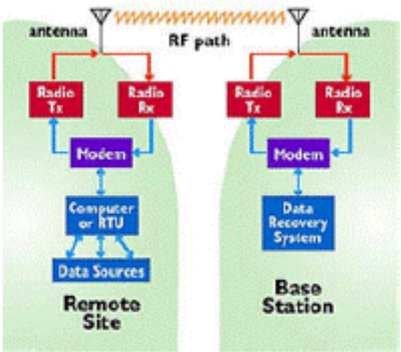
Telemetering

Telemetry is defined as the sensing and measuring of information at some remote location and then transmitting that information to a central or host location. There, it can be monitored and used to control a process at the remote site.

The basic concept of telemetry has been in existence for centuries. Various mediums or methods of transmitting data from one site to another such as copper wires and optical fibres have been used. Data radio provides a wireless method for transmitting the information. Telemetry using radio waves or wireless offers several distinct advantages over other transmission methods. Some of these advantages are:

- No transmission lines to be cut or broken.
- Faster response time
- Lower cost compared to leased lines
- Ease of use in remote areas where it is not practical or possible to use wire or coaxial cables
- Easy relocation
- Functional over a wide range of operating conditions

Components of a typical wireless telemetry system



At the remote site, a sensor or sensors are typically the data source. The output of the sensor(s) is converted to digital data by a small computer device or RTU (Remote Terminal Unit). The RTU is interfaced to a modem device that converts the digital data into an analog signal that can be transmitted over the air. The radio transmitter then transmits the signal to the host site radio receiver. Now the process is reversed.

The modem takes the analog signal received and converts it back to a digital form that can be processed by the data recovery equipment.

In a typical application, the base or host site requests data from the remote site(s).

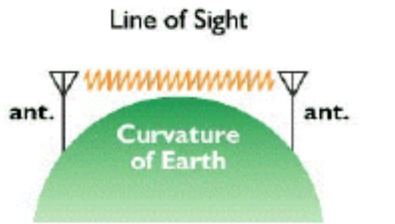
The base transmits a request to the remote unit telling it to send its data. The base reverts to a receive mode and awaits the transmission from the remote site. After the remote sends its data, it goes back to a receive mode waiting for further instructions to come from the base. Once the base receives the remote site information, it may send additional instructions to that site or continue on to request data from the next remote site. This polling process continues until all the remotes in the system have sent their data.

Radio propagation - SENDING DATA THROUGH THE AIR

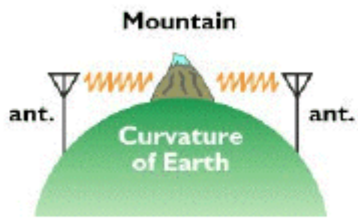
Radio waves are propagated when the electrical energy produced by the radio transmitter is converted into magnetic energy by the antenna. Magnetic waves can then travel through space. The receiving antenna then intercepts a very small amount of this magnetic energy and converts it back into electrical energy that is amplified by the radio receiver. Thus, sending information through the air.

Data Transmission - HOW FAR CAN DATA BE TRANSMITTED?
Propagation characteristics of radio waves are subject to many variables that affect the range and performance of a radio system. The main consideration is the loss in the transmission path between the transmitter and receiver. Factors affecting this loss are obstacles and power loss.

The most reliable system will employ a "line-of-sight" design where the radio wave travels directly from the transmitting antenna to the receiving antenna without obstructions as shown below left. However, the curvature of the earth limits the line of- sight distance. If the transmitting and receiving antennas are too far apart, the earth will block the radio wave. The maximum line-of-sight transmission distance is determined by antenna height and may be limited by other obstacles as shown below.



