International Coal Prep 2011
Annual Coal Processing Exhibition and Conference

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Application Considerations

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GCI THE FORCE... ...IN CONTROL®

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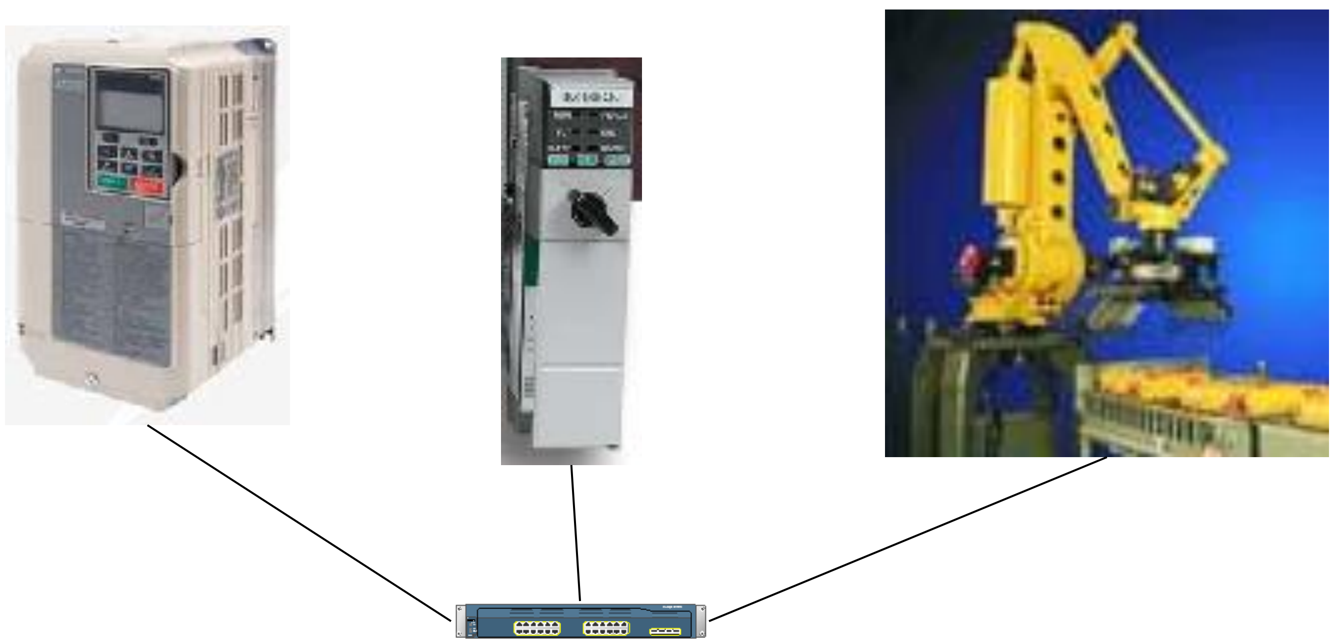
Ethernet Dominates on the Plant Floor



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Recognize Any of These ?

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Answers:

10 BASE 2 RG 58/U (Thin Ethernet)

Thinnet NIC

50 Ω Terminator

AB Pyramid Integrator Ethernet Interface

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Today's wireless network

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Workshop Goals

- **Wireless communication terminology**
- **Radio system hardware**
- **Wireless application planning and design**
  - **Functional Requirements**
  - **Site Requirements**
  - **Topology Configuration**
  - **System Gain Calculations**
- **Review of Application Examples**

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Brief Discussion of Radio Terminology Technology

- Signal Strength
  - Gain
- Radio Hardware Components
  - Transceiver
  - Antenna

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THE BASICS – SIGNAL GAIN

- Gain is a term used to quantify the transmission and reception characteristics of radio components.
- Gain is a ratio of device power relative to a reference power of 1_{mW} (device $power_{mW}$ / 1_{mW} = device power).
- Gain is expressed in decibels (dB) which is a logarithmic value.

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THE BASICS – SIGNAL GAIN

$$Gain_{dB} = 10 \log_{10} (\text{device power}_{mW} / 1_{mW})$$

or

$$Gain_{dB} = 10 \log_{10} (\text{device power})$$

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Amplifier Gain dBm

When comparing the relative power or sensitivity of a radio amplifier, the term ***gain*** expressed as dBm (decibel relative to milliwatt) is used.

Example 1 – A radio device transmits an amplified signal with a power output of 1W at the antenna connection. What is the radio transmitter's gain in dBm?

Using the formula above: Gain = $10 \log_{10} (\text{device power}_{mW} / 1_{mW}) =$

$10 \log_{10} (1000_{mW} / 1_{mW}) = 10 \log_{10} (1000) = 10(3) =$ ***30dBm***

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Amplifier Gain

Example 2 – A radio receiver circuit is sensitive to an incoming signal with a power level of 10_{pW}. What is the receiver's gain in dBm?

Using the formula above: Gain = $10 \log_{10} (\text{device power}_{mW} / 1_{mW}) =$

$10 \log_{10} (10_{pW} / 1_{mW}) = 10 \log_{10} (10_{pW}/1000000000_{pW}) =$

$10 \log_{10} (.000000001) = 10(-9) =$ ***-90dBm***

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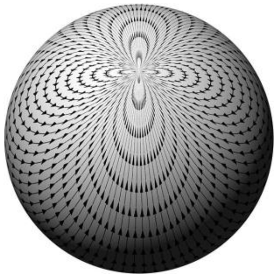
Antenna Gain dBi (Isotropic)



Theoretical Isotropic Antenna with EM Field of 1 $_{mW}$

When comparing antenna focusing characteristics using the 1 mW Isotropic reference, the term ***gain*** expressed as dBi (decibel relative to Isotropic) is used. The theoretical gain of an isotropic antenna = 10 $\log_{10}(1) = 10*0 =$ $\mathbf{0}_{\mathbf{dBi}}$.

