REMOTE MONITORING OF ER PROBES USING A 900MHZ MESH NETWORK

Timothy H. Bieri
BP Exploration (Alaska), Inc.
CIC Group
900 East Benson Blvd.
Anchorage, AK 99519

Robert Steele
Rohrback Cosasco Systems
11841 East Smith
Santa Fe Springs, CA 90670

ABSTRACT

At Alaska's North Slope, existing fields span a large geographic area where three phase production fluids can cause severe corrosion. To monitor corrosion and provide feedback for the chemical mitigation program, electrical resistance probes connected to remote data collectors are installed at approximately 80 locations. Measurements are made on a four hour interval at each location, and data are collected during weekly site visits. A wireless remote monitoring unit utilizing a mesh network of 900 MHz spread spectrum radios was developed to collect data from the existing hardware and transmit it to a central location. In a pilot project, five remote monitoring units and one central unit were successfully deployed in the summer of 2005.

Keywords: remote monitoring, remote data collector, electrical resistance, digital network, mesh network, smart radio, data packets, frequency hopping, spread spectrum

BACKGROUND

BP Exploration (Alaska), Inc. is the operator of Greater Prudhoe Bay (GPB), which is one of several fields located along Alaska's North Slope (see Figure 1). GPB is a remote field that is spread across an area of ~400 mile^2 (1,036 km^2) with drill sites connected by a road network. Three-phase production fluids coming from wells are combined together and transported to separation facilities via flow lines. With 12% CO_2 and water cut in excess of 70%, sweet corrosion can be severe and is mitigated with continuous injection of corrosion inhibitor. Electrical resistance (ER) probes are used to monitor short term trends in corrosion rates on the flow lines and provide feedback to the chemical mitigation program. There are ~80 ER probes in service throughout GPB, making measurements on 4-

hour intervals. The data are stored in a remote data collector (RDC) and downloaded to a handheld unit once per week by a technician. The data are then uploaded from the handheld unit to a database where they are available for analysis.

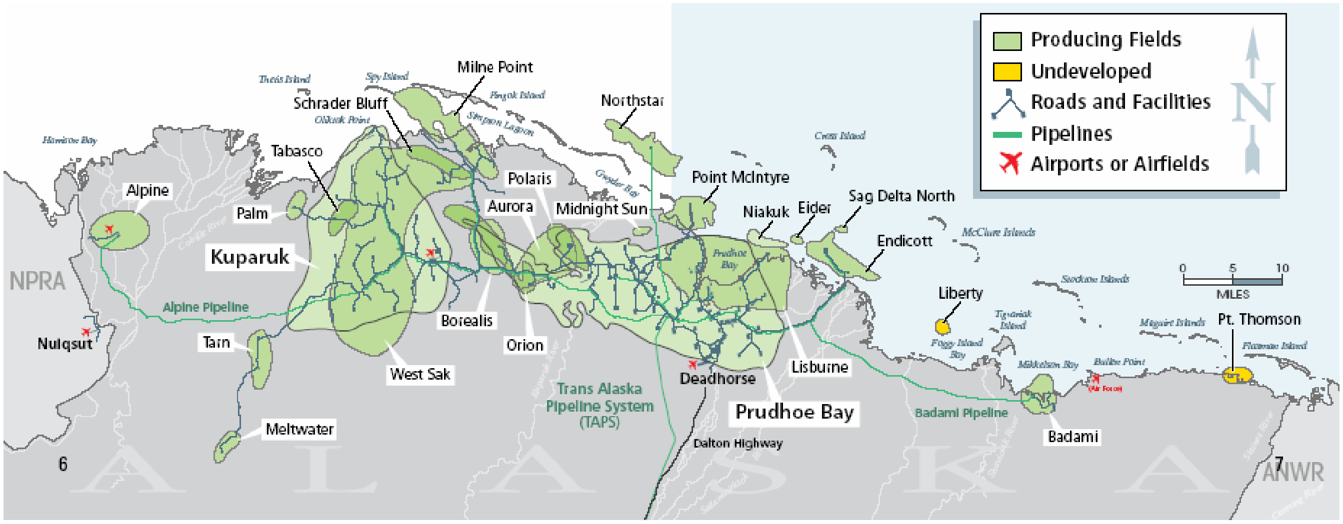

Figure 1 - Alaska's North Slope Oil Fields

The ER probe locations are typically remote from any power or communication infrastructure. This lack of infrastructure provided the reason to evaluate wireless remote monitoring technologies. The term "wireless remote monitoring" can have many meanings[1]; within the context of this paper it is considered a Class 5 network that has no immediate operational consequence.

