, rely on TID memory to prevent this. TID memory is factory locked for legitimate tags and cannot be rewritten.

**Tag Roadmaps**

The ISO-B protocol was developed in the 1990's by Amtech, acquired by Intermec, then adopted within ISO 18000-6. Since the ISO-B 4x enhancement by Philips in 2002 there have been no enhancements or other activity in the ISO 18000-6B section of the standard. On the other hand, ISO-C is an active standard with chip designs by numerous competing companies, such as NXP, Texas Instruments, Alien, and Impinj. The ISO-C tags currently available from NXP have state of the art sensitivity and so require less reader transmit power to get excellent read range. This reduces the power requirements on the reader which yields longer reader life and higher reliability.

In addition, there are activities under way within ISO to extend the ISO-C protocol. The new functionality includes protocol enhancements for semi-passive design, higher levels of tag and reader security features, and support for even higher reverse link frequencies to further reduce the effects of phase noise. The AVI market can leverage these technology advances by adopting a thriving open standard such as ISO-C.

**Conclusions**

This paper has compared ISO-B and ISO-C on a number of fundamental system design considerations which are important for AVI applications. It is not surprising that ISO-C is without exception superior to ISO-B, given that ISO-C was designed 6 years later by a group of industry and academic leaders in wireless technology. ISO-C uses modern subcarrier modulation techniques to allow dense reader operation with no reader synchronization and improve performance in the presence of phase noise. The 3M™ 5100 multi-protocol reader takes full advantage of the flexibility and features available in ISO-C for state of the art adaptive digital signal processing and adaptive multi-access algorithms.

In any RFID deployment the performance of the system cannot be considered alone. The total cost of the deployment must be considered. The total cost of the system is made up of the equipment cost, installation and maintenance cost, operation cost, and the efficacy of the system. Generally for AVI applications, the total cost of the system will be dominated by the last item: the effectiveness of the system. What is the system cost when the read accuracy is only 90% of vehicles? What about 80% or 70%? Using 3M’s 5100 with ISO-C tags on 3M’s specially designed AVI inlays can achieve 99.8% vehicle accuracy, even in high speed or poor weather conditions. Together with unsurpassed reader reliability and ease of installation the 5100 solution yields lowest total system cost and highest AVI revenues available.
References


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