UNDER STANDING RADIO FREQUENCY

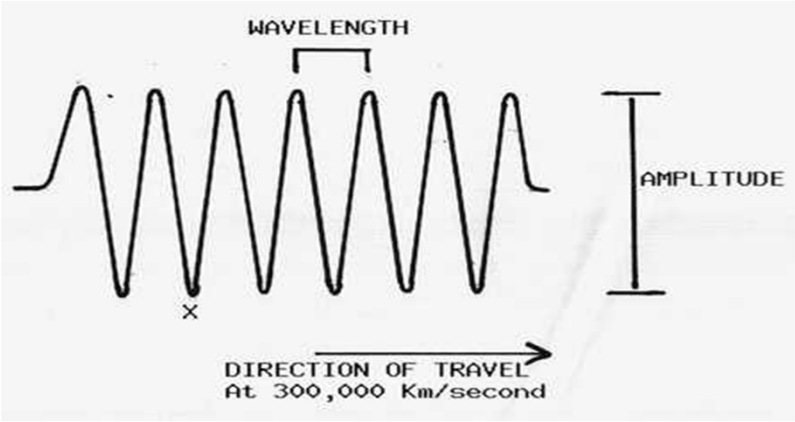
Badger Meter

UNDERSTANDING RADIO FREQUENCY

Regional Sales Meeting – March 1 - 2, 2011

RADIO PROPAGATION

- "Radio" consists of electromagnetic waves measured in "***Hertz***", or waves per second



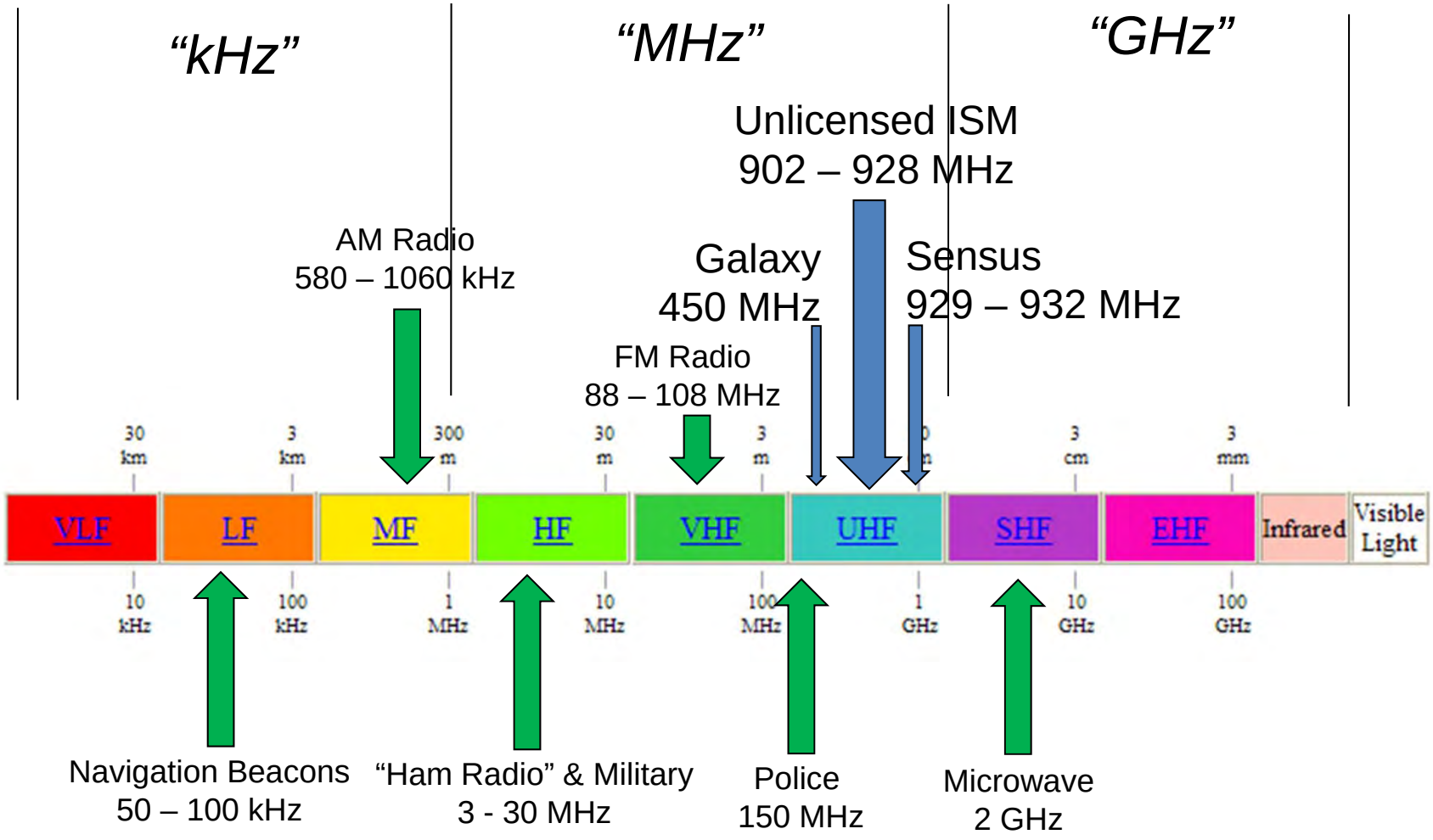
"kilo" = "thousands" = "kHz"
"Mega" = "millions" = "MHz"
"Giga" = "billions" = "GHz"

RADIO SPECTRUM

Type	Frequency	Applications
ELF	30 – 300 Hz	Remote Control
VF	300 – 3,000 Hz	Voice, Analog Phone
VLF	3 – 30 KHz	Submarine, Long-Range
LF	30 – 300 KHz	Long-Range, Marine Beacon
MF	300 KHz – 3MHz	AM Radio, Marine Radio
HF	3 – 30 MHz	Amateur Radio, Military, Long Distance Aircraft/Ships
VHF	30 – 300 MHz	TV VHF, FM Radio, Aircraft
UHF	300 MHz – 3 GHz	Cellular, TV UHF, Radar, ISM
SHF	3 – 30 GHz	Satellite, Radar, Terrestrial Wireless Links
EHF	30 – 300 GHz	Experimental, WLL
IR	300 GHZ – 400 THz	LAN Infrared
Light	400 – 900 THz	Optical Communications

