Spread spectrum communications for oil & gas operations:
Radio technology offers new SCADA options for reliable data transmission

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As oil and gas companies work toward greater automation and adopt more e-business solutions, the challenge of getting real-time, reliable data from remote locations continues to be a significant hurdle.

Today, the technology for electronic flow measurement (EFM) and remote terminal unit (RTU) equipment is well-established. There are also powerful software products available for archiving, auditing, and displaying the collected data. The single biggest problem remains communications: It's commonly believed that over 80% of SCADA problems result from communication failures.

To complicate things further, the licensed radios that have been the backbone of SCADA and telemetry systems are no longer always an option. For example, in many areas of the United States, no more licenses are available. Because of the saturation of existing licenses, the US Federal Communications Commission (FCC) has re-farmed licenses to create smaller broadcast areas, less bandwidth, and smaller frequency-variations allowances.

Spread spectrum emerges as SCADA solution

A few years ago, a new SCADA radio medium – spread spectrum – became available. These systems operate on a shared frequency, offering many advantages and new versatility to SCADA operators.

All spread spectrum radios share the band from 902-928 MHz, or the 2.4-2.4835 GHz band. And now, a new spread spectrum frequency is being released at 5.7 GHz. It is important to note that the higher the frequency, the less forgiving the communication path. This is to say that the higher the frequency, the more potential for problems resulting from trees, hills, and buildings – at the higher frequencies, even weather can affect the signal.

Two types of spread spectrum radios are in industrial use today: "direct sequence" and "frequency hopping". Both technologies employ digital packet data. The data packet size is often user-configurable, and can range from 9 to 100 bytes/packet. The frequency hopping radios change their frequencies between two and several hundred times per second, sending one packet on each frequency. It is critical that all radios in a network be synchronized to hop to the same frequencies at the same time, and in the same order.

When spread spectrum first became available, the transmit range of these radios was very limited – usually no more than two miles (3.2 kilometers). But, as with many innovations, the demand from industry coupled with technological advances led to a radio product that can, in some instances, communicate over 60 miles (96 km) without a repeater.

Information requirements

In the oil and gas industry, custody-transfer data is mission-critical information. Data loss or corruption is unacceptable.

In conventional licensed radio systems, the data is acquired through a polled response. A host computer polls its slave, and requests the accumulated data. Many of these systems are limited to baud rates of 9,600 or 4,800 bits per second.

In contrast, spread spectrum radios can be set to talk to a host computer or EFM at speeds of 115K baud (approximately 12 times faster than a 9,600-baud connection). And because the speed of the end device and the radio-over-the-air speed are independent. spread spectrum networks can communicate radio-to-radio at speeds of 188K baud, regardless of the RTU or EFM port speed setting.

- With some spread spectrum radios, each device in the field could theoretically be set to different baud rates, and the system would still operate normally. In today's need-to-know economy, speed of polling time can be critical to the success of a SCADA system. In many applications, alarms and gas flow data are being gathered over the same radio network. The faster a network can gather data, the more versatile it becomes: When you have high-speed radios, you can bring back larger files, or poll more frequently.
- Some spread spectrum radios can bring back real-time alarms during a polling cycle. The alarm packet slides through on the hopping cycle between packets of flow data. High-quality spread spectrum radios can enable store and forward operations. In effect, the radio can act as a repeater, buffering data from other radios to be forwarded on the host.

Licensed radios are limited to one repeater per network. This repeater is actually two radios tied together: one radio talks to the host, while the other talks to the slave sites. Every slave site must be able to transmit to the one repeater. If the slave cannot see the repeater, this site will not report into the telemetry system, and its information must be hand collected.

On the other hand, each spread spectrum radio in a network is capable of acting as a repeater. Some spread spectrum radios support an unlimited number of repeaters in the network. This feature allows an end-user to transmit data around hills and mountains, or down into valleys, by using a wireless "daisy chaining" of radios. In some models, repeaters may also function as slaves and repeaters at the same time, enabling repeaters to also be used as data-collection points. These features can reduce system costs by allowing operators to use fewer radios to accomplish the same task.

