Overview of Wireless Technology Implementation

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What is going on with Wireless

- Shift in focus from condition monitoring to the mobile workforce
- Ongoing work on industry wireless protocols
- New engineers expect mobility
- Most applications based on Wi-Fi technology
Nuclear Guidance on Wireless Technology

- **IEC TR 62918 Ed. 1.0 – Released July 2014**
  - General Overview of Wireless Technologies
  - Description of Existing Wireless Installations
- **EPRI TR-102323 Rev 4 – Released Dec 2013**
  - Address Exclusion Zones
  - Spectrum Management
- **Miscellaneous Documents**
  - NRC: Applications and Coexistence
  - EPRI: General Guidance and Implementation
Guidance Under Development

• IEC Wireless Standard Development
  – Build upon IEC Report
• IAEA Coordinated Research Project
  – Report of Wireless Technology
• NRC Reg. Guide 1.180 Revision 2
  – EMC Wireless Guidance: Exclusion Zones
• EPRI TR-102323 Revision 5
  – EMC Wireless Guidance: Exclusion Zones
  – Build upon Appendix
• IEC 62003 Ed. 2
  – EMC Standard
Applications of Wireless Technology in Nuclear Power Plants
On-line Monitoring – Wireless Applications

Arkansas Nuclear One (ANO)
- Containment Cooling Fans
- CEDM Cooling Fans
- Oil Collection Tanks

High Flux Isotope Reactor (HFIR)
- Cooling Tower Fans
- Cold Source Expansion Engines

Benefits:
- Automatically Perform Routine Surveillance Testing on Equipment
- Enables Monitoring in Hard to Access or Hazardous Locations
- Provides Solution to the High Cost of Running Cable
NPP Application: ANO Containment Fans

- **Purpose:** Circulate and cool containment air maintaining uniform ambient temperature, preventing localized ‘hot spots’

- **Significance:** Failure of a single fan causes unit to shut down if repair takes longer than 72 hours

- **Current data collection:** Every 9 months

- **Failure history:** 1 fan failure every 4 years

- **Average downtime due to fan failure:** 5 days
# In-Containment Specifications

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Description</th>
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<tbody>
<tr>
<td>EMI/RFI</td>
<td>System must not interfere with existing equipment, nor be impacted by the target environment; communication frequency must be 2.4 GHz.</td>
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<tr>
<td>Cyber Security</td>
<td>System must incorporate Wi-Fi Protected Access II (WPA2) security features</td>
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<tr>
<td>Fire Load</td>
<td>System must not add appreciable combustible material to containment</td>
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<tr>
<td>Secure Anchoring</td>
<td>System must be anchored such that it cannot be dislodged and swept into the sump system</td>
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<tr>
<td>Ambient Environment</td>
<td>System must survive at 95°F, relatively low humidity, and low levels of radiation (e.g., &lt;1 mrem/hr)</td>
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</table>
ANO Containment Wireless
Cooling Fan Vibration & Tank Level

Unit 1 Cooling Fans

Unit 2 Cooling Fans

Unit 1 Oil Tank Level
WiFi Data displayed in ANO Plant Computer
HFIR System Description

Cooling Tower

WAP

Antenna

Data Acquisition and Analysis

Engineer's Desktop

Wireless Transmissions

Cooling Tower

Expansion Engines

HFIR Network

HFIR Client

HFIR Client

HFIR Client

AMS Equipment Health Monitoring System for HFIR

Operations

Config.

Limit Parameters

Schedules

Cooling Tower System Selected

System Status

Alarm Status

System Maintenance

Troubleshooting

View Acquisition

View Trends

View Waveforms

EXIT
Vibration Analysis at HFIR Expansion Engines

- Analysis shows smooth operation of 3 engines
- 4th engine shows erratic and high vibration levels
- Engine failed in service in the next operational cycle
EMI has Hindered Wireless
What is the Issue?

- Most equipment was not qualified
- Equipment that was qualified was only tested to 1 GHz
- Qualification testing may not have replicated the plant installation
  - Door may have been closed
  - Cabling may not have matched plant wiring
  - Configuration may not have replicated installation
- Assumption is made that 4 V/m is tolerable by plant equipment
  - In some cases this may be overly conservative but in other cases it may not be adequate
  - This really only applies to equipment that was tested to 10 V/m (8dB greater)
- EPRI and NRC both provide an equation for calculating the exclusion distance that is based on free space propagation
Exclusion Zone distance is dependent upon transmitter power and antenna gain.

\[
d = \frac{\sqrt{30P_t G_t}}{E} \text{ (meters)}
\]

Where:
- \(d\) = exclusion zone distance (in meters)
- \(P_t\) = the effective radiated power of the EMI/RFI emitter (in Watts);
- \(G_t\) = the gain of the EMI/RFI emitter (dimension less); and,
- \(E\) = the allowable radiated electric field strength of the EMI/RFI emitter (in Volts/meter)
Can you hear me now?