AMR utilizes the UHF radio spectrum; usually 450 MHz, 900 MHz and 1.4GHz

RADIO SPECTRUM ALLOCATION



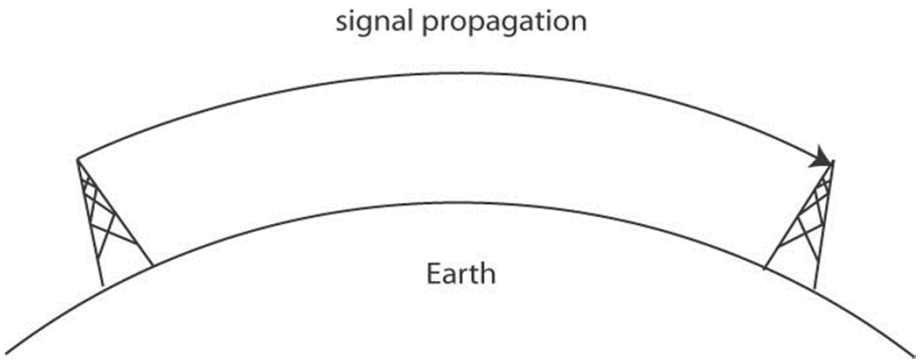
THREE MEANS OF RF PROPAGATION

Ground Wave Propagation
-applies to frequencies 0-2 MHz
Sky Wave (Ionospheric) Propagation
-applies to frequencies 2-30 MHz
Line of Sight Propagation (LOS)
-applies to frequencies 30+ MHz

Method of propagation depends on the frequency

GROUND WAVE PROPAGATION

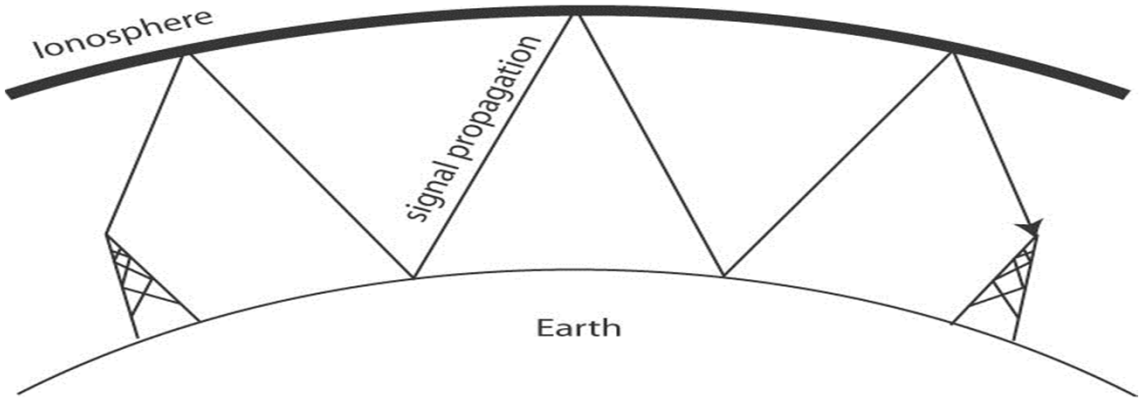
- Applicable at frequencies 0-2 MHz
- Follows contour of the earth
- Very long distances possible
- Affected by reflection, refraction and scattering by objects on the ground
- Typical application: AM radio



Not applicable in AMR applications

SKY WAVE OR IONOSPHERIC PROPAGATION

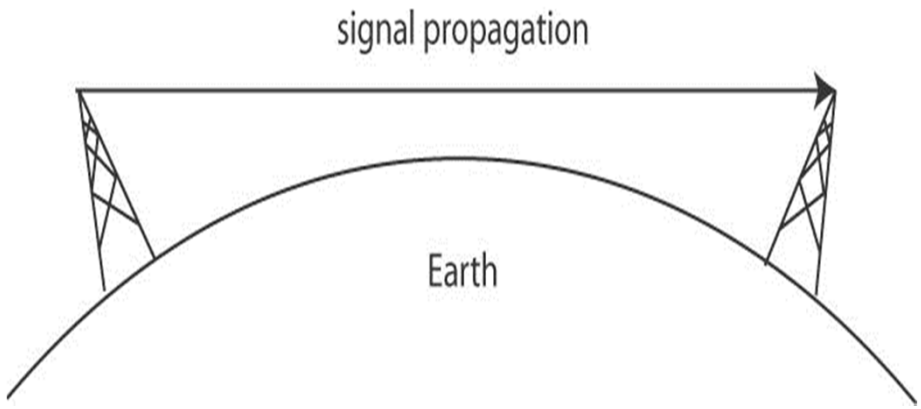
- Applicable at frequencies 2-30 MHz
- Signal reflected from ionized layer of atmosphere
- Signal can travel a number of hops
- Typical situation: shortwave radio



Not applicable in AMR applications

LINE OF SIGHT PROPAGATION

- Applicable at 30 MHz and above
- Transmitting and receiving antennas must be within line of sight (LOS)



LOS applications include AMR, SCADA, cell phones, wireless networks

SIGNAL STRENGTH, OUTPUT POWER, AND PATH LOSS

- Radio waves start out at a certain strength, and lose their strength due to distance traveled and impediments along the way.

1 Good
2 Weaker
3 Poor (trees)
4 5 None

- This is referred to as “Path Loss” or “Attenuation”, and is measured in units called a deciBels, or dB. Decibels are “logarithmic”. Who cares? Most don’t, but Engineers do because they add up easily.

$$30dB + 10dB - 70dB = -30dB$$

- Output power is typically measured in the unit of *Watts* (“W”), but can also be measured in a unit known as “*dBm*”, or decibels referenced to 1 milliWatt. Again, using units in dB’s is easy for Engineers to manipulate, and thus output power is seen frequently using this unit of measure.

$$P_{dBm} = (10LOG_{10}(P_{Watts})) + 30$$

SIGNAL STRENGTH, OUTPUT POWER, AND PATH LOSS

Or, just skip the formula and memorize the following six powers:

0dBm = 1mW

+10dBm = 10mW

+20dBm = 100mW (i.e. 0.1 Watt)

+24dBm = 250mW (i.e. 0.25 Watt)

+27dBm = 500mW (i.e. 0.5 Watt)

+30 dBm = 1000mW (i.e. 1 Watt)

Note Also: Every 3 dB is a halving or doubling of power:

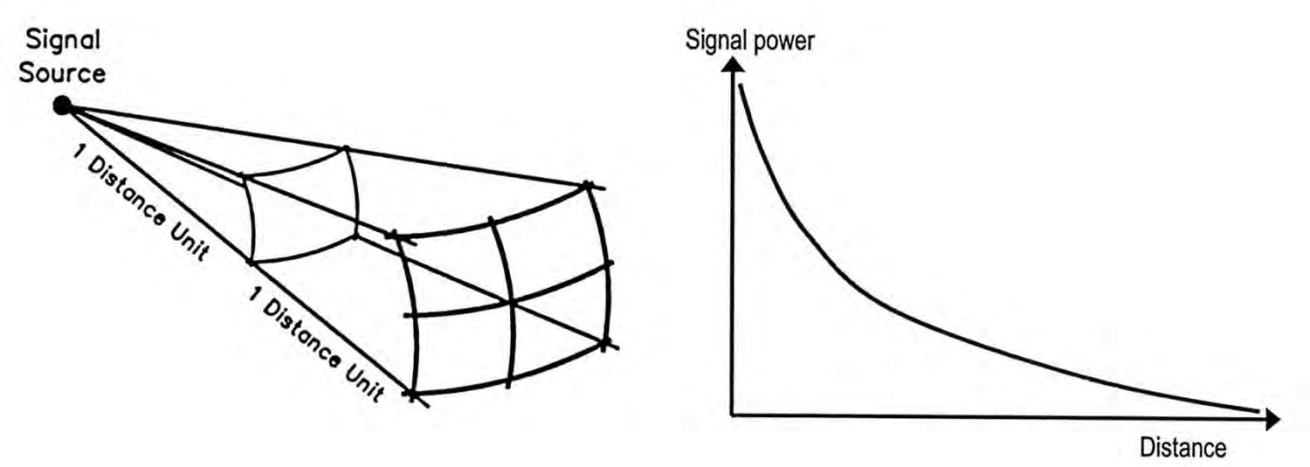
Example 1: +27 dBm (500mW) + 3 dB = +30 dBm (1000mW)

