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A Comparison of Approaches to Short-Range Wireless Communications in Nuclear Facilities

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Introduction

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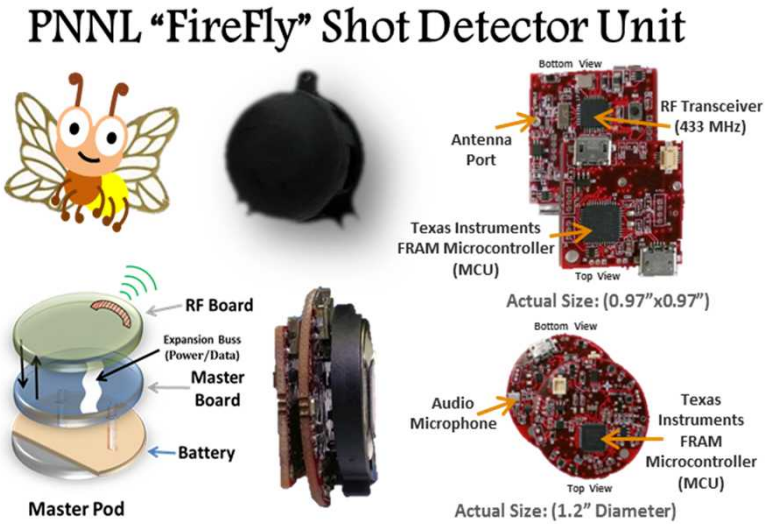
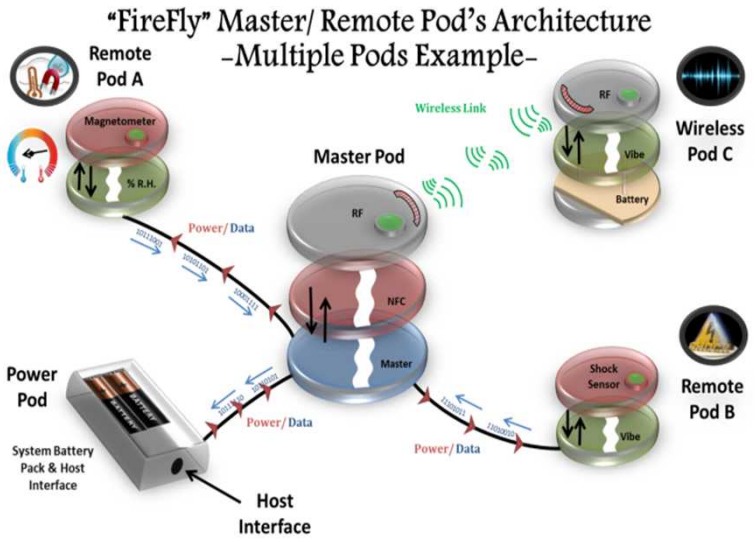
- Technical measures for monitoring and verification are becoming increasingly capable in:
  - International nuclear safeguards
  - Nuclear materials management
  - Future arms control concepts
- Small, short-range wireless networks are featured in new concepts in all of these domains
  - Active monitors and other transitory devices offer enhanced item tracking
  - Wireless communications reduce infrastructure burden
- Wireless capability has become more reliable, cheaper, and faster in recent decades
- Five approaches – ranging from mature to novel – for the use of short-range wireless communications in nuclear facilities are discussed

Active RFID

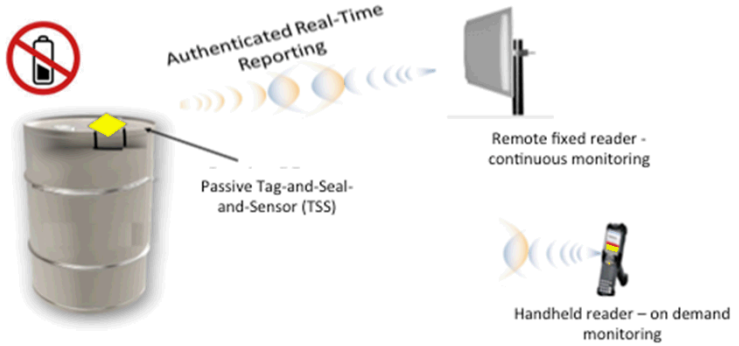
- Active, two-way radio frequency (RF) communications
  - Active = battery powered
- Can provide a unique ID as well as sensor data to a base station
- Can use unlicensed ISM bands
- Can be very small



