White Paper

Improving Plant Production with Wireless Condition Monitoring

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Introduction

Mechanical failure of motors, drives and other vital electromechanical equipment are among the most common reasons for production stoppages. Fortunately, recent advancements in vibration monitoring and data analysis have lead to condition monitoring systems that can accurately detect a problem before failure, thus reducing costly machine shutdowns and maximizing production output. These systems are installed on the monitored equipment and are typically networked back to a central computer for data analysis and alarm annunciation. Because the machines may be in remote locations where network infrastructure is not available, or on moving platforms where hardwired network connectivity is not practical, wireless communications is a networking alternative that offer installation cost savings, quicker deployment and even improved reliability in certain situations.

Implementation Challenges

For many industries, the purchase of a condition monitoring system is easily justified with a simple return-on-investment (ROI) calculation. For a relatively nominal cost, vital machines may be retrofitted with condition monitoring to reduce operating failures. However, there are additional costs to consider when network infrastructure is not available or practical. This extra expense can include fiber optic cable installation, conduit engineering/installation, trenching between buildings, leasing phone lines for remote sites, and installation of festooning or slip rings for moving equipment. These additional costs may push the ROI out beyond what management will accept.

If the monitored machine is in a remote location within the factory where network infrastructure is not available, cable installation is necessary. The installation costs of cable in an industrial plant can vary greatly based upon the type of plant and physical configurations. For example, studies have shown that average cable installation in a chemical plant is $40 per foot ($120 per meter), while cable installation within a nuclear power plant can be as much as $2,000 per foot ($6,000 per meter)[1]. The actual cable cost depends on the location of the machine relative to existing network infrastructure, type of cable needed (e.g. fiber optic), conduit engineering (if needed), labor cost rates and if trenching is required.

If the machine is in a remote location several miles (kilometers) or more away, then leasing phone lines for communications is required. Leased phone line costs usually include an initial activation/installation fee and then a monthly fee based upon speed of service. Since vibration monitoring is continuous and typically data intensive, the phone line service must support a high enough speed for continuous monitoring. Phone line service to remote sites such as pump stations are also prone to communication failures due to poor line quality and reliability may be of concern. Wireless cellular services are sometimes an option for remote sites, but

[1] Using PCs for machine Condition Monitoring, Plant Engineering December 6, 2004

are subject to service availability and limited in speed. Cellular data subscription costs may also be expensive.

If the machine is on a moving platform (such as an overhead crane, transfer car or conveyor system), then connecting the condition monitoring system to the plant network is a particular challenge. Depending on the speed and distance that the platform travels, traditional cabling methods such as festooning may be possible. However, festooning is subject to wear and tear, and is itself a reliability concern as cables may break. For spinning platforms, slip rings with Ethernet support are available but are expensive and require periodic maintenance. Some machines may move so fast, that the only practical communication method is wireless RF.

Given the challenges of networking condition monitoring systems, wireless communications offer lower installation costs (shorten ROI time), eliminate phone lines and remotely monitor machines that were not practical before. But wireless technologies and equipment vary widely in performance and reliability in industrial installation. Designing a successful wireless network requires an examination of current wireless usage, RF paths and environmental challenges of the industrial plant.

Industrial Wireless Technologies

The most common approach to wireless Ethernet is RF transmission in the spread spectrum bands. Globally, the 2.4 GHz and 5.8 GHz bands are available for license-free use in most countries.

Spread spectrum literally means *spreading* the RF energy across the entire (or wide portion of the) *spectrum*. This technique permits relatively high speed communications while being designed to operate in noisy environments where multiple RF systems are present. There are two major methods of spreading RF energy: Direct Sequence and Frequency Hopping. Both methods have advantages and disadvantages for industrial wireless communications.

Direct Sequence uses a wide channel within the band to simultaneously modulate a highly encoded bit pattern (see Figure 1.)

