

Industrial Wireless: Solving Wiring Issues by Unplugging

Industrial environments present extreme challenges for wireless communications.

Industrial environments are uniquely different from office and home environments. High temperatures, excessive airborne particulates, multiple obstacles and long distances separating equipment and systems, are special challenges that make it difficult to place and reach sensors, transmitters, and other data communication devices.

These – and a thousand other factors – create a very unique, complex, and costly challenge for establishing data communication channels that will be reliable, long lasting, and cost effective.

For example, a primary difficulty faced by many companies, is the need to connect remote equipment sensors to central monitoring systems. Inside a steel mill, the environment is extremely intense: excessive heat, heavy machinery, large distances, and high levels of EMI significantly shorten the lifespan of wires and network equipment.

Conversely, a tank farm does not deal with those kinds of harsh environment issues, but does run into distance and cost issues when connecting to their sensors and equipment.

These are two extreme cases, and, of course, the industrial world contains everything in between, in varying degrees of complexity.

Historical Challenges With Industrial Wireless

Wireless I/O has had a rocky past and typically has not performed well enough to endure the harsh demands of industrial applications. There are several reasons for this:

- **Signal Echo** – Typical open radio frequencies (900 MHz and 2.4 GHz) used within today’s wireless data communication applications have a reasonable penetration rate through office cubicles, drywall, wood and other materials found in a home or office, but tend to bounce off larger objects, metals, and concrete. This bounce can redirect the data signal and return it to the original transmitter, causing an “echo” or “multi-path”. First generation wireless systems easily became confused with this type of interference and would cancel transmission all together. The result was a state referred to as “radio null” and prevented data communication.
- **Noise** – The electromagnetic emissions created by large motors, heavy equipment, high power generation and usage, and other typical industrial machinery could create extremely high levels of “noise” that interfered with early wireless equipment. In these “noisy” environments, transmitters and remote nodes were unable to “hear” each other, resulting in frequent data loss.
- **Channel Sharing and Interference** – Radio frequency space became enormously crowded. FCC approved frequency spectrums were shared by many devices, including those utilizing WiFi (IEEE 802.11) and IEEE 802.15.4 and, frequently, the result was data confusion as receivers and nodes gathered and sent information on the same channel as other devices in the area.

Signal echo, noise and channel sharing can deteriorate or even stop data flow over wireless networks.

- **Industrial Protocols Not Supported** – The vast majority of early wireless devices were designed for home and inter-office use. Because of this, very few engineers were addressing the industrial protocols such as Modbus or the need to move from wireless to RS-232, 422 or 485 supports. Additionally, casing, circuitry, and connections were designed for lightweight usage and were inadequate for rugged industrial settings.
- **Distance** – The sheer distances between central control systems and remote sensor and equipment eliminated the feasibility of early wireless systems with ranges of several hundred feet or more.
- **Security** – Early adoption of the IEEE 802.11 standards created a large number of security issues and continues to require a high level of counter-measures to ensure the safety of data and business systems.

So, while the fundamental premise of wireless was a clear answer to many industrial data communication challenges, the reality was that unless these obstacles could be overcome, wireless was not a solution at all.

Certain New Methods and Technologies Solve Wireless Issues

New technologies and transmission methods overcome industrial environment challenges.

Over time, this has changed, as new technologies have entered the picture. Today, there is a wide array of data communication solutions that could resolve challenges facing industrial environments.

Here is a snapshot of the options you have with some corresponding pros and cons. When looking for the optimum industrial wireless solution for your situation, carefully consider these factors

Echo, Noise & Channel Interference

Several transmission and modulation schemes have been developed to counter the effects of echo, noise, and channel sharing. Here are two of the best to look for.

Caution: All wireless transmitters, nodes and equipment on your network must support the same transmission scheme to operate properly.

- **FHSS** (Frequency Hopping Spread Spectrum) – Data is transmitted on a single channel at a time, but the channel is rapidly and constantly changing or “hopping”. This scheme requires low bandwidth.
- **DSSS** (Direct Sequence Spread Spectrum) – Data is transmitted simultaneously over every available channel, making it a bit more reliable in “noisy” environments, but is also bandwidth intensive.

Advanced transmission schemes reduce echo, noise, and channel sharing issues.

In addition to these transmission schemes, there are several design and development standards that play an essential role in establishing reliability, security, speed, distance and efficiency. Determining your best solution depends on your application and needs. In outlining the various wireless options below, the “Pros and Cons” list are from a typical industrial environment perspective.

- **Wi-Fi (IEEE 802.11 b/g/n)**

Wi-Fi is the de facto standard home and office wireless network solutions.

Pros - This standard forms the staple of home, business and office networking and is widely used for its high data transfer rate abilities (max throughput of up to 54Mbit/s with 12Mbit/s being typical).

Cons - However, complying with the standard, requires excessive overhead in terms of power consumption, software, processor resources, short ranges (160m max) and size of physical components, making it less than effective in most industrial situations.

Bluetooth and ZigBee compete in the market and in frequency space for small data packet delivery over short distances.

- **Bluetooth (IEEE 802.15.1)**

Pros - Bluetooth has gained popularity because of its small physical size and instant network setup. 3 classes allow Bluetooth to move data anywhere from 3m to 100m away.

Cons - Bluetooth has a relatively high duty cycle (especially in 2.0 and early versions), minimal data throughput (currently a maximum of 3 Mbit/s is possible) and requires a fairly defined line-of-site because of its low penetration qualities.