WIRELESS REMOTE MONITORING REQUIREMENTS

General Hardware Requirements

Given the significant investment in existing hardware and training, designing a wireless solution that would interface with the existing hardware was one of the chief requirements. Secondary requirements for the new Remote Monitoring Unit (RMU) included:

- Reducing technician visits from once per week to once per quarter,
- Operating in an extremely remote and harsh environment,
- Providing power and control of a suitable communication device,
- Providing data logging capability (possible future use with other applications),
- Utilizing modular construction for ease of installation and maintenance,
- Operating from a field replaceable battery pack (or from an optional external power source),
- Providing secure data transmissions,
- Allowing remote reconfiguration of the hardware,
- Providing for system expansion or redeployment.

Selection of a Communication System

Central to the process of recovering data from remote locations is the communication system itself. In choosing the most appropriate communication system, a number of technologies were evaluated including two-way paging, cellular, satellite, and radio (VHF, UHF and microwave). Each of these options was assessed against a list of important selection criteria, including the following:

- o System reliability,
- o Maintaining data integrity,
- o Operating in remote areas, without the need for communication infrastructure,
- o Unrestricted volume of data,
- o Recurring communication fees,
- o Interference and compatibility with other nearby communication systems,
- o Operating at temperature extremes,
- o Power consumption,
- o Integration into the RMU,
- o Expansion capability.

Prior experience in using all of these types of communication systems helped make the selection of both the type of communication and the specific manufacturer easier. A series of “smart” radios utilizing 900 MHz digital spread spectrum frequency hopping to form a mesh network was determined to be the most suitable communication system meeting the selection criteria.

System Reliability: The top priority is network reliability. No single radio failure should be able to impact the network. The radio network is inherently robust because each radio operates as a node in a mesh (see Figure 2). Each radio operates with distributed network intelligence as a “smart” radio that can automatically and dynamically map its nearby neighbors and then route data via the most efficient path.

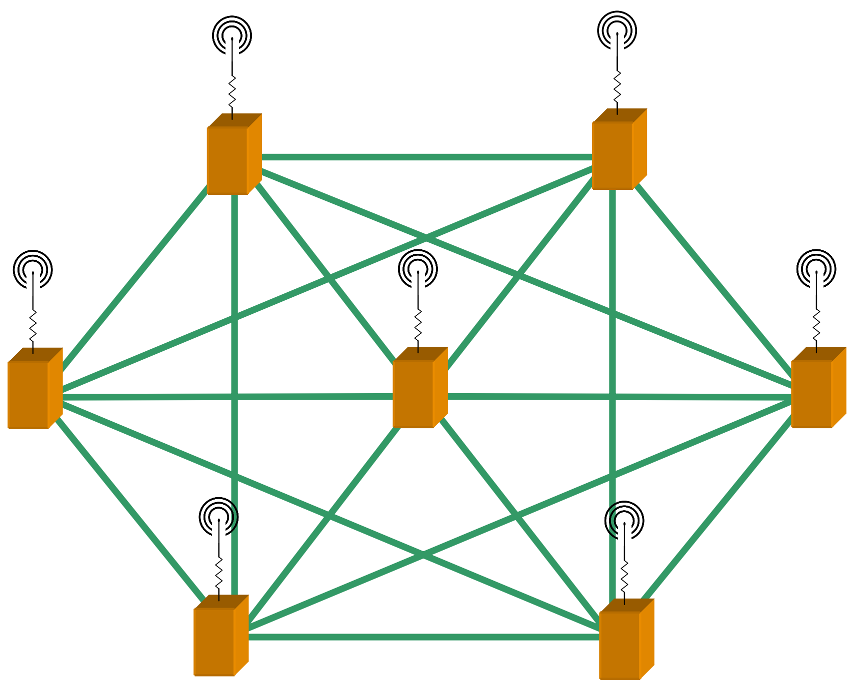

Figure 2 - Mesh network diagram

Data Integrity: At the start of each data transmission, the smart radio breaks larger pieces of data into smaller groups or “packets” of data. These smaller packets of data are transmitted to the destination and reassembled. Transmitting data in small packets improves transmission reliability.

