

Advanced SAW Devices for RFID and Sensing Applications

Passive Wireless Sensor Tag Workshop

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The West Lake Club, Houston, TX

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Passive SAW Wireless Sensors

- Presentation Overview
- RF SAW / GST Introduction
- SAW Sensor Advantages
- SAW Sensor Technical Challenges
- Preview of “Hundred Sensor” System
- Demonstration
- Summary

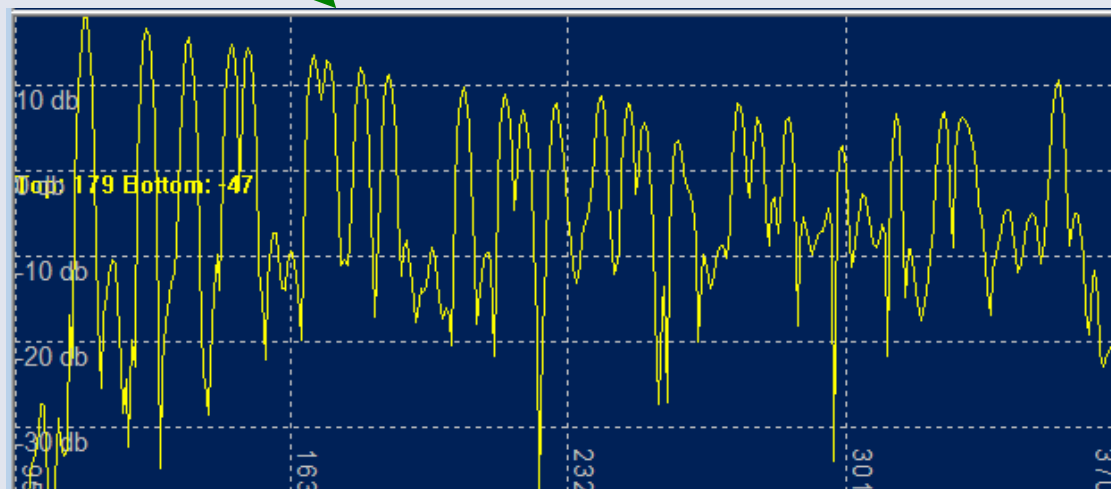
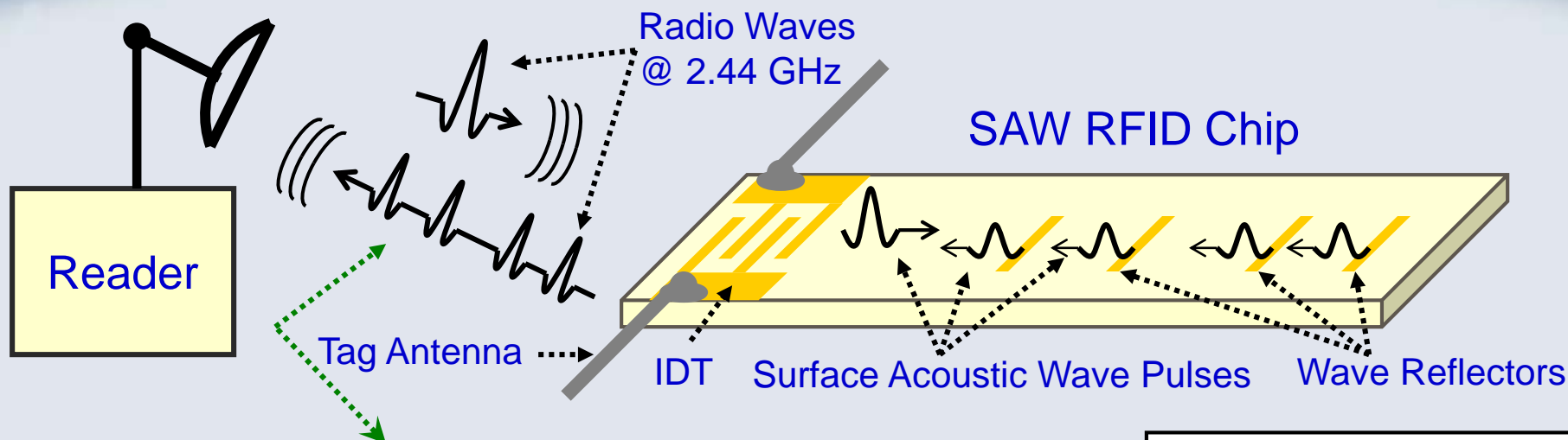
Presentation Overview