Data errors and communication failures

In a licensed radio system, the master polls the slave at the request of the host, and the software at the host is responsible for re-polling if it receives no response. Many RTUs and EFMs are able to signal if they enter alarm conditions, but most do not know if the master has actually received their alarm. Additionally, in areas where signal strength is weak, the slaves do not know if their data actually reached the master.

With spread spectrum networks, manufacturers have compensated for these potential problems in several ways. Some spread spectrum radios are able to do "smart retries" and send message acknowledgements.

- When a slave's message is sent to the repeater, the repeater acknowledges that it received the message, and instructs the slave to go into idle mode.
- The repeater is now responsible for sending the message to a higher level: That level may be another repeater, or the master radio. This repeater will continue trying until it receives an acknowledgement from the next radio in the network.

With licensed systems, the receiving radio has no knowledge about whether the data it receives is corrupted. Spread spectrum radios can detect errors in the transmitted data, using one of two methods for handling data errors.

1. FER (forward error correction). This is an algorithm designed to correct errors based on the mathematical probability of what the data should have been. The problem with FER is that as

signal strength fades, there is a point at which more of the data is corrupt than correct, and you may actually introduce errors into the data by trying to do correction.

2. Check sums. The second error-handling method is 16- or 32-bit CRC check sums. With this method, each data packet is analyzed by the receiving radio to ensure that all of the transmitted data has actually arrived, remained intact, and was received in the correct format. If a problem is detected, the receiving radio calls back to the sending radio and requests a retry. The advantage with CRC check sums is that you have a true digital device – it receives either error-free data, or receives nothing.

System design

An important step in choosing radios is engaging someone qualified to assist in the design, installation, and implementation of your radio network. Collecting the necessary GPS (global positioning system) coordinates is another important task for satisfactory system design.

Next, each required radio link should be plotted using "path study" software. Novices often believe that their proposed links "are no problem," or "cover a short distance across flat ground." But too often, in reality there are 50+ feet (15 meters) of elevation change, in the form of a hill between sites, and the antenna height is 10 ft (3 meters) on each end – making a successful radio system design much more challenging.

After establishing the individual links, the entire network should be designed to be as robust and reliable as possible. Software enables designers to preplan the location of repeaters, slave sites, and slave repeaters (EFM sites where a radio is acting as both a repeater and a slave). The software should be capable of providing aerial views of the topographical area to be mapped, and topographical cross-sectional views of the individual links.

Several commercial software packages support analysis of signal strength between links, and help determine the necessary antenna heights and antenna sizes needed to ensure communication. Preplanning the location of repeaters will save hours of frustration during installation.

System operation

Modern spread spectrum radios are reliable and relatively low-maintenance. A key challenge is that EFM, RTU, and radio applications in the oil and gas industry require electrical power; lightning protection; and water-, dust-, and insect-proof environments; often at very remote locations.

Good spread spectrum radios are designed to accommodate low power requirements, have built-in surge protection, and are UL (or CSA) Class I Div II approved. Yet no communications device is likely to withstand a direct lightning strike. When choosing a radio provider, look for a manufacturer providing a long warranty period and low-cost, no-hassle replacement for radios that are damaged by lightning or acts of God.

Most spread spectrum radio manufacturers provide diagnostic software allowing users to monitor an entire network from the host computer. Some diagnostic programs can actually be run while the system is polling for data, because the diagnostic packets slip between the data packets. And since the over-the-air transmission rate is 188K baud, this is transparent to the user. Good diagnostic software will allow a technician to:

- Find out if a radio is receiving and transmitting,
- Check the temperature and battery voltage of a radio,
- Measure signal strength and background noise level, and
- Access other important radio features.

