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Second Environment Sensor For Tube Launched Non-Spun Munitions

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Smooth vs. Rifled Bore Launch Environment Sensing

- **First environment indicator**
  - Setback is a robust first environment for both artillery and mortar rounds
- **Second environment indicator**
  - Artillery rounds typically employ spin to sense launch environment and to activate reserve power sources
  - Spin cannot be used for smoothbore mortars and other non-spun munitions
  - Mortars often use air-driven turbines to sense air flow as a second environment and to generate power

Alternative 2nd Environment Sensor

- Mortar and other non-spun munitions could employ an electrically-sensed muzzle exit signature for a second environment indicator
- A sealed electronic sensor would not have environmental exposure concerns as turbines do
- Goal of sensor is to determine a unique tube signature that clearly indicates a launch environment

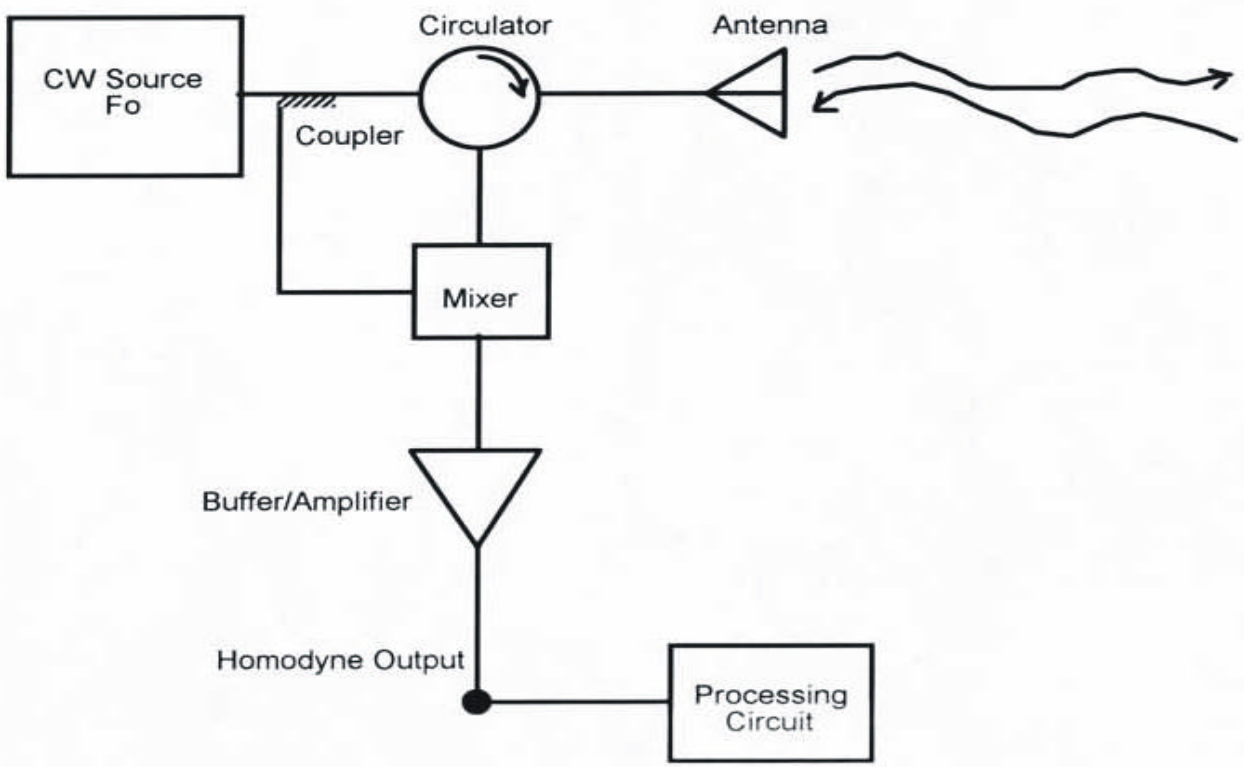
2ND Environment Sensor Overview

- **RF-based 2nd environment sensor**
  - Active sensor that transmits RF energy, which propagates in mortar tube as though in a circular waveguide
  - Some RF energy is reflected back from the impedance mismatch between mortar tube muzzle and free space
  - Sensor output at any moment is the instantaneous sum of transmitted and reflected waves at that point in the tube
  - Sensor output contains velocity information