Each radio also employs encryption security and error checking algorithms to further assure message integrity and data reliability.

Unrestricted volume of data: Beyond the limitation due to battery constraints, there is no restriction on the amount of data that the radio mesh network can handle.

Communication Infrastructure: Since the radios create a mesh network allowing communication from any point to any other point, there is no need for a communication infrastructure as is needed for cellular, paging, or satellite communications. Eliminating that communication infrastructure is important because common communication systems may be sporadic or even totally lacking in remote locations.

Communication Costs and License Fees: Monthly communication costs for a large network can be high. Eliminating communication infrastructure also removes on-going communication costs. This radio system has no monthly communication charges.

The 902-928 MHz frequency range is used worldwide for unlicensed industrial, scientific, and medical instrumentation (ISM). In a few countries, some of the frequencies in this range may be unavailable for general use, and the radios selected can be programmed not to use specific frequencies as required on a country-by-country basis.

Interference: The spread spectrum asynchronous frequency hopping technique allows simultaneous users of the frequency spectrum to coexist without interfering with each other and also without being interfered with by radios outside the network system. For many years, operating radios with the narrowest bandwidth possible was the target goal in order to minimize interference. Low cost digital radios operating for short periods of time on many frequencies (spread spectrum frequency hopping) allow many users to use the same frequency spectrum.

A pseudo-random frequency hopping technique guarantees that the next frequency is not near the prior frequency and allows each radio to use well-developed narrow bandwidth techniques. Since each frequency is used only for a very short time (less than 400 milliseconds), interference on that frequency is unlikely. However, should interference or noise block the data packet from being received, the radio network would detect the missing data and resend the packet, if need be by using different radios in the mesh network. Even in the presence of interference, data are not lost.

Integration into the RMU, power consumption, and operating at extremes of temperature: Battery power dictated that the communication technology use low power. The selected radio has low receive power consumption, is transmit-power limited by regulation, and is specified to operate over a wide range of ambient temperatures. To offset the low transmit power, high gain omni-directional antennas were planned for all locations, with each antenna mounted as high and as clear of obstructions as possible.

Expansion Capability: Because each radio can speak to and respond to neighboring radios, each radio is an equal participant in the network. Each radio can function both as an end device and as a repeater for other radios. Each radio employs automatic rerouting if a particular data path is unclear, and can automatically minimize the number of hops between radios. As the network expands with the addition of more units, the radios have more routing choices and the network becomes inherently more robust. This built-in scalability allows easy system expansion, including the option of repositioning units to meet new field needs.

Limitations: One inherent communication limitation of the radios is transmission range. While communications in the 900 MHz frequency range are “line-of-sight”, the ability for the radios to mesh minimizes this limitation since the each radio only needs to “see” another radio versus seeing the base radio. Preliminary signal mapping indicated transmission distances between 5 and 10 miles (8 to 16 km).

RMU Design and System Integration

A key part of the instrument design was the power source. Lack of available AC power dictated the need for an alternate power source. Wind driven sources were rejected because the various points being monitored were too far apart to share power, and having individual wind driven power sources for each of the many locations would be cost prohibitive. Indeed, the cost of providing a power source for many separate locations ruled out other options as well. While solar power could be utilized cost effectively at some locations, this project required year-round operation in the Artic region with long periods of darkness. As a result, battery power became the power supply of choice.

Long-term operation from a battery required balancing a number of factors, including available battery chemistries, shelf life (battery self discharge when disconnected), operation a very low temperatures (where some battery chemistries would freeze), change in battery capacity versus temperature, the amount of data being transmitted, how frequently data was being transmitted, and the nature of discharge peaks caused by digital radio transmissions.

A field-replaceable, multi-cell lithium battery pack was designed to provide a year's power supply with once per week data transmission, or six months with once per day transmissions. Batteries from multiple manufacturers were tested in an environmental temperature chamber using real RMUs to verify battery and RMU performance.