Example 2: +27 dBm (500mW) – 3 dB = +24 dBm (250mW)

SOME FACTORS AFFECTING LOS COMMUNICATIONS

- Free-space attenuation
- Absorption
- Reflection
- Diffraction
- Scattering
- Transmitter power
- Receiver sensitivity
- Antenna design and configuration

FREE-SPACE ATTENUATION



Radio waves weaken as the distance from the source increases because energy is dispersed over larger and larger areas

ABSORPTION

RF energy is absorbed by
non-conducting (non-metal) objects

ABSORPTION

Structures in the transmission path absorb some of the RF

ABSORPTION

Landscaping and vegetation can increase the challenge of reading a specific meter

ABSORPTION

Water absorbs RF

ABSORPTION




Environmental conditions change over time

ABSORPTION

Temporary environmental changes may increase absorption

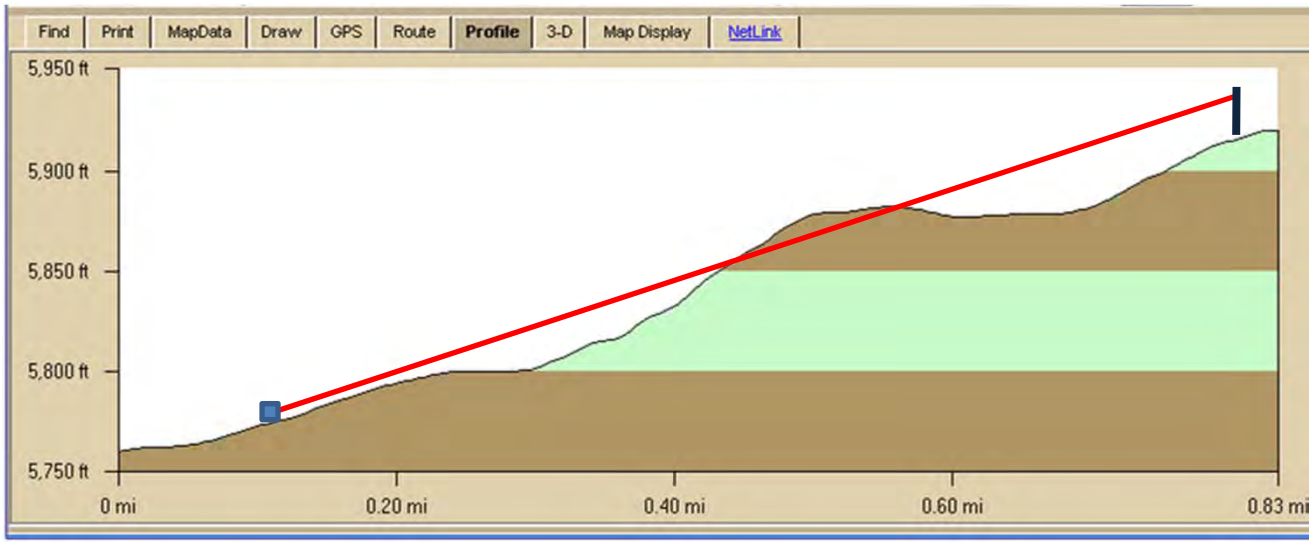
ABSORPTION

Seasonal changes add or
reduce absorbing vegetation

ABSORPTION

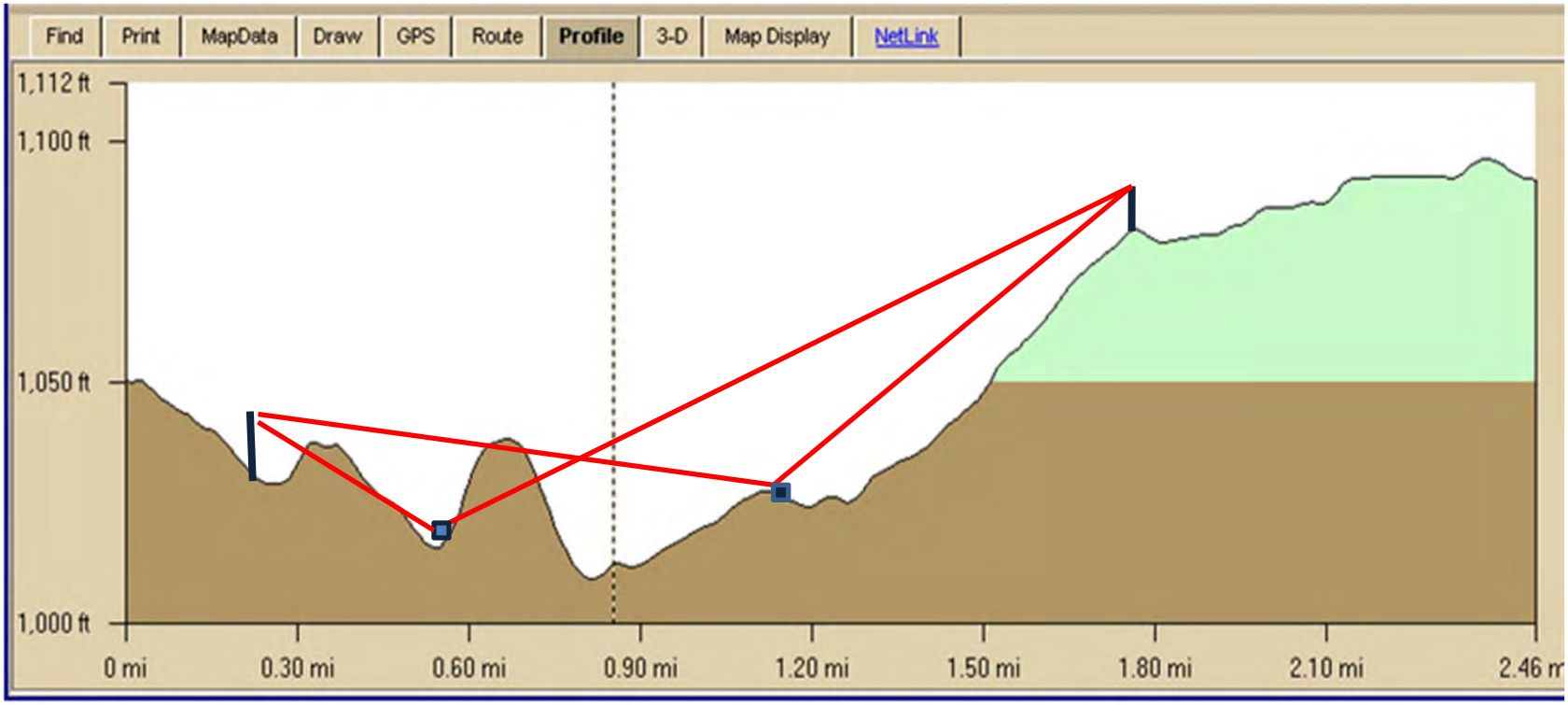
Pine trees absorb more RF than leafy trees

ABSORPTION



Fixed Networks have to consider the topography and it's impact on line of sight between endpoints and gateway.

