



PWST SAW Temperature Sensor System

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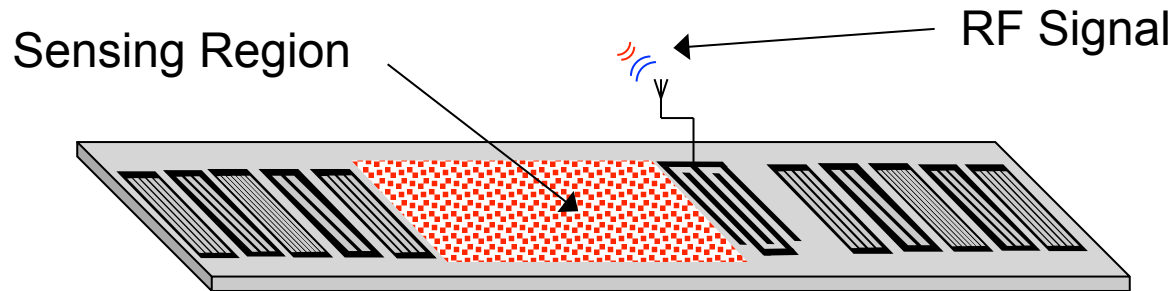
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Outline

- Overview of prior work
- Summary of recent work
- New set of 32 temperature sensors
- Software radio transceiver implementation
- Demo
- Discussion

How do SAW sensors work?



Features

- ◆ Operate wirelessly
- ◆ RFID capable
- ◆ Require no batteries
- ◆ Sensitive/accurate measurements
- ◆ Real-time measurements
- ◆ Last for decades
- ◆ Survive & operate in extreme environments
- ◆ Low cost - based on established technology

Benefits

- Eliminate wiring harness; Low installation cost
- Operate on rotating parts
- Individual sensor ID enables multisensor systems
- No battery changes; Low maintenance cost
- Comparable to wired sensors
- Rapid response; Variable sampling rate
- Suitable for embedded use and long-term monitoring
- Cryogenic to 1000°C+; Measure where Si fails
- Radiation hard
- Existing manufacturing infrastructure
- Enable low cost distributed sensing

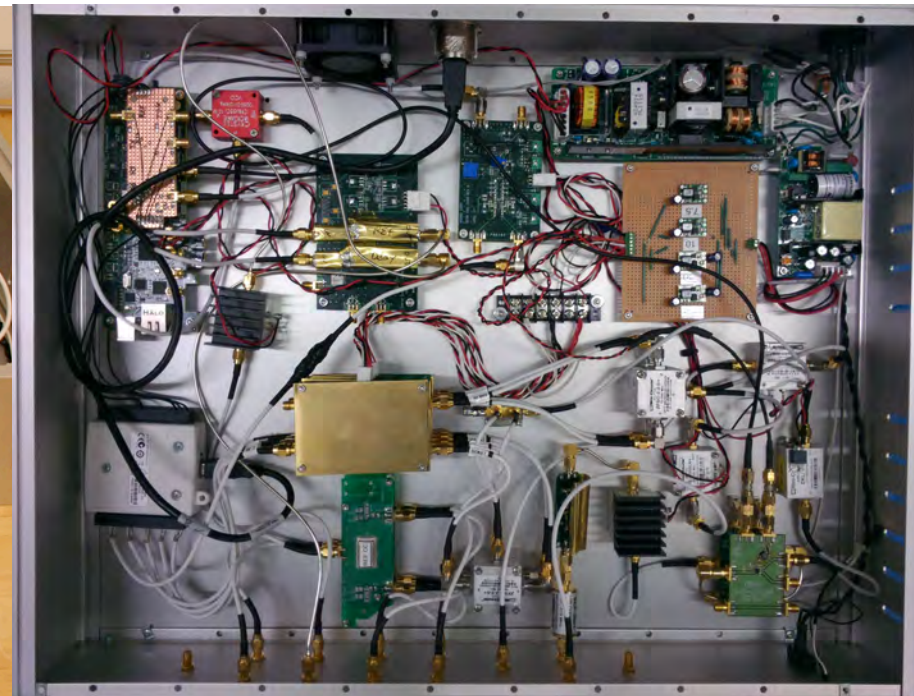
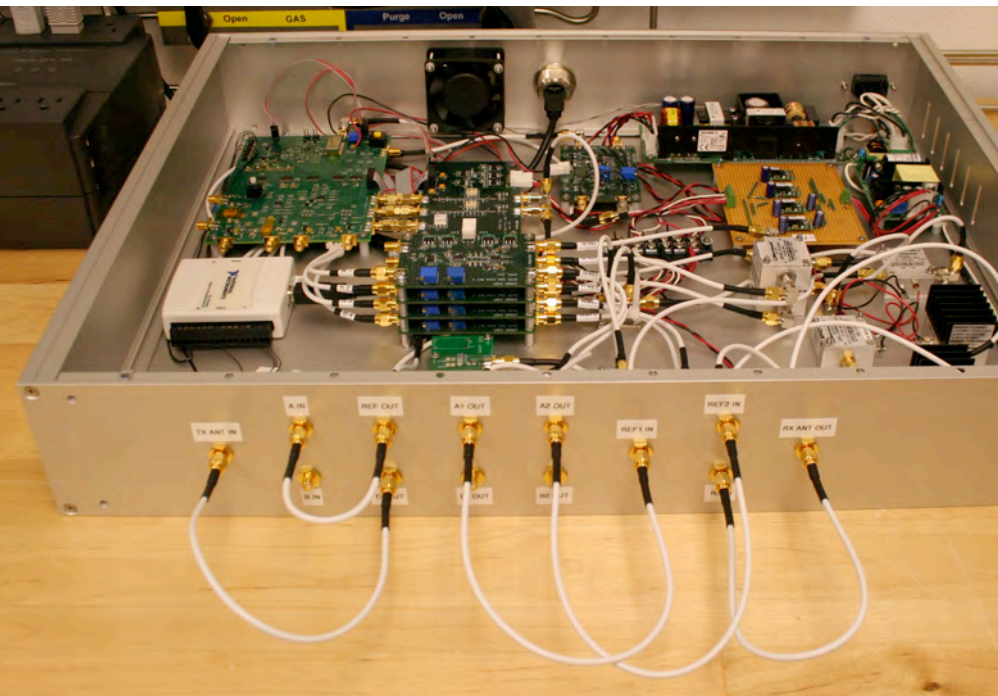
Overview of prior work:

- > Coded sensor-tag wireless interface devices
 - > Read SAW code & sensor reading
 - > Impedance varying & voltage producing sensors
 - Temperature sensors
 - Strain gauges, AE sensors
 - Switch positions, bus voltages

- > Temperature sensors ← Focus on these today
- > Hydrogen, methane, hypergol sensors
- > Humidity sensors
- > (Cryogenic) liquid (level) sensors
- > Concrete maturity monitor
- > Biosensor for infectious agents (CT)

Overview of prior work, contd:

- > Last PWST meeting, presented humidity sensor system
 - 16 individually identifiable sensors, manual selection of one
 - Quantitative humidity responses
 - Not calibrated responses
- > Mixed signal wireless transceiver system

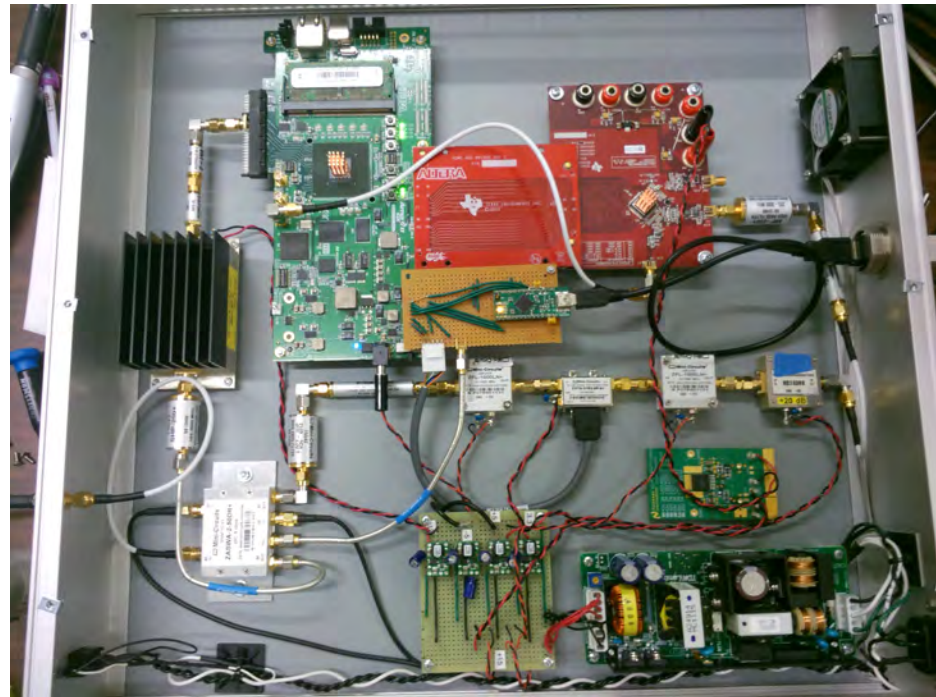


Overview of prior work, contd:

- > Focused on advances in code anti-collision
 - Barker Coding with time, frequency diversity:
prototyped 100 sensor-tags
 - DSSS codes with time, frequency diversity:
Current project produced 32 temperature sensors
- > Observations led to an emphasis on ability to:
 - Identify each sensor
 - Calibrate sensor responses
 - Maintain accuracy with sensors operating simultaneously