Key hardware features of the instrument design included:

- Operation over an extended temperature range, -40 °F to +140 °F (-40 °C to +60 °C)
- A NEMA 4X outer enclosure and a sealed electronics inner enclosure for environmental protection
- Multiple RS-232/RS-485 data ports for connection to the RDC, the radio, and a notebook computer
- An embedded microprocessor for overall control
- A real time clock for RMU wakeup (powered by an independent lithium backup battery)
- Non-volatile data storage memory
- DC to DC power conversion to power the radio

In addition, to allow for feature enhancements and changes in operation, the instrument was designed to allow field upgrades of the microprocessor firmware.

All of the data being transmitted was sent to a central location (Base Station), which consisted of an identical radio as used in the RMU, which was attached to a personal computer (PC). The PC ran custom developed software that received data from each RMU. This allowed the user to change the RMU reporting schedule, change the RDC configuration, and configure the received data into files to be merged with an existing database used for on-going corrosion analysis.

PILOT PROJECT FIELD DEPLOYMENT

Five remote units and one central unit were deployed during the summer of 2005. Refer to Figure 3 and Table 1 for locations and distances between units. The locations for these units were selected to provide a good cross-section of transmission distances, make use of known obstructions which would force certain radios to relay data, and provide general accessibility from the base station location.

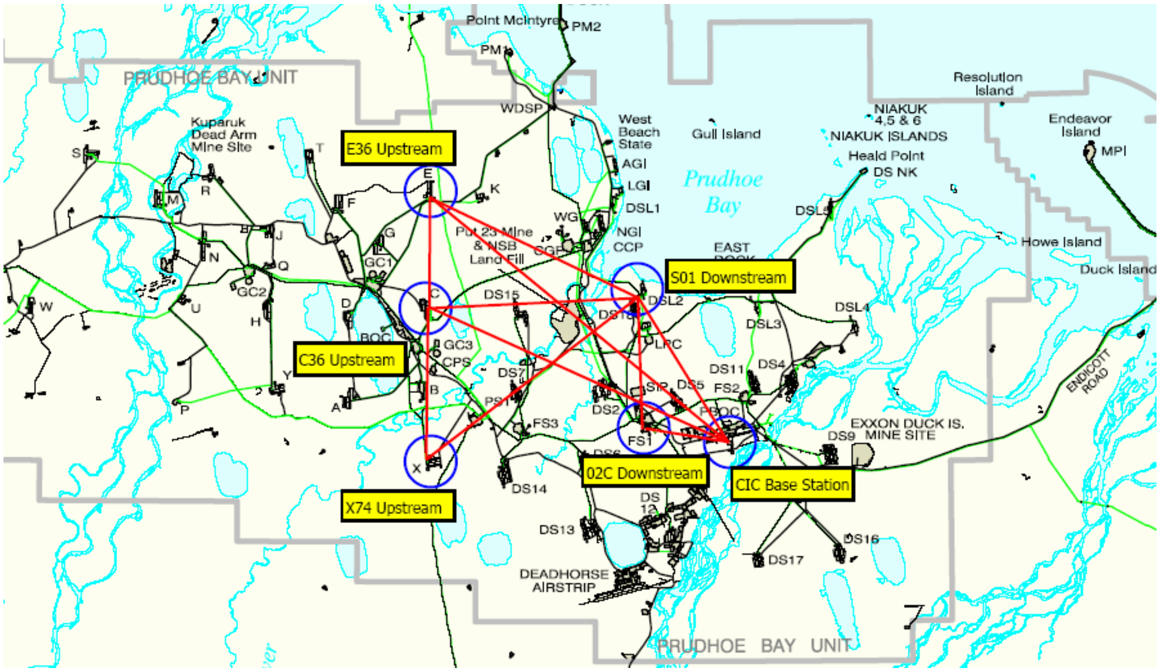

Figure 3 - Pilot locations and communication paths

Table 1 - Pilot transmission distances

	Distance, miles					
	CIC	**02C**	**S01D**	**E36U**	**C36U**	**X74U**
CIC		2.0	4.3	9.6	8.1	7.5
02C	2.0		3.2	7.8	6.1	5.6
S01D	4.3	3.2		8.0	5.3	6.7
E36U	9.6	7.8	8.0		3.0	6.5
C36U	8.1	6.1	5.3	3.0		3.5
X74U	7.5	5.6	6.7	6.5	3.5	