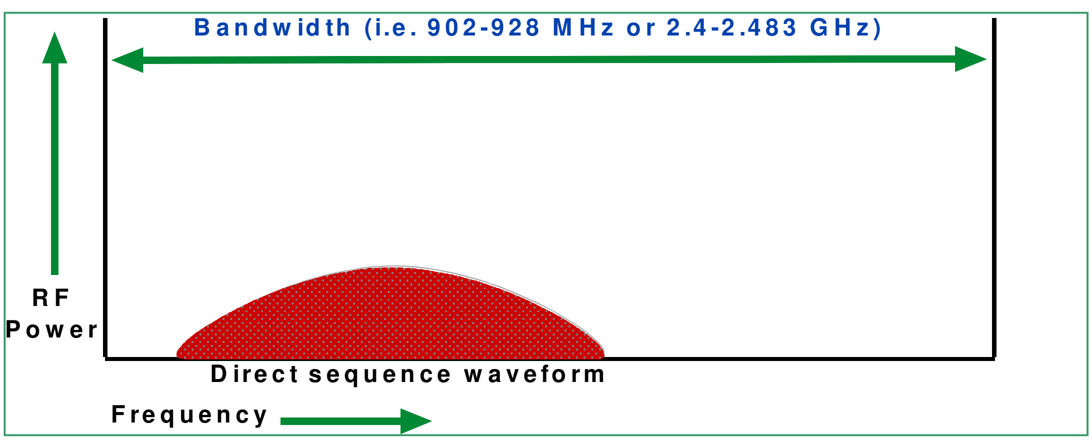

Figure 1. Direct Sequence Waveform

Direct Sequence offers the fastest spread spectrum data rates as the wide channel permits transmission of complex modulation schemes. *Orthogonal Frequency Domain Modulation* (OFDM) is a complex modulation technique capable of fast data rates and is used extensively in the IEEE 802.11g supporting RF data rates up to 54 Mbps.

Direct Sequence is the method used by all popular open Wi-Fi standards today including IEEE 802.11b, 802.11g (both transmitting in the 2.4 GHz band) and 802.11a (transmitting in the 5.8 GHz band). While the wide band modulation offers high speed, it also makes the RF system more prone to noise problems when multiple systems are operating in close proximity. For example, IEEE 802.11b has thirteen available channels (only eleven channels in some countries), but only three channels don't overlap (see Figures 2 and 3).