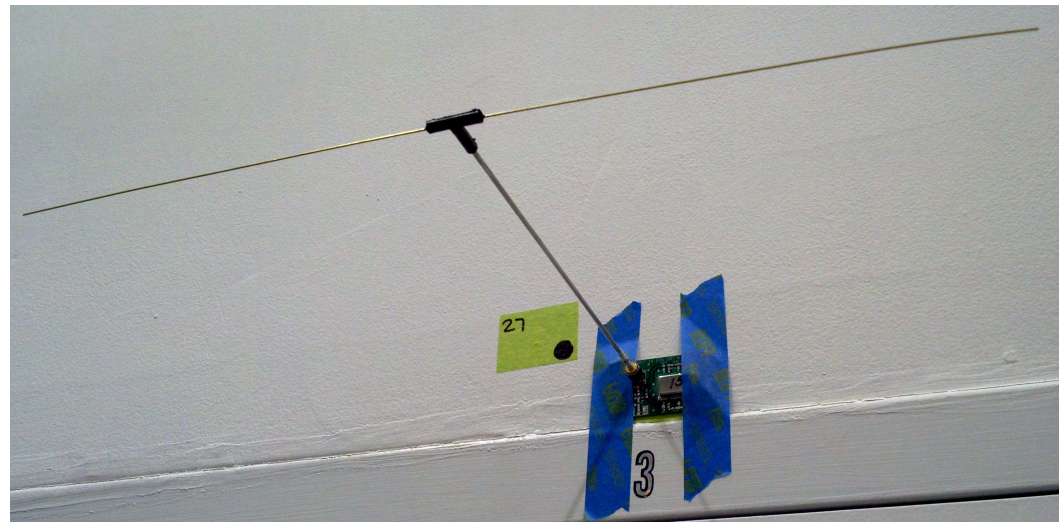
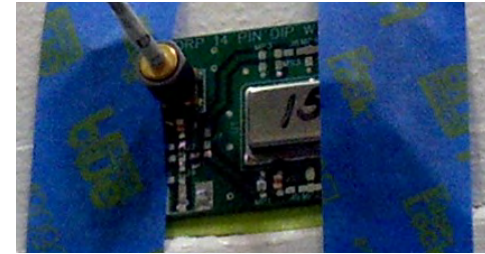
Summary of Recent Work:

- > Developed under NASA Phase II SBIR NNX11CC11C
- > Developed software-radio based transceiver
 - Simpler
 - Utilized COTS eval boards and components
 - Reads all sensors simultaneously in FOV
 - Measurements out to 55 feet (thus far)
 - Antennas limit perf.
- > Developed set of 32 temperature sensors
 - Time diversity
 - Frequency diversity
 - Code/chirp diversity



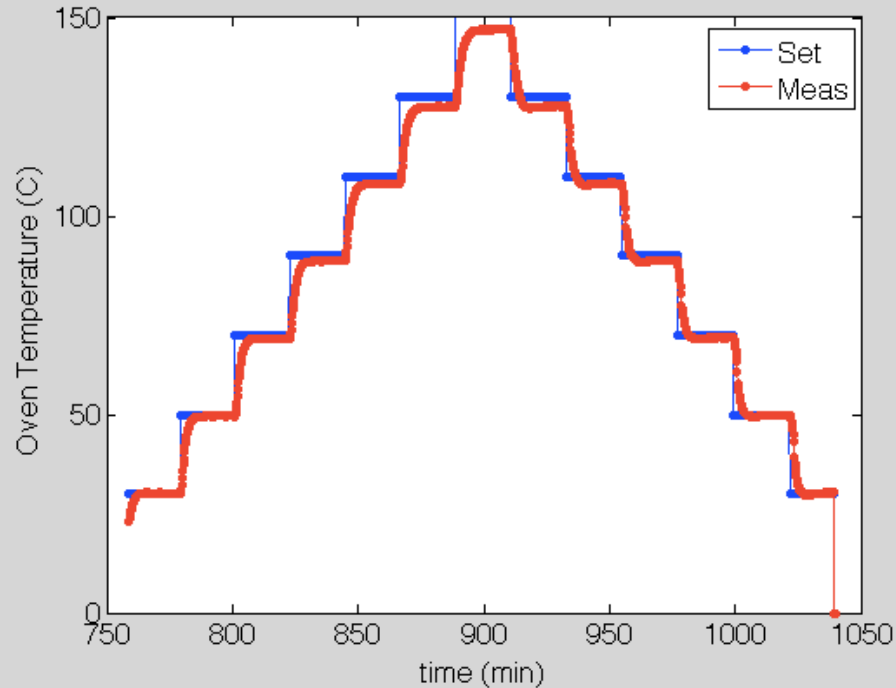
Set of 32 Temperature sensors:

- > Reflective differential delay lines
 - Time diversity
 - Frequency diversity (200 MHz – 400 MHz)
 - Code/chirp diversity
 - Wireless test fixture with sensor and antenna matching
- > Antenna responses limit sensors
 - Near field particular problem
 - Frequency dependent
 - Now testing far field
 - Note: No advanced antenna techniques used thus far – focus instead on reducing sensor interactions