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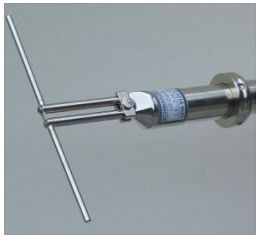
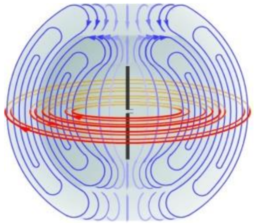
Antenna Gain dBd (Dipole)

Dipole Antenna with EM Field of 1.64 $_{mW}$

The closest real antenna that exhibits isotropic characteristics is a simple two wire dipole. The gain of a dipole relative to an isotropic reference = 10 $\log_{10}(1.64_{mW} / 1_{mW})$ = 10 $\log_{10}(1.64)$ = 10*0.215 = **2.15_{dBi}**. The term ***gain*** expressed as dBd (decibel relative to dipole) is used.

$0_{dBd} = 2.15_{dBi}$, or $gain_{dBi} = gain_{dBd} + 2.15$

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Unlicensed Radio Frequencies

The FCC allocates a range of frequency bands designated Industrial, Medical, and Scientific **(ISM)** that do not require licensing. These bands are @ 900 MHz (902 – 928), 2.4 GHz (2.400 – 2.483), and 5.8 GHz (5.725 – 5.850) ***at a maximum power output of 30dBm.***

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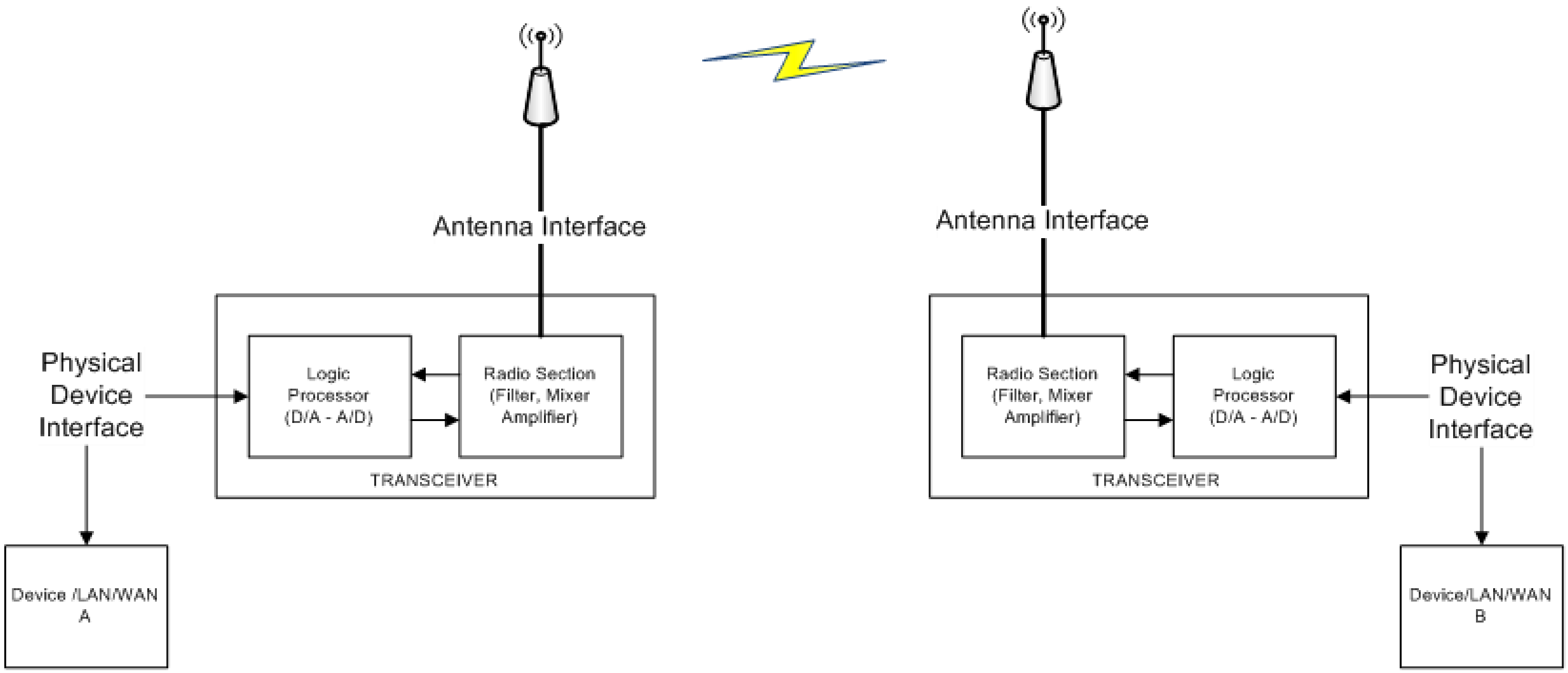
Block Diagram of Radio Components



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Understanding Radio Antenna Systems

- EM transmission through an antenna is analogous to light traveling through an optical lens. The lens does not add to the quantity of light but acts to focus the available light to increase the observed intensity at different locations.
- An antenna acts to focus as well as be sensitive to RF energy in a specific pattern. Antenna gain is a measure of the signal focus.
- Antennas are typically designed to provide either uniform or directional sensitivity.

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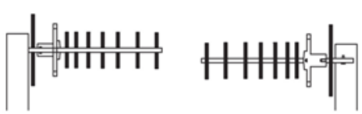
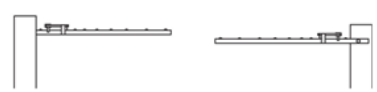
Yagi Antenna

A ***Yagi*** antenna design will generate and be sensitive to RF energy in a focused pattern which is parallel to the direction and in the same plane as the antenna is mounted.

