INNOVATING NUCLEAR TECHNOLOGY

ANALYSIS AND MEASUREMENT SERVICES CORPORATION

Implementation of IIoT and Wireless Technologies in US NPPs

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Presentation Outline

- **Summary of AMS Activities Associated with Wireless Technology**
- **Overview of IIoT and Wireless Sensor Selection and Implementation**
- **Considerations Associated with Wireless Technology**
  - Coverage
  - Spectrum Management
- **Addressing EMI/RFI Concerns**
  - Reducing Exclusion Zones
  - Verifying Equipment Immunity

Research Projects Conducted by AMS

- **Sensor Specification (EPRI ID: 3002011818; Published: 2018)**
  - Identified commercially available wireless sensors capable of deployment in a nuclear facility for various condition monitoring applications
  - Developed implementation guideline for implementation of wireless sensors in NPPs
  - Characterized the electromagnetic emissions from several wireless sensors
- **Wireless Technology Assessment (EPRI ID: 3002012707; Published: 2018)**
  - Characterized the electromagnetic emissions from commonly used mobile wireless devices such as cell phones, tablets, and laptops
  - Developed exclusion zones for various wireless protocols (Wi-Fi, Bluetooth, LTE) including a risk-informed analysis approach
- **Spectrum Management (Under Development)**
  - Documenting techniques for determining/monitoring the wireless spectrum
  - Developing strategies for wireless coexistence to prevent interference and allow for future expandability

Wireless Monitoring of Arkansas Nuclear One (ANO) Containment Fans

- Background:
  - Four fans to circulate air in containment
  - Failure of a single fan puts plant into 72 hour LCO. Repairs typically take 5 days
  - History of a fan failure once every 5 years
- Problem:
  - Fans are not accessible for routine monitoring during plant operation
  - Previous data collection: Once every 18 months
- Solution:
  - Developed a wireless system that will routinely collect vibration data from the four fan motors
  - Wi-Fi network established in containment
  - Copper and fiber optic data communications through containment wall

Important Wireless Sensor Characteristics

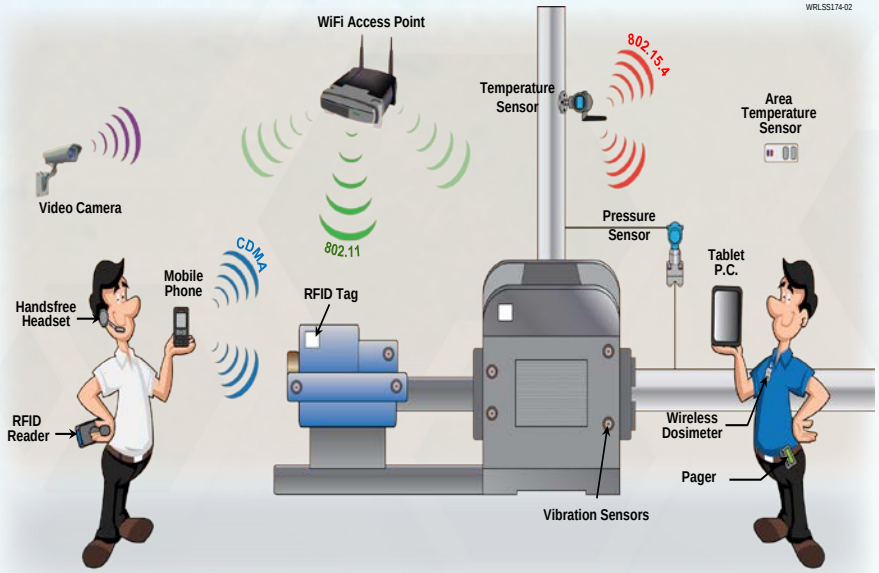
Protocol	Sensor	Considerations
• Pros: Single infrastructure; Established Coexistence • Cons: Limited Solutions	• Pros: Optimal solutions • Cons: Additional infrastructure	• Coverage • Throughput • Power Requirements • Frequency