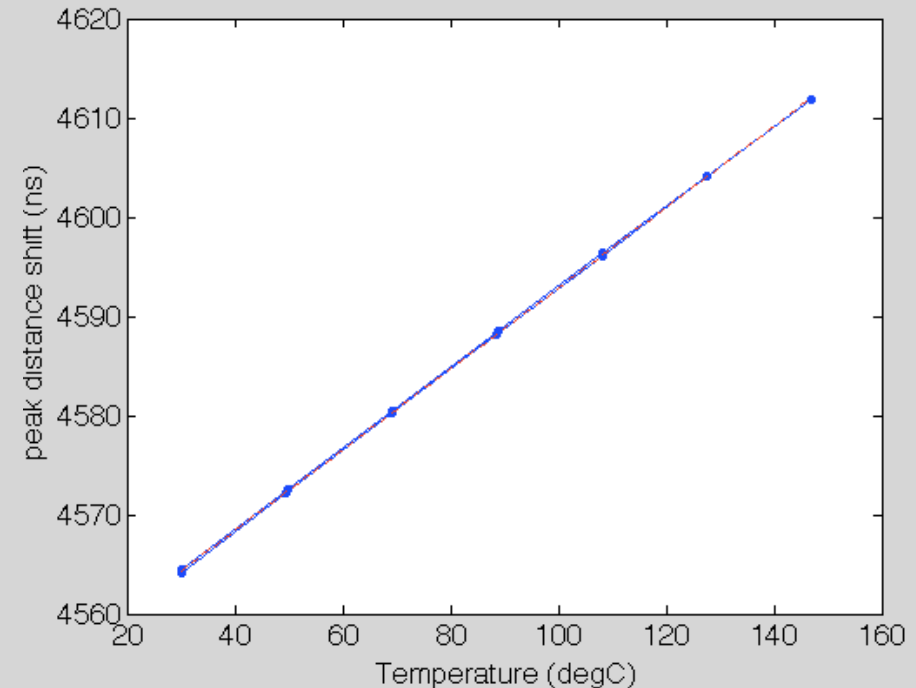
Set of 32 Temperature sensors:

> Typical temperature testing for single sensor



Temperature Profile

Sensor Response



Software-radio Transceiver System:

> Operation:

- PC-based user interface
- Spread spectrum RF activation of all sensors in FOV
- Receive & digitize responses
- Synchronous data accumulation
- Interpret each sensor measurement

> Antenna issues dominate responses in near-field

> Calibration required with sensors & antennas installed

> Wireless measurements at up to 55 ft range (space limited)

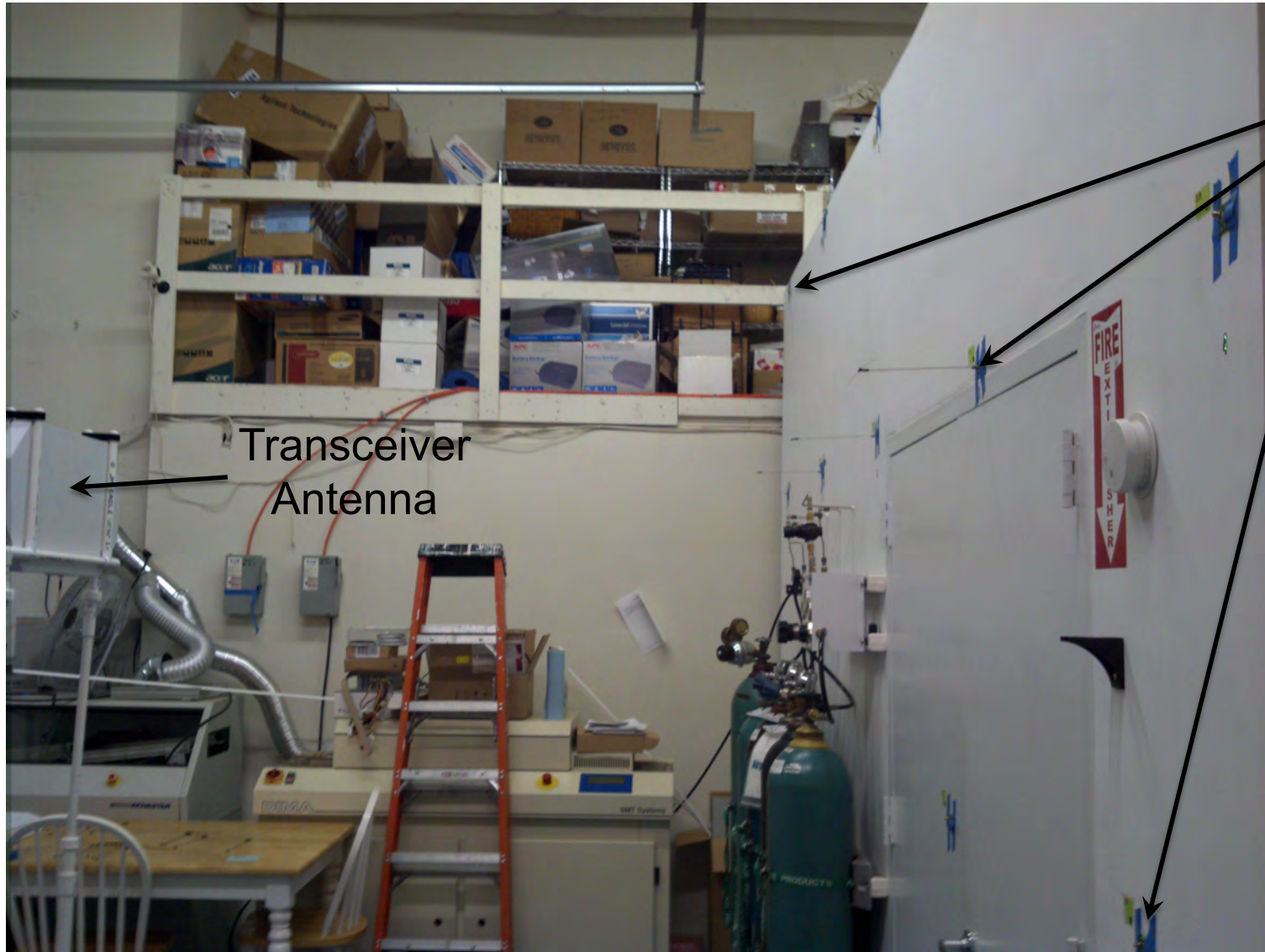
Wireless test setup:



Sensors

Transceiver
Antenna

Wireless test setup, contd:

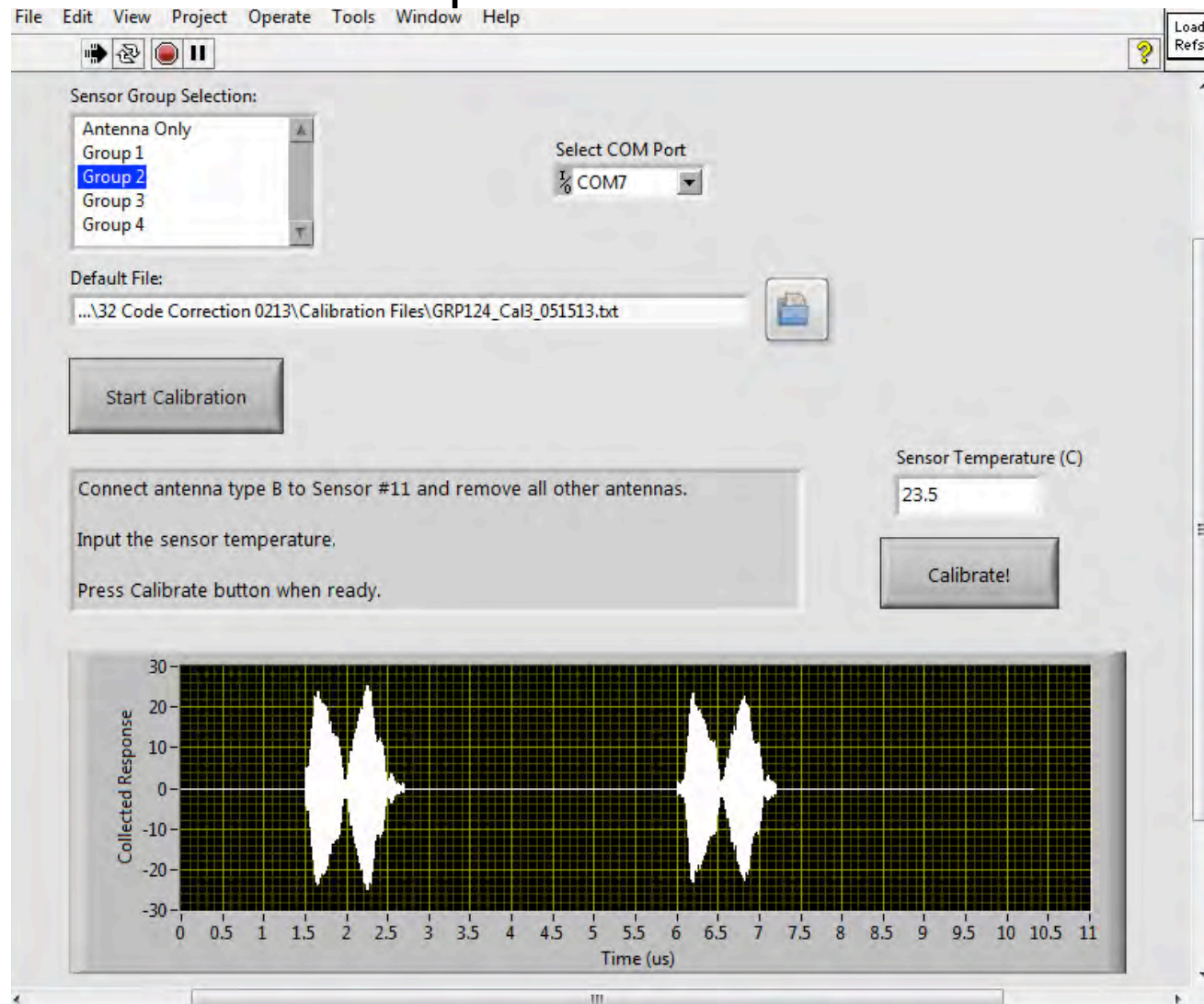


Transceiver
Antenna

Sensors

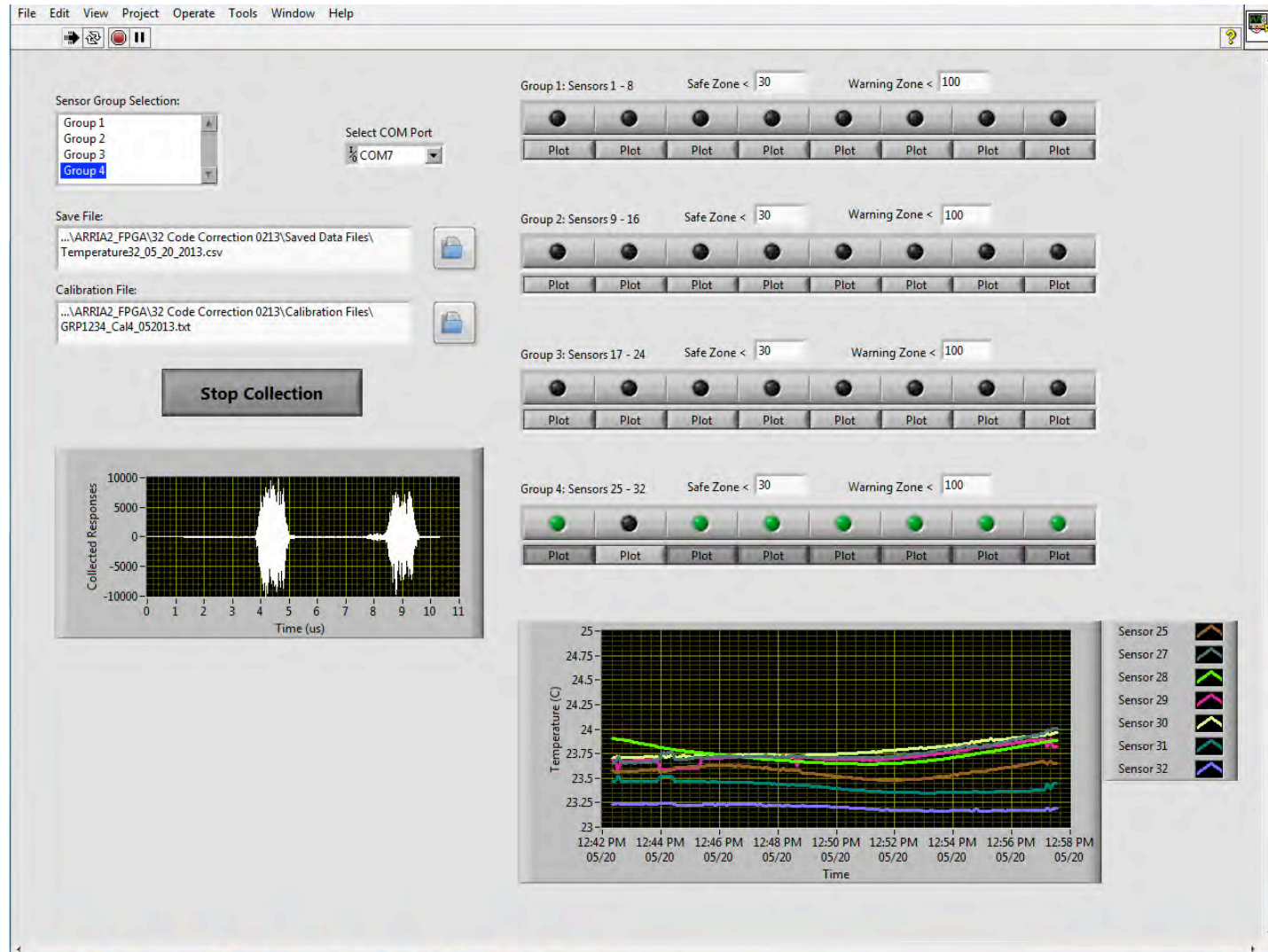
Transceiver User Interface: Calibration

> Antenna interactions require in-situ calibration of sensors

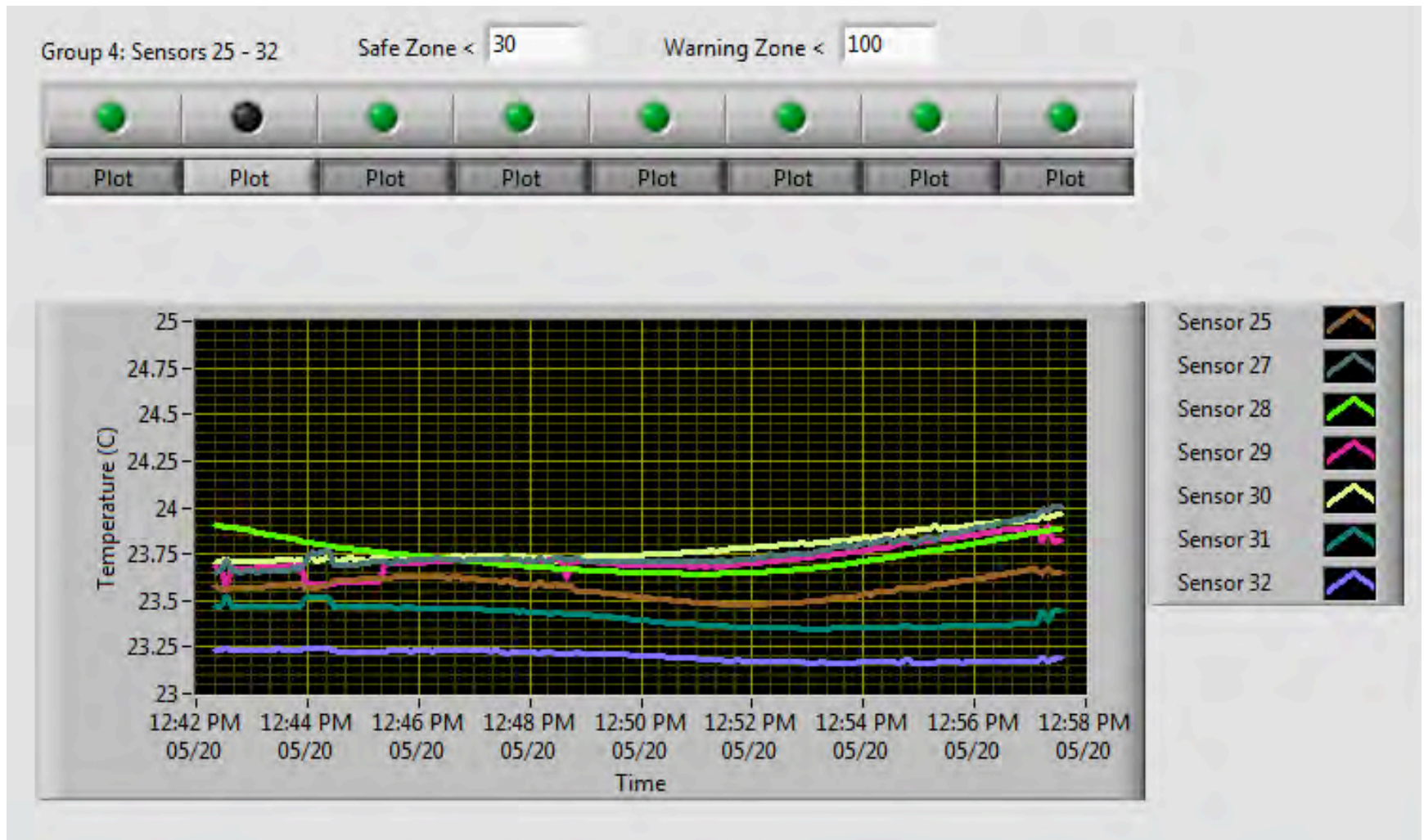


Transceiver User Interface:

> Room temperature operation, 7 devices (group 4)

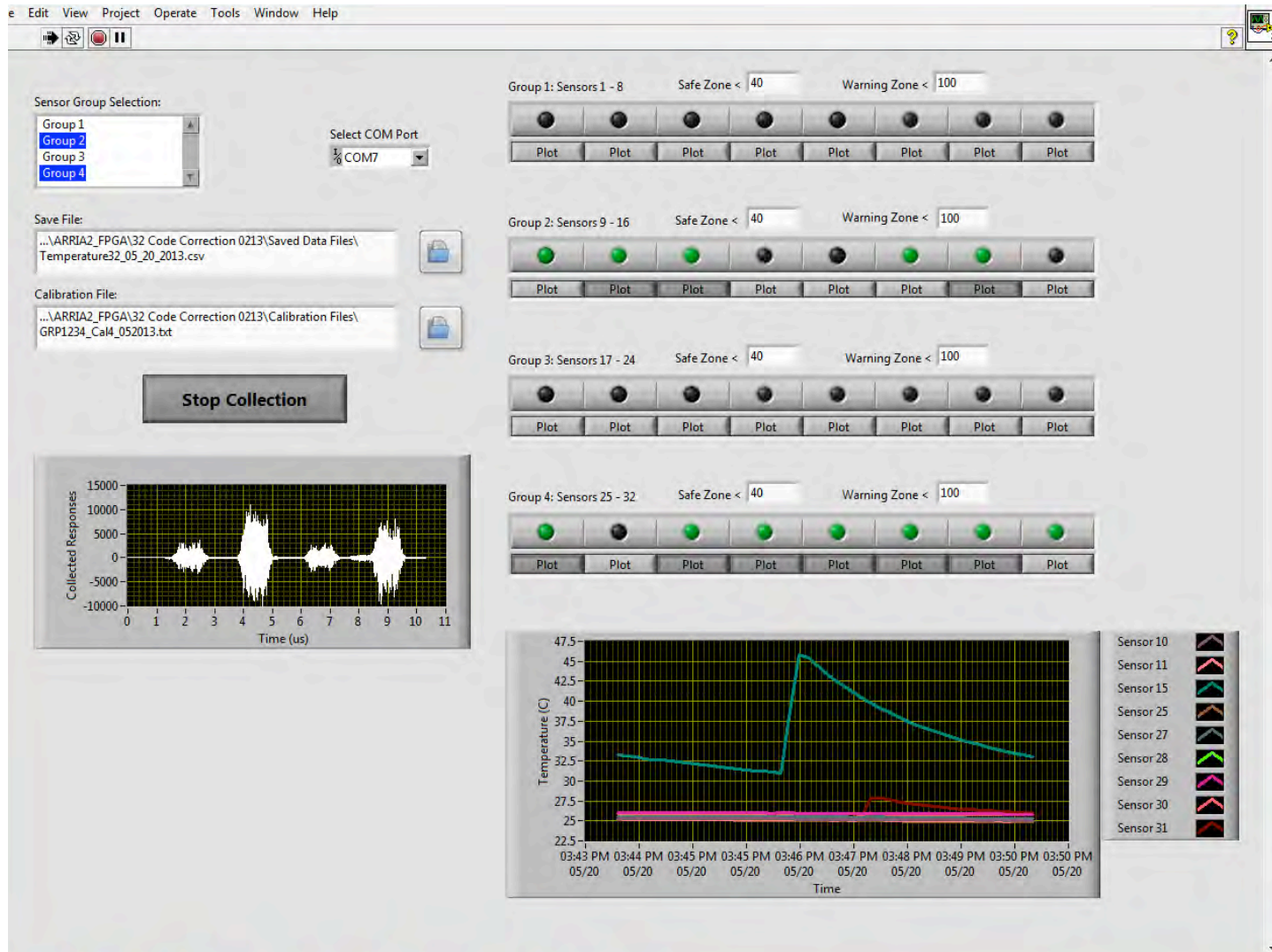


Expanded view:



Transceiver System user interface:

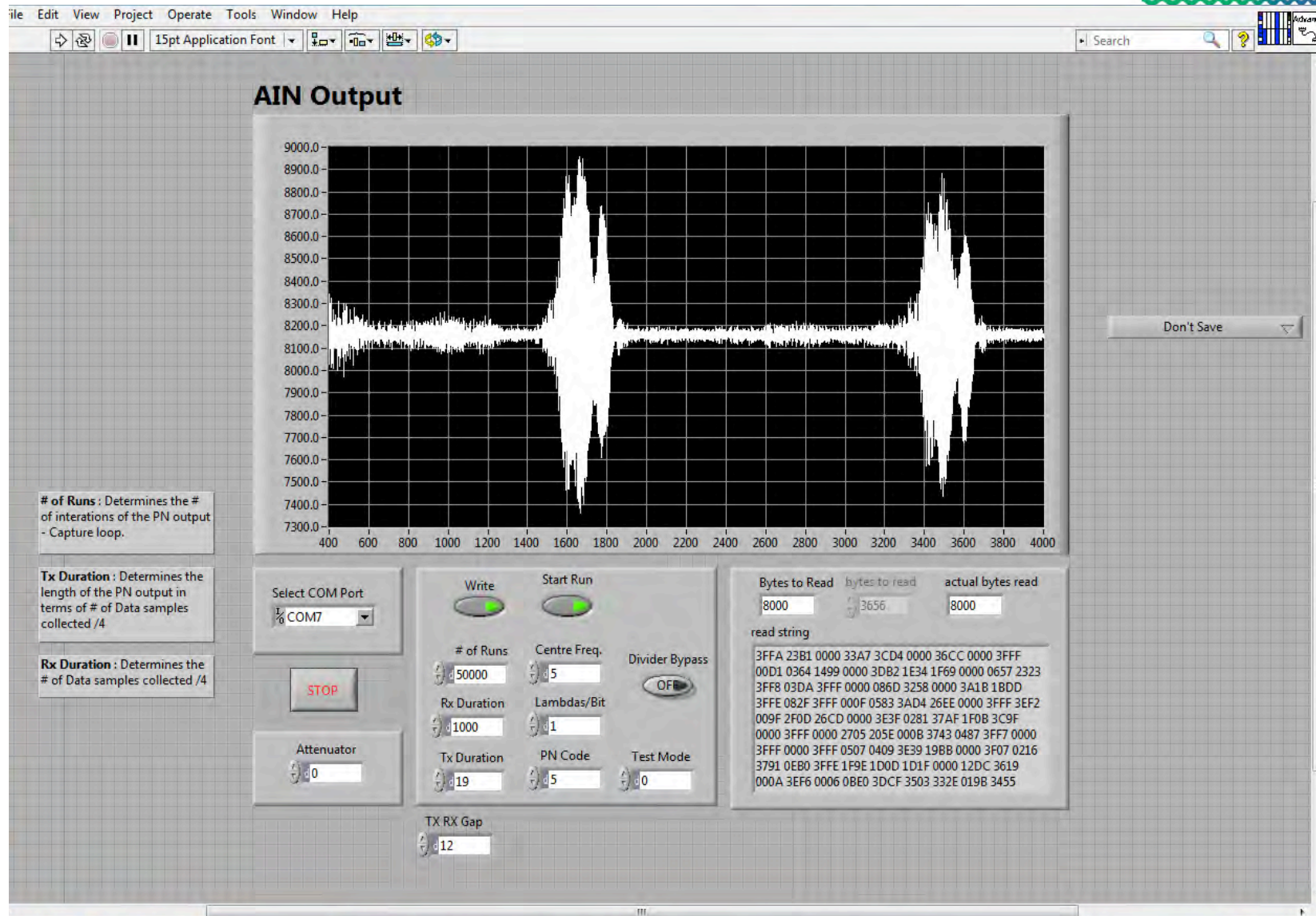
> Multi-sensor heating test



Expanded view:



Wireless measurement at 55 ft range:



Demonstration

- > Multi-sensor heating & cooling test
- > Room size limits number of sensors shown

Conclusions & Discussion

- Designed and manufactured 32 individually identifiable SAW temperature sensors
- Developed software-radio based wireless SAW sensor interrogation system
- Demonstrated calibrated wireless temperature sensing with $<0.1^{\circ}\text{C}$ precision, range varies from about 8 ft to over 55 ft (limit TBD)
- Delivering 32-sensor system to Marshall Space Flight Center and demonstrating system operation mid June, 2013
- Calibrated wireless operation of multiple sensor-tags operating simultaneously is achievable



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Any questions or comments?

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Thank you

