The Reliability of Spread Spectrum Radio for Monitoring and Control in Industrial Environments

Wireless radio technology has long been used in the form of fixed frequency radio in our homes and cars and to transmit data in industrial applications. Operation requires a government license that theoretically prevents other broadcast signals inside the "bandwidth" and territory covered by that license. This high power output allows transmission across great distances and “blasting” through obstacles. The downside is an almost immediate drop off in performance if interference (man-made or environmental) moves into the allocated bandwidth. Limited available frequencies also means that users, particularly in urban areas, must often wait years for a license.

To allow greater access and utilize new radio technologies dealing with interference, in 1987 the FCC allocated ISM (Industrial, Scientific, Medical) spread spectrum bands.

Radio technology has been used in the telemetry world for years instead of costly long run cable. Licensed radios and even spread spectrum radios are commonplace in the wide-open spaces of the oil fields and outlying municipal water systems around North America. Here, reliability depends on the FCC maintaining the end-user’s exclusive rights to that portion of the bandwidth. Reliability is purchased or, in the case of spread spectrum radios, often maintained simply because there aren’t other radios competing for the bandwidth in the same area.

New technology is enabling greater use of spread spectrum radio for monitoring and control in industrial environments. Today, we can securely move small amounts of sensor and control information including transmission of mission critical data through heavy interference. Distances between the transmitter and receiver of 300 feet to 15 + miles are achieved while maintaining reliability and information integrity.

A typical dilemma faced by tank farms illustrates the technology. Scattered I/O from multiple tank levels on one side of a highway must be relayed to a DCS or similar system across the road. Digging trenches, laying conduit, and pulling cable makes acquiring these signals costly - not to mention the costs of engineering and inspections and the time needed to acquire right of way prior to implementing the solution. Wireless I/O interfaces are less expensive - in some cases costing tens of thousands of dollars less.

An industrial wireless I/O interface can send analog and discrete signals from a sensor to a PLC or from a PLC to a pump. In this case, reliably reporting levels, pressure, flow and alarms or to control pumps, valves and switches by updating data far more often than required.

<u>The Key to a reliable Industrial wireless I/O interface</u>

Reliability is maximized through frequent sampling of small data packets. Small information packets are a critical component to designing a reliable industrial wireless interface. Whereas traditional telemetry SCADA requires lots of information to be sent through the air, cable replacements for industrial I/O require only bytes of information to be moved. Since errors occur when bits are received incorrectly, the smaller the packet the less chance for error.

Applications such as alarms are essentially one bit of information that is either ON or OFF (4-20mA current loop output is usually transmitted in one or two bytes). Data checks values to detect changes. Each packet in an independent update, eliminating the need to include networking information. Sampling more often than needed provides real time data and allows data to be lost if the radio environment is cluttered by heavy interference.

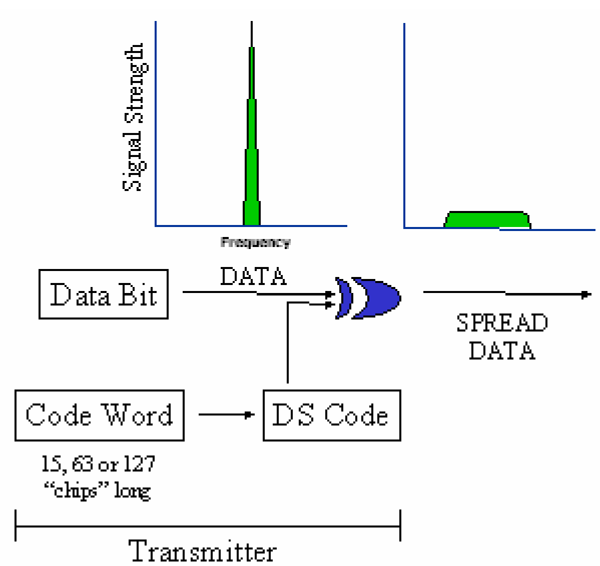
Small packet size can also yield more Power Per Bit. Given a pristine radio environment, there is a clear relationship between speed and distance (here, speed equates to baud rate). In a setting with no interference, if one watt of transmit power is applied to a transmitter sending out information at a slow speed, that radio will fire its signal farther than a radio sending out information at a high speed. The more Power Per Bit, the better able you are to penetrate walls, bounce around tanks and propagate through maze-like metallic structures. The flip side is that more bits per second in transmission reduces Power Per Bit. Therefore, in applications where I/O is moved 300 feet to 15 miles, a small number of bits stand a better chance of making it to the receiver than a large number.