The units are essentially asleep 99% of the time, programmed to wake up at a specific date and time. Once the radios are powered, they establish the mesh network. The control module interrogates the RDC and downloads the data. The data are then transmitted and several data checks performed at the base station. Once all the data are transmitted, the units wait for a specified period of time to receive the current time, next wake up time, and any configuration changes. Once the cycle is complete, the units go back to sleep.

Figure 4 shows the components of the RMU. Figure 5 shows a typical installation before insulating the RMU and securing the cables. Figure 6 shows the insulating enclosure that captures waste heat from the pipeline keeping the RMU warm, thereby increasing battery life.

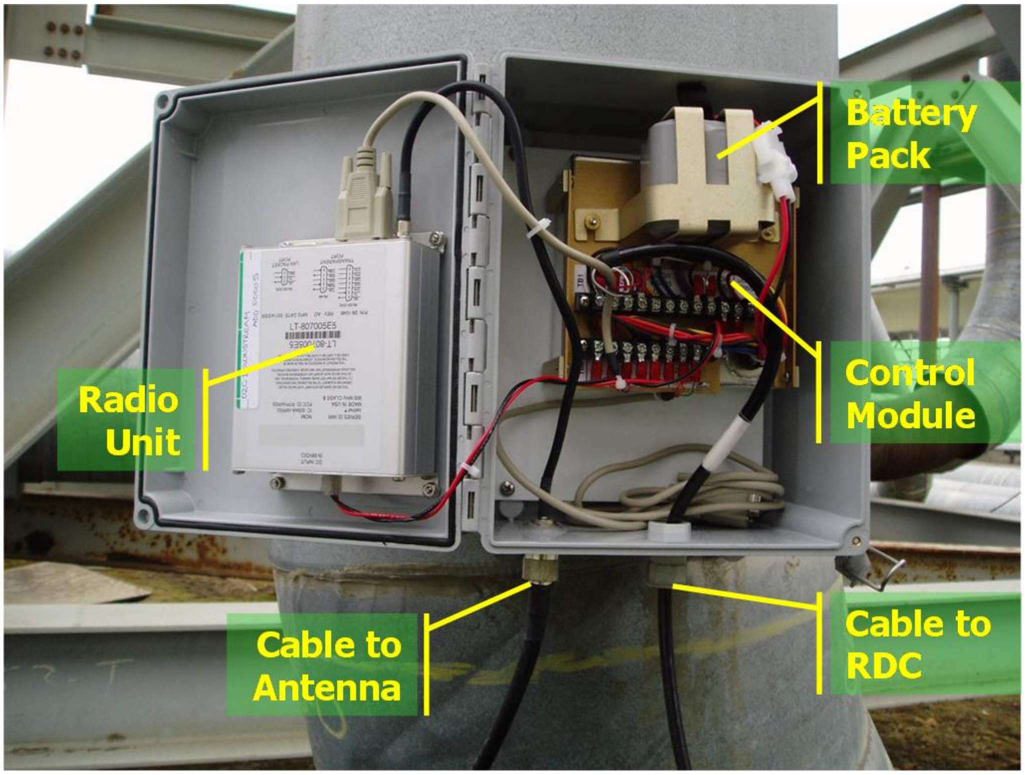

Figure 4 - Remote Monitoring Components

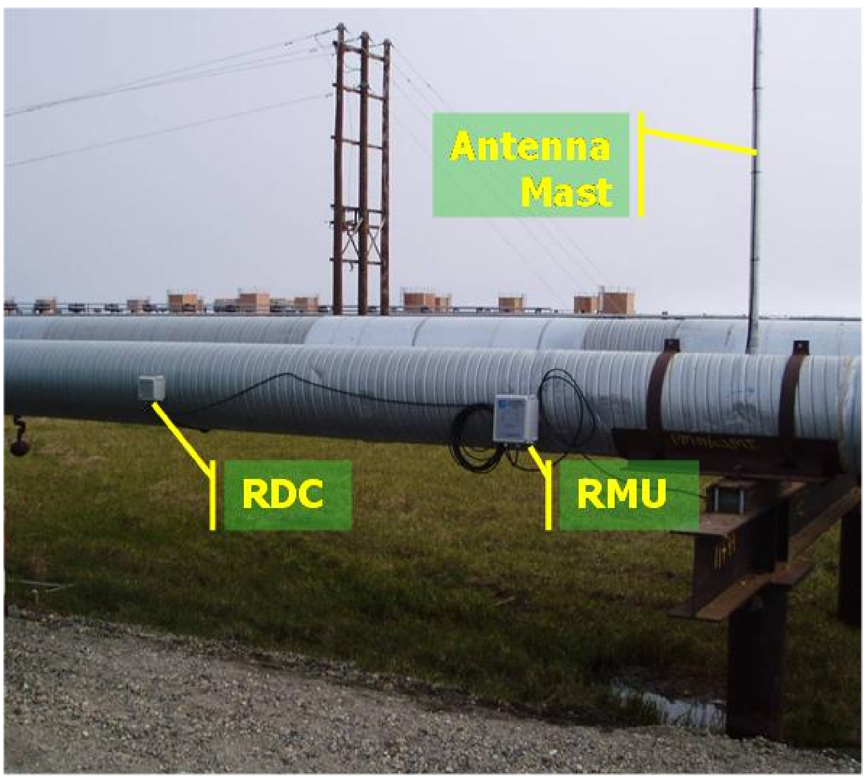

Figure 5 - Typical deployment

Figure 6 - Insulating Enclosure

The units have been operational for ~3 months and have performed nearly as expected. One of the RMUs did have a problem with the radio unit and was sent back to the manufacturer for diagnostics. The remaining units continue to operate sending data on a daily frequency.

Operational testing verified the ability of the radios to network and relay data. Transmission distance was better than expected with the maximum range between 10 and 15 miles, depending on terrain. The units will undergo several more months of operational testing through the winter. In addition, a detailed cost benefit analysis will be performed in order to support deployment of additional units.

As with any pilot project there were areas of improvement identified in both the hardware and software. These improvements were prioritized and several software improvements have been implemented through either firmware upgrades or PC software upgrades. Certain hardware improvements were implemented in the field while others required additional testing by the manufacturer. These improvements will be incorporated into the hardware if the project moves forward with additional units.

BENEFITS

ER probes respond quickly to changes in system corrosivity. Having access to these data on a timely basis allows the engineer to optimize the chemical usage and minimize corrosion damage to the asset.