- A SAW-based passive wireless temperature sensing system is presented that features:
 - More than 100 sensors with a single reader
 - Large sensor reading range
 - Solves near/far simultaneous reading challenge
 - Wide temperature range
 - Cost effective

RF SAW / GST Introduction

- RF SAW, Inc. provides SAW-based passive RFID and wireless sensing based on Global SAW Tag (GST) technology
- GST used on International Space Station
- World leader in SAW tag anti-collision
- World leader in high-data content SAW tags

RF SAW's Global SAW Tag System



Actual 96-Bit Wireless Tag Waveform

GST Features

- Trillions of Trillions of ID Numbers
- Inherent Temperature Sensing
- Inherent Tag Localization

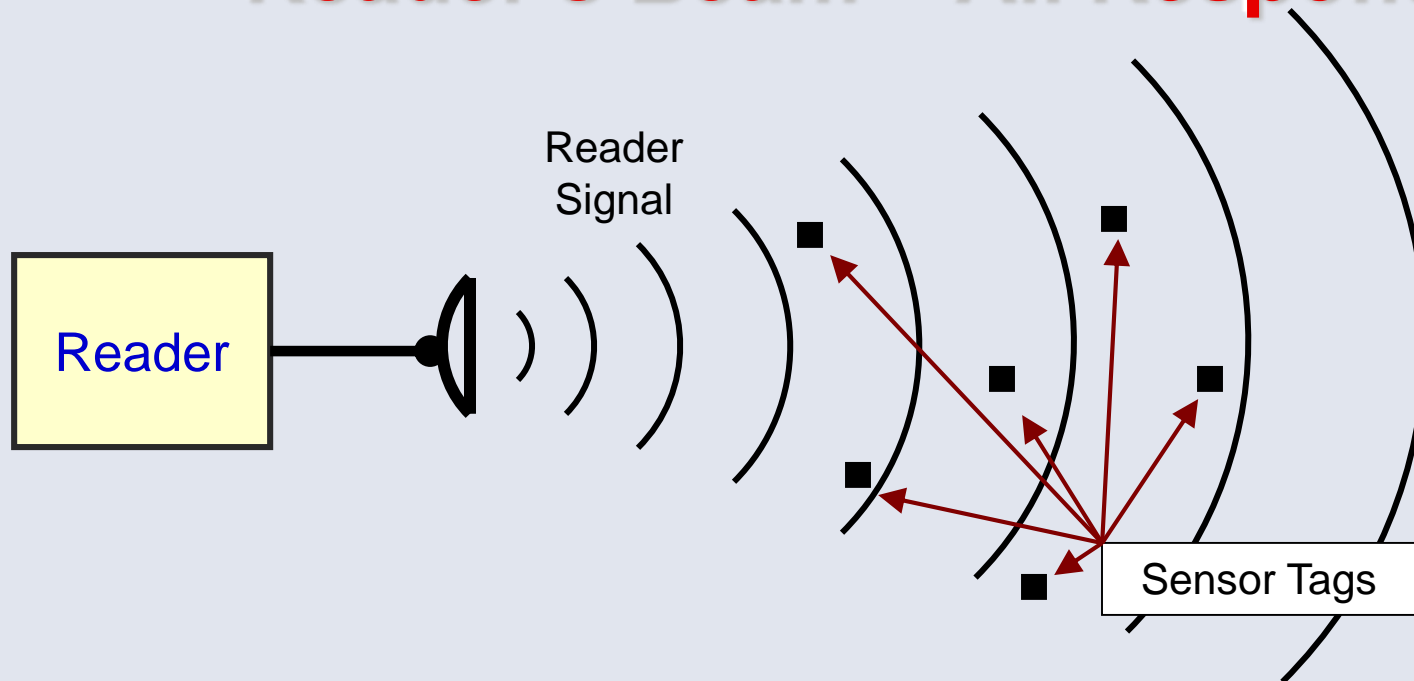
Advantages of SAW-Based Sensing

- SAW is inherently passive and wireless
- Sensing modalities include temperature, strain/pressure, gas/liquid (surface loading), location, and individual sensor identification
- Longest passive sensor reading range
- Tolerant to high-energy radiation e.g. nuclear
- Globally legal 2.45 GHz operating frequency
- SAW readers can use very low RF power, HERO certified for safe use on munitions