Power Output

- IEEE 802.15.4: 1mW
- Bluetooth: 100mW
- Wi-Fi: 250mW
- Cell Phone: 2 W
- Walkie Talkie: 5 W
Don’t forget the antenna

Omni-Directional Antenna

Directional Antenna
Frequency DOES MATTER

The diagram shows a comparison of various frequency bands and their measured output of pressure transmitters. The x-axis represents frequency in MHz, ranging from 100 to 6000 MHz. The y-axis shows the measured output of pressure transmitters in various units.

- **Site Radios**
  - Frequency range: 100 MHz to 600 MHz
  - Measured output peaks at 0.018

- **Site Radios**
  - Frequency range: 600 MHz to 1000 MHz
  - Measured output peaks at 0.016

- **Cell Phone / Hands Free Headsets**
  - Frequency range: 1000 MHz to 1500 MHz
  - Measured output peaks at 0.014

- **Cell Phone**
  - Frequency range: 1500 MHz to 2000 MHz
  - Measured output peaks at 0.012

- **Network Connectivity 802.11n**
  - Frequency range: 2000 MHz to 2500 MHz
  - Measured output peaks at 0.01

- **Cordless Phones / Network Connectivity**
  - Frequency range: 2500 MHz to 3000 MHz
  - Measured output peaks at 0.008

The diagram visually represents the measured output of pressure transmitters across different frequencies, emphasizing that frequency does indeed matter in these applications.
Limitations of exclusion zones

- Adequate/Clear Signage
- Knowledgeable Personnel
- Varying output power of different devices
- Inadequate clearance
- Improperly applied
- Based upon an assumed level of immunity
- Continuously updated for new equipment
Example Exclusion Zones from a Nuclear Utility

- Laptop computer/VoIP communication devices
  - Exclusion distance = 32”
- Tablet computer such as the iPad (without integrated cell phone – recommended - or cell disabled) and other handheld logging devices (use iPad mini distance);
  - Exclusion distance for iPad 2 = 4 FT
  - Exclusion distance for iPad mini / iPad Air = 6 FT
  - Exclusion distance for iPad 4 = 8 FT
- Wireless vibration monitoring probe
  - Exclusion distance = 24”
- Wireless dosimetry
  - Exclusion distance = 12”
Methods for Overcoming Exclusion Zone Limitations

• Hope for the best
• Perform an engineering evaluation of the equipment to assess its vulnerabilities to wireless
• Harden equipment against wireless signals
• Perform qualification testing of similar equipment at the manufacturer’s facility/warehouse/training center/simulator
• Perform in-situ immunity testing of the plant equipment
• Install new equipment with demonstrated immunity to wireless
• Reduce output power of wireless devices
Diablo Canyon Investigating Wireless

• Fire sparked need for evaluating impact of wireless devices on plant equipment

• Implementation Project
  – Walkdown of Equipment
  – Characterize Electromagnetic Environment
  – Immunity testing of plant equipment
Immunity Test Diagram
Plant Equipment Tested for Immunity

- Various Barton and Rosemount Pressure, Level, and Flow Transmitters
- Various Relays and Modules associated with 4160V Vital Bus
- Seismic Trigger Instrumentation
- Digital Feedwater Control System Development Simulator
- Turbine Control System Development Simulator
- Source Range Nuclear Instrumentation System Training Drawer
- Intermediate range Nuclear Instrumentation System Training Drawer
- Solid State Protection System Training Cabinet
- Radiation Monitors

These devices tested represent a total of 1702 installed devices in the plant.
Identification of Vulnerable Equipment

- Barton 763 Pressure Transmitter
- Barton 368 & 369 Pressure Transmitters
- Victoreen Radiation Monitor model 876A:
- Rochester Position Transmitter Model SC-1300R
- Victoreen radiation detector and preamplifier assembly model 943-25T
Summary

• Wireless technology can be successfully used in a nuclear power plant

• The risks and concerns can be addressed and mitigated

• Guidance and OE is being gathered and developed

• How can wireless benefit you?
Thank You