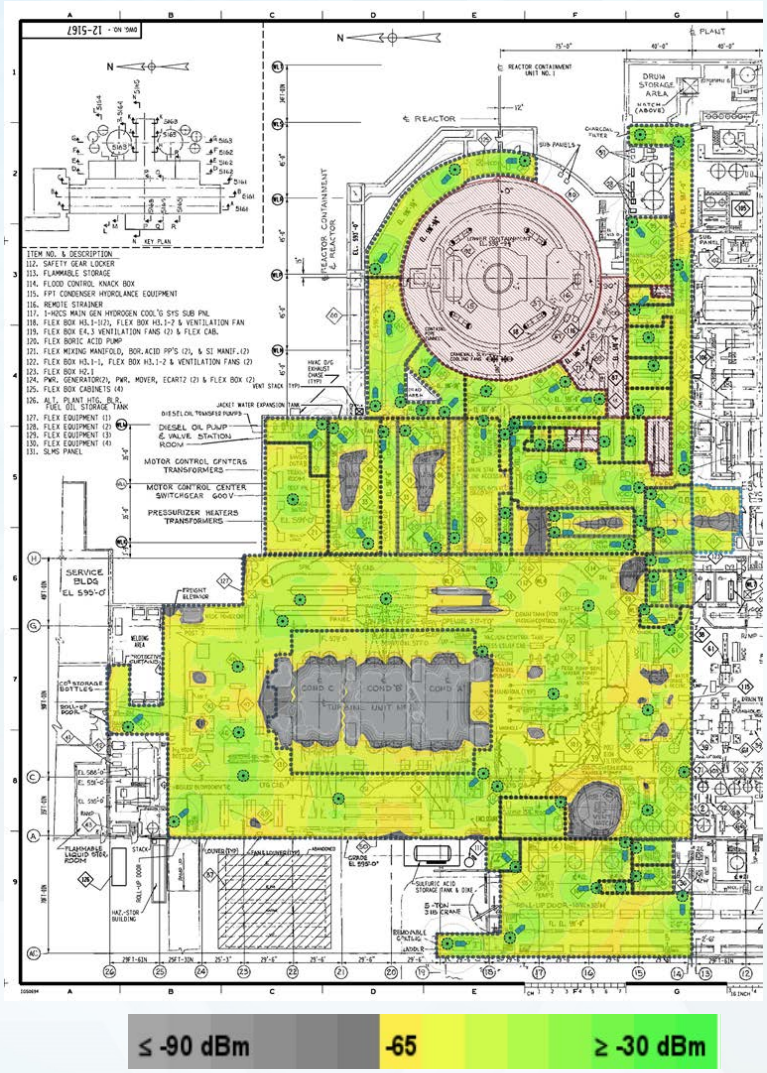
Condition Monitoring of NPP Equipment using IIOT Technologies

- **Equipment Being Monitored**
  - Pumps and Motors
    - Feedwater
    - Heater Drain
    - Condensate
    - Intake, Component, and Turbine Cooling Water
    - Reactor Coolant and Circulating Water
  - Valves
    - Main Feedwater Regulating Valves
    - High Pressure Feedwater Heater Level Valves
  - Transformers
    - Start-Up Transformers
    - Main Transformers
    - Auxiliary Transformers
- **IIOT Technologies**
  - Vibration Sensors
  - Wireless Gauge Readers
  - Data Mining Algorithms combining New and Existing Sensor Data

Potential Walkdown Activities

- **Evaluate Plant Environment**
  - Existing technology and exclusion zones
  - Potential monitoring locations
  - Coverage mapping
- **Identify Possible EMI Issues**
  - Possibly susceptible equipment
  - Deficiencies in equipment installation





Example Strategies for Wireless Equipment Condition Monitoring

Requested Parameter	Monitoring Options
Pump Suction & Discharge Pressure	Non-Intrusive: Wireless Gauge Reader or Wireless Camera Intrusive: Analog Gauge Replacement with Wireless Gauge Reader, Secondary Digital Gauge with Wireless Capability, or Digital Gauge Replacement with Wireless Capability
Pump Vibration	Non-Intrusive: Stand-Alone Wireless Vibration Transmitter or Wireless Transmitter Connected to Multiple New Accelerometers
Motor Bearing Temp	Non-Intrusive: Wireless Gauge Reader or Wireless Camera Intrusive: Gauge Replacement with Wireless Capability
Motor Vibration	Non-Intrusive: Stand-Alone Wireless Vibration Transmitter or Wireless Transmitter Connected to Multiple Accelerometers/Proximity Probes
Motor Current	Semi-Intrusive: Current Transducer Connected to Wireless or Wired Transmitter (Line Powered)

Exclusion Zone Calculations

$$d = \frac{\sqrt{30 P_t G_t}}{E} (meters)$$

Where:

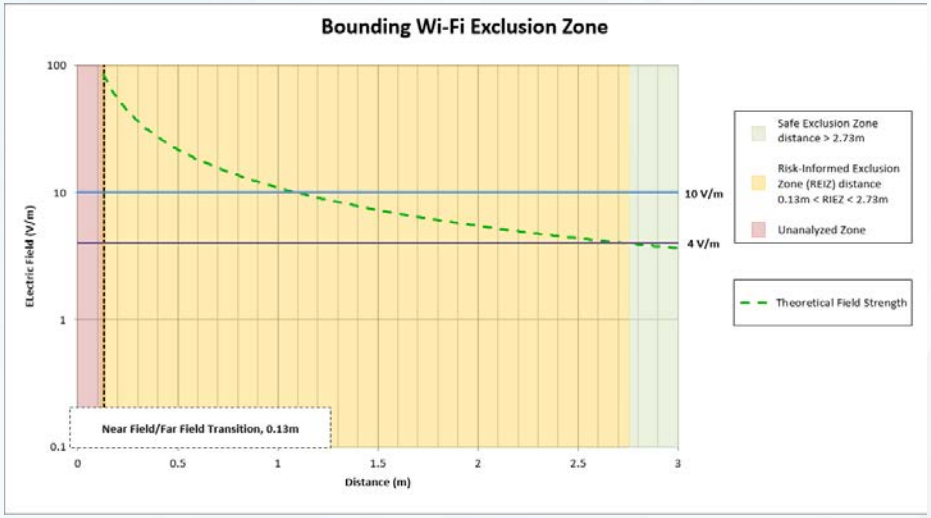
d = *exclusion zone distance* (*in meters*)

P_t = *the effective radiated power of the EMI/RFI emitter* (*in Watts*)

G_t = *the gain of the EMI/RFI emitter* (*dimensionless*)

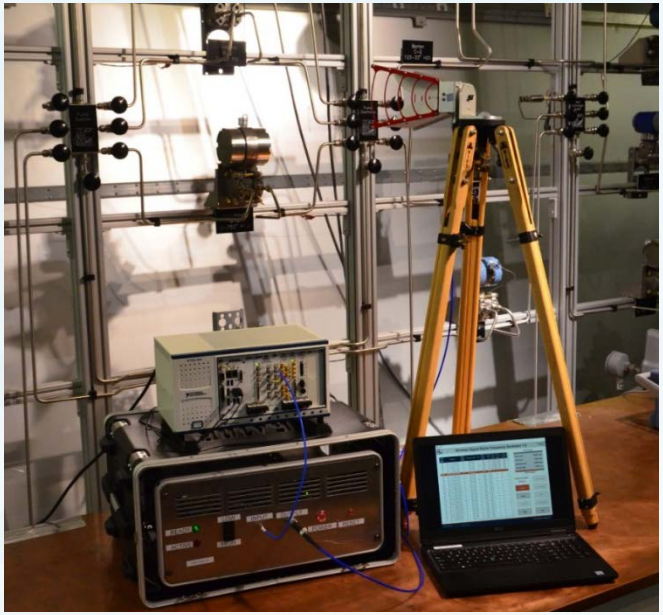
E = *the allowable radiated electric field strength of the EMI/RFI emitter (in Volts/meter).*

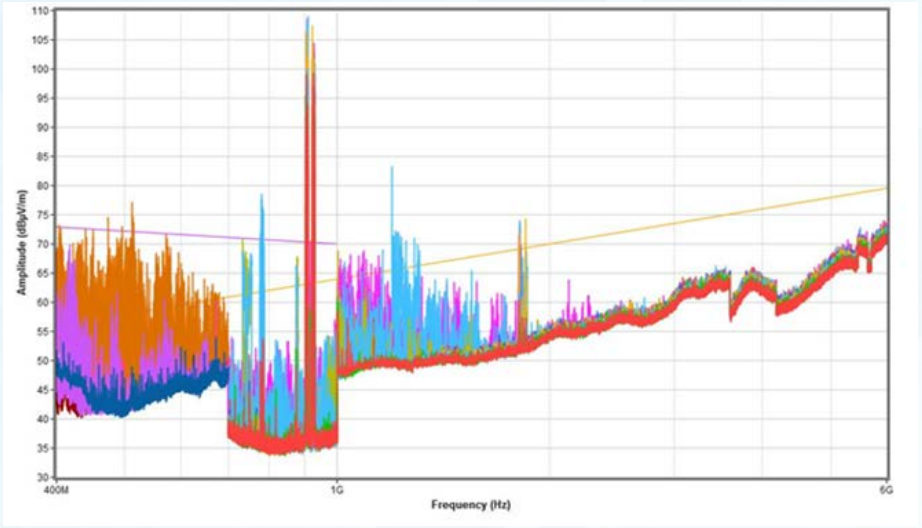
Wireless Device	Exclusion Zone Distance (feet)
Wireless Dosimetry	1
Laptop Computer	3
iPad 4	8
Walkie Talkie	13



In-situ Immunity Testing and Emissions Mapping

- **Immunity Testing**
  - Based on MIL-STD 461 High Frequency Radiated Susceptibility, Electric Field (RS103)
  - Performed In-situ or in an EMC Laboratory





- **Emissions Mapping**
  - Based on MIL-STD 461 High Frequency Radiated Emissions, Electric Field (RE102)
  - Passive measurements to characterize plant environment
  - Performed In-situ or in an EMC Laboratory

Summary

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Thank You!

Questions?