Image Formation Through Walls Using a Distributed Radar Sensor Network

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Technologies for Homeland Security and Law Enforcement

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THROUGH WALL SENSING IS IMPORTANT FOR URBAN OPERATIONS

- Both military and law enforcement face same problems
  - intelligence for building clearing, hostage, search situations
    interior features, presence of people
  - operations carried out by small teams of individuals

- Most current through wall sensing systems designed to be handheld
  - provides limited view of operational space
  - situational awareness limited to person using sensor
  - hands no longer free to use weapon
  - changes way members of team coordinate as a unit

- Options for sensors using all members of team make sense
  - maintains way members work as a team
  - provides each with same situational awareness
  - leaves hands free to use weapon

- Current program exploring a distributed sensor option

DISTRIBUTED IMAGING NETWORK CONCEPT

Concept Elements	Characteristics	Enables
Distributed sensor nodes on individuals on vehicles set in place	Frequency agile radar Coherent detection Random array Stationary or mobile	Dismounted operations Standoff surveillance Resolution where needed
Processing (fusion) network timing and control sensor location data and results	Imaging and motion 3 dimensions Weapons detection	Sensing through walls Sensing on the move Hostile ID
Command and Display individual mounted operation control command	Global views Local views	Situational awareness individual command elements

- **Individuals and vehicles become sensor nodes**
- **Random array improves imaging by reducing ghosts**
- **Wireless network receives data and distributes information**
- **View of operational space changes as sensors move**
- **Modular approach allows operational flexibility**
- **Network centric sensor**

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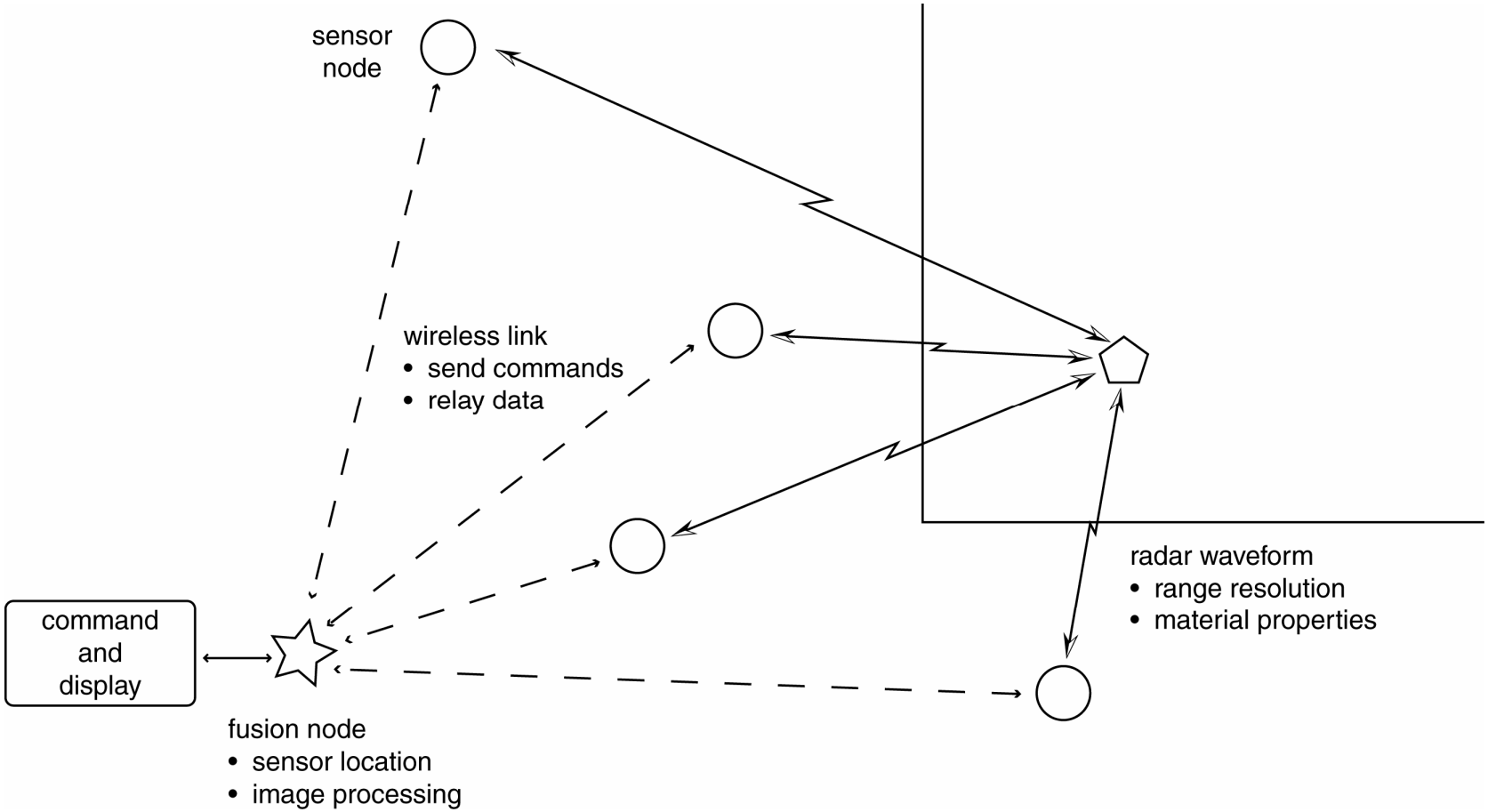
CURRENT DEVELOPMENT ARCHITECTURE