Because the radiation pattern is planer, two Yagi antennas should always be mounted in the same orientation.





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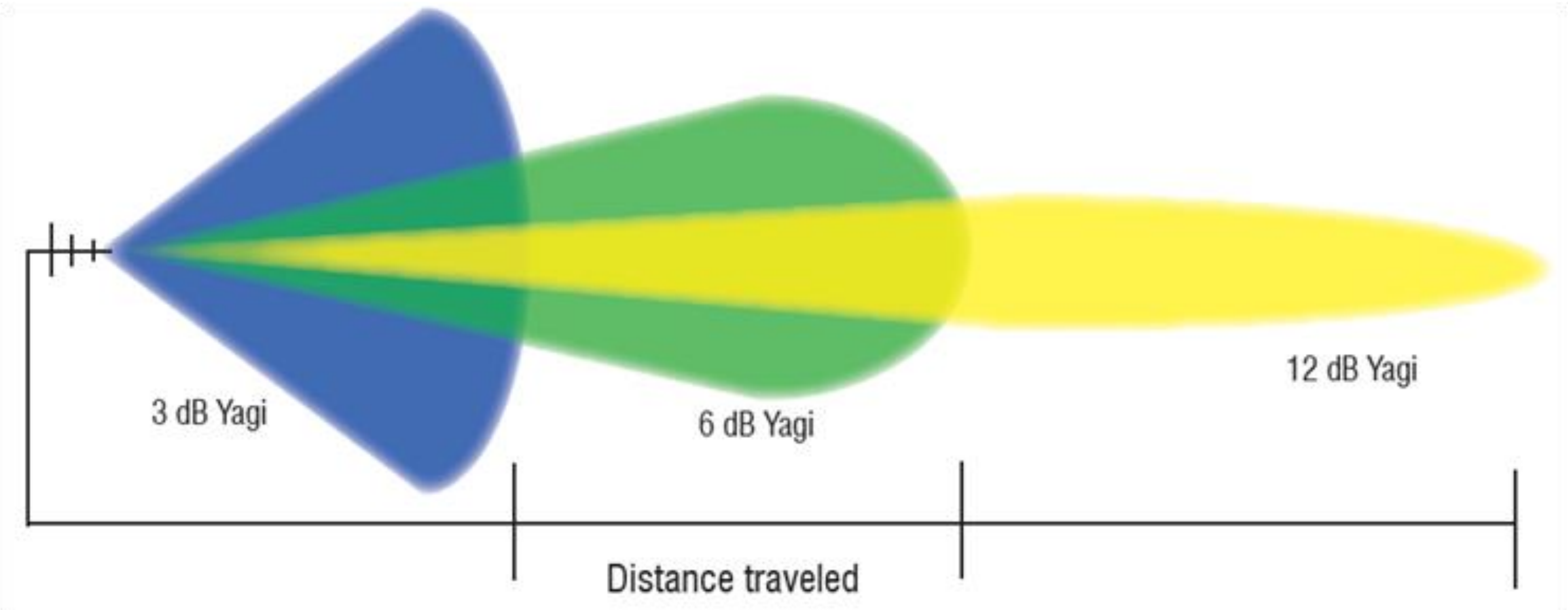
Yagi Antenna EM Dispersion vs. dB



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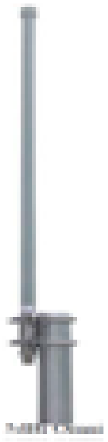
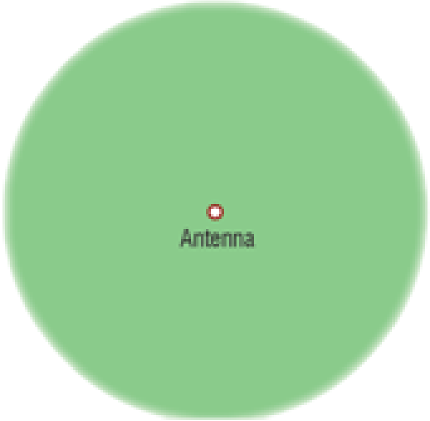
Omni Antenna

- An Omni-directional antenna is designed to provide sensitivity that is in a uniform radial pattern in the plane perpendicular to the direction the antenna is mounted.





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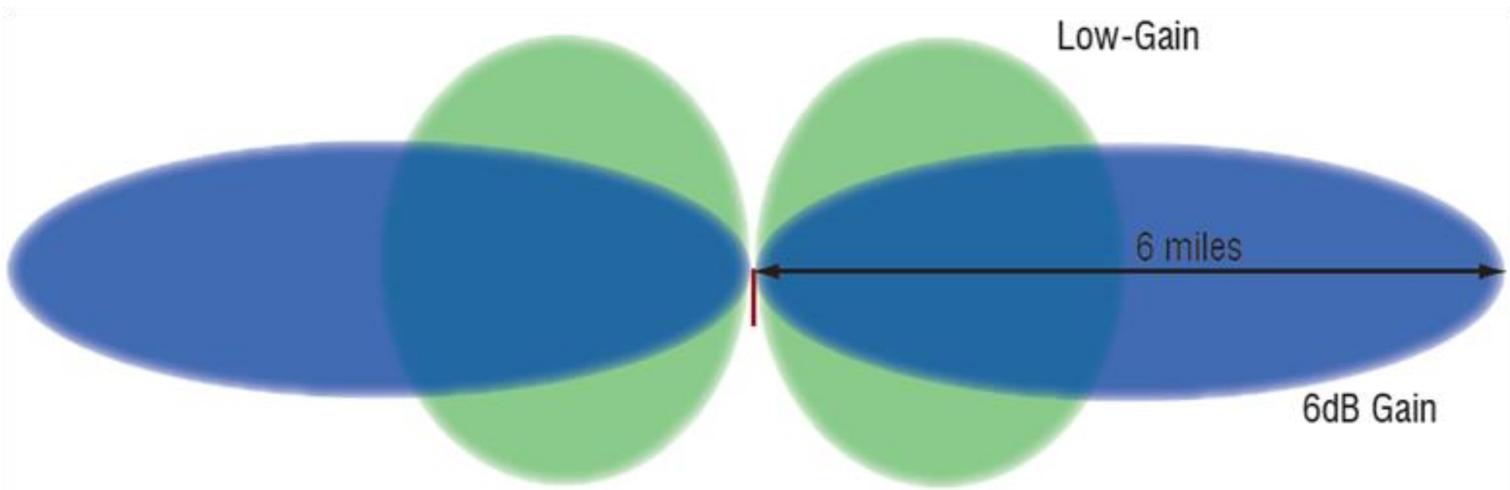
Omni Antenna EM Dispersion vs. dB