ABSORPTION



The endpoint on the left has LOS issues with both gateways. The endpoint on the right has LOS issues with one gateway but not the other.

OVERCOMING ABSORPTION

Strive for clear line of sight between transmitter and receiver; minimize obstructions in RF path

OVERCOMING ABSORPTION

Mount remote transmitter high in basement and near outer wall

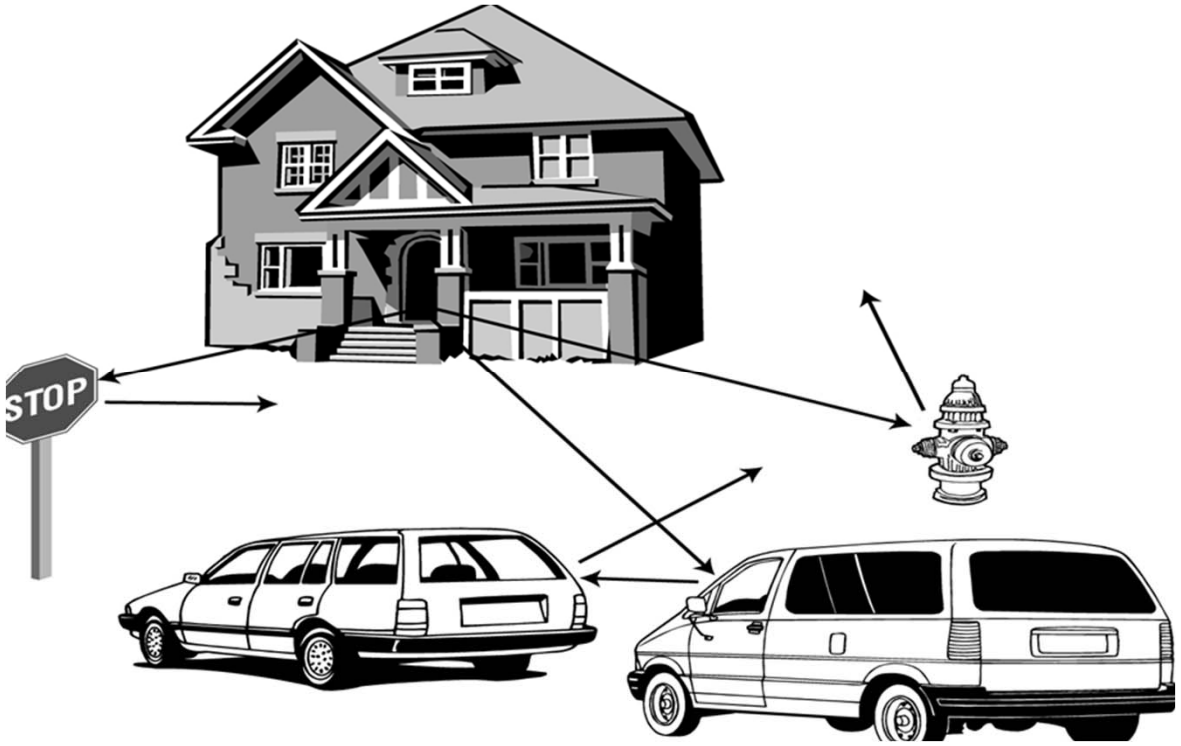
OVERCOMING ABSORPTION

Keep pit transmitter clear of dirt, grass and debris

SOME FACTORS AFFECTING LOS COMMUNICATIONS

- Free-space attenuation
- Absorption
- **Reflection**
- Diffraction
- Scattering
- Transmitter power
- Receiver sensitivity
- Antenna design and configuration

REFLECTION



RF signal reflection occurs with variety of conducting (metal) objects

REFLECTION

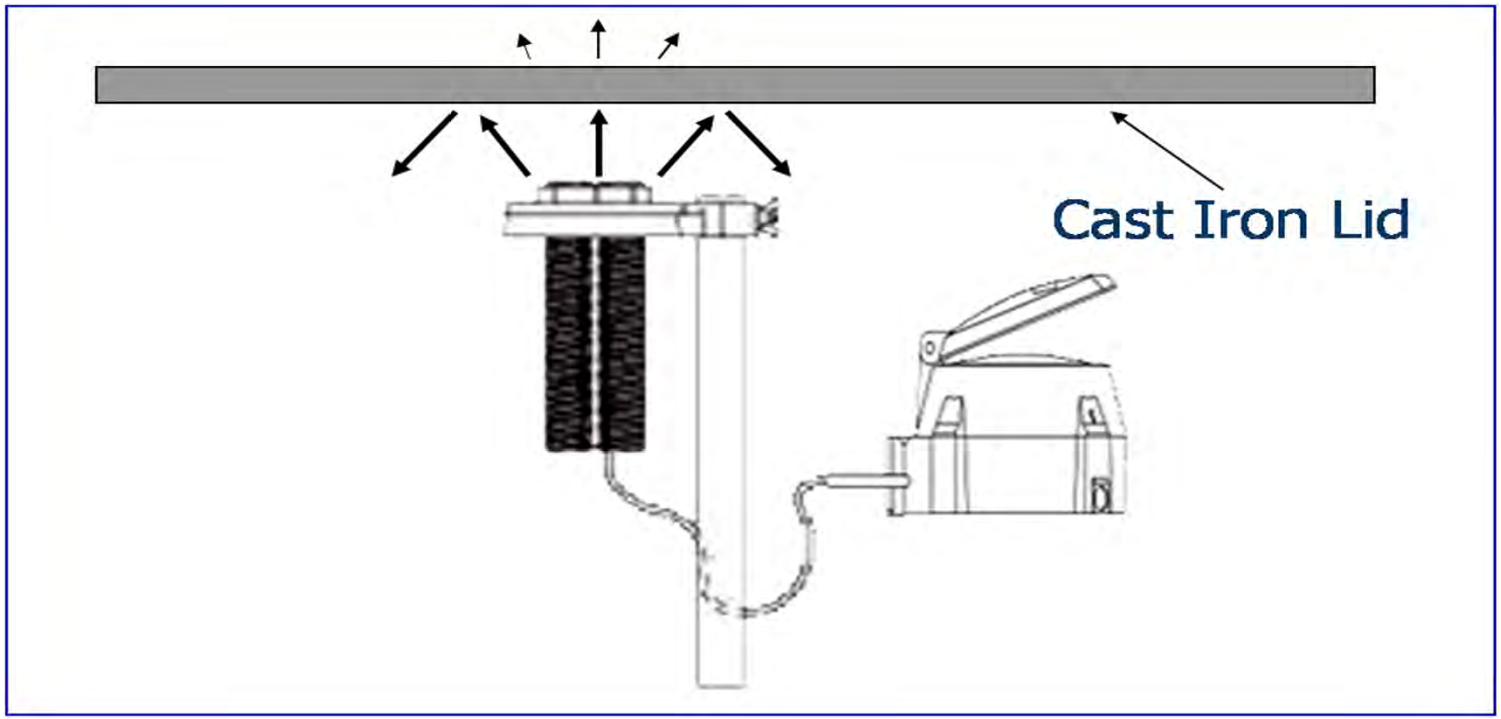
Chain link fences are reflective and can limit the RF signal passing through