Line-of-sight transmission



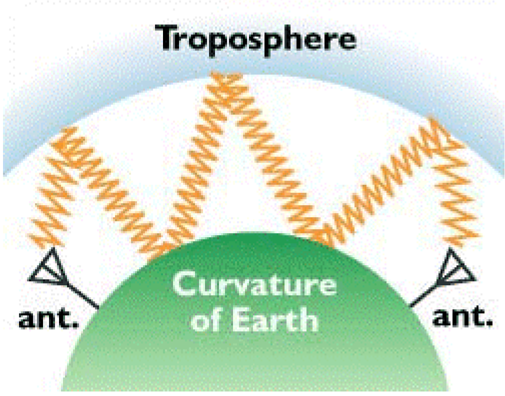
Line-of-sight obstacle

Once a transmission path is determined, signal power comes in to play. In general, signal power decreases in proportion to the square of the distance. For example, if the distance doubles, power decreases by four times. However, in actual practice, power drops off much faster because of attenuation caused by obstructions, trees, foliage, and other factors. This results in the power typically dropping off at a rate to the fourth power of the distance.

Frequency bands
Telemetry radio systems are normally configured as a fixed base station that obtains information from another fixed station at a remote site. Certain frequencies that can be used for fixed operation have been allocated. Some frequencies available in the VHF band, UHF band and 900 MHz band for this type of operation.

VHF band (150-174 MHZ)
Man-made noise such as that from automobiles and power lines, and skip interference caused by radio waves reflecting off the ionosphere back to earth, are much less of a problem at the VHF frequencies.

Guided propagation or ducting which is a phenomenon where a radio wave is trapped between the earth and the maximum height of the radio wave path is prone to occur at this frequency band. It causes the wave to travel much further than line-of-sight. This ducting occurs rarely and may cause interference with direct wave signals.



UHF band (450-470 MHZ)
This band is the one most often used in recent years because of the number of channels available. Range is not quite as good as at VHF, but this band is free of most man-made noise, skip interference and ducting effects. Absorption by trees and foliage causes a greater path loss, but penetration into buildings is better because the short wavelength signal has the ability to reflect off conducting objects.

900 MHZ band (928-960)
Skip Interference and ducting are insignificant in this band. However, foliage absorption of the short wavelength is greater which reduces range. In addition, moving objects in the communications path can cause fading due to multipath reception. Multipath reception occurs when the direct wave and a reflected wave arrive at the antenna at different phase angles. (See Below) This phase difference occurs because the reflected wave has to travel further than the direct wave. This causes canceling which weakens the received signal.

Multipath reception
Multipath reception can also occur at the lower frequencies, but is more of a problem at the higher frequencies because of the ability to reflect off objects increases with frequency. This problem is most common with communication between two moving vehicles or one moving vehicle and a fixed station. However, it can also occur when two fixed stations are communicating, if there are moving vehicles or other types of moving reflective objects in the communications path.

Antenna system design
The design of the transmit and receive antenna system is important because it determines how well energy is transferred from one antenna to the other. Some of these factors are gain, directivity, polarization and height above the ground.
Antenna height is simply a matter of the higher the better. Increasing the height extends the line-of-sight distance and reduces the effects of objects on the ground.

Radio waves are somewhat like light waves in that they tend to travel in a straight line. However, radio waves also tend to refract or bend as they follow the curvature of the earth. This extends the radio horizon beyond the optical horizon. This bending is caused by the tendency of a radio wave to travel slower as the density of the air increases.

The distance in miles from antenna to the optical and radio wave horizon is determined as follows:

Optical Horizon Distance = $\sqrt{2h}$

Radio Horizon Distance = 1.33 x $\sqrt{2h}$

Where, "h" is height in feet.

The maximum possible distance at which direct-wave transmission is possible between transmitting and receiving antennas at given heights (the line-of-sight distance) is equal to the sum of the horizon distances calculated separately for the individual antenna heights. When the distance involved is less than line-of-sight, the path is sometimes referred to as the optical path.

As the distance between the transmitting and receiving antennas increases, the energy concentration for a given area decreases. Therefore, the distance from the transmitting antenna also determines how much energy an antenna intercepts. This loss of signal strength due to increased distance is known as path attenuation and is expressed in decibels or dB.

Telemetry radio range

The following are the steps that can be taken to determine radio range:

1. Determine the line-of-sight transmission distance.
2. Select the antenna height above the average terrain.
3. Calculate the transmitter and receiver transmission line losses at the operating frequency.
4. Determine transmitter power output and receiver sensitivity in dBm.
5. Determine transmitter and receiver antenna gain.
6. Calculate the path loss at the operating frequency.

