Basic Applications of Telemetering Systems
Class # 3050

Tommy Mitchell
Regional Sales Representative
ABB Inc., Totalflow Div.
2004 N. Minnesota
Shawnee, OK, USA

Introduction

In a fast changing natural gas industry today it is important for companies to utilize all available technologies in order to safely operate and maintain a competitive edge in today's market place. One of many available technologies is telemetering. To understand telemetering let us first give a good definition of telemetering and how it applies to today's natural gas industry. Telemetering is defined as: "The science of sensing and measuring information at a remote location and transmitting that data to a convenient location to be read and recorded". From this definition we can see that telemetering, as it applies to the natural gas industry, is simply a way to gather, read and record data remotely so it can be utilized. Some of the most common reasons companies install a basic telemetering system today are safety, increase production, improve operations efficiency, and monitor pipelines. However with today's advanced Flow Computers and RTU designs the reasons listed above can be easily achieved in most cases by installing one unit per location. It is the intent of this paper to cover basic telemetering principles as they apply to areas of the Oil and Gas Industry.

Figure 1 below is an example of a remote device and end devices being monitored and controlled.

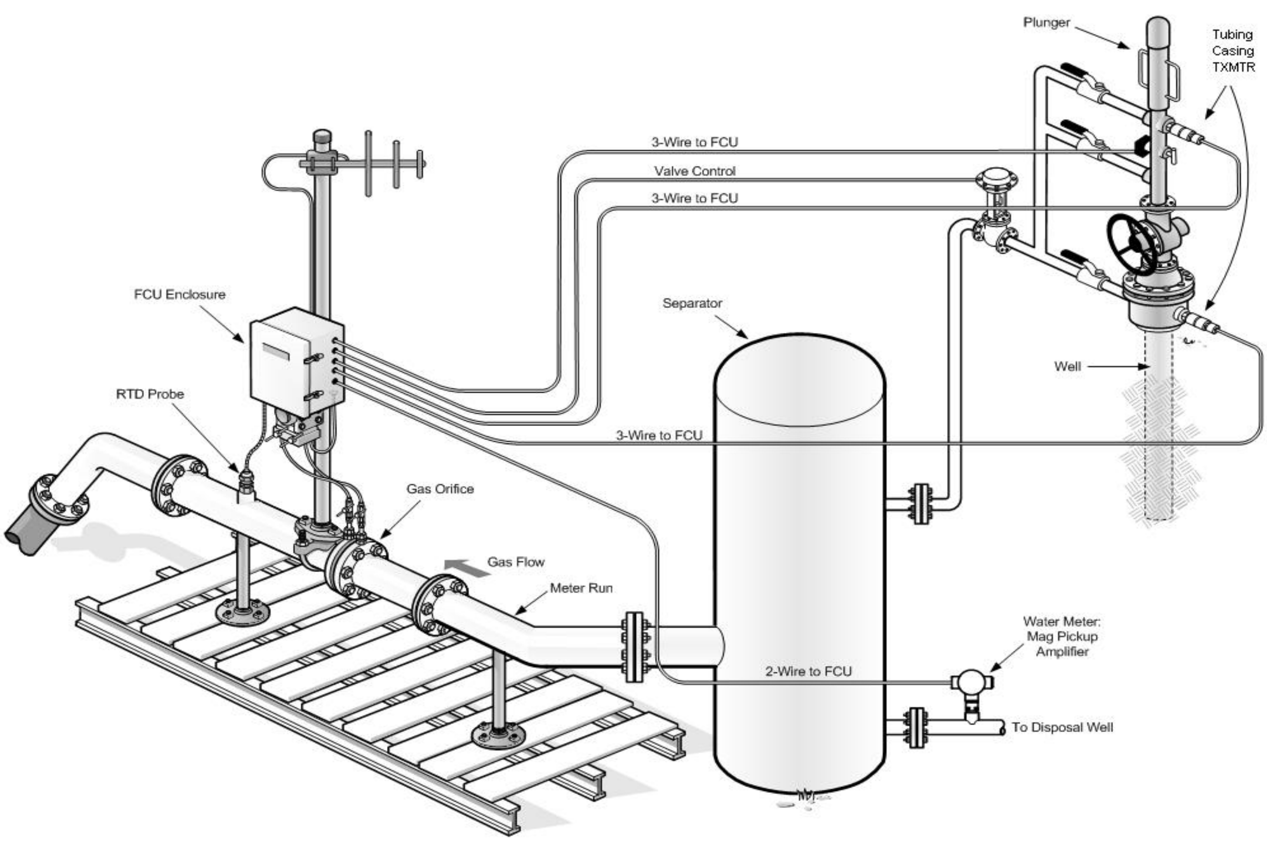


Figure 1

Host System

The Host Computer is the Master in a Master/Slave communication system. The Host System can be as simple as a single stand alone PC or as complex as multiple PCs scattered across LANs [Local Area Network] or WANs [Wide Area Networks]. In a basic telemetering system the primary responsibility of the Host is communicating with the remote devices. Often the Host also performs functions like scheduling for collecting and storing processed flow data, collecting raw data, providing this data to other systems, editing the raw flow data, building reports, polling devices for alarms, processing these alarms (for call out purposes), listen for remote devices to *cry out* with alarms, managing who has access to what data, and downloading information to the remote device (nominations, analytical data, calculation parameters, set points for control, etc).

Between the Host System and the remote devices there is typically some type of communication port controller. This software acts as a traffic cop to make sure that all requests from the Host System or other workstations gets processed and routed to the appropriate port, and passes the retrieved data back to the host. Some Systems may have multiple layers of software between the host and remote devices. This software is called a communication driver. A communication driver (Protocol) is nothing more than a translator between the Host System and the remote devices. The communication driver takes the request from the Host and translates it into a protocol (language) that the remote device understands. It then takes the received data from the remote device and converts it back into a generic format that the Host understands.

Remote Devices