A higher gain Omni antenna will have a narrower sensitivity in the vertical plane.



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Radio Transceiver Frequency

- 900 MHz – Range up to 40 miles clear line of site or 1500 ft w/obstacles penetration, data rate 400 – 800 Kbps.
- 5.8 GHz – Range up to 40 miles clear line of site, no obstacle penetration, data rate up to 10 Mbps.
- 2.4 GHz – Used predominately for indoor WI-FI.

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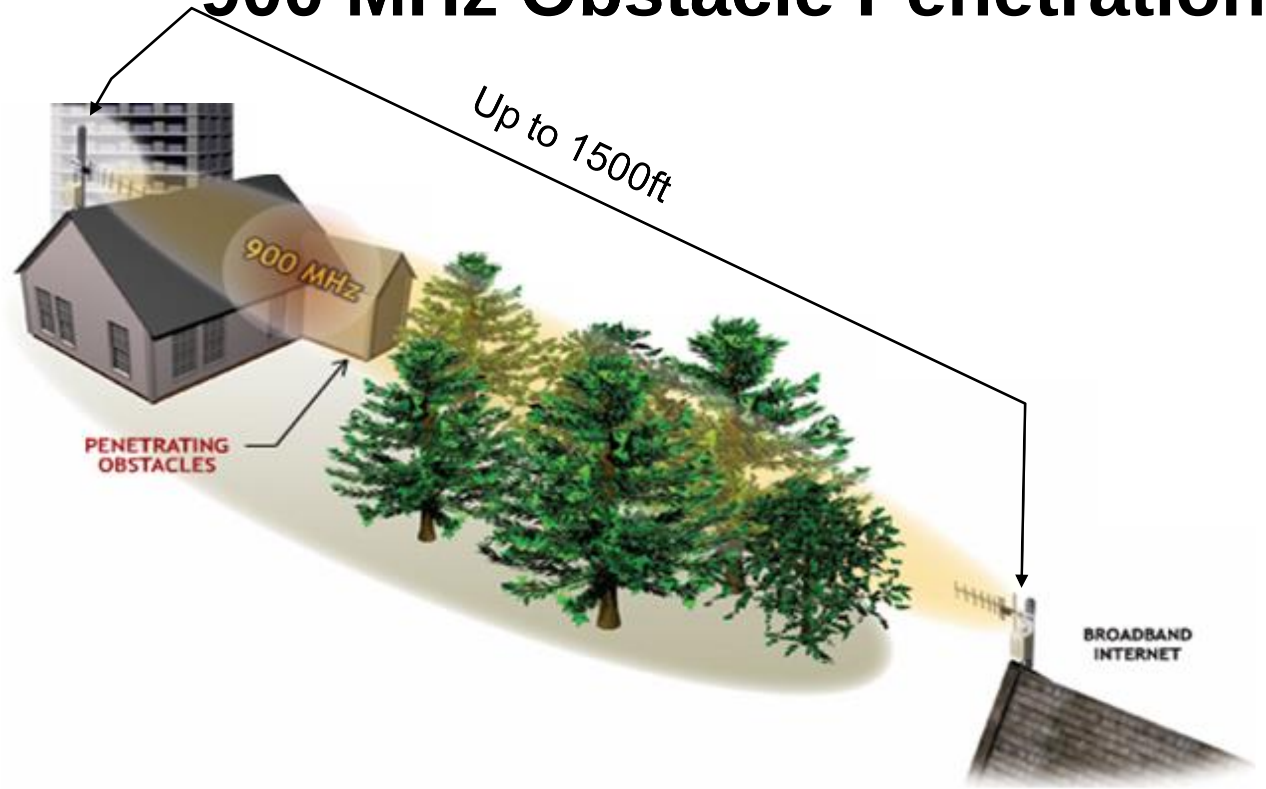
900 MHz Obstacle Penetration



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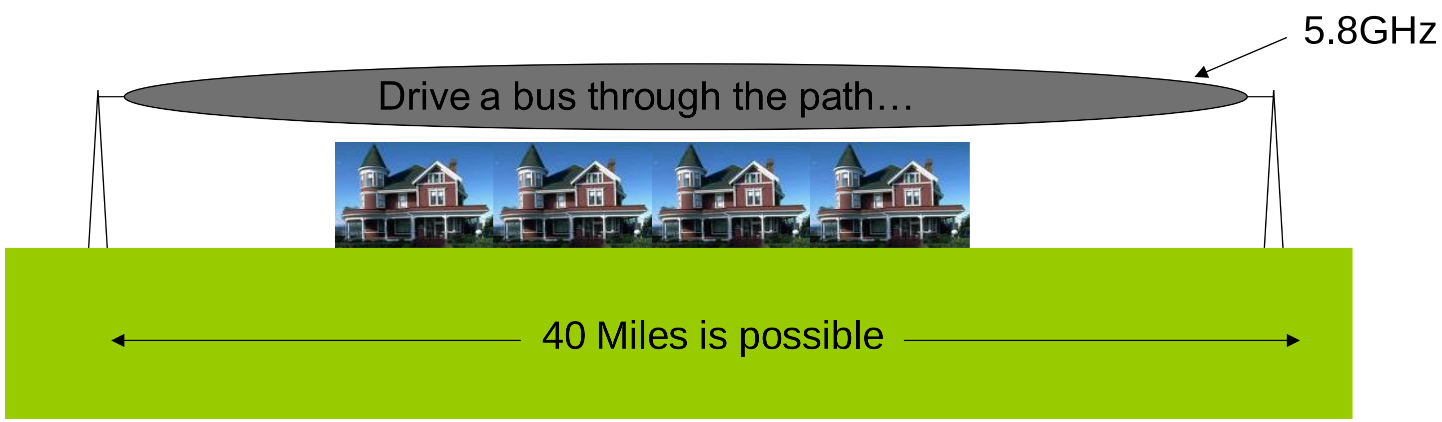
5.8 GHz Clear Line of Site