Once these parameters have been determined, an estimate of the RF link range can be done.

The following information describes the calculations for each of the steps listed above.

The line-of-sight distance can be determined by the following equation:

D (optical) = 2 hr + 2 ht

D1 (radio) = 1.3 x D

Where,

D = Distance in miles to optical horizon

D1 = Distance in miles to radio horizon

Ht = Transmitter antenna height

Hr = Receiver antenna height

For example, assume that the antenna heights above the spherical earth are 25 feet for the receiver and 100 feet for the transmitter. Line-of-sight distance would then be:

D = 2 (25) + 2 (100) = 21.2 miles

D1 = 1.3 (21.2) = 27.5 miles

Determining the line-of-sight distance does not guarantee that much range. The transmitter power, receiver sensitivity, transmission line loss, antenna loss or gain, and operating frequency must also be considered. The line-of-sight distance only means that the curvature of the earth does not block the signal. To determine path loss with these factors, assume that the RF system has the following fixed parameters:

Transmitter RF Power Output 2.0 watts (33 dB)
Operating Frequency 450 MHz
Total Tx Trans Line Loss (Heliax, 100 ft.) 0.85 dB
Total Rx Trans Line Loss (RG/U, 25 ft) 1.25 dB
Receiver 12 dB SINAD Sensitivity 116 dB
Transmit and Receive Antennas 0 dB gain, 7-element yagi
Determine the path loss at radio line-of-sight using 100 and 25 foot antennas at 450MHz by using the following general equation:

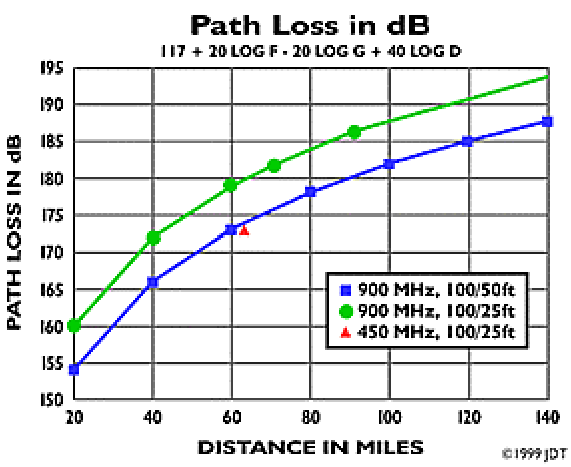
PL = 117 + 20 log 10 f MHz - 20 log10 hthr + 40 log10 D

Where,
PL = Path loss in dBm
117 is a constant
f = Operating frequency
ht = Transmitter antenna height
hr = Receiver antenna height
D = Distance between antennas

Plugging in the data gives the calculation:

PL = 117 + 20 log10 f MHz - 20 log10 (100') (25') + 40 log10 27.5 miles
PL = 117 + 53.06 - 67.9 + 57.5 = 159.6 dB

Therefore, path loss at radio line-of-sight is 159.6 dB at 450 MHz with a receiving antenna height of 25 feet and a transmitting antenna height of 100 feet. The figure below shows the relationship between path loss and radio range in miles over smooth earth with the above listed conditions.



Path loss chart

Transmitter power output is +33 dB or 2.0 watts. With 159.6 dB path loss, the signal at the receiver site is +33 dB-159.6 dB = -126.6 dB which is 10.6 dB below the receiver 12 dB SINAD sensitivity of -116 dB which was arbitrarily chosen.

Fading is a random increase in path loss caused by abnormal propagation conditions. When these conditions occur, path loss may increase 10-30 dB or more for very short periods of time. Therefore, it is important to design the system to compensate for fading.

Another method that can be used to increase radio range is to add a repeater to the system. A repeater receives the signal from the base and retransmits it at a different frequency to the remote site. This can effectively double the range of the system as shown at left. At the UHF frequencies, the input and output frequencies of the repeater are normally separated by 5 MHz.