Most host software packages will generate alarms if data is not received at predetermined times, notifying the technician to run diagnostics. The spread spectrum radios can easily be maintained by field technicians who are familiar with normal RTU or EFM operations. These radios can be configured, installed, or replaced in a few moments, using a laptop computer and a screwdriver. Many radios require only a four-wire connection, for power, ground, transmit, and receive.

One of the most troublesome problems with licensed systems is the "chirping radio." This refers to a radio that hangs up in transmit mode, and holds the frequency hostage by remaining in a continuous broadcast mode. No other radio can communicate while this radio holds the frequency, so no EFM reports are possible, and no alarms can come in. It is almost impossible to determine the location of a "chirping" radio without driving to every location and unplugging each radio until the system becomes free.

In contrast, spread spectrum radios do not "chirp," because they are hopping on many different frequencies. It is possible for an RTU or EFM to hold the radio "high," meaning it is being told to continuously broadcast. By using appropriate diagnostic software, this radio can be easily located and isolated from the host computer, and taken off line remotely, thus eliminating the need to drive to every location for diagnosis.

Licensed radios were designed to operate in an interference-free environment. When they do encounter interference, data can be lost or corrupted. In today's SCADA world, because the licensed frequencies are already occupied in many areas, there are increasing odds that interference will occur. Spread spectrum radios are designed to handle interference, and to operate in an atmosphere where they must share the frequency.

Expected results

A well-designed spread spectrum radio system will generate reliable measurement data and send real-time alarms from remote locations. Generally, spread spectrum radios transmit at 1 Watt of power at the radio, which can be boosted to 4W of radiated power at the antenna.

Licensed radios are allowed higher output power (5 Watts at the radio), but this does not prevent problems inherent with that technology. On the other hand, spread spectrum devices can be used in multiple repeater patterns to provide equal or greater signal coverage over long distances. It is reasonable to expect spread spectrum to provide service that equals or exceeds the performance of licensed radios.

- Spread spectrum radios do not require licenses (which are unavailable in many locations), so there are no recurring fees or monthly service charges.
- These devices are faster, and allow quicker polling times than licensed radios.
- A network of spread spectrum radios will normally require fewer devices than a licensed radio system, because licensed radios require two radios to create a repeater. Many spread spectrum devices can be programmed to be a master, slave, repeater, or slave/repeater, allowing the operator to stock fewer spare parts and simplify repair or replacement.

Hybrid communication systems

One of the qualities that makes spread spectrum radios attractive to oil and gas operators is the ability to "tail-end" these devices onto other communication mediums. The two most common tail-end additions are: 1) adding spread spectrum to licensed radios, and 2) combining spread spectrum with CDPD modems.

In a licensed system, spread spectrum can be added by installing a licensed radio "back-to-back" with a spread spectrum device: This simply requires connecting the two radios with a hard-wire connection between their RS-232 ports. The end result is a licensed radio-to-spread spectrum repeater.

A tail-end connection to CDPD is also created by connecting the RS-232 ports of the two devices. This type of tail-end connection makes it possible to "jump" over hundreds of miles (kilometers) to a CDPD site from the host, and then to poll a group of sites in a given area on the spread spectrum system. Since all the radios are coming back to one CDPD, this means only one CDPD monthly charge for all of the sites. By purchasing one of the "all you can eat" menus for the single CDPD site, it is possible to bring back dozens of sites for as little as $50 per month in total cost.

Conclusion

Just as many tools are needed to build a house, many tools are needed to build an enterprise-wide communication solution. In challenging terrain, and in applications involving large numbers of EFMs or RTUs, spread spectrum is a robust, reliable alternative. However, satellite, CDPD, or landline might have advantages over spread spectrum in some cases.

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For data collection in the oil and gas industry, spread spectrum is relatively new. Only a few years ago, EFM was a new technology, and many operators would never have predicted the thousands of EFMs that are in use today. Similarly, some would never have envisioned the thousands of spread spectrum radios in use for collecting data in remote locations. Spread spectrum radio is the emerging communications solution.

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