The Types of Spread Spectrum:
FCC allows two methods for building a license-free spread spectrum radio: Direct Sequence Spread Spectrum (DSSS) or Frequency Hopping Spread Spectrum (FHSS). Differing physical mechanisms for dealing with and rejecting interference means DSSS and FHSS behave differently in industrial settings.

Interference and how DFSS and FHSS address it are vital to understand. Wireless radios encounter interference through EMI or RFI from industrial equipment; from other licensed users (even in ISM bands), or from unlicensed radios (especially in ISM).

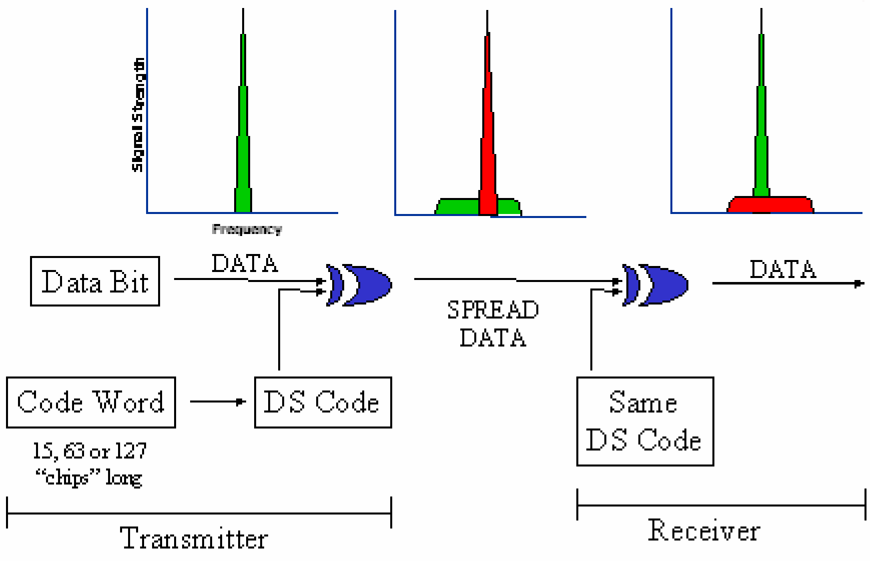
In DSSS radios, a data packet starts out as "narrow data." It then generates a random code word for every bit in that packet. These code words spread the narrow data being sent and "widen" it across a much wider bandwidth.

Signal strength at any one frequency is reduced as the energy is spread.



