Using Wireless Networking and Remote Sensor Monitoring in Pivot Irrigation

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Abstract. As the automation of both private and corporate farms is embraced, the use of sophisticated pivot irrigation systems and smart agriculture practices is readily being adopted. Many new telemetry technologies are available today. It is common to have 100 percent communication to all farm pivot locations and see data throughput from pivot sites of 19.2 kbps up to 115.2 kbps.

The latest telemetry trend is "wireless instrumentation" or the ability to control or monitor analog and digital signals without the constraints of wire. These signals may be used to communicate to and from the pivot to the farm to check moisture and temperature sensors, chemical soil samples, wind speed for the best time to water, the actual pivot location and pump power usage. This capability, together with Internet access, allows the entire pivot system to be viewed anytime via a smart telephone. The farm can remotely operate the pivot system, report and view status changes, and see the remote sensors' status. Until recently, all these field devices had to be hard-wired or use expensive cellular or satellite hardware. Now they can be done wirelessly utilizing spread spectrum 900MHz or 2.4GHz radios that have input and output control functions built right in. Some licensed VHF or UHF radio systems also offer IO options.

This paper reviews the advantages of using non-fee-based wireless networking and remote monitoring to more affordably, effectively track and report on pivot irrigation farms. It offers examples with pros and cons between traditional and newer approaches.

Kewords. Pivot irrigation, wireless networking, remote monitoring, spread spectrum, instrumentation.

Introduction and Background

Figure 1 - AmWest, Inc. installing pivot control box.

As the automation of both private and corporate farms is embraced, we see the use of sophisticated pivot irrigation systems and smart agriculture practices due to new technologies (see Figure 1). The human imagination continues to create new ways to use this technology and push those technology providers for more powerful tools. Ten to 15 years ago, even the most advanced automated pivot systems seldom used telemetry, and, if they did, the data throughput was extremely slow and seldom provided coverage to all the pivot irrigation sites. Some of the wireless technology also was expensive. Therefore, the telemetry technology was difficult to use effectively because only some sites could be remotely monitored or where farms were paying by the data byte or monthly usage fees to the technology provider.

With many new telemetry technologies available today, it is common to have 100 percent communication to all farm pivot locations and see data throughput from pivot sites of 19.2 kbps up to 115.2 kbps. Additionally, high speed backbone telemetry is available with both serial and Ethernet connectivity with speeds close to a megabit per second range. With the use of IP wireless devices, MPEG4 IP Ethernet cameras can be added to the system for remote viewing of the pivot system and to check on the field crop or farm conditions. In addition, hybrid wireless systems can be utilized where needed to combine different wireless technologies over large geographic areas or remote locations. This can include both cellular, satellite and microwave products that can be deployed for remote areas, or if a higher speed backhaul of data is required.

Figure 2 - Automated pivot irrigation SCADA system software by Reinke Irrigation

New radio products keep shrinking in size - but are getting smarter and most have both serial and Ethernet data interface options. Hybrid systems that use a mix of technologies is common as well, and can help save costs by using one technology that has monthly costs or fees and piggy-backing on to that network with a license-free system that can collect all the data from the local pivot irrigation sites back to that location. The use of GPS tracking devices is quite common to help with the location of the trailing end sprinkler on the pivot line and this information can be displayed on a computer screen or a PDA phone.

SCADA definition – Supervisory Control and Data Acquisition

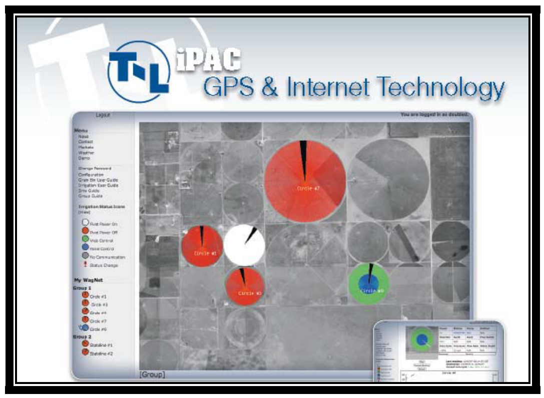

Figure 3: T-L Irrigation iPAC Control system


Figure 4: Lindsay Irrigation Field NET Software

The latest telemetry trend is "wireless instrumentation" or being able to control and/or monitor analog and digital signals without the constraints of wire. These signals may be used to communicate to and from the pivot to the farm to check moisture and temperature sensors, chemical soil samples, wind speed for the best time to water, the actual pivot location and pump power usage that can be viewed anytime. The capability with Web Internet access allows the entire pivot system to be viewed via a smart telephone or the user can look at a Website anywhere to have access to all the data and view the pivot irrigation system remotely. With this technology, the user of the farm can remotely operate the pivot system, report and view status changes, and see the remote sensors' status. Until recently, all of these field devices that had to be hard-wired, or use expensive cellular or satellite communication hardware, now can be done wirelessly and without any cost to the user using unlicensed spectrum with "spread spectrum 900MHz radios." These radio products also can have input and output control functions built right in or can integrate into a remote terminal unit (RTU) or some other type of control device. One way they can send this information from the sensors to the host is using standard Modbus protocol and assigning Modbus registers to the field input devices.