Passive SAW Wireless Sensors

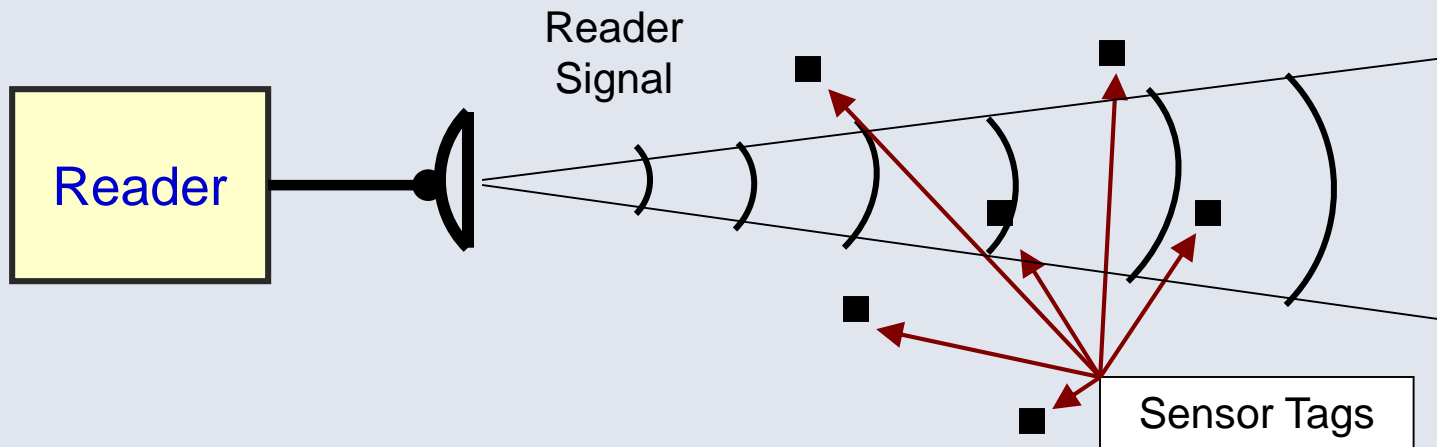
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Multi-Sensor Collision: Many Tags in Reader's Beam – All Respond



- All SAW tags respond simultaneously
- Collision is inevitable in multi-sensor applications

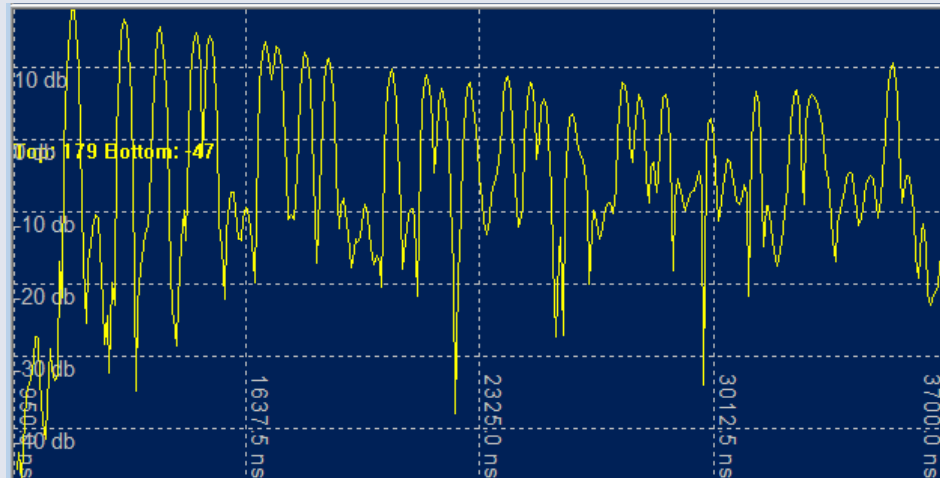
Narrow Reader Antenna Beam Limits Number of Colliding Tags