In a Master/Slave arrangement the slave device is often referred to as the remote device. The most common of these field remote devices are EFM [Electronic Flow Meter], RTU [Remote Terminal Unit], and PLC [Programmable Logic Controller]. The small list of devices above can also be multi-functional. For example, most RTUs today can also function as a PLC or EFM. Most EFM's can also perform the task of an RTU or PLC. And most PLC's can perform measurement functions. Some of the most common operations these Remote Devices perform are to read field end devices, perform flow volume calculations based on given parameters, perform control logic functions, and store data (raw and processed) to make it available to other systems and the Master or Host system.

Field End Devices

Most field devices that provide outputs to Remote Devices can be grouped into three types: Discrete or Digital Input (DI), Analog Input (AI), and Pulse Input (PI)

Digital Input (DI) can only have two states, "On = 1" or "Off = 0". An example of discrete or digital as it applies to our industry today would be a valve position switch. In this example our valve will have two switches, one to indicate full-closed status and one to indicate full-open status. In this example the remote device will require two DIs (digital inputs). Within the remote device we will use DI1 as the full-closed status and DI2 as the full-open status. If we start with the valve closed, the "Closed" valve position switch will also be closed and complete the electrical circuit. The remote device will sense DI1 as an "On" state or "1". If someone were to start opening the valve one of the first things that the remote device would sense is the electrical circuit on DI1 switching to an open state, "Off" or "0". At this time the remote device will sense both DI1 and DI2 as an open circuit, "Off" or "0". The inputs will remain in this state until the valve has been fully opened or closed. Let's assume that the valve continues to be opened until it is fully open. At that time, the "Open" valve position switch will be closed and complete the electrical circuit on DI2, "On" or "1". The remote device would then indicate valve fully "Open". Within the remote device logic we can also program the Remote Device to indicate that the valve is in "Travel" when DI1 and DI2 are both "Off" or "0".

Analog input (AI) is represented by a continuous variable. One of the most common devices in our industry is an analog transmitter. An analog transmitter acts as a current or voltage regulator in relation to a calibrated span. Below is a typical example of an analog transmitters output calibrated to a remote device.

Transmitter (Output)	FC/RTU (Analog Input) (AI)
0 (PSIG) applied to transmitter = 4 milli-amps or 1 Volt	4ma or 1 Volt = 0 (PSIG)
50 (PSIG) applied to transmitter = 12 milli-amps or 3 Volts	12ma or 3 Volts = 50 (PSIG)
100 (PSIG) applied to transmitter = 20 milli-amps or 5 Volts	20ma or 5 Volts = 100 (PSIG)

Pulse Input (PI) can best be described as a continuous frequency. Frequency is the number of oscillations or cycles per unit of time. Two of the most common end devices that output a frequency are turbine meters, for the measurement of natural gas and water, and ultrasonic meters. A simple example of how the remote device can take this PI and convert it into an uncorrected volume of gas is as follows: The turbine meter has a K Factor of 100. This K Factor of 100 is equal to 1 cubic foot of gas passing through the turbine meter. If the remote device measured 100 pulses from its PI in a time span of one minute we can now calculate an uncorrected volume of gas. 100 pulses = 1 cubic foot of gas per minute multiplied by 60 (number of minutes per hour) for an uncorrected flow rate of 60 cubic feet per hour (cf/hr) or commonly referred to as 1440 cf/day flow rate.