REFLECTION

Metal pit lids reflect RF inside the pit, which is then absorbed by the earth

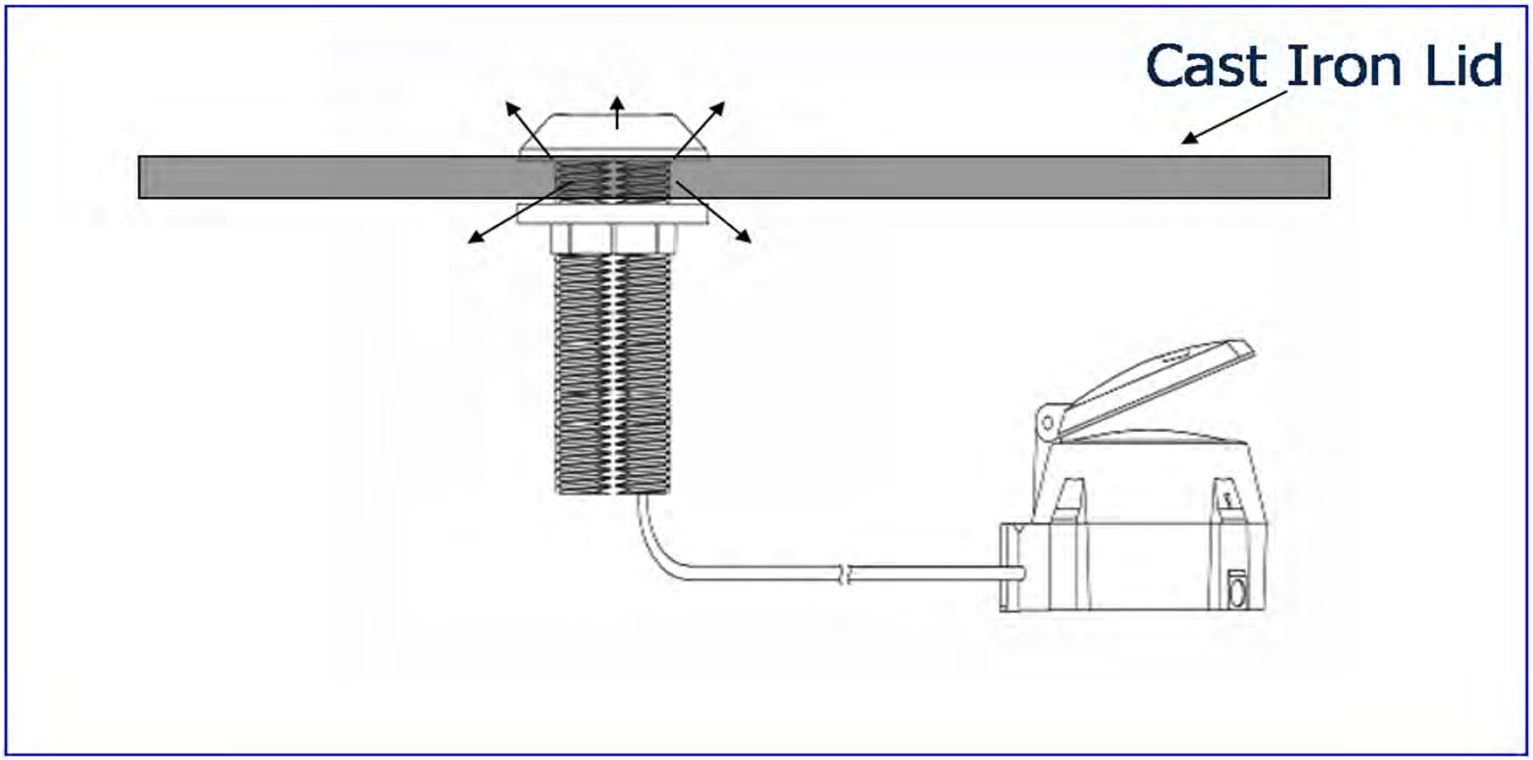
REFLECTION – METAL LIDS

- Significant amount of radiated power is reflected back into the pit
- For network applications, endpoints need to be mounted through non-metal lids for optimal performance



REFLECTION – METAL LIDS

Even “through the lid” installations have significant interaction of the metal lid and the antenna, reducing radiated power