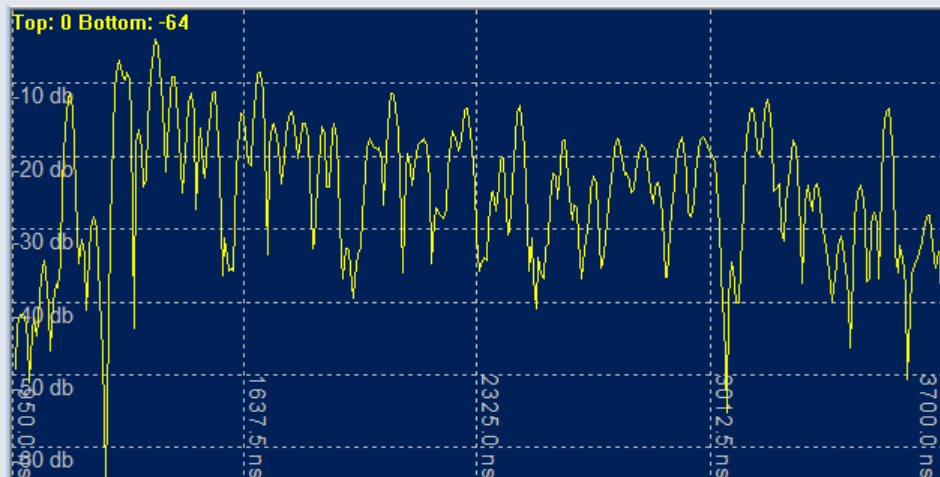
- Narrow antenna beam reduces collision but is not a complete solution
- Remaining collision will be resolved using code division signal separation

Code Division SAW Tag Signal Separation

➤ Single Tag

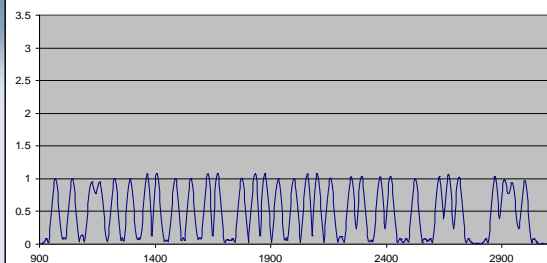


➤ 14 Tags in Collision

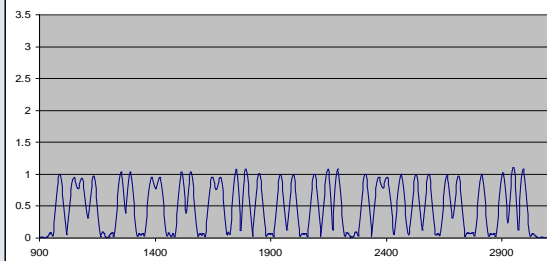


Anti-Collision Matched Filter Processing

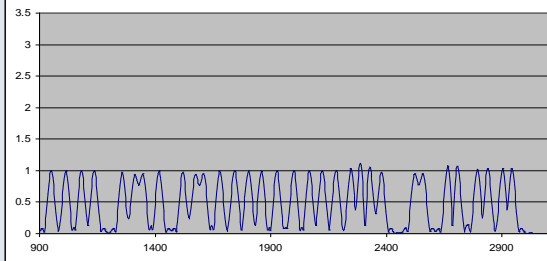
tag: 10410



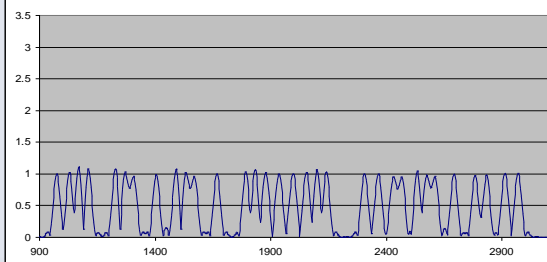
tag: 10000



tag: 9723

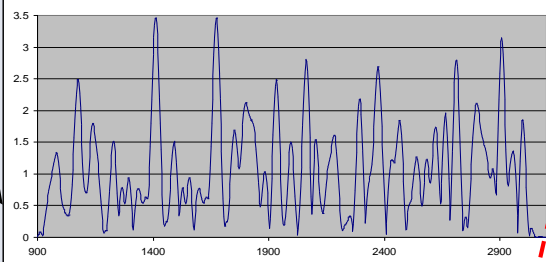


tag: 10168



Sum of Tag Signals

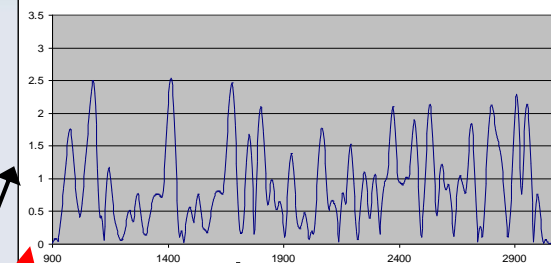
Composite Signal



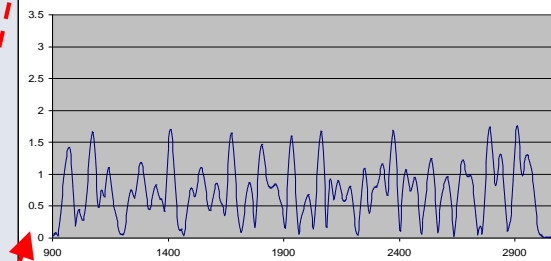
**Matched filtering &
signal subtraction**