Remote monitoring reduces the travel required to obtain data and allows technicians to focus on troubleshooting versus routine data gathering. If deployed on a field wide basis, remote monitoring would save ~15,000 miles/year of driving and ~500 hours/year of technician time. Further, it reduces the risk associated with driving on hazardous road conditions during a significant portion of the year. The units are expected to result in an increase in the overall data availability and optionally increase the data frequency (tradeoff against battery life).

Certainly the technology is not limited to solely ER probe data. There are many possible uses for this remote monitoring system and the radio mesh network. Applications such as logging and transmitting data from other sources (e.g. 4-20 mA transmitters), enhanced digital ER transmitters, process parameters, and even closed loop process control are possible through this system.

CONCLUSION

Corrosion mitigation at GPB is through chemical mitigation. Corrosion monitoring provides identifies changes in fluid corrosivity and provides feedback to the mitigation program. ER probes and data collectors are installed in many locations and collect data six times per day. These data are downloaded by a technician into a handheld unit and then uploaded into a database for analysis. A wireless remote monitoring solution was developed using a 900 MHz digital mesh network. Hardware was developed which meets key criteria including integration with existing monitoring equipment. Five units have been deployed in a pilot project and the initial results are encouraging. Freeing up technician time from routine tasks and reducing driving time, timely access to data for feedback into corrosion mitigation programs, and the potential for other uses of the wireless network are some of the initial benefits. Additional improvements to the hardware and software have been identified and a detailed cost-benefit analysis needs to be performed. The units will continue to operate over the coming winter and the decision to deploy more units will be made during the first half of 2006.

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