Several pivot irrigation companies offer some type of wireless communication service that might include cellular, satellite, unlicensed or licensed radios or a combination of two technologies, depending on the farm location. The use of these wireless devices allows farm managers to view the operating status of the irrigation system, how much water is being used, the power consumption, and weather and soil conditions. Web-based programs allow access to this information from anywhere in the world as long as users have Internet access and the information can be displayed on PDA type cellular phones.

Some of the management tools that have been in the market place for a while include OnTrac from Rienke Irrigation, iPAC from T-L Irrigation (see Figure 3), Remote Tracker from Valley Irrigation, Field Net from Lindsay Corporation (see Figure 4) and Control Master from Pierce Irrigation (see Figure 5), to name a few. Some use their own software packages or web interfaces and others use off-the-shelf SCADA software, like Wonderware, Citect or Intellusion that can be customized specifically for each user and is fairly inexpensive. The use of field sensors and weather monitors is another way to optimize and ensure that the correct amount of fertilizer, water and time of watering is applied.

The use of wireless has created an influx of technology that has impacted the speed, size and variety of devices that can be embedded into the controllers, sensors and remote devices that have very small power requirements and can run off small lithium batteries or small DC power sources. The new wireless products have become smarter and have the capability to work in several different field environments. Along with all the new wireless products, there are several new antenna options available today that can help with difficult antenna mounting locations, constrained space, and variety of gain and antenna patterns.

Wireless devices with IO (input and output) capability are common, and analog and discrete information can be sent back and forth from the radio to the host or SCADA software. The most common way of doing this is using Modbus protocol and assigning Modbus register values to the input and output required. (see Modbus definition) These devices include pressure, temperature, flow sensors or valves that can be remotely turned on or off. Pump status and GPS coordinates can be carried back to the host computer and displayed with the SCADA software.

Figure 5 – Pierce Irrigation Control Master software and controller

History of the Modbus protocol

Some communication standards just emerge. Not because they are pushed by a large group of vendors or a special standards organization. These standards—like the *Modbus interface*—emerge because they are good, simple to implement and, therefore, are adapted by many manufacturers. Because of this, *Modbus* became the first widely accepted fieldbus standard.

Modbus established its roots in the late 1970's. In fact, it was 1979 when PLC manufacturer Modicon—now a brand of Schneider Electric's Telemecanique—published the Modbus communication interface for a multidrop network based on a master/client architecture. Communication between the Modbus nodes was achieved with messages. It was an open standard that described the messaging structure. The original Modbus interface ran on RS-232, but later Modbus implementations used RS-485 because it allowed longer distances, higher speeds and the possibility of a true multi-drop network. In a short time, hundreds of vendors implemented the Modbus messaging system in their devices and Modbus became the de facto standard for industrial communication networks.

The great thing about the Modbus standard is its flexibility, but, at the same time, it also is the ease of implementation and use of it. There are intelligent devices, like microcontrollers, PLCs, etc. that is able to communicate via Modbus, but many types of sensors that have standard analog or discrete outputs can send their data to host systems. While Modbus previously was used on wired serial communication lines, there also are extensions to the standard for wireless communications and TCP/IP networks.

Modbus Message Structure

The Modbus communication interface is built around messages. The format of these Modbus messages is independent of the type of physical interface used. The same messages used on *Modbus/TCP* are the same as on plain old RS232 over Ethernet. . This gives the Modbus interface definition a very long lifetime. The same protocol can be used regardless of the connection type. Because of this, Modbus allows users to easily upgrade the hardware structure of an industrial network without the need for large changes in the software. A device also can communicate with several Modbus nodes at once, even if they are connected with different interface types, without the need to use a different protocol for every connection.

Figure 6 -- AmWest, Inc. installing the Pivot Controller with 900MHz Radio

Center Pivot Innovators

Even before the first patent on center pivot technology ran out, **Valley Manufacturing** (later named **Valmont Industries**) had competitors. Lawsuits often followed, but the competition pushed innovation forward. Valmont is headquartered in Valley, Neb.