Basic Telemetry Systems

Telemetry according to Webster's On-Line Dictionary is: **1**. Automatic transmission and measurement of data from remote sources by wire or radio or other means.

Using the definition above would define some of our basic SCADA [Supervisory Control and Data Acquisition] systems in service today in the Oil and Gas Industry. Today's oil field telemetry systems are made up of many different devices. A typical basic telemetry system will have a Host Computer with many remote devices. (See figure 2)

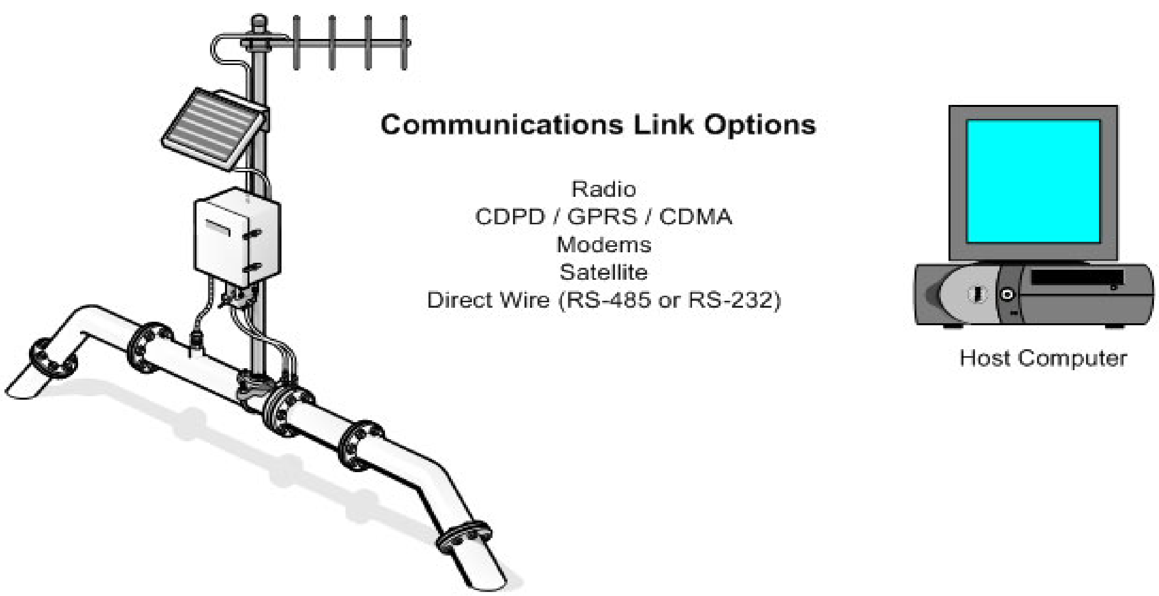


Figure 2

Communication Protocols

As stated earlier a protocol is nothing more than a translator between a Host System and a remote device or could also be defined as rules determining the format and transmission of data. There are hundreds of different protocols in service today, but the two that make up most of the communications in the Oil & Gas Industry are Modbus and Proprietary, or a variation of these.

Modbus

Modbus protocol was originally developed by Gould, and is described in depth in the document titled "Gould Modbus Protocol Reference Guide" published January, 1985 by Gould Inc., Programmable Control Division, Andover, Massachusetts.

Modbus uses the master/slave communications concept. Slave devices speak only when spoken to by the master. Each slave is identified by an unsigned, one byte number ranging from 1 to 247 (inclusive). A slave must send a single response to a master's request for data. The two most common formats of modbus protocols are RTU and ASCII. Below are two examples:

Modbus RTU message frame format:

Packet	CRC
N x 8 bits	16-bits

Packet: The packet field consists of the Modbus packet being sent or received. Packet format varies with the function being performed and the register group being accessed.

CRC: The error check field consists of a 16 bit cyclic redundancy check calculated over the length of the packet Field.

Modbus ASCII message frame format:

BOF	Packet	LRC	EOF	Ready
:	2 x Number of bytes in Modbus packet	8-bits	CR	LF

BOF: A colon (:) character is used to indicate beginning of frame.