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Design – Functional Considerations

- What's the application (I/O control, SCADA, video surveillance)?
- How many remote locations must be connected?
- What protocols are already in use?
- Will this system be attended or unattended/fully automated?

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Design – Bandwidth Considerations

- On-line PLC programming (100 – 500 Kb)
- Video surveillance (800Kb w/MPEG4 compression)
- LAN/WAN bridging (10Mb – 100 Mb)

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Design – Site Survey

- System topology based on number and location of communicating devices
- Distance and clarity of sight between communicating devices/systems
- Existing wireless systems and or other RF sources at the site

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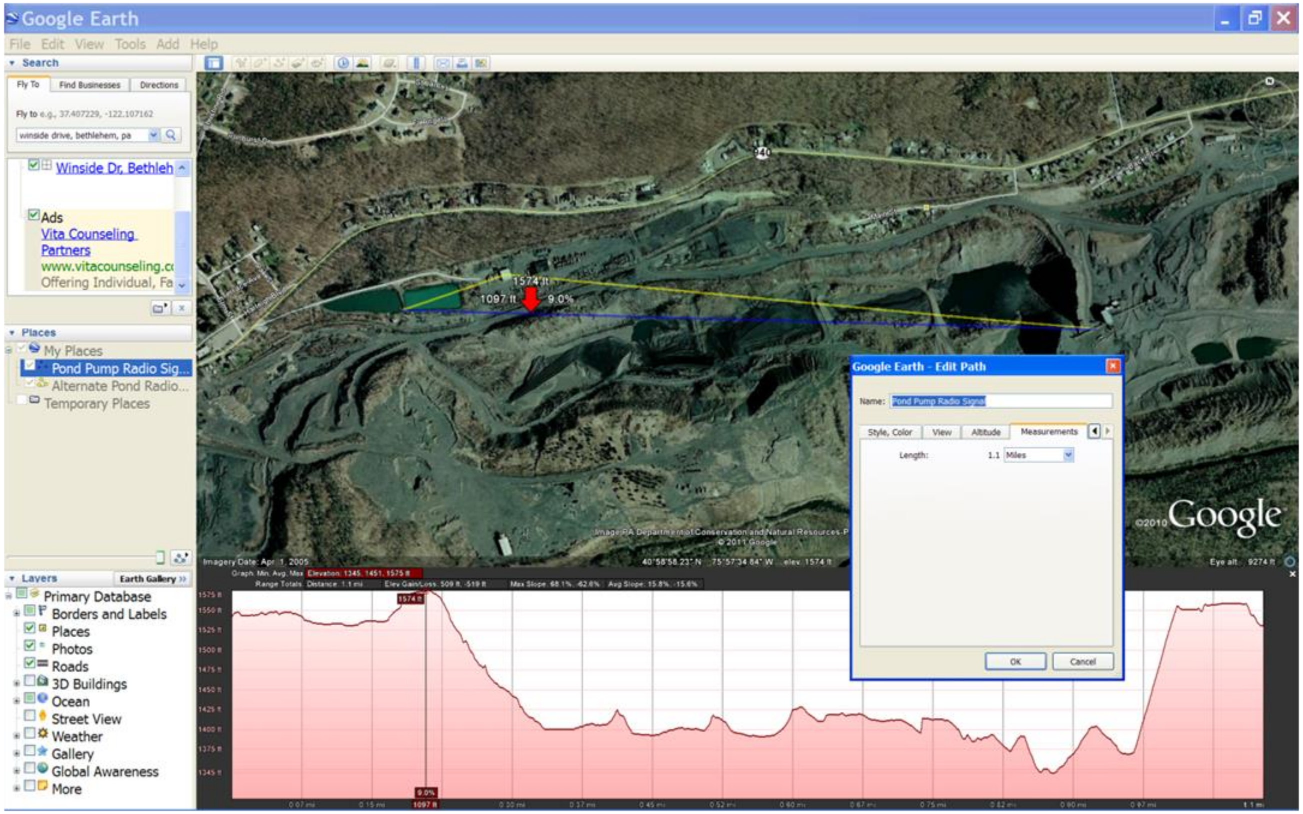
Site Survey Tools – Google Earth