The Raincat. By 1959, an Australian company had modified the basic Valley approach and produced a center pivot system called the Grasslands. It featured many innovations that would become the standards for the industry in the future. The machine had electric motors to drive it (rather than water drives) and a truss system under each pipe span to bow and support the pipe (rather than overhead cables). A California pump manufacturer, Layne and Bowler, brought the system to America, put rubber tires on it and renamed it the Raincat. But California farmers didn't need center pivots as badly as farmers on the Plains. So, the company went through several ownership changes, eventually landing in Greeley, Colo. Raincat went out of business in the early 1980s.

Reinke. Richard Reinke was a Nebraska farmer's son who taught himself to be an engineer and draftsman. In 1954, he started Reinke Manufacturing in Deshler, Neb., and introduced his first center pivot system in 1966. To avoid infringing on Valley's patents, Reinke had to come up with new ideas, and he did. He was the first to make his electric drive systems reversible, so that a farmer could back the system up. He was the first to put his electric motors in the middle of each tower base and connect drive shafts to the gearboxes on each wheel. He was the first to patent the "bow-string" truss system under the pipe spans that most pivots use now. He was the first to use a electrical "collector ring" to transfer power from the pivot point down the spans so that a wire wouldn't wrap up as the pivot went around and have to be unwrapped after each revolution. In all, he patented more than 30 innovations for center pivot designs. Richard Reinke died in 2003 at the age of 80, but his company is still operating in Deshler. They've diversified into building trailers and chassis equipment for over-the-road trucks.

Lindsay. Lindsay Manufacturing is based in the small Nebraska town of the same name where Paul Zimmerer and his two sons set up shop in 1958. First, they made tow-line irrigation systems. Ten years later, they came out with their first center pivot system under the name "Zimmatic." Because the terrain around Lindsay was hilly, they introduced a "uni-knuckle" joint at each tower instead of the ball-joint that other builders used. This allowed the Zimmatic to move over very rough hills and valleys. They also used an external collector ring – instead of Reinke's internal ring – to transfer electrical power down the system. The company grew fast, and in 1974 the Zimmerers sold out to DeKalb AgResearch. But the family continued to operate the firm. Finally, in 1988 the company again went independent through an over-the-counter stock offering.

T-L Irrigation. Leroy Thom was a Hastings, Neb., area farmer who had tried his hand at everything from custom combining to irrigation engineering. In 1969, he and his two sons, Dave and Jim, decided they could improve on the other center pivot designs by using hydraulic motors on each tower. Hydraulics would enable their systems to move around the field at a constant rate rather than starting and stopping at set intervals. The company claims that their systems are more reliable, can be fixed by farmers who are used to hydraulic systems and apply water more evenly. Today, T-L Irrigation employs more than 250 people in Hastings.

Lockwood Corporation actually started in 1935 in Gering, Neb., to produce potato-farming equipment. In 1969, it decided to get into the irrigation business and bought a small Texas firm that was making the "Hydro-Cycle" pivot system. It moved the operation to Gering and completely redesigned the system. It became one of the five largest manufacturers of center pivot systems. In the late 1990s, the company went through ownership changes and is now known as Universal Irrigation Company, although the systems are still marketed under the Lockwood brand name.

AmWest, Inc. is located in Ft. Lupton, Co. For more than 25 years, AmWest has delivered full-service water equipment strategies, technology, installation, maintenance and expertise to its customers primarily through out the Rocky Mountain region, but also on a global scale (see

Other Innovators. Over the years, there have been more than 80 individuals or companies who have tried to make and sell center pivot systems. Some of the smaller companies were bought by the giants. For instance, when Valmont realized that farmers saw an advantage in the undertruss system to support the spans, they bought out a small company in Grant, Neb., that was building an undertruss system.

Other small companies started up, fought for market share for a while and migrated to other businesses.

Kroy. In York, Neb., a car dealer named Paul Geis had a small business making irrigation pipe and began making center pivot systems in 1968. He marketed the systems under the name of "Kroy" – York spelled backward. But his compressed air drive system didn't really catch on. Geis sold the center pivot business to a well driller in Sidney, Neb., who quit the business in the late 1970s. Geis continued to manufacture aluminum and PVC pipes and fittings for industry, construction and other irrigation methods.

Oasis. Just down the road from York in Henderson, well driller Gus Thieszen took his own chance in the center pivot business in the late 1960s. Thieszen brought out his "Oasis" model center pivot then, but the system never really caught on. He stopped manufacturing the system after only a few years. He was one of scores of Ag innovators who tested the market and had to fold up their enterprise.