- **Completely wireless system is program goal**
- **Major issues**
  - **timing and control, sensor location, and processing speed**
  - **how small a movement can be detected**

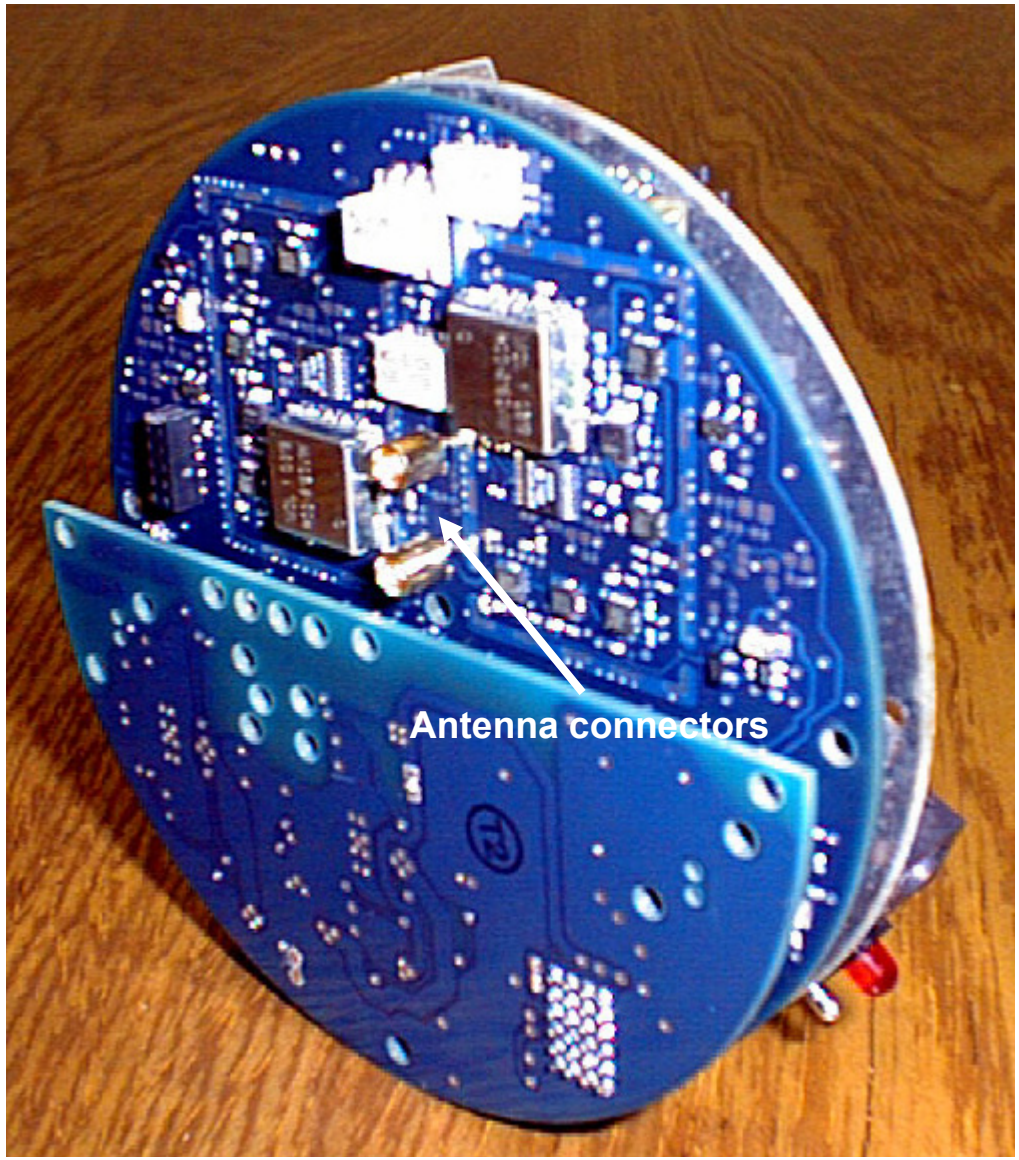
COMMAND, DISPLAY AND FUSION NODE

- Currently provides the following:
  - sets all sensor parameters
  - fuses data from all sensors
  - performs sensor location
  - processes all data
  - forms images
  - operates with either wired or wireless link