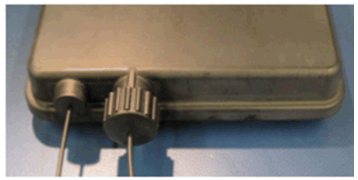


Passive RFID

- Passive – no battery
- Tag communicates with backscatter communication – it can only respond to a request from a reader
  - Both the power for the tag and the communications to the tag come from the reader
  - Reader power is at FCC approved limits
  - Received power at the tag is few microwatts
- LLNL TSS includes dynamic data authentication and AES encryption



Lawrence Livermore RF Tag-and-Seal-and Sensor (TSS)

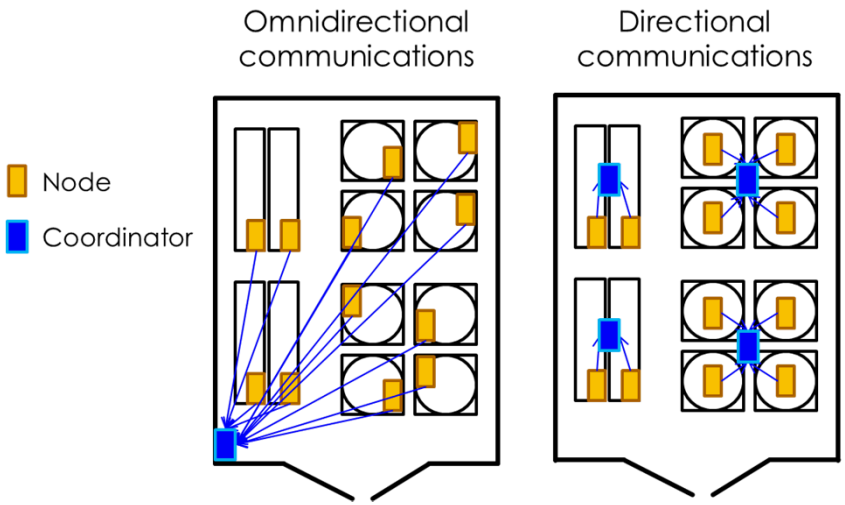


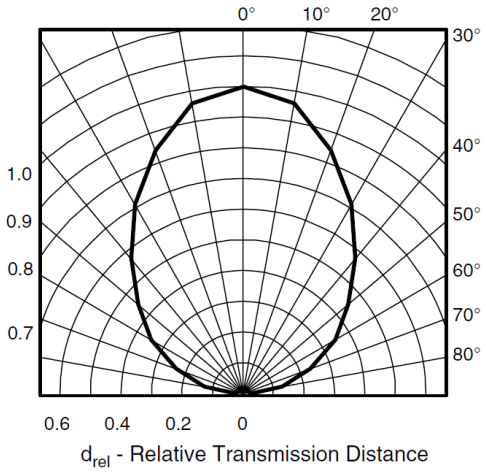
RuBee

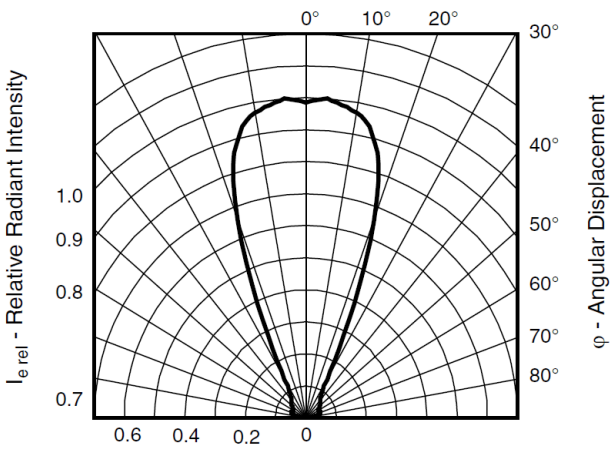
- Active tags that use magnetic fields instead of electric fields for communication
- Tags can transmit through metal
- Have been certified for zero standoff from explosives
- Security improvement - magnetic signal drops off with the cube of distance (RF drops off with the square of distance)
- Approved for use with tooling at Pantex
- Large antennas needed for good sensitivity, but these can be in the floor, ceiling, or walls