Pivots Go Worldwide. Today, only six center pivot manufacturing companies remain, and the four largest – Valmont, Lindsay, Reinke, and T-L – are in Nebraska. Wade Rain and Pierce Irrigation are in Oregon. On this "Then & Now" page, today's center pivot market is outlined in www.livinghistoryfarm.org.

Also, Robert Daugherty remembers how the worldwide market for Valmont pivots just seemed to develop as news of the innovation spread around the agricultural community. The other manufacturers saw similar interest, but worldwide market challenged some of the smaller manufacturers.

Ref: http://www.livinghistoryfarm.org/farminginthe50s/water_05.html

Figure 7 and Figure 8 – AmWest, Inc. installing a control box with a 900 MHz Spread Spectrum Radio

Conclusion

The use of wireless products will continue to grow. With commercial farms trying to conserve water resources, manage power use, have access to the health of the pivot system and handle the crops that grow at anytime and anywhere - they will need more wireless technology. The bandwidth requirements will increase too, and other IP devices will be added and be more common place. New embedded products will help save costs and be part of the system instead of being an after thought. The use of different radio frequencies, field sensors, faster connection speeds and other wireless products will continue - software and other services will help the farm and farmer have all the information they need at their fingertips (see Figure 9 and Figure 10).

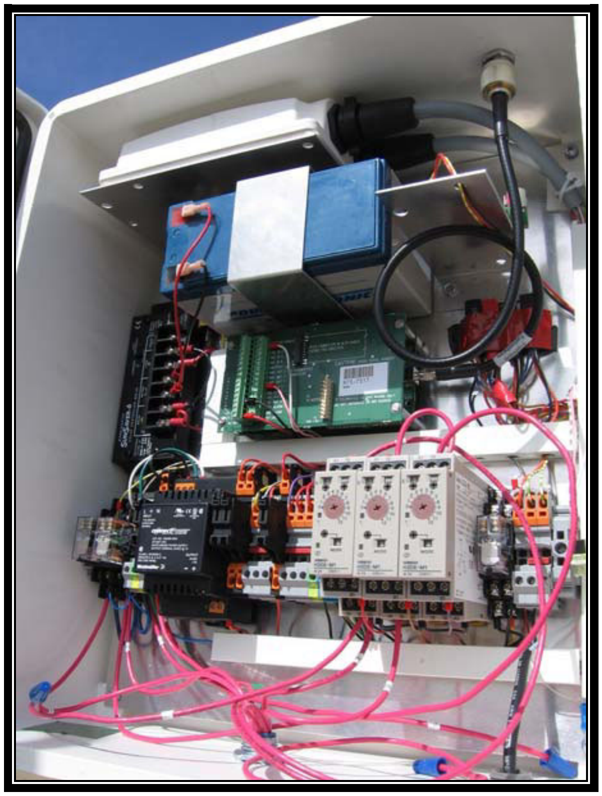

Figure 9 -- Master RTU/ Controller and 900MHz Radio that communicates to each pivot control box at the Farm.

Figure 10 --New variable frequency drive for the pivot irrigation water pump that will save energy costs and help prolong the Pump life.

Acknowledgements

I appreciated the opportunity I had to visit with all of the Pivot Manufacturers and for all the engineering, skills and hard work that it takes to manufacture Pivot Irrigations systems and many are installed all over the world. We have many arid places on earth that irrigation is the only way Farmers can grow crops and produce. I also want to express gratitude to AmWest Controls for the resources, pivot irrigation experience and actual field photo's. Finally, for Wessel's Living Farm in York, NE. I applaud their efforts, resources, farm information and the work they do for the preservation of rural farm life in America.

Wessels Living Farm
5520 South Lincoln Ave.
York, NE 68467 (Just south of Interstate 80 and US Highway 81)
It's open each Wednesday (excluding holidays) for tours, or by special appointment.

Founded in 1993, FreeWave Technologies manufactures the most reliable, high performing, lowest power consumption, spread spectrum and licensed radios for mission-critical data transmission. Through engineering excellence and a relentless commitment to best-in-class manufacturing, FreeWave customers enjoy superior radio up-time, range and the lowest cost of ownership available. Based in Boulder, Colorado, FreeWave designs and manufactures radios that are the leading choice for oil and gas, utility, military and numerous other industrial applications. Organizations that count on radio data communications for operational success – where failure and down-time are not an option – trust FreeWave for custom network design, system engineering and customer support that is unparalleled in the market. For more information visit the company's website at www.freewave.com.

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