Packet: The packet field consists of hexadecimal ASCII characters representing the Modbus packet being sent or received. The number of characters is twice the number of bytes in the Modbus packet because each packet byte is converted into two hexadecimal ASCII characters ('0'-'9','A'-'F'.)

LRC: The error check field consists an 8 bit longitudinal redundancy check calculated over the length of the packet field before it is converted to hexadecimal ASCII.

EOF/Ready: A carriage return and line feed are used to delineate end of frame.

Error Checking

When data is being sent from the host device to the remote device or the remote device is sending data to the host it is very important that this data be error free. There have been several schemes developed to detect these errors. One of the most common in use today is known as "*cyclic redundancy check"* (CRC), and is normally 16 bits in length or two 8-bit bytes. It is based on the standard of the American National Standards Institute (ANSI). In the CRC checking method, the CRC is appended to the block of data to be transmitted. The remote device uses the same predefined generating polynomial to generate its own CRC based on the received message block and then compares the internally generated CRC with the transmitted CRC. If the two match the receiver transmits a *positive acknowledgment* (ACK) communications control character to the host device, which not only informs the remote device that the data was received correctly but also informs the device to send the next of any remaining blocks of data. If an error has occurred, the internally generated CRC does not match the transmitted CRC and the receiver will transmit a *negative acknowledgment* (NAK) communications control character that requests the transmitting device to retransmit the block previously sent. Below is an example of a common generating polynomial:

CRC-16: $G(X) = X^{16} + X^{15} + X^{5} + 1$

<u>Communication Devices</u>

Two of the most commonly used devices for remote communications are modems and radios.

<u>Modems</u>

Modems take the digital signal produced by a host or remote device and converts (modulates) it into an analog tone that is then transmitted over the telephone lines. The receiving modem converts these analog tones (demodulates) into a digital signal for the end device. This is where the acronym for modem comes from (***Mo****dulator*-***Dem****odulator*).

<u>Wireless Communications</u>

Radios and wireless modems are the most common forms of communication in the Oil and Gas Industry. Typically most oil and gas sites are in very remote locations so the use of land lines and modems may not be possible at all or cost effective. However, there are times when a land line modem can be installed as close to the well sites as possible and then short hopped by radio the remaining distance to each site. The remainder of this paper will list a few of the communication options that are available today.

CDPD – Cellular Digital Packet Data

CDPD has been around the oil and gas industry since the mid 1990's. It has served the oil and gas industry well. One of the advantages of CDPD is it uses the existing infra-structure of the cell phone systems. It also has a static TCP/IP address, which allowed you to access your end devices from anywhere you have an internet connection. AT&T announced in October, 2002 that it would not be issuing any new CDPD/IP addresses as of March, 2003, and that the network would be decommissioned in March, 2004. Verizon, the other major CDPD operator has also announced plans to take down their network. CDPDs days seem numbered.

GPRS – General Packet Radio Service

GPRS is the 2.5G wireless packet data standard for GMS cellular networks, such as AT&T and Cingular (which are converting their networks from an earlier PC3 technology called TDMA to support GPR3) and T-Mobile. GPRS is based on a modulation technique known as Gaussian minimum-shift keying (GMSK). EDGE is based on a new modulation scheme that allows a much higher bit rate across the air interface – this is called eight-phase-shift keying (8 PSK) modulation. Since 8 PSK will also be used for UMTS, network operators will need to incorporate it at some stage to make the transition to third-generation mobile phone systems.

Frequency wavelength	*400, 900, 1800, 1900 MHz*
Data bandwidth	*9600 bps to 115 kbps*
Security measures	*GMSK*

CDMA – Code Division Multiple Access

CDMA is a “spread spectrum” technology that enables multiple signals to share a single transmission channel, maximizing the use of available bandwidth. It adds up to rock-solid data transmission – average rates of 50-70 kbps – that won’t degrade with network usage.

Frequency wavelength	*800, 1900 MHz*
Data bandwidth	*9600 bps to 14.4 kbps*
Security measures	*DSSS*

Satellite

Satellite maybe the only option for some remote parts of the country. They are typically a very reliable means of communication, however, if your system requires you to move large amounts of data across their network, operational cost should be considered. Satellite providers typically charge by the byte of data transmitted, often making this cost prohibitive for one or two locations. The advantage is the very large bandwidth available, so users often will use satellite as a back haul from remote areas where they have a concentration of wells all talking through a data concentrator to one satellite modem.