Optical

- Directional communications
- Infrared used widely
  - Remote controls
- Mature
- Low security and safety risks
- Environmental noise can be high

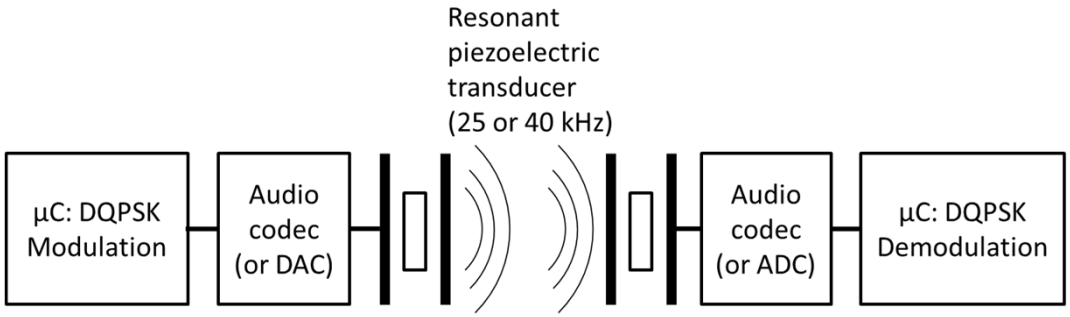






Acoustic

- Range from highly directional (high frequency ultrasonic) to nearly omnidirectional (low frequency audio)
- High signal-to-noise ratio at ultrasonic frequencies due to very little environmental noise
  - Audio signal can be as low as normal speaking volume for short-range communications
- Novel technique using mature technologies
- Multi-path interference can be an issue



Comparison

Approach	Data Rate[1]	Safety	Security
Active RFID	High; typical ~50 kb/s, up to Mb/s	Potential issues with RF around explosives	Signal can travel outside of room (but all communications are encrypted and authenticated)
Passive RFID	Moderate; ~10 kb/s	Potential issues with RF around explosives	Signal can travel outside of room
RuBee	Very low; ~200 b/s	Slight concern if power levels are very high, but in almost all cases, there is no safety concern	Signal drops off faster than RF
Optical	Moderate; ~5 kb/s	No safety concern	Line-of-sight signal stays in room
Acoustic	Low; ~1.5 kb/s	No safety concern	Signal stays in room and drops of quickly

1. Data rates are all for short-range communications, i.e., within a 10 meter range

Comparison

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Approach	Flexibility of Movement	Power Consumption of Transitory Node	Maturity
Active RFID	Omnidirectional and only one reader needed in a room	~50 mA when active; ~1 µA when inactive	High; uses COTS components
Passive RFID	Can be omnidirectional with one reader or more directional to distinguish location	Zero (no battery; a small amount of power is harvested from the reader)	High; uses COTS components with custom authentication and encryption implementation
RuBee	Omnidirectional and only one antenna and reader needed in a room or more can be used to distinguish location	~50 mA when active; ~1 µA when inactive	Moderate
Optical	Line-of-sight requires specific locations	~25 mA when active; ~1 uA when inactive	High for other applications; low for nuclear facilities
Acoustic	If directional, requires specific locations	~100 mA when active; ~1 uA when inactive (estimated)	Low

Conclusion

- Interest is growing in the use of sensors and sensor networks in nuclear facilities for the purposes of future arms control verification, international nuclear safeguards, and nuclear materials management.
- Short-range, wireless communications are necessary for many of these concepts.
- Various approaches to these communications have been identified and outlined, including active RFID, passive RFID, RuBee, optical, and acoustic approaches.

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