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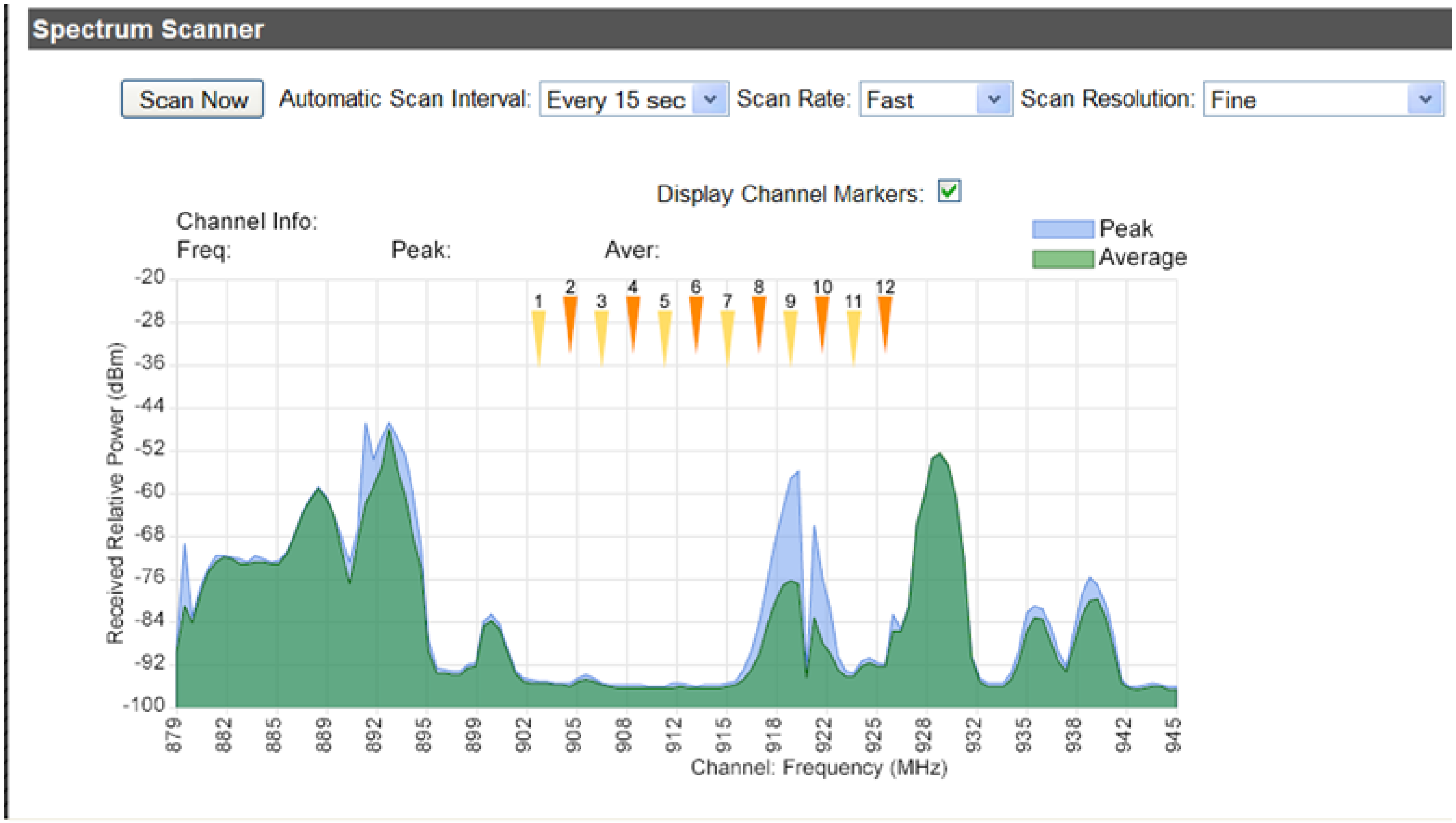
Site Survey Tools – Frequency Spectrum Analyzer



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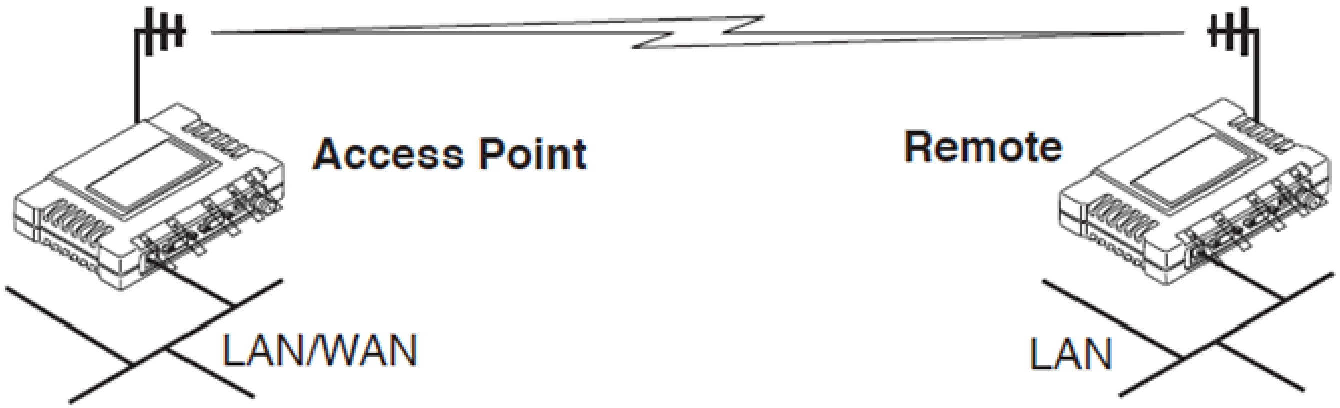
System Design – Point to Point Topology