**Signal after
Subtraction
of Signal 1, 2, 3 & 4**

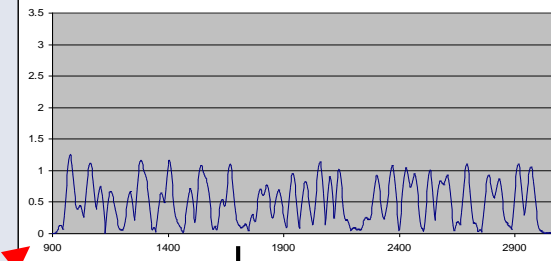
After Detecting and Removing Tag: 10410



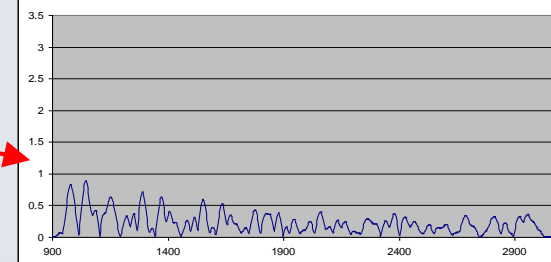
After Detecting and Removing Tag: 10000



After Detecting and Removing Tag: 9723



After Detecting and Removing Tag: 10168



Preview of Demonstration

- Demo will show code-division signal separation
 - 10 temperature sensors simultaneously in a single antenna beam
 - Heat gun temperature change will be observed

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Resolving SAW Sensor Collisions Using Code Division Signal Separation

- Technique is well known in digital cellular phones
- Code division requires use of code families with good cross-correlation properties
- For temperature sensing, detection is based on code changes caused by temperature changes
- Temperature induced code changes destroy the good cross-correlation properties of known codes
- Temperature tolerant codes have been discovered