- Images formed and displayed at at up to 10 frames per second with COTS PC

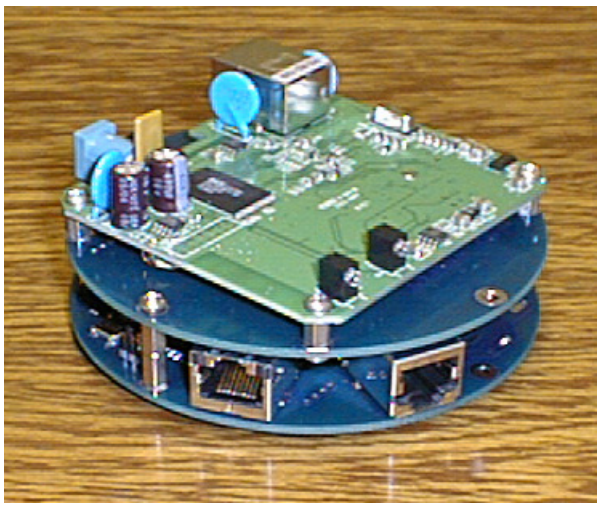
RADAR HARDWARE

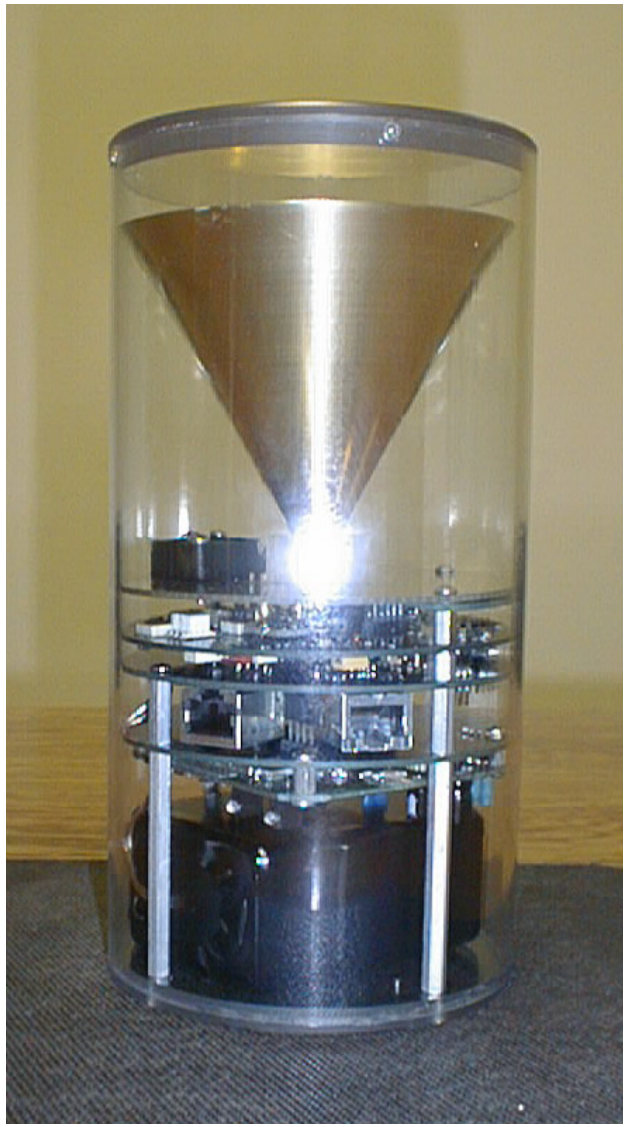
- 500 - 2000 MHz
- 10 μsec per point
- software defined
- 50 mW power output
- battery powered
- 13 watts
- ~ $1,000 parts cost



WIRELESS SYSTEM SENSOR NODE

- D-Link wireless bridge used to control radar
- Inverted discone antenna
- Independent radar package 8.5” tall by 4.25” diameter
- 2.25 lbs