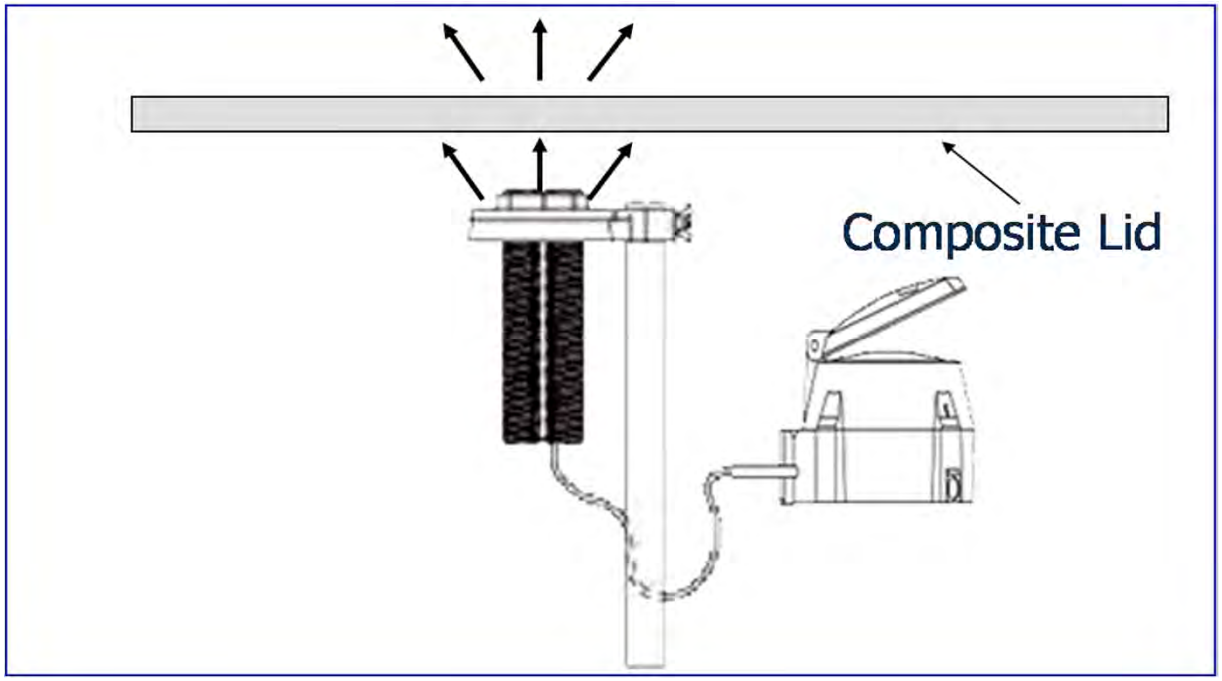
SIGNAL STRENGTH, OUTPUT POWER, AND PATH LOSS

Type	Loss	Output
Plastic	-7 dB	+20 dBm
Armorcast	-10 dB	+17 dBm
Concrete	-14 dB	+13 dBm
Metal Mesh	-17 dB	+10 dBm
Solid Metal	-30 dB	-3 dBm

	dBm	Watts
One watt endpoint	+27 dBm	500 mW

REFLECTION – METAL LIDS

- Composite lids have no reflection and little absorption
- This is the preferred approach to fixed networks
- Absorption is still a factor, which is why endpoints should be mounted through the pit lid



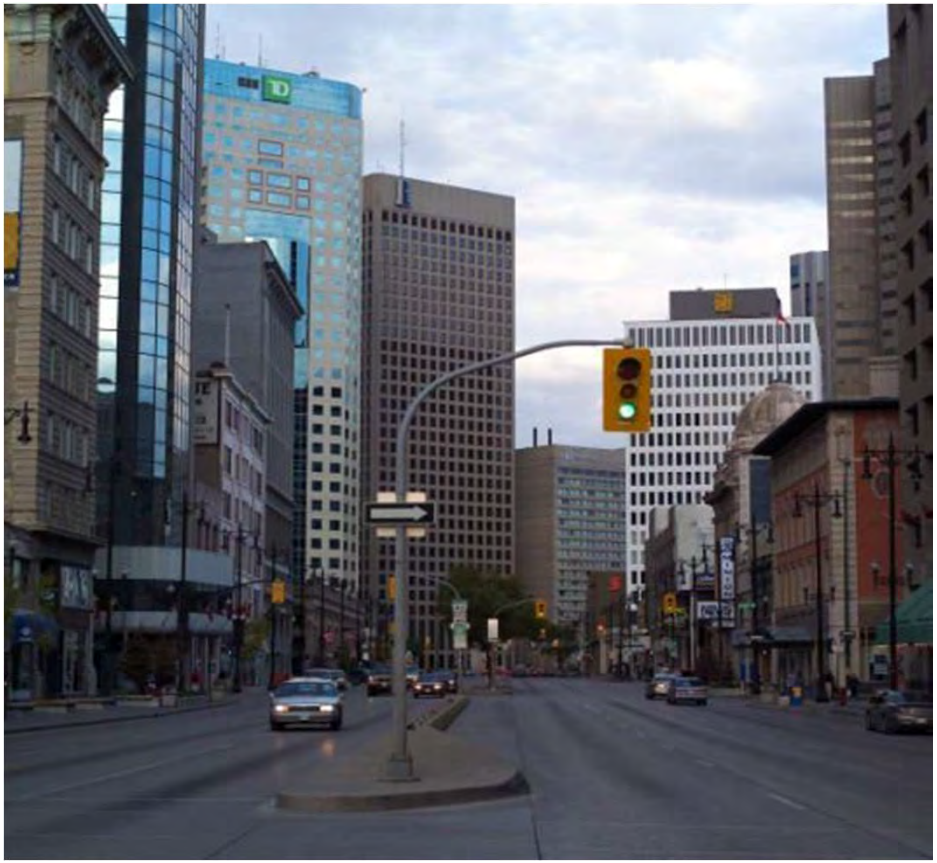
REFLECTION

Aluminum siding and flashing around the foundation is reflective, affecting basement transmitters

REFLECTION

Vehicles cause reflections; some metal objects may be temporary while others may be permanent

REFLECTION

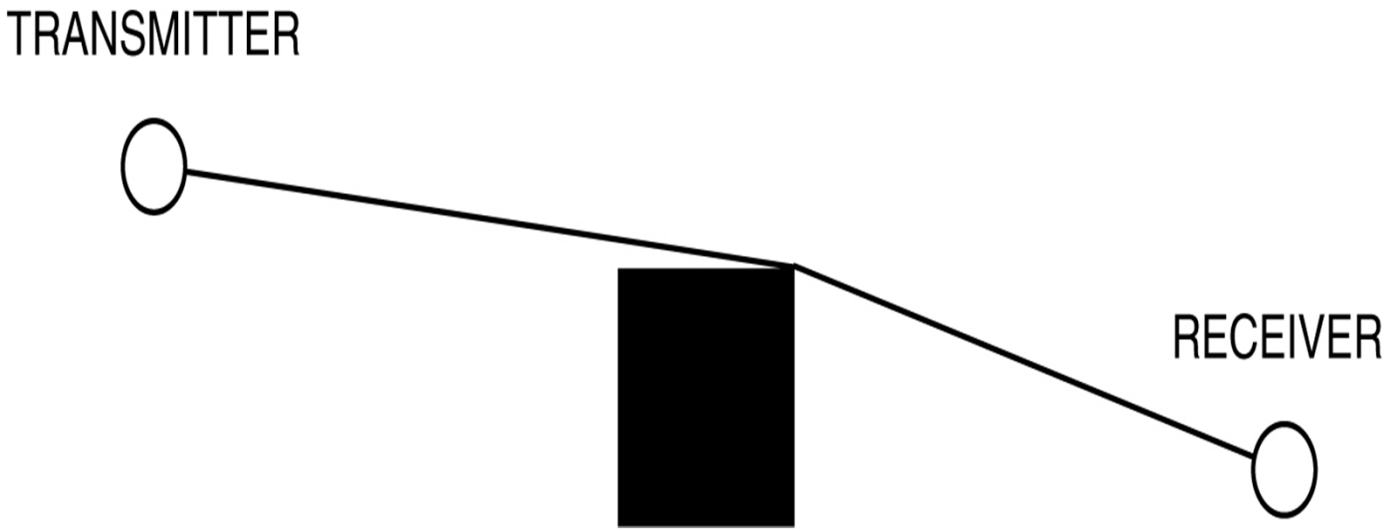


While concrete exteriors will absorb,
metal exteriors will reflect

SOME FACTORS AFFECTING LOS COMMUNICATIONS

- Free-space attenuation
- Absorption
- Reflection
- **Diffraction**
- Scattering
- Transmitter power
- Receiver sensitivity
- Antenna design and configuration