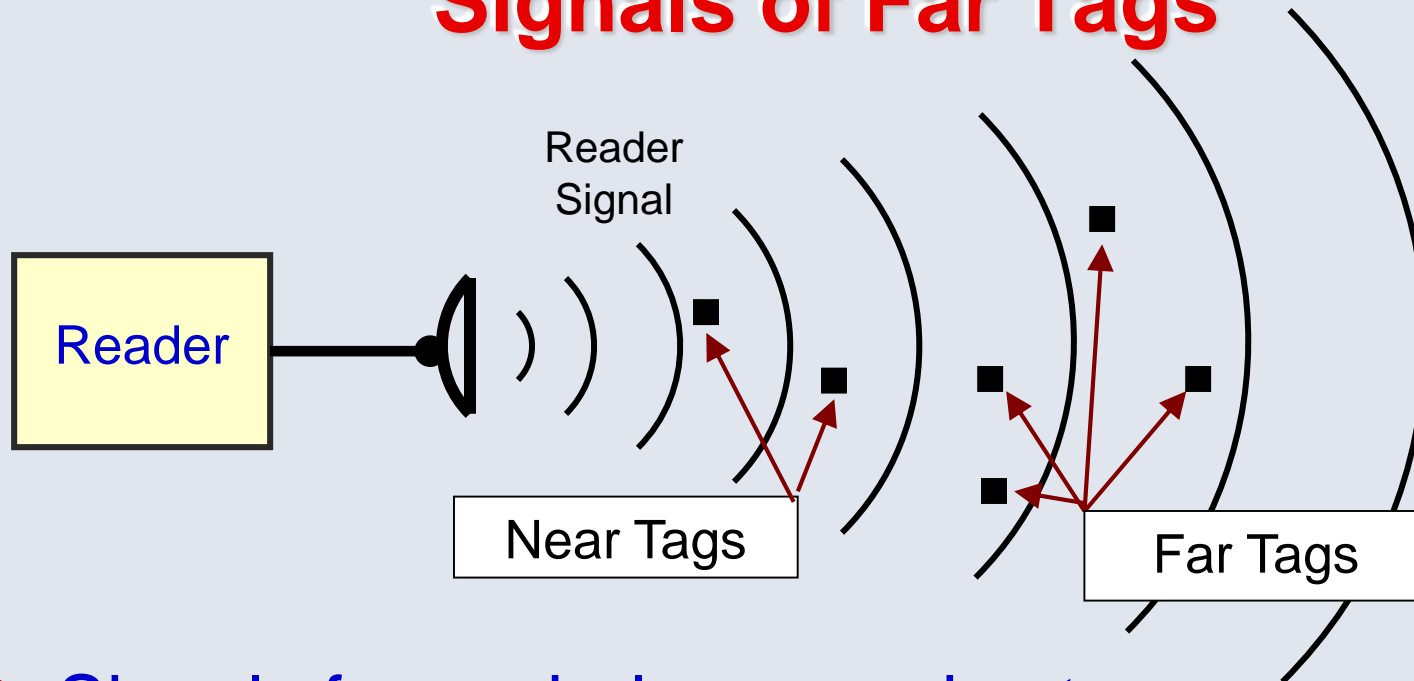
Temperature Tolerant Code Families

- These new codes have good cross-correlation (i.e. anti-collision) properties for all code pairs for arbitrary device temperatures
- Cross-correlation properties are mathematically provable for all code pairs in a single family
- Code properties have not yet been mathematically proven when all codes in a family are present
- Good cross-correlation has been proven by brute force search for over all temperature combinations and all tag ranges for a 5-member code family

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Near/Far Effect: Strong Signals from Near Tags Overwhelm the Weak Signals of Far Tags



- Signals from wireless passive tags vary as R^{-4}
- Near tags can negate large reading range
- Use different time slots for different tag ranges

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Design of “Hundred Sensor” System

- A family of tag 30 codes comprised of
 - Six separate time slots for different ranges
 - A 5-member temperature tolerant code family in each slot
- Up to 8 narrow beam-width 2.45 GHz antennas oriented in different directions
- Interrogator with 8 separate antenna ports
- Enable > 100 sensor per interrogator with theoretical capability of 240 sensors ($30 \times 8 = 240$)

Preliminary Specification - 1

- Total Sensors per Interrogator
 - Typical: > 100
 - Max: 240
- Interrogator Antenna Ports: 8
- Sensors per Antenna: Up to 30
- Temperature Range:
 - -150° to +200° C standard
 - -150° to +300° C with high-temperature housing

Preliminary Specification - 2

➤ Accuracy:

- $\sim \pm 2^{\circ} \text{ C}$ without calibration
- $< \pm 1^{\circ} \text{ C}$ calibrated

➤ Reading Speed:

- 30 sensors per second
- Higher rates upon request

➤ Wireless Reading Distance:

- 10 m (~ 30 ft.) typical
- 30 m (~ 100 ft.) with high-gain tag

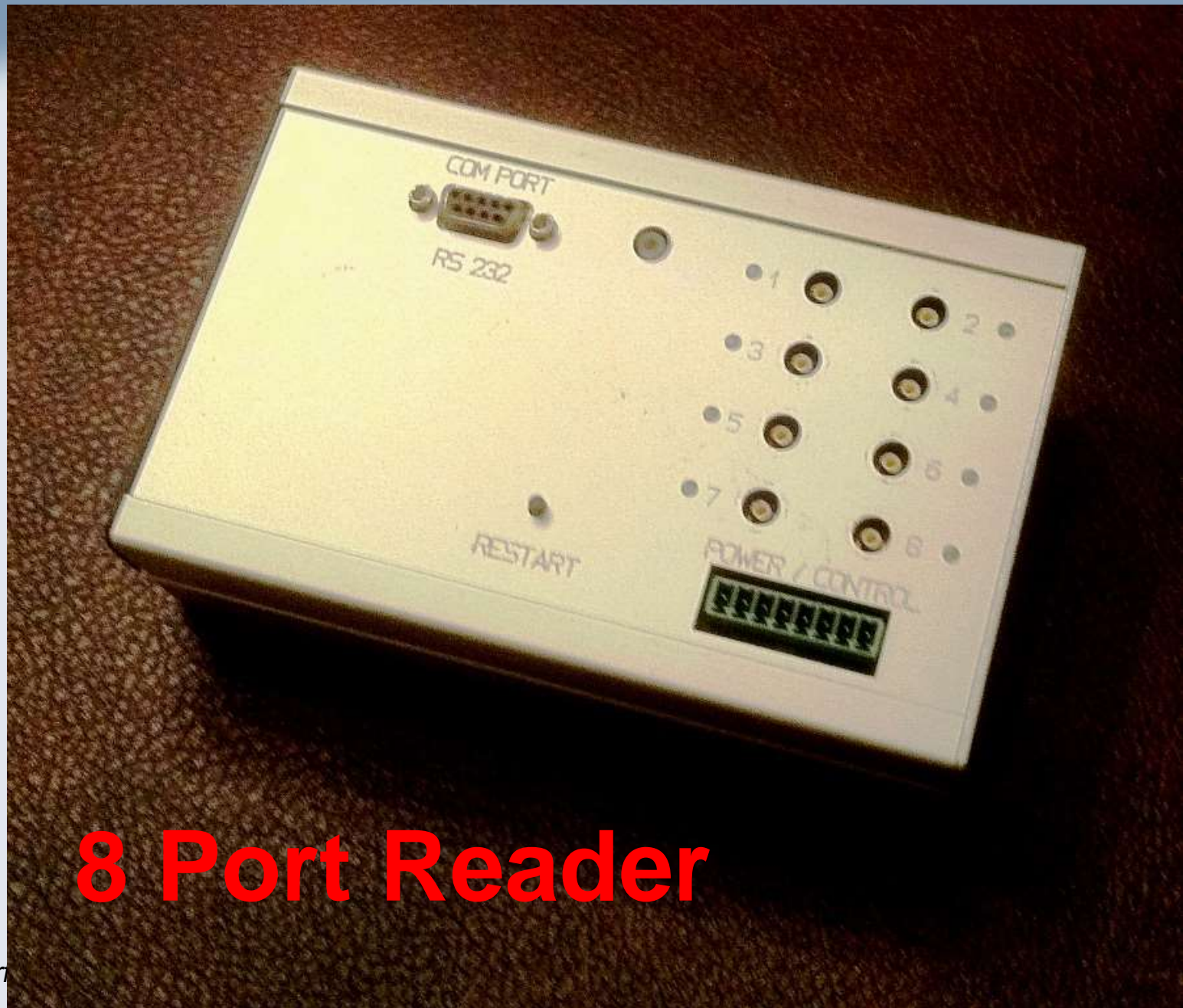
Preliminary Specification - 3

➤ Near/Far Performance:

- > 50 dB Near/Far Rejection Ratio
- Near/Far Range Ratio: From 1:1 up to 1:20

➤ Availability: Q4 2011

- Preproduction reader was shown above



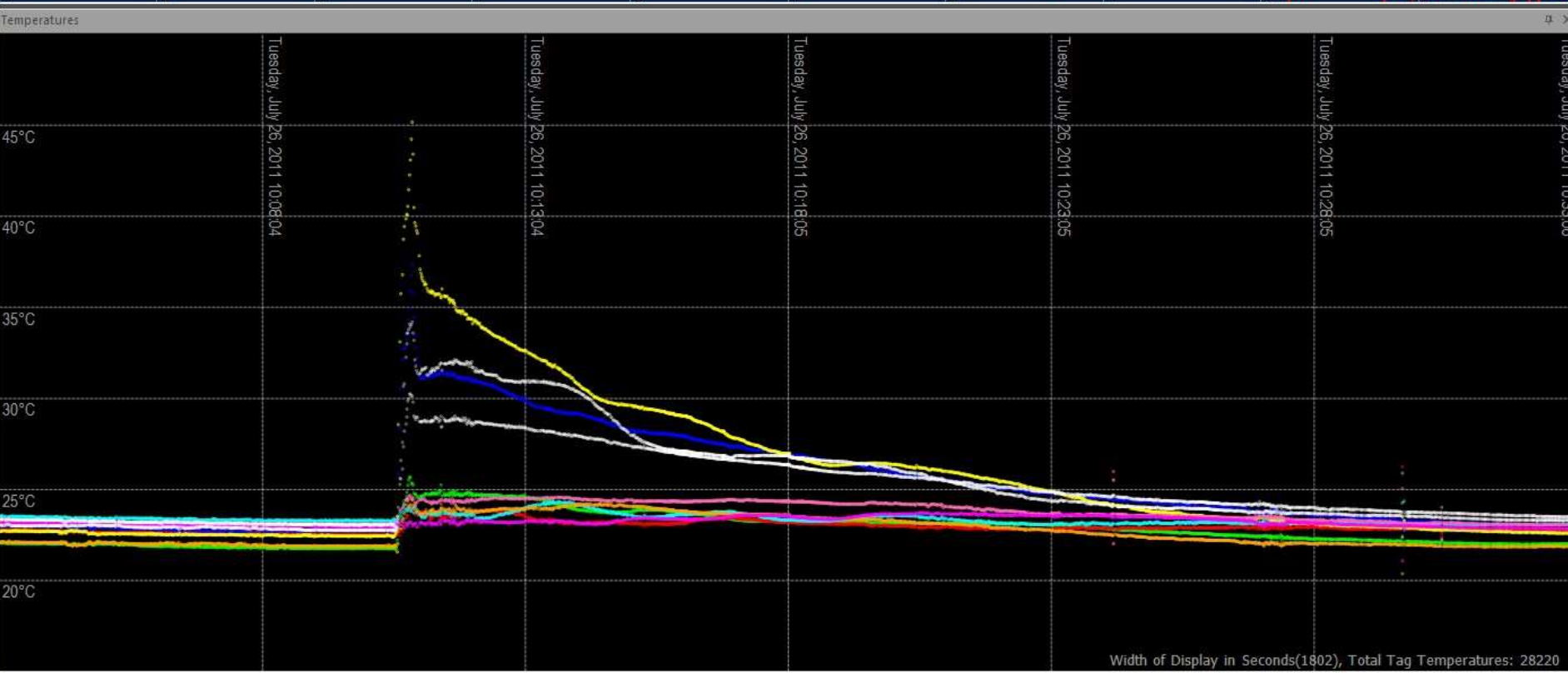
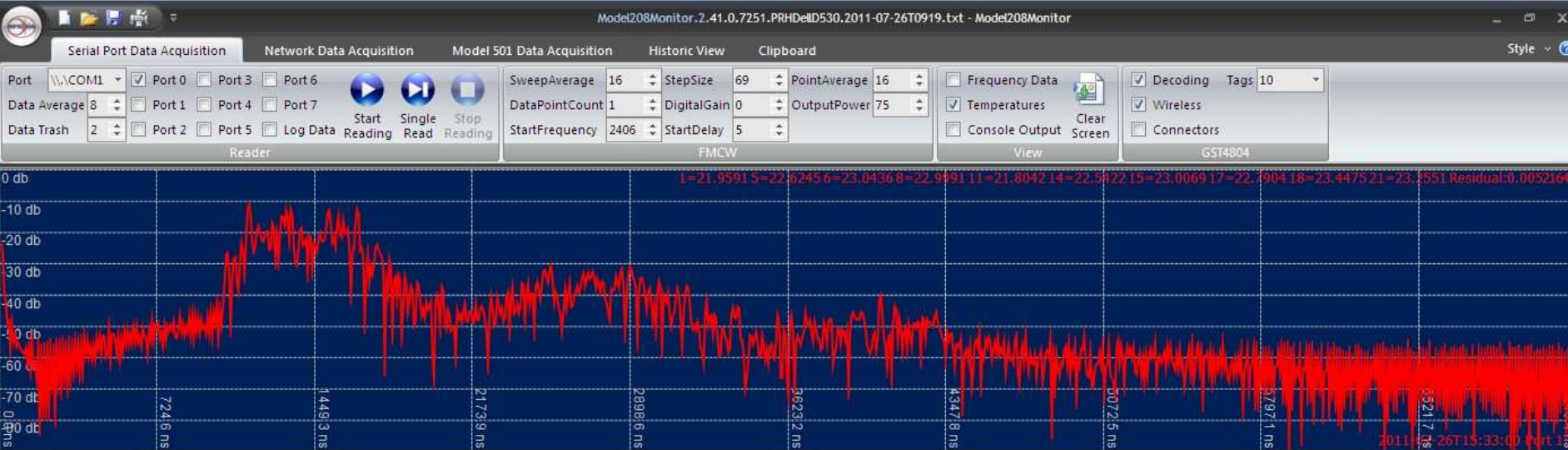
8 Port Reader

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Demonstration Overview

- Simultaneous reading of 10 tags
- Signal separation using only code division
- Will show system response to heat gun induced temperature change



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