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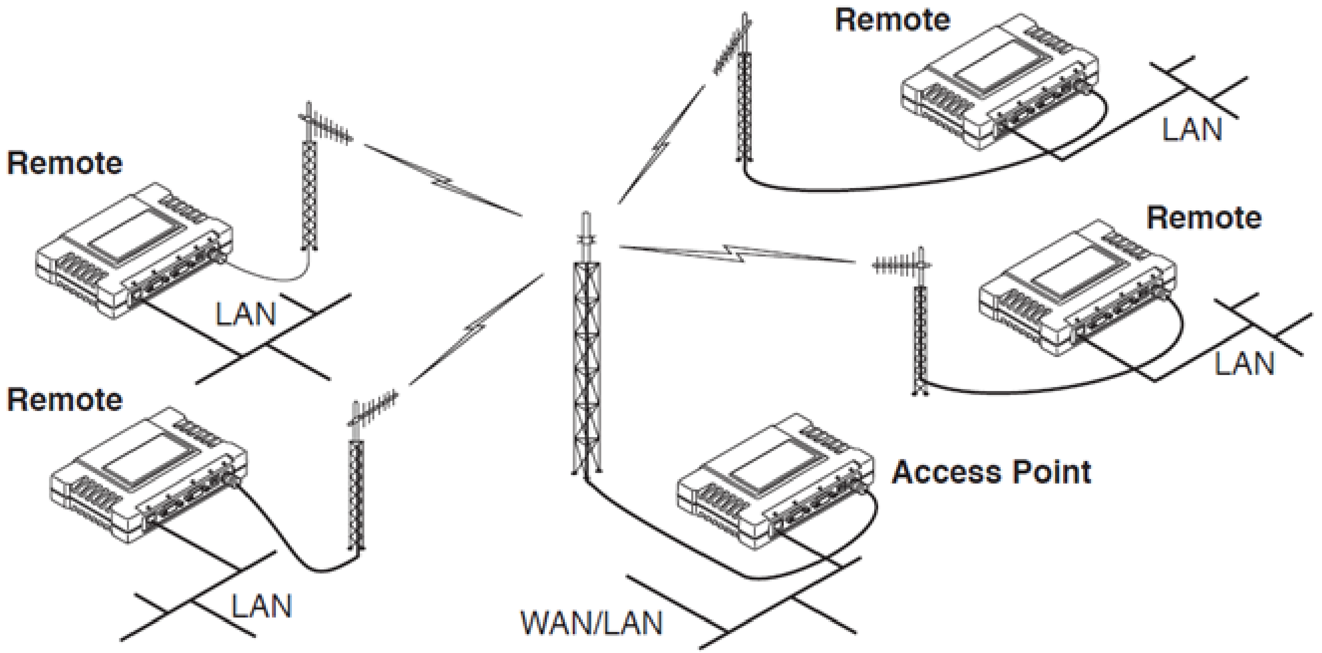
System Design – Point to Multipoint Topology



- Usable bandwidth is reduced by number of remote clients

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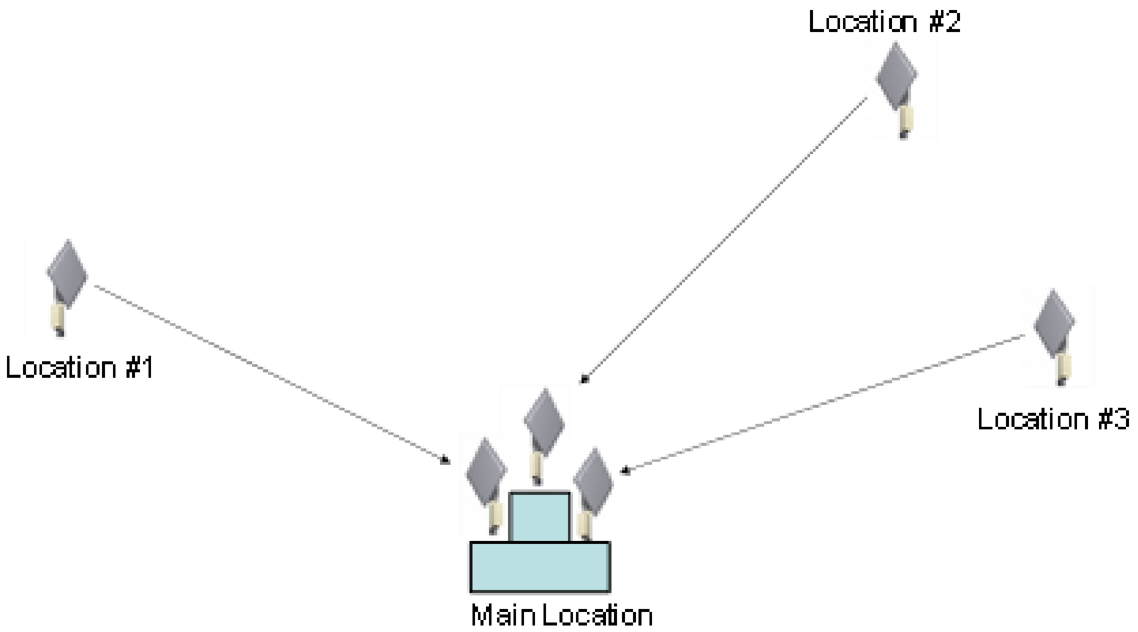
System Design – Alternate Point to Multipoint



- Usable bandwidth is available to each remote client

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System Design – System Link Budget

Once the overall design strategy has been determined, selection of radio hardware requires an estimation of the overall wireless system gains and losses. Each component of the system will be accounted for in a **Link Budget** calculation as follows:

Calculated Received Gain = Transmitter Gain + Antenna 1 Gain + Antenna 2 Gain – Free Space Loss – Component Loss

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System Design – Hardware Gains

- Transmitter (amplifier) gain is the power output of the transmitter section in decibels dBm. This will be specified by the manufacturer.
- Antenna gain is the focusing characteristic. This will be specified by the manufacturer for a given antenna design in either units of dBi or dBd. Remember that if a dBd gain is provided, the value 2.15 dB must be added to yield an equivalent dBi gain.