DIFFRACTION

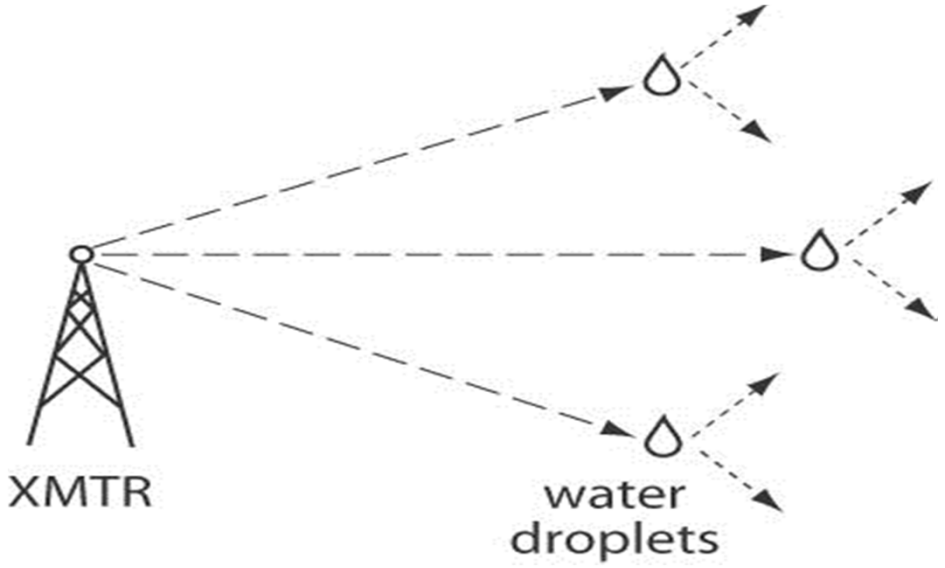


Radio waves can bend when they encounter a surface with sharp edges

SOME FACTORS AFFECTING LOS COMMUNICATIONS

- Free-space attenuation
- Absorption
- Reflection
- Diffraction
- **Scattering**
- Transmitter power
- Receiver sensitivity
- Antenna design and configuration

SCATTERING



Radio waves are scattered when encountering particles such as rain or fog that are equal to or smaller than the wavelength of the signal

SCATTERING

Fog, rain and snow cause scattering; absorption will also occur

SOME FACTORS AFFECTING LOS COMMUNICATIONS

- Free-space attenuation
- Absorption
- Reflection
- Diffraction
- Scattering
- **Transmitter Power**
- **Receiver Sensitivity**

- Antenna design and configuration

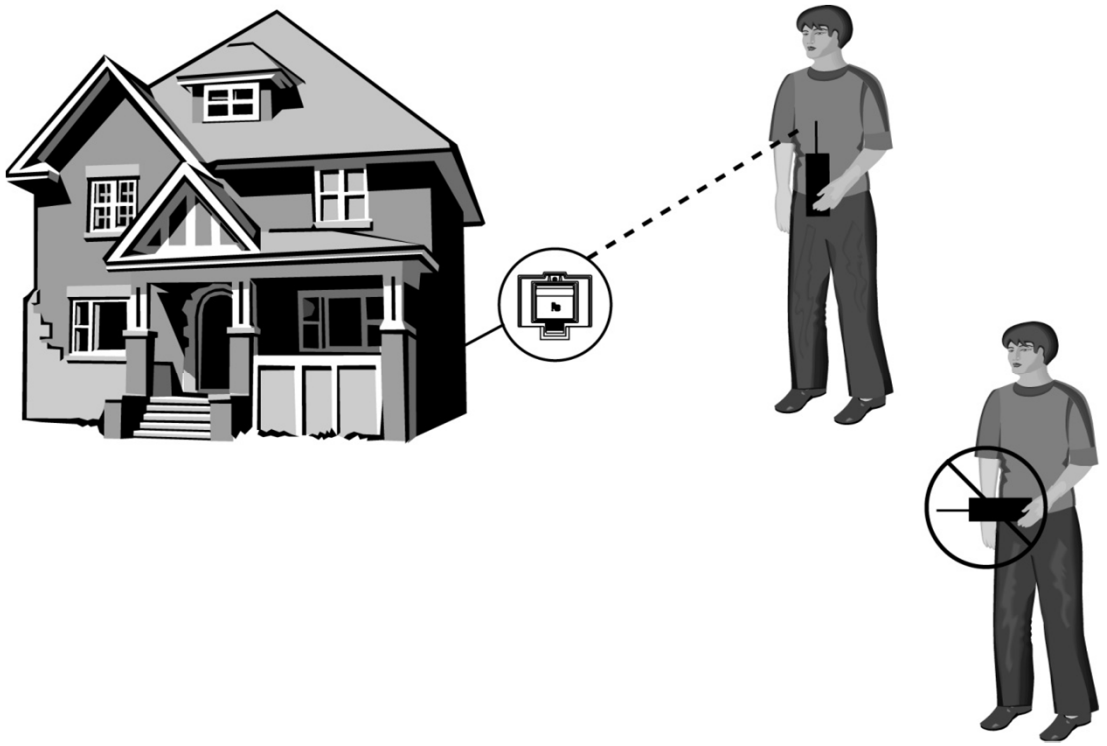
TRANSMITTERS AND RECEIVERS

- Endpoint power dictated by FCC, modern design concepts, and battery capacity
- Receiver sensitivity and signal-to-noise ratio determine if a signal can be heard
- Very low temperatures may have negative affect on receiver and endpoint performance due to effect on battery energy

SOME FACTORS AFFECTING LOS COMMUNICATIONS

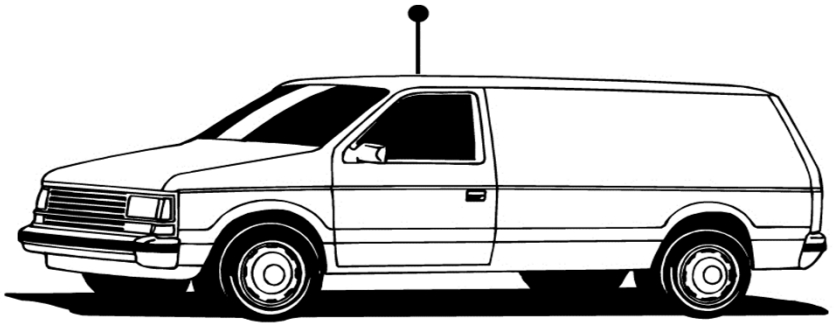
- Free-space attenuation
- Absorption
- Reflection
- Diffraction
- Scattering
- Transmitter power
- Receiver sensitivity
- **Antenna Design and Configuration**