Ultra High Frequency - UHF Band (450-960 MHz)

These radios have provided many years of reliable service in the Oil and Gas industry and continue today to service the industry well. The 900 MHz is the better choice of the two. It was designed for data only and unlike the 450-512 MHz, should not have to compete with voice traffic. 900 Mhz does require line of sight. License and tower space for both of these can be very hard to acquire.

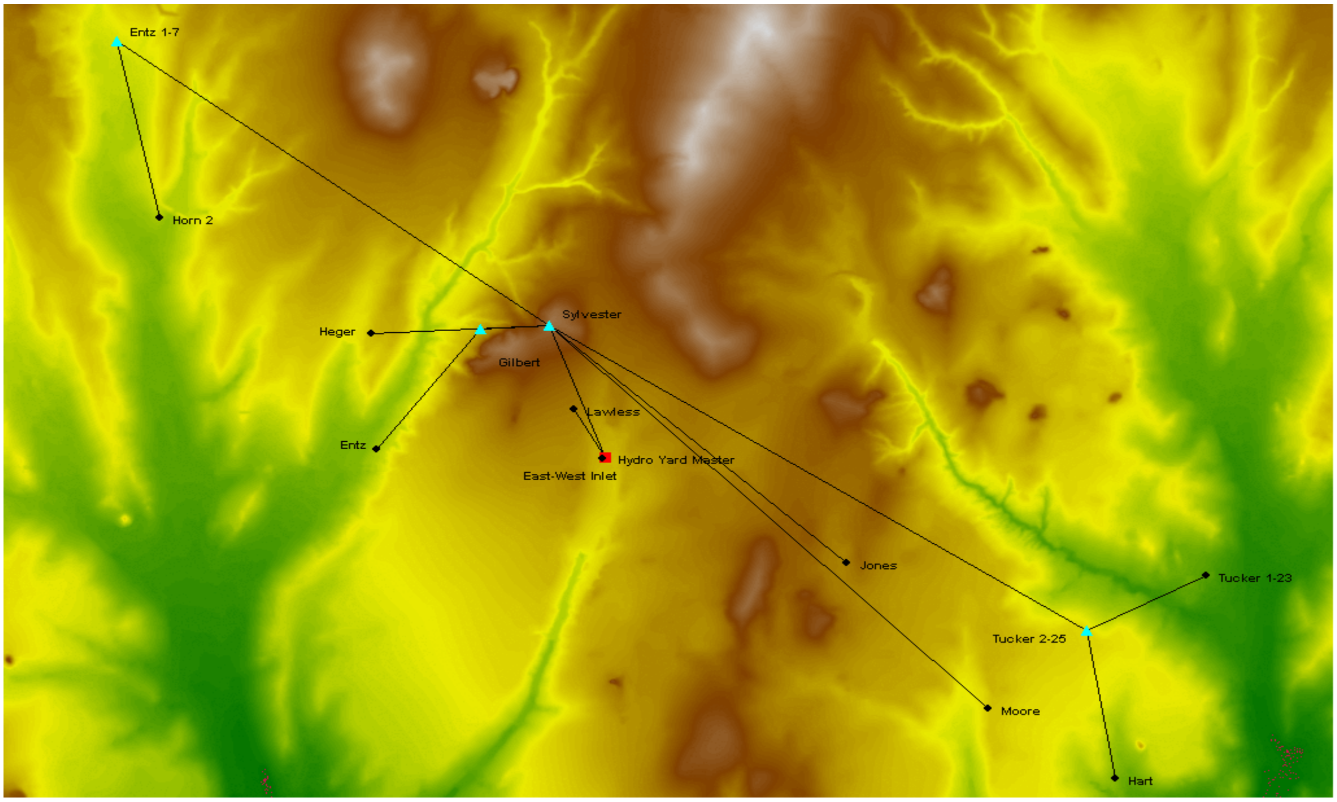
Spread Spectrum

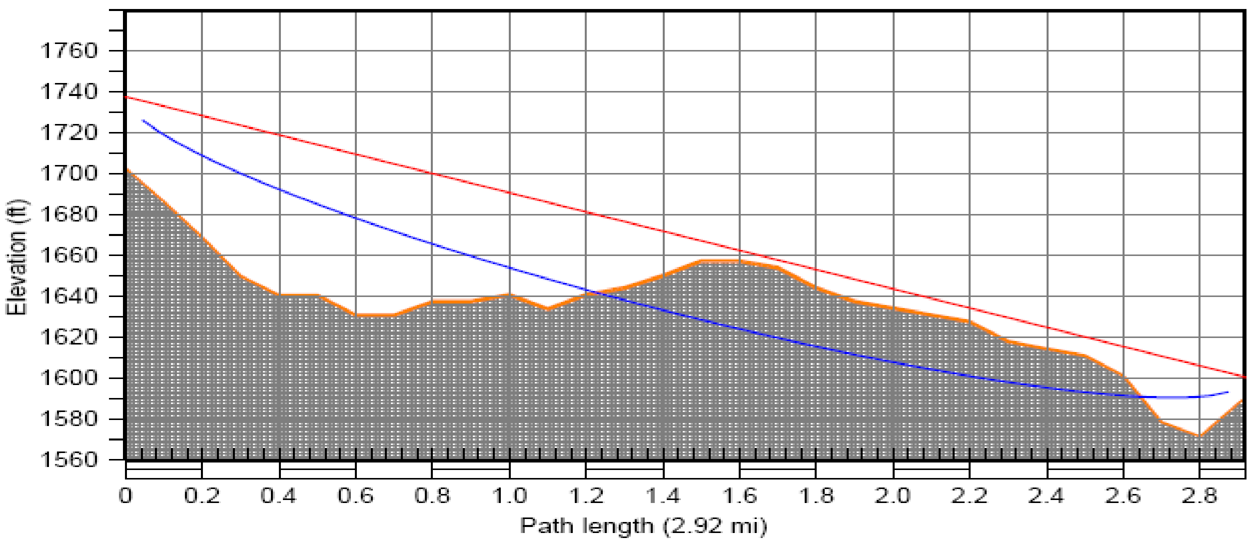
A few years ago a new radio medium became available. However, the basic technology has been around since the 1940’s. Spread Spectrum was originally invented for the U.S. Navy during World War II. All spread spectrum radios share the band from 902 MHz to 928 MHz, or 2.4 GHz to 2.4835 GHz, and there is a now a new spread spectrum frequency being released at 5.7 GHz. By federal regulation a Spread Spectrum radio can only have an output of 1 Watt of radiated power at the radio and 4 Watts at the antenna. Today Spread Spectrum is providing the oil and gas industry with a very reliable, low power and low cost solution to many telemetering systems. A few of the things that make Spread Spectrum such an attractive communication solution are there are no Federal Communications Commission (FCC) license required, radios utilize encryption to insure security and 32 bit CRC with auto data retransmission, fast baud rates up to 115.2 Kbps, and some Spread Spectrum radios have the ability to be a slave or slave/repeater. Spread Spectrum radios can also be installed as a complete stand alone system or can be integrated into an existing communication system. Some examples of this would be the use of a communication device such as land line modem, CDPD, satellite, or a licensed radio system to cover a long single span distance of hundreds of miles and then “mate” to a Spread Spectrum network to gather data over a Spread Spectrum radio network. This allows the user to communicate with multiple devices in the field, as opposed to paying monthly fees for each individual device. Spread Spectrum radios do require line of sight.