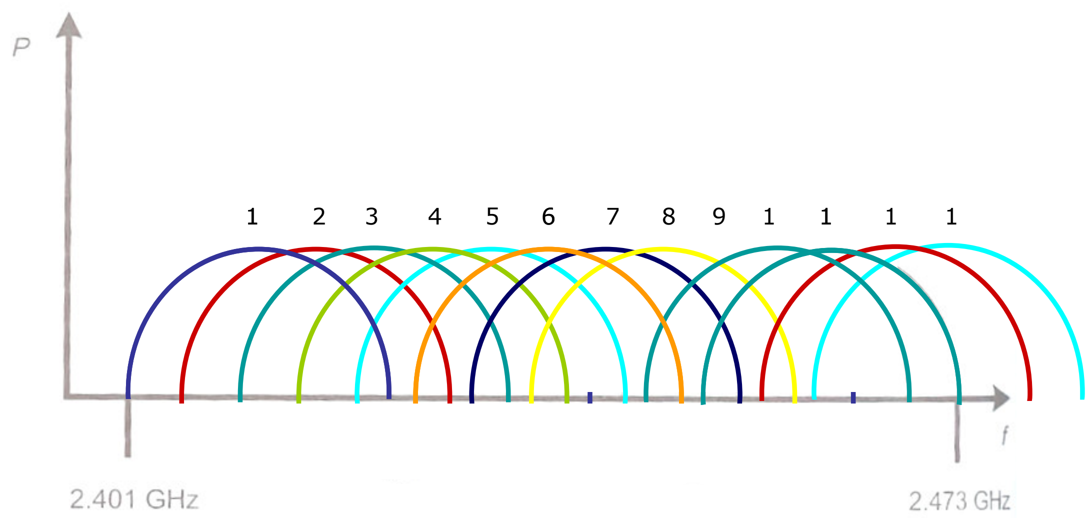

Figure 2. 802.11b Direct Sequence Channels

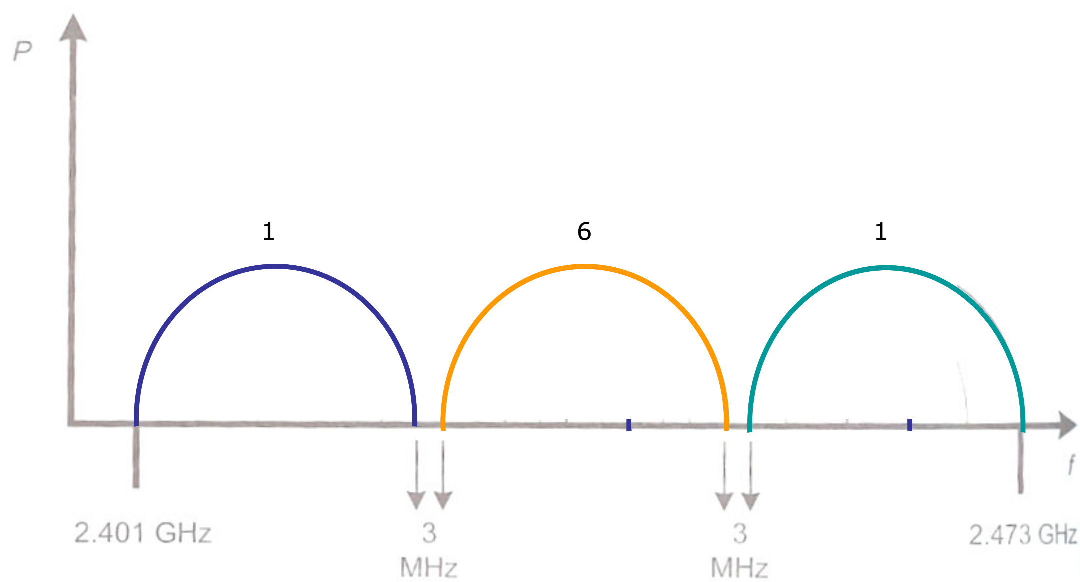

Figure 3. Non-overlapping 802.11b Channels

Due to overlapping channels and the popularity of Wi-Fi systems in plants, band over crowding and RF saturation can lead to poor wireless performance.

Frequency Hopping is a very popular technique for industrial systems because it has outstanding noise immunity techniques. Unlike Direct Sequence, Frequency Hopping uses many smaller channels in the spectrum and rapidly changes channels or "hops around" from channel to channel (see Figure 4).