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System Design – Free Space Loss

- Free space loss is the physical loss of electro-magnetic energy during propagation.
- The equation used by radio engineers to estimate the free space loss between two isotropic antennas is $L = 20 \text{ Log}_{10} (4\pi d/\lambda)$. L is the power loss in dBi.
- The equation simplifies to **$L = 20 \text{ Log}_{10} (\text{Freq}_{\text{MHz}}) + 20 \text{ Log}_{10} (\text{Distance}_{\text{miles}}) + 36.6$**

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System Design – Component Loss

- The antenna's physical interface to the transceiver is a critical component that must be accounted for during the system design process.
- Each connecting device (cable, adaptor, etc) will act to ***attenuate*** or decrease the overall gain of the antenna system. The attenuation gain specifications for each component are typically provided by their manufacturer in units of dBi or dBd.
- Cable attenuation gain specifications are given in units of dB per unit cable length.

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System Design – Safety Margin

- Once the **Calculated Received Gain** is obtained, it is compared to the radio receiver sensitivity specification, which is supplied by the radio manufacturer.

  Calculated Safety Margin = Calculated Received Power – Receiver Hardware Sensitivity.

- Each radio manufacturer will specify a safety margin value which is a minimum performance comfort zone. The calculated safety margin should be ≥ manufacturer specified safety margin.

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System Design – Hardware Selection

- The results of the **Link Budget** calculation will dictate the maximum estimated distance between any two antennas at a given radio frequency.
- Distance can be increased by selection of a higher gain antenna.
- ***It's important to remember that FCC regulations restrict the maximum forward gain of any unlicensed radio transmitter not to exceed 30 dBm. It's the responsibility of the designer to ensure that these rules are enforced.***

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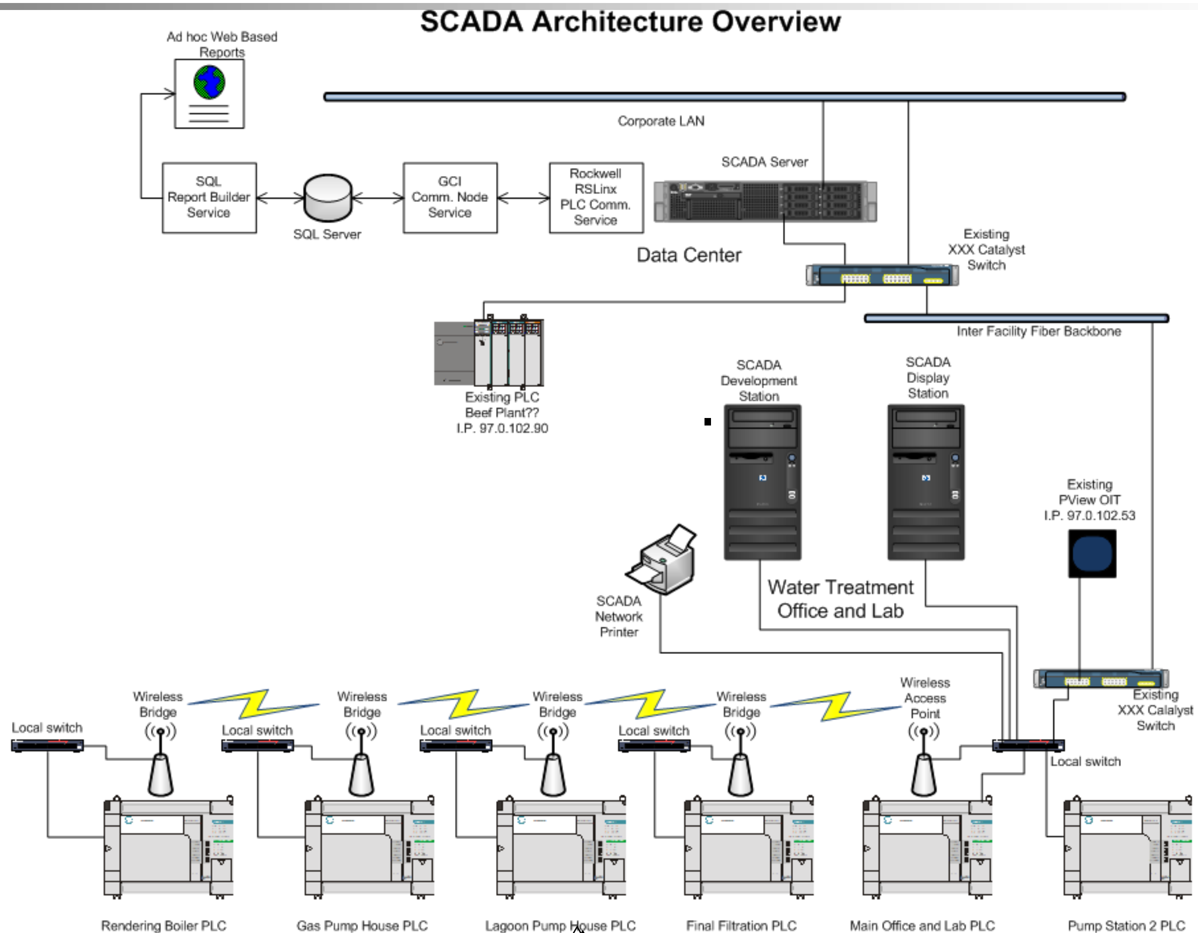

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SCADA Application Challenges:

- Point to Multipoint configuration reduced overall bandwidth for each remote PLC system
- Large cellular array on the site premises caused interference
- Existing I/O telemetry system caused interference
- Resulting communication errors further reduced overall system bandwidth

Solutions:

- Background noise and number of radios hampered the throughput of the system. Configured the sever PC to provide a clock synchronization update event once per day for all PLC's and workstations. Used each PLC system to pre-process data and events to be collected by creating a time stamp and storing data entries in a logical memory stack. These stacks were unloaded to the server database when bandwidth conditions were favorable.

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Application Examples – Attended Conveyor Control

- Mobile attended system with dedicated Access Point I/O radio and multiple remote push button stations
- Allow truckers to start and stop coal loading conveyor from within vehicle cab

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Application Examples - Remote Pump Station

Wireless Pump Control Circuit.pdf

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QUESTIONS