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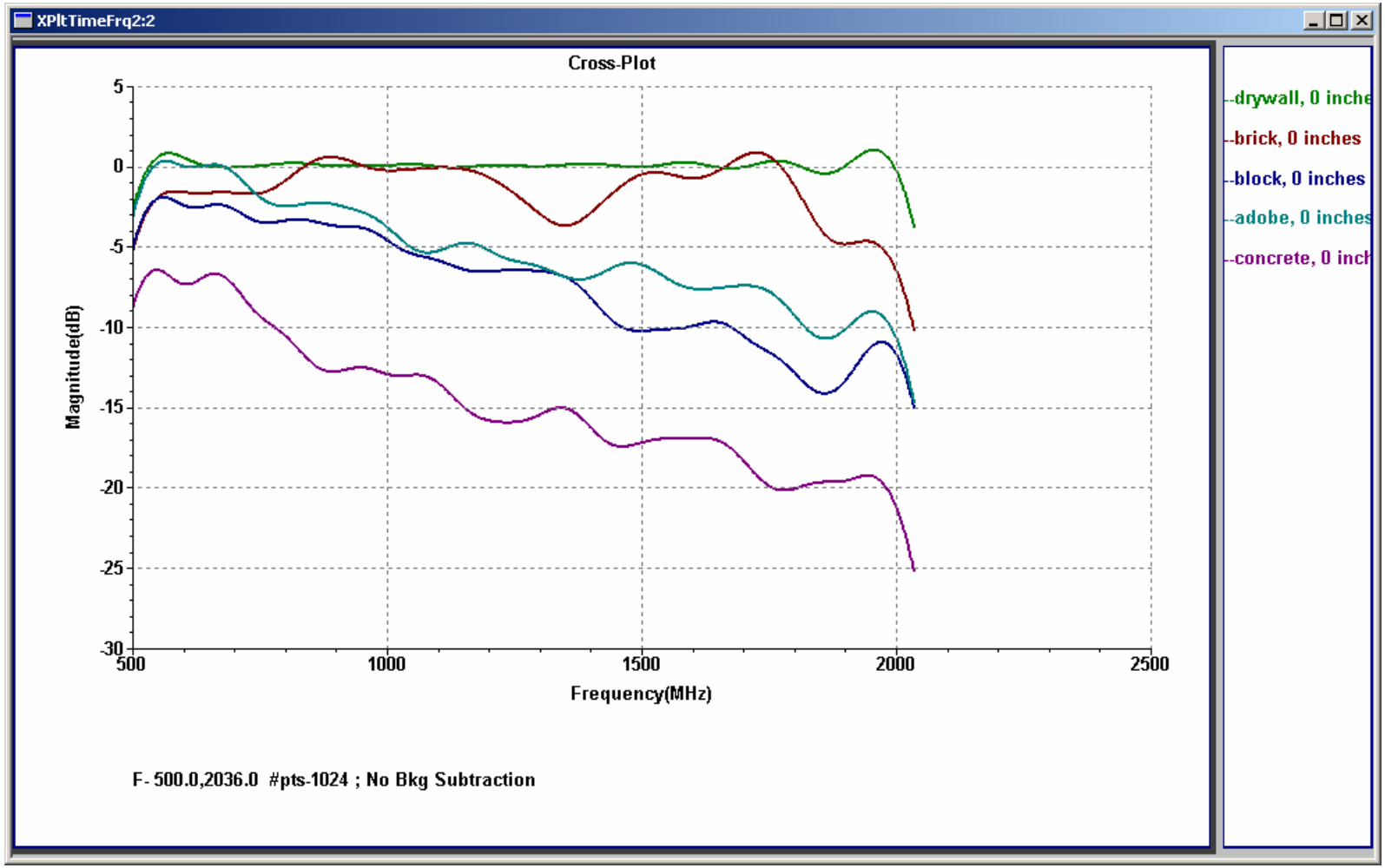
TESTING RESULTS

- Static testing performed to characterize properties of different walls
  - drywall, brick, block, adobe, reinforced concrete, stucco
  - wall attenuation generally increases with frequency
  - dielectric constant is relatively insensitive to frequency
  - stucco is relatively transparent above 900 MHz
- Dynamic testing performed to test motion detection algorithms
  - person walking or sitting behind wall
  - breathing simulator behind 12´´ reinforced concrete wall
- Open field measurements
  - measurements of person to determine SNR of for current hardware
  - data to characterize sensitivity of motion detection algorithms
  - used with attenuation data to predict sensor performance

NORMALIZED ATTENUATION RESPONSE FOR 12´´ THICK WALLS



- Comparison of normalized response for 5 different wall types
  - all measurement points are with antennas right against the wall

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