- **ZigBee (IEEE 802.15.4)**

Pros - Relatively speaking, ZigBee is the new kid on the block, but it has several things going for it. It is far more power-friendly than Wi-Fi and Bluetooth because of its advanced sleep and sniff abilities. Additionally, it has high penetration ability, and operates with an even smaller physical footprint than Bluetooth.

Cons – Zigbee has a low data at rates of up to 720 kbit/s, and has poor interoperability. Additionally, because it is relatively new, hardware developers are still refining and defining their systems.

Proprietary RF gives industrial engineers the freedom and flexibility to custom design wireless solutions for their environment.

- **Proprietary RF (non-standard)**

Pros – Proprietary RF (PRF) provides you with an exact solution to meet your specific needs. Modulation schemes, distances, throughput, casing, configurations, etc... can all be customized to your liking. With PRF, interference issues virtually disappear because you are no longer fighting for the exact same channel sequences that standardized protocols and formats use. PRF tends to be more power-friendly as well because the protocol and hardware configuration does not require an exact set up that may or may not be more energy efficient. For this same reason, costs can actually be lower. PRF can operate in both the 900Mhz and 2.4Ghz frequencies, giving you greater control over distance, penetration, and channel interference. Additionally, there are many PRF off-the-shelf solutions that may meet your needs, saving the time needed for customization.

Cons – PFR does not provide interoperability with any of the established wireless standards and is considered by some to create vendor lock-in.



Here is a chart comparing the various aspects of your wireless solutions:

	Wi-Fi	Bluetooth	ZigBee	PRF
Frequencies	2.4GHz and/or 5GHz	2.45GHz	915MHz(US) 868MHz (EU) 2.4GHz (global)	900MHz(US) 868MHz(EU) or 2.4MHz (global)
Channels	16 @ 2.4GHz 80 @ 8GHz	79	10 @ 915MHz 26 @ 2.4GHz	16 to 79 (can be customized)
Range (Indoor)	70m	Class1=1m Class2=10m Class3=100m	20m	1000m
Range (Outdoor)	160m	100m	100m	40 miles (with high-gain antenna)
Data Rate (Max)	54Mbits/s (with12Mbits/s typical)	3Mbits/s	250Kbit/s	721Kbit/s to 72Mbit/s
Transmission Scheme	DSSS	Adaptive FHSS	DSSS	FHSS or DSSS
Power Sources	Wired	Battery/ Wired	Battery/ Wired	Battery/ Wired (industrial power source compatible)
Uses	Cable replacement, large data transfer, networking	Short distance cable replacement	Monitoring and Controlling	Cable replacement, Monitoring, Controlling, Data Transfer
Max Nodes	32	8	>64,000	Variable
Stack Size	1000KB	720KB	250KB	Variable
Transmit Power (Max)				1W

If circumstances allow you to select a RF standard or off-the-shelf solution, then your options are fairly clear. In terms of range, penetration, frequency, data rate, etc... you have a set base line to choose from. However, if your environment cannot be modified to fit these standards, you'll need to consider proprietary RF. Here are some important things to consider:

Range Considerations

Range is determined by four elements:

- **Transmit Power** – Transmit power refers to the amount of power that is emitted from the antenna port of the radio device. Proprietary RF is regulated in the US for up to 1W. This provides substantial benefits when long ranges are needed, because the higher the transmit power, the “louder” the signal, thus the further it can travel.
- **Receiver Sensitivity** – Sensitivity defines how well remote receivers can “hear” the signal. Sensitivity is significantly impacted by antenna type and hardware configurations.
- **Line of Sight (LOS)**– RF signals are different from the visual spectrum of the human eye, being elliptical rather than linear. For maximum communication the fewer barriers along the LOS between receiver and transmitter, the better. Frequency and transmit power levels have the most impact on how well the signal can negotiate physical and EMI line of sight barriers.



- **Data Volume** – The data rate and volume will also impact your range. Large data packets are more difficult to transmit than smaller packets and will typically reduce range.

Antenna Considerations

Antenna selection will depend on your communication needs, with system array and range being the biggest factors.

Two Types of Antenna



- **Directional** – Sends and receives the signal in a single direction. Think of a football, with antennas located at either end of the ball. This imagery is important because interference can occur at any point within the spectrum. This antenna will give you the largest range. Examples: Yagi, Dish, and Panel.

Directional Antennas



Omni - Directional Antennas

- **Omni-Directional** – Sends and receives the signal in a linear radius. Think of a doughnut with the hole being the location of the antenna. This antenna will allow the largest number of nodes. Examples: Vertical Omnis, Ceiling Domes, and Rubber Ducks.

System Configuration Types

- **Point to Point** – Moving data from one single location to another single location.
- **Point to Multipoint** – Moving data from a single location to multiple locations.

Summary

With today's technology, the possibility of a wireless industrial data communication environment is stronger than ever. Issues that have plagued the wireless option are being minimized, especially as proprietary RF becomes fine-tuned to address specific challenges. Industrial companies can now create extensive data communication networks in the harshest of environments while achieving these advantages:

- **Low Costs** – Wireless equipment represents a substantial savings over the cost of cabling, installation and configuration of wired networks.
- **Longevity** – Sensors, transmitters and receivers can be designed for the harshest of environments, with many operating at temperatures between -40° to 85° C. Concerns about wires deteriorating or needing to install multiple signal boosters over long distances are eliminated.

- **Swift Deployment** – Wireless systems can be almost instantly deployed, modified and taken down, saving valuable human resources.
- **Easy Configuration** – Many wireless systems are plug-and-play, self-configuring and self-repairing. Proprietary RF systems like Zlinx come with easy-to-use, free configuration software to make set-up and customization quick and easy.