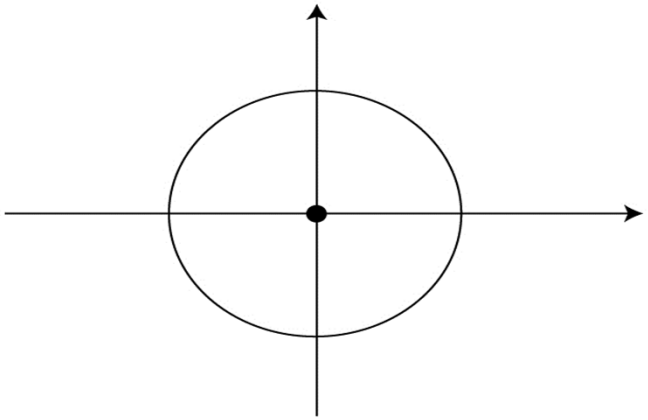
ANTENNA ORIENTATION



Both transmitter and receiver antennas must be properly oriented with respect to each other to maximize energy transfer

OMNI-DIRECTIONAL ANTENNAS

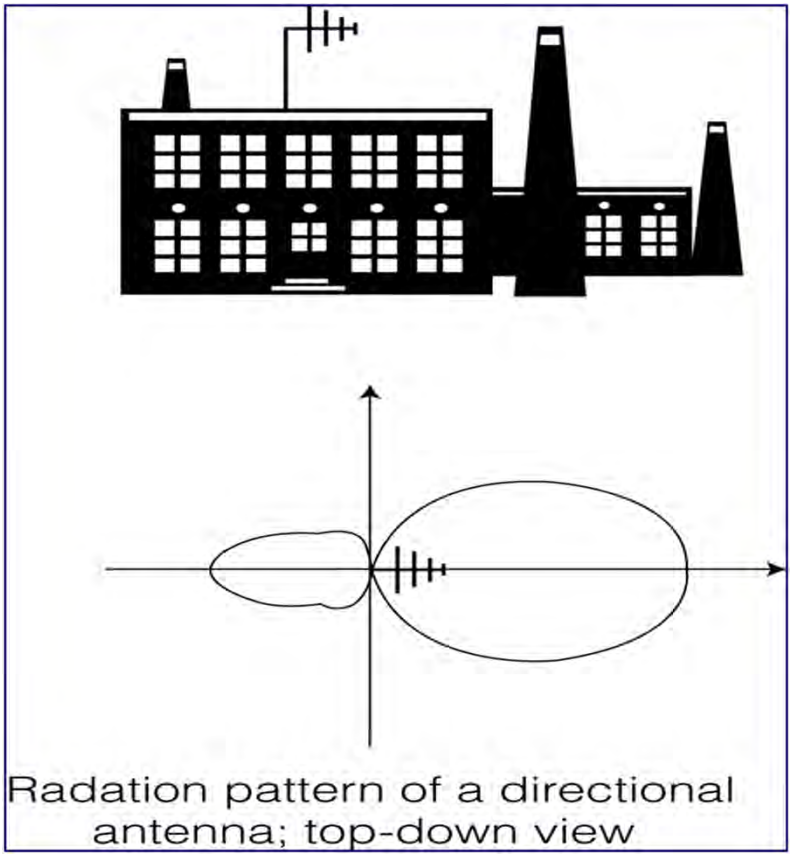




Radiation pattern of a vertical antenna;
top-down view

Omni-directional antennas are typical for AMR

DIRECTIONAL ANTENNAS

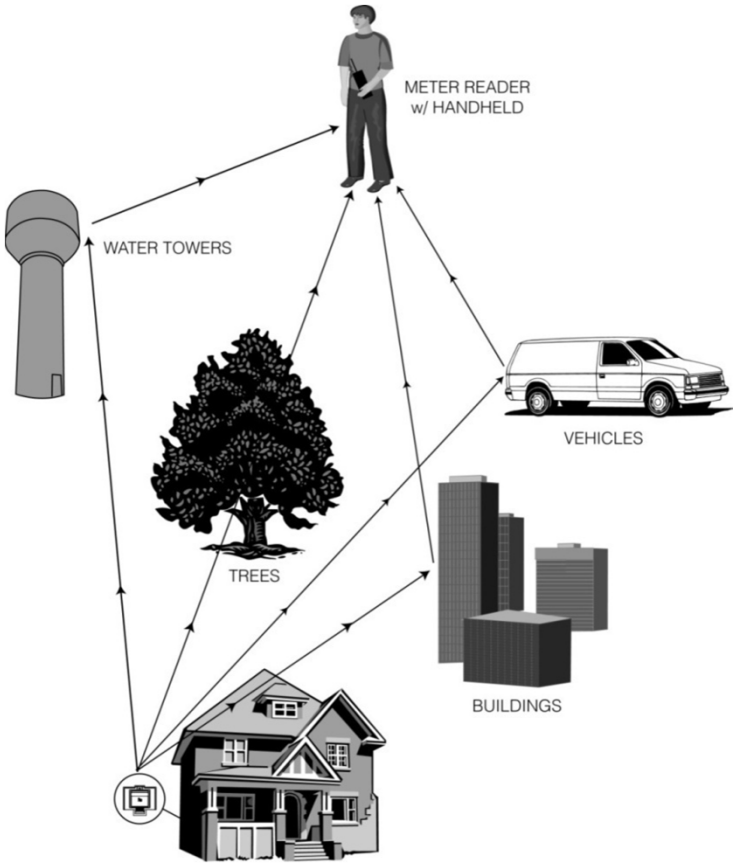


Directional antennas typical in SCADA but not AMR

ANTENNA CONSIDERATIONS

Separate multiple antennas as much as possible to avoid interaction

THE BOTTOM LINE



It’s difficult to predict RF paths

THE BOTTOM LINE

- RF transmission is influenced by many factors
- Specific applications will experience greater range while others will experience reduced range
- Conditions are continually changing

THE BOTTOM LINE

- Good installations will strive for a clear line of sight between endpoint and receiver
- Signals may still be received even though they are seriously degraded
- Multiple paths might either enhance the received signal or create a dead zone
- Maximum distance will vary for each transmitter/receiver combination

INSTALLATION TIPS

- Carefully follow installation instructions
- Try for a clear line of sight; locate endpoint to minimize obstructions
- Remote endpoint must be used in basement floor joists or on the outside of the building as alternative to an integral for basement applications

INSTALLATION TIPS

- Badger Meter requires that all Pit Endpoints be installed thru-the-lid using only non-metal lid (no integrals) for optimal performance

METER READING TIPS

- Systems will perform best when there is a clear line of sight between the gateway and the endpoint
- Two way systems may require additional infrastructure to ensure the communication to and from the endpoint is established
- Keep pit lids free of dirt, grass, debris

INTERFERENCE AND LICENSED VS. UNLICENSED

- Interference is going to happen on licensed and unlicensed channels.
- “Unlicensed” doesn’t mean “Unregulated”.
- ORION has been designed to communicate across the ISM band to get reading data through if interference does occur.
- If you’re licensed to a specific frequency and you have an issue with interference, you’re stuck, you can’t move.
- Additionally, the government still owns the frequency and is able to change the rules as needed.
- “Licensed” doesn’t guarantee you won’t have interference.

THANK YOU.