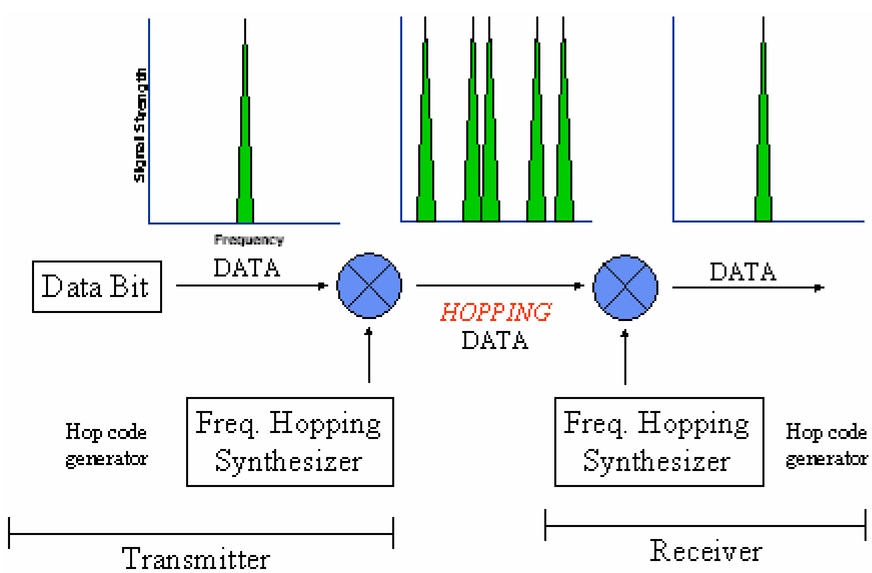
The spreading code is re-applied at the DSSS receiver. The signal is de-spread and data is retrieved. Canceling spreading leaves data in its original state.

Narrowband interfering signals pass through only one spreading code generator (entering after the transmitter, but before the receiver) and are spread by the same code de-spreading the original data.



Reliability depends on the signal strength and Signal to Interference Ratio to get by the widened interferer. In short, as the power of the interfering signal increases, the threshold is reached and the radio fails.

With FHSS radios, the complexity lies with the hopping synchronization of the narrow data signal that remains unaltered. Data remains narrow from transmitter to receiver. The FHSS radio is a narrow band fixed frequency radio - but only for an instant – before it hops to another fixed frequency radio on another channel, and then another, and another, and so on. And it has plenty of room to hop. The 902-928MHz ISM frequency band is wide enough to hold approximately 1000 licensed narrowband radios.



Small packets of data are sent to the receiver with hops in a pseudo random pattern to more than 50 different frequencies around the band, before repeating the hopping sequence. Encounters with a significant interfering signal on a frequency generate error detection and the packet is discarded. The hopping sequence continues and data updates are resumed. Interfering signals can knock one packet out of a FHSS radio's hop pattern, but the rest of the updates get through, no matter how powerful the narrowband interference.

This is very different from DSSS, which maintains error free transmission of its data until the interferer goes over the top of its jamming margin, at which point the throughput of the DSSS quickly drops to zero…not appropriate for mission critical industrial I/O.

FHSS radios do not *"avoid"* interference, they *"tolerate"* it. Each packet is checked and when interference is encountered, the bad packet is not processed. As the hopping pattern continues, the radio moves along its sequence looking for the next packet to get through cleanly, at which time the good data is output. Slow and steady, FHSS radios are the industrial I/O tractors.

FHSS also has the unique advantage of being a small moving target. Throughput does not cease until the entire ISM frequency band at any one location is theoretically plugged. This enables the FHSS to reliably get small redundant messages through areas of heavy interference even as interference increases.

In a low to medium interference environment – one in which the interfering signal strength is below the jamming margin of the DSSS – 100% of the DSSS message will get through while the FHSS will experience packet losses due to the interference. In this case, the DSSS radio is a good choice for large packet messages.

In heavy interference environments– where interfering signals exceed the jamming margin of the DSSS – the DSSS radio will cease to work. The FHSS continues to function until the entire ISM frequency band is jammed (a very unlikely scenario). FHSS is the perfect choice for small packet redundant data – for example, alarm and emergency stop signals – because even though packets are lost, others get through.

The redundancy of data transmission and small packet size make FHSS the preferable choice for industrial wireless I/O applications such as simple analog and digital signals. The technology provides relability even in confined environments where many FHSS radios operate.

FHSS industrial strength radios including DIN rail mount wireless I/O (such as DIN rail mounted version from Phoenix Contact), are rapidly gaining market acceptance. New technology will continue to improve application usage making wireless I/O commonplace in harsh industrial environments in the years to come.