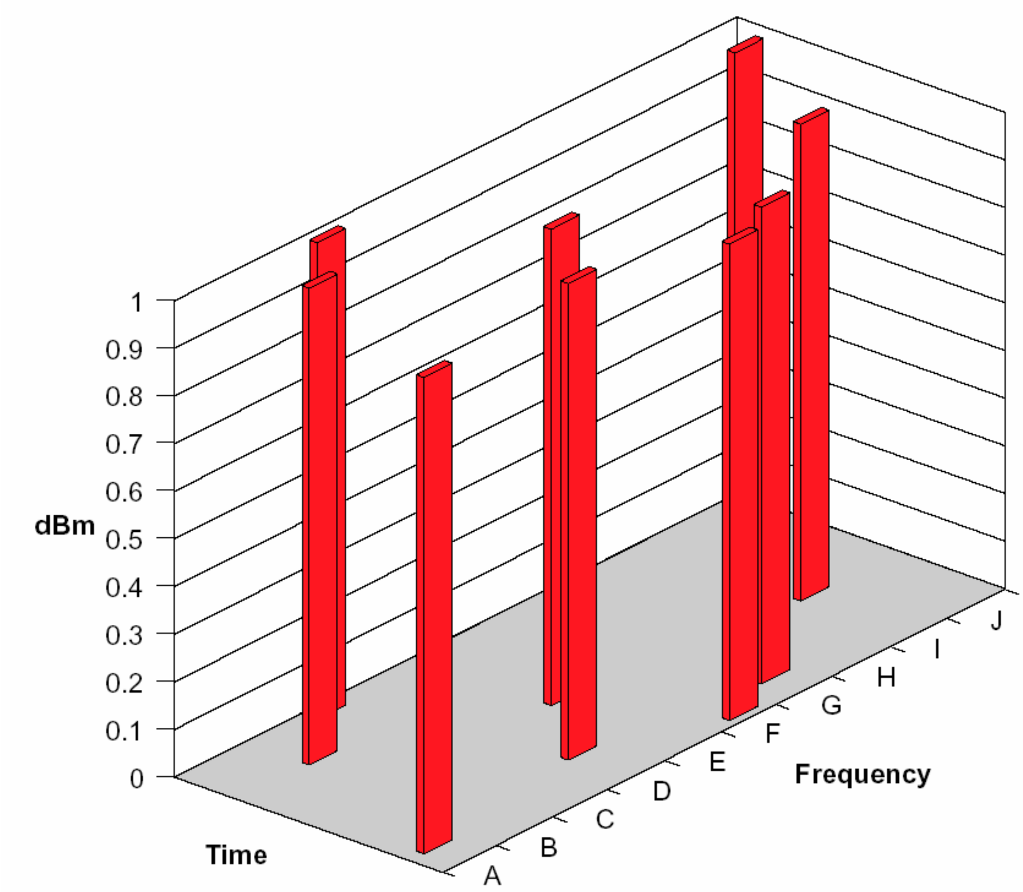

Figure 4. Frequency Hopping Channels

By incorporating error correction techniques, frequency hopping offers the best chance for successful data transmission as the transmitter will send the packet over and over again *using different channels* until an acknowledgement is received.

The disadvantage of Frequency Hopping is that it is slower than Direct Sequence and has longer data latency. Most Frequency Hopping systems are limited to 1 Mbps or less RF data rate. But if the data rate is fast enough for the application, the reliability of frequency hopping is tough to beat especially if more RF systems will be added in the future.

Frequency hopping modems are proprietary, meaning that each manufacturer uses their own technique and vendor X will usually not communicate with vendor Y. While this is potentially a disadvantage for commercial systems, it can be desirable for industrial systems for two reasons: Security and isolation from the wireless IT system.

Because the frequency hopping technique is not based upon an open standard, the manufacturer can use unique authentication processes and sophisticated encryption techniques. While security has significantly improved in Wi-Fi systems with WPA and WPA2 standards, hackers will continue to look for holes. Many industrial Wi-Fi manufacturers now include an option to hide the access point by not transmitting its SSID beacon. This technique is effective at hiding the access point from potential hackers.

Frequency hopping also offers plant managers the ability to operate their own wireless network separate from the IT department. Because of the popularity of 802.11 technologies for wireless network access, warehouse barcode systems and video surveillance, proprietary frequency hopping systems may be the best choice for industrial systems and keep the peace between department managers.

Wireless and Condition Monitoring Integration

Most condition monitoring systems have an Ethernet communication option for network connectivity. Ethernet is the most easily adaptable interface for wireless if two considerations are observed: Data rate (bandwidth) and data latency.

These considerations especially come into play when multiple remote machines are monitored. It is important to design an RF network that effectively reaches all remote sites while maintaining adequate data rates. If the number of remote machines is high, then it may be best to install separate RF systems to maximize the performance of each system.