Sensor Development Activities

- Defined sensor architecture
- Collected data in lab on mock-ups of 60mm, 81mm, and 120mm mortar tubes. Data included time-zero, sensor output, and tube exit indication
- Collected time-zero and sensor data under ballistic conditions on 60mm, 81mm, and 120mm mortars at APG. Data was collected using on-board recorders
- Analysis of collected data and work on sensing and processing algorithm development

Sensor Architecture



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Typical Lab Test Set-up

60mm mock-up tube

Lab test vehicle

RF absorbent to minimize reflections

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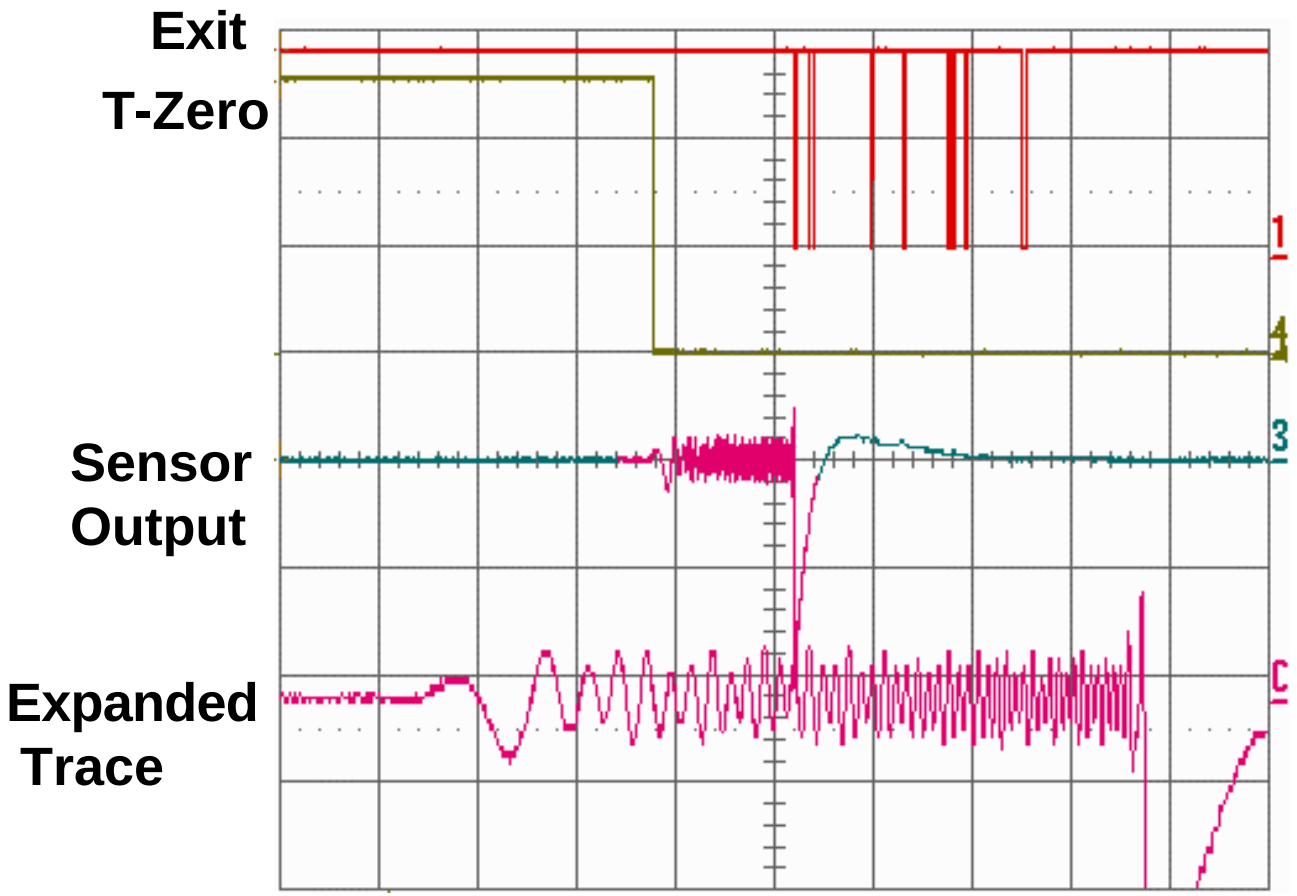
Signature of Microwave Transmitter in a 60mm Tube