<u>Conclusion</u>

The most important part of any telemetering system is the communication link. There are a lot of questions that need to be asked and answered before you should consider the implementation of any telemetering system.

A few of these questions would include what is the overall objective of this project, will there be one or multiple hosts in multiple locations, remote devices (what type and their locations), what type of communication equipment, what protocols, what data and how much needs to be collected, how often is this data needed, who needs what data, how often do these devices need to be polled for alarms, do the end devices have “cry out” alarm capability, and how often will you be downloading data from the host system to the remote devices. POWER is often overlooked. Most remote devices are battery powered with solar charging. Radios and modems are typically the largest consumer of this power. If AC power is not available, always over size your solar powered system. Another important consideration of any telemetering system is hiring a reputable communication company to be involved from the start of your project. Before setting up any radio system it is critical to do a “path study” and system design for the proposed system. Below is an example of a “path study”. Good luck!





Sylvester	
Latitude	35 25 02.64 N
Longitude	098 34 39.90 W
Azimuth	134.66°
Elevation	1703 ft ASL
Antenna CL	35.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

Moore	
Latitude	35 23 15.54 N
Longitude	098 32 27.60 W
Azimuth	314.69°
Elevation	1591 ft ASL
Antenna CL	10.0 ft AGL

	Nov 14 06	