Machine locations and building structures will determine antenna placement and may be another reason to consider multiple RF systems. Many industrial systems also support packet repeating to aid in RF signal propagation while also creating self-healing meshes.

Finally, it is very important for the wireless equipment to be designed specifically for industrial installations. Key specifications to examine are RF power output (higher is usually better), operating temperature, built-in diagnostics, hazardous certifications (if necessary) and, perhaps most importantly, the support staff's level of industrial networking knowledge.

Wireless Condition Monitoring Application Examples

Remote condition monitoring can benefit just about every industry where electromechanical machines are vital to production. Several applications where wireless condition monitoring is particularly effective include monitoring of pumps in wastewater treatment plants, drives used on oil/gas drilling rigs, drives on assembly lines in automotive plants and overhead cranes in hot metal mills.

One particularly interesting application is power plant cooling fan monitoring. A coal fired power generation plant wanted to monitor their cooling fans located at the base of their cooling towers. The cooling fans are mounted in very harsh areas where hot steam is always present. When a fan would fail, the tower had to be shutdown to allow a technician to repair, thus reducing the power output of the plant, sometimes during peak demand periods. By installing the condition monitoring system, the plant would be able to schedule fan repair during non-peak shutdowns.

The condition monitoring system was relatively easy to install, except that the towers lacked Ethernet network infrastructure. The cost of pulling fiber optic cable was estimated at over $100,000 and would take more than six months to install.

The power plant investigated using wireless Ethernet and discovered that it would only cost a small fraction of fiber, and could be installed within three weeks. The installation went very smoothly and the system has been reliably operating for over five years (see Figure 5.)

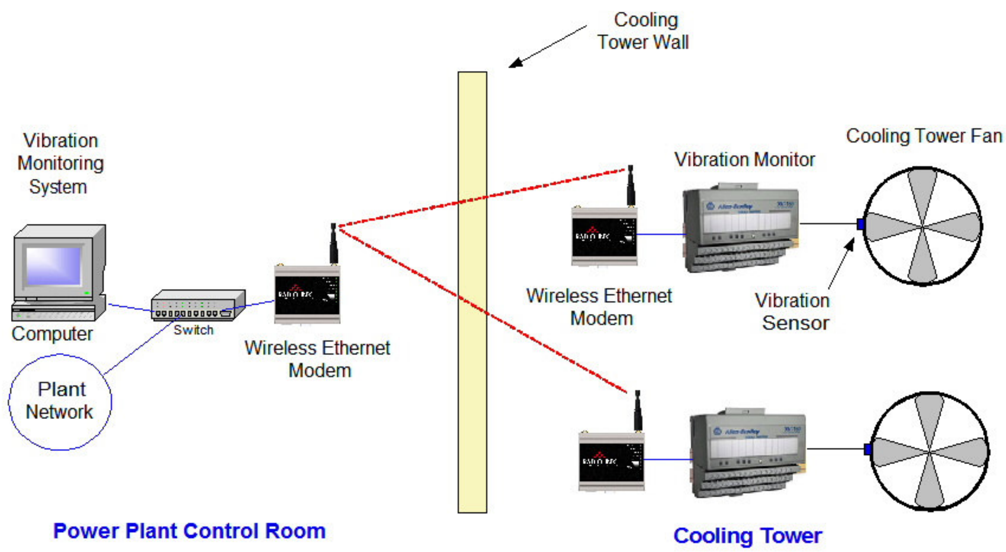

Figure 5. Wireless Cooling Tower Application

Summary

Advances in vibration analysis have lead to modern condition monitoring systems that can significantly improve plant production. Unfortunately, the costs of networking these devices can be very high or impractical. Industrial wireless technologies offer an alternative to hardwired networking and can result in lower costs and better reliability. Care must be taken, though, to choose the best technology and wireless hardware to insure a successful system.

About the Author

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