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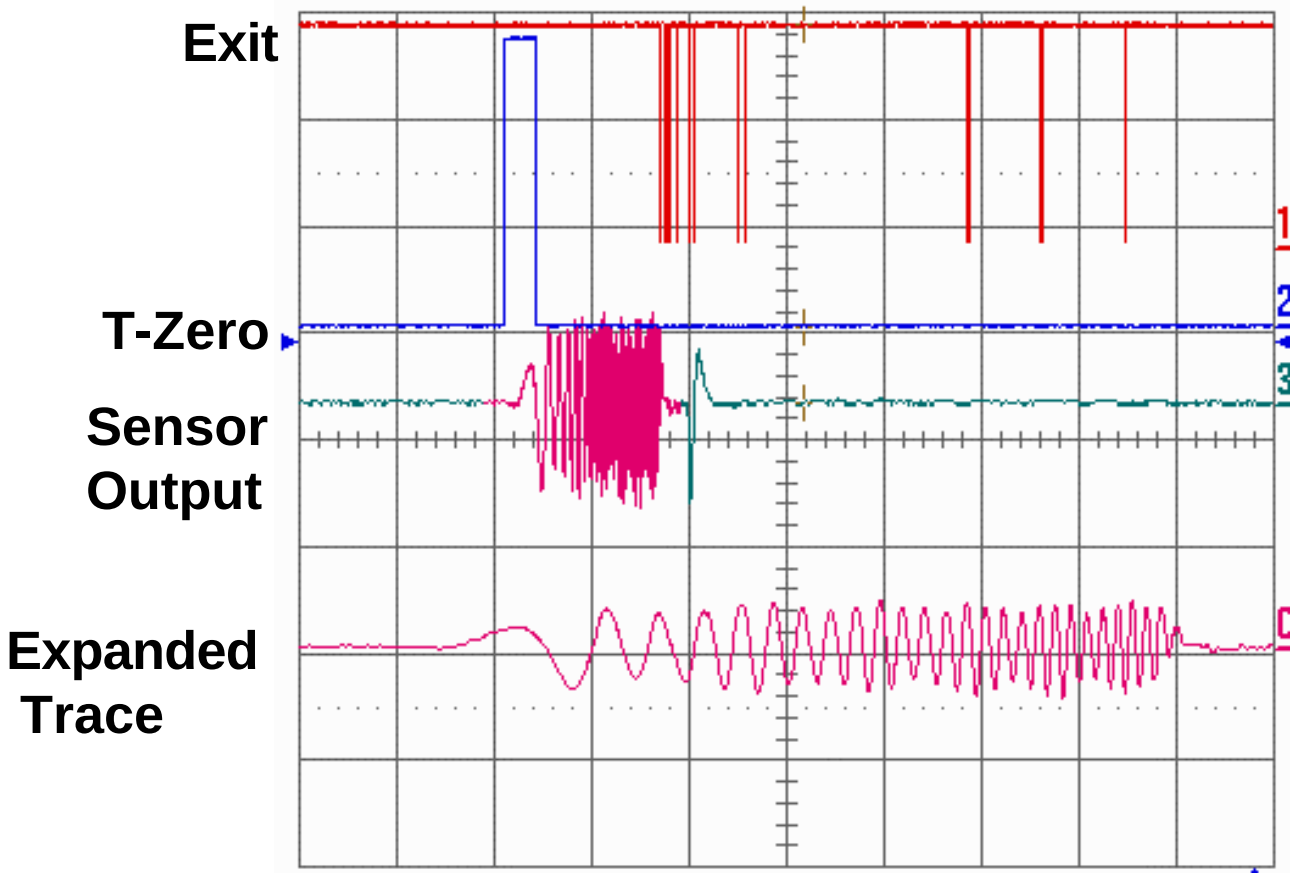
Signature of Microwave Transmitter in a 81mm Tube



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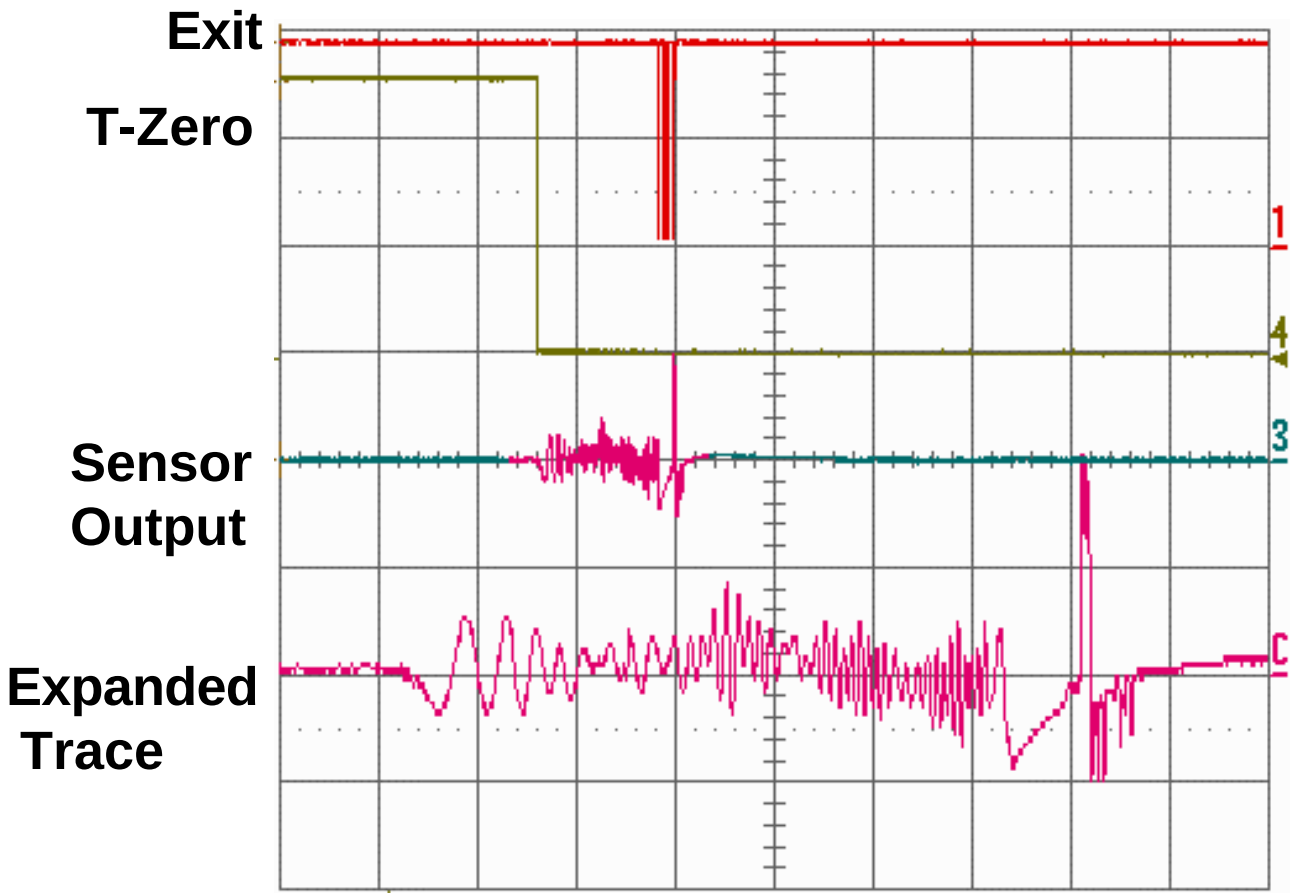
Signature of Microwave Transmitter in a 120mm Tube



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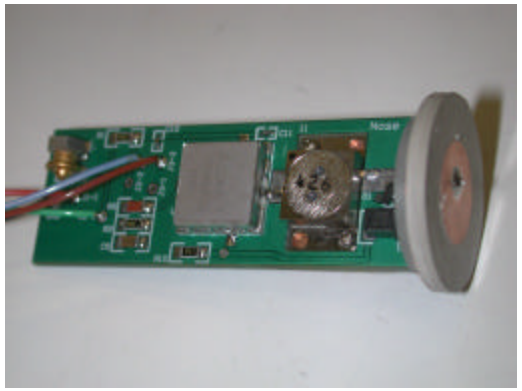
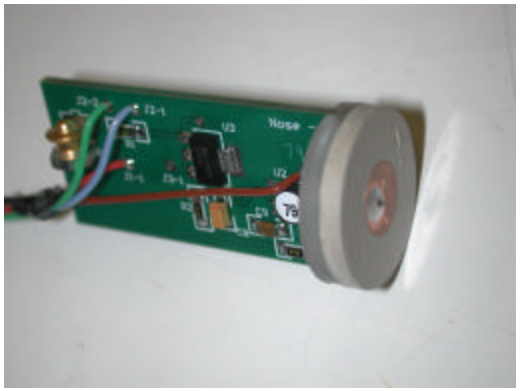
RF Sensor Test Matrix

		60mm	81mm	120mm
Ballistic Test #1	Charge	Qty	Qty	Qty
	1	2	2	3
	2	1	1	1
	3	1	1	1
	4	2	2	3
Ballistic Test #2	1	3	2	3
	4	3	2	3

Ballistic Test Hardware





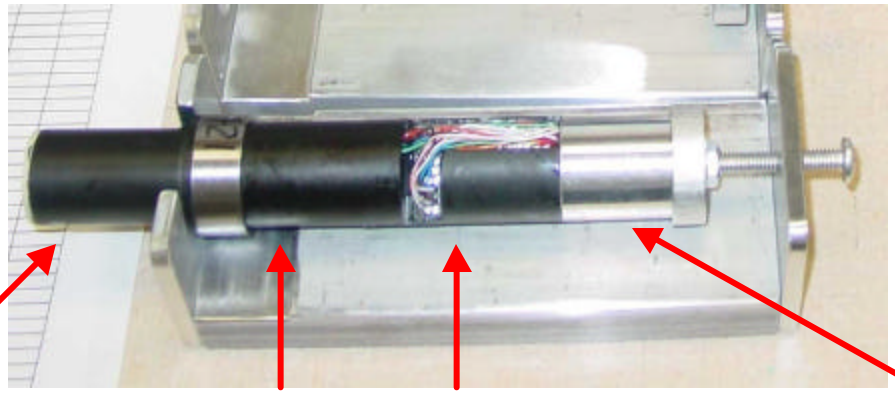
81mm test circuit board and vehicle

60 / 120mm test circuit board and vehicle

Ballistic Test Hardware During Assembly

Test Vehicle Parts

Pre-assembly testing



Potted sensor **Battery** **Data recorder** **Connector cup**

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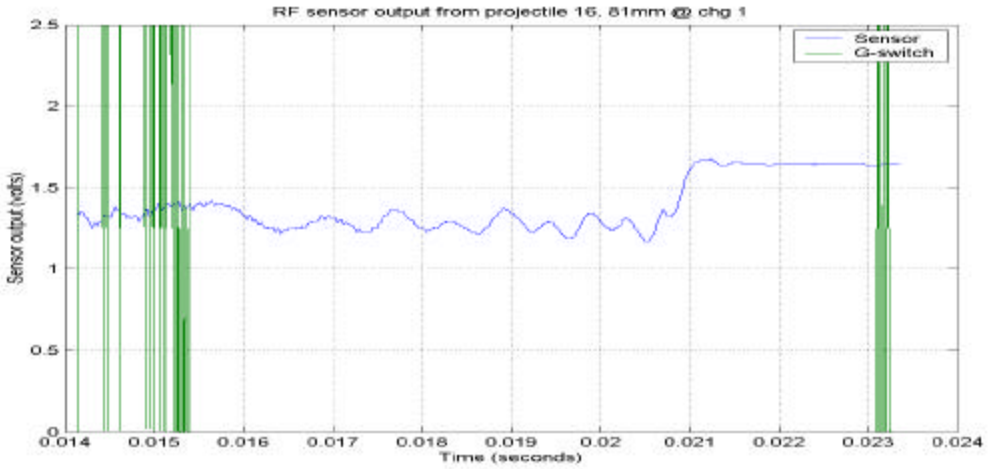
Ballistic Test Results

Field test results were drastically different from lab results!

- Setback, balloting and other shocks induced high noise levels into the circuitry
- Potting compound degraded IF signal
- Outward flaring of mortar tube lip reduced the amount of energy reflected back, thus lessening the sensitivity and effectiveness of the sensor

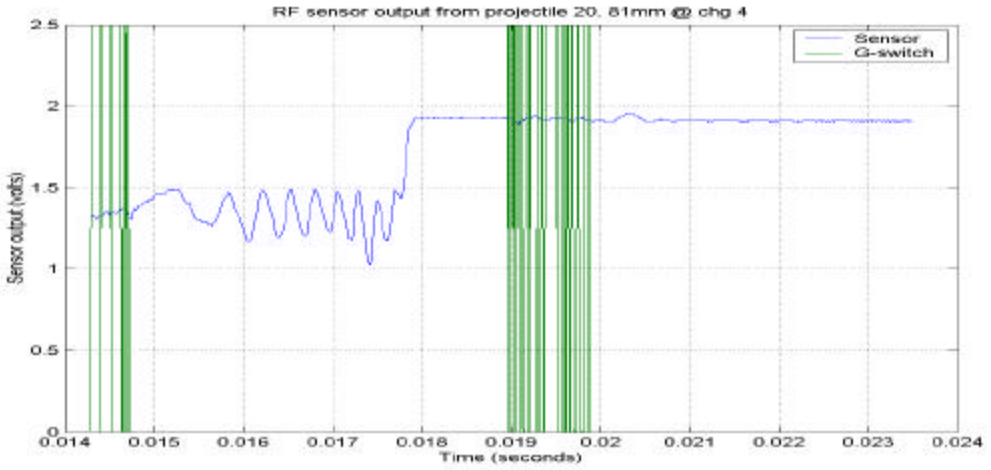
Test Results - Raw Sensor Data

81mm Chg.1 (Lower velocity)



Sensor output contains velocity information

81mm Chg.4 (Higher velocity)



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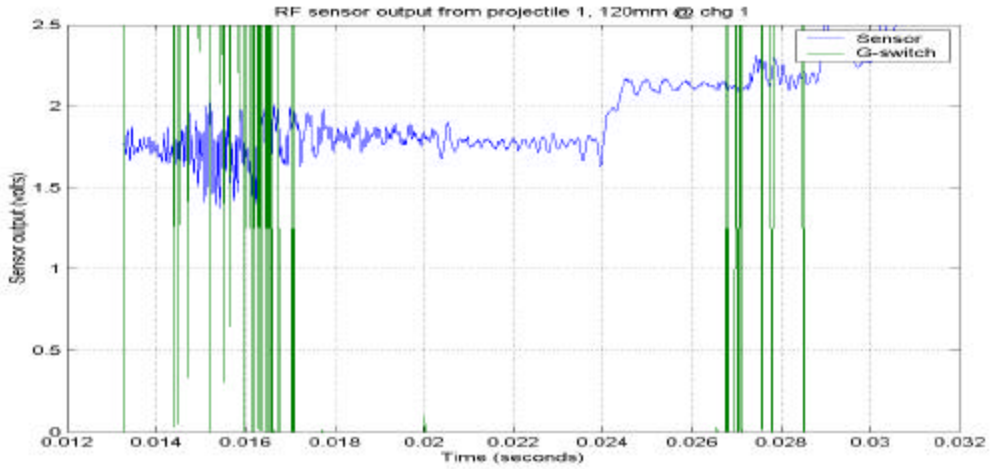
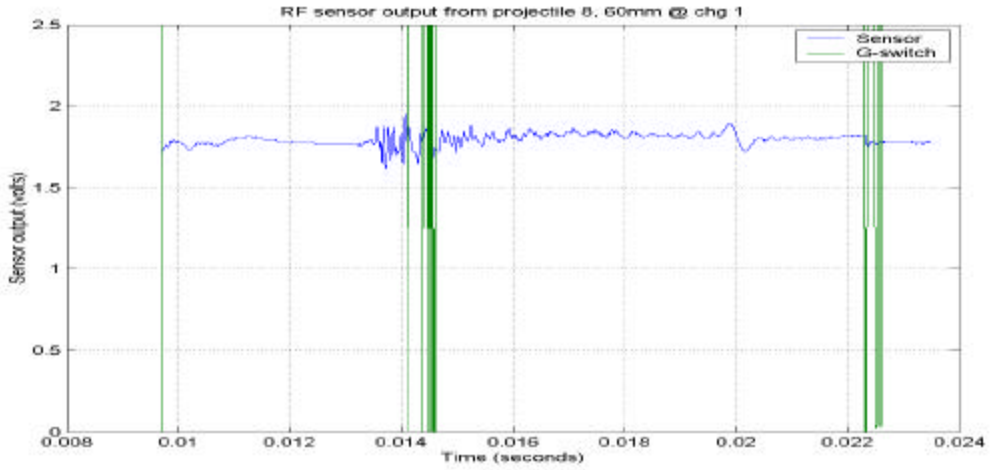
Test Results - Raw Sensor Data

120mm barrel (69.1”)



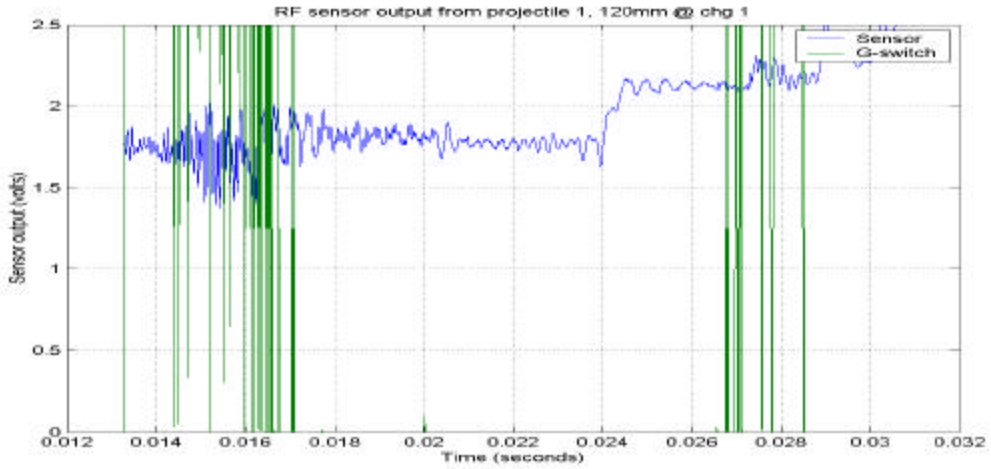
Sensor output contains weapon information

60mm barrel (35.3”)



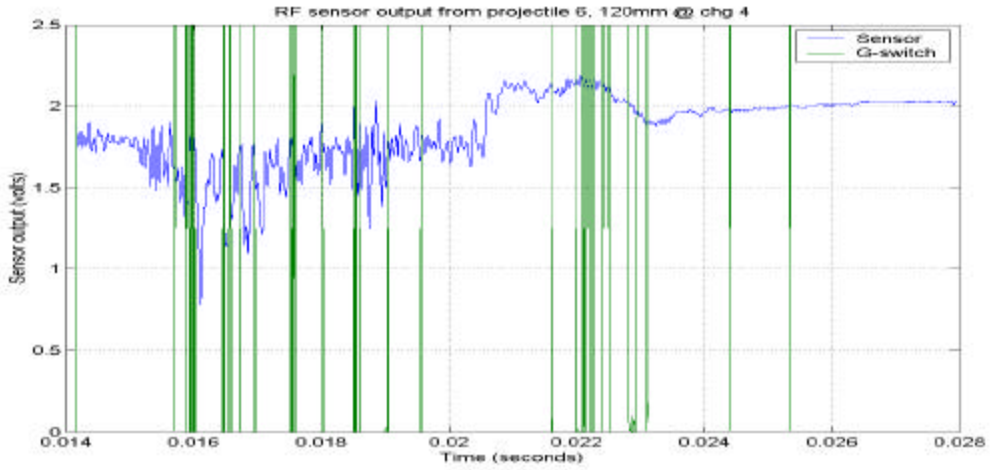
Test results - Raw Sensor Data

120mm, chg 1



Induced noise can drastically increase with firing charge

120mm, chg 4



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2nd Environment Sensor Task Summary

Completed:

- In-lab tube characterization tests (60, 81, 120mm)
- Ballistic environment tube measurements conducted in 60, 81, and 120mm mortar tubes at all charge conditions and ambient temperature
- Sensor data reduction and analysis conducted

Conclusions

Overall, the sensor shows promise, but it needs work

- Further investigation of waveguide propagation phenomena
- Refinement of detection and processing algorithm
- Redesign of RF and IF circuitry to minimize noise, temperature effects, unexpected interactions and energy losses
- Blast shield for 81mm and vehicle-mounted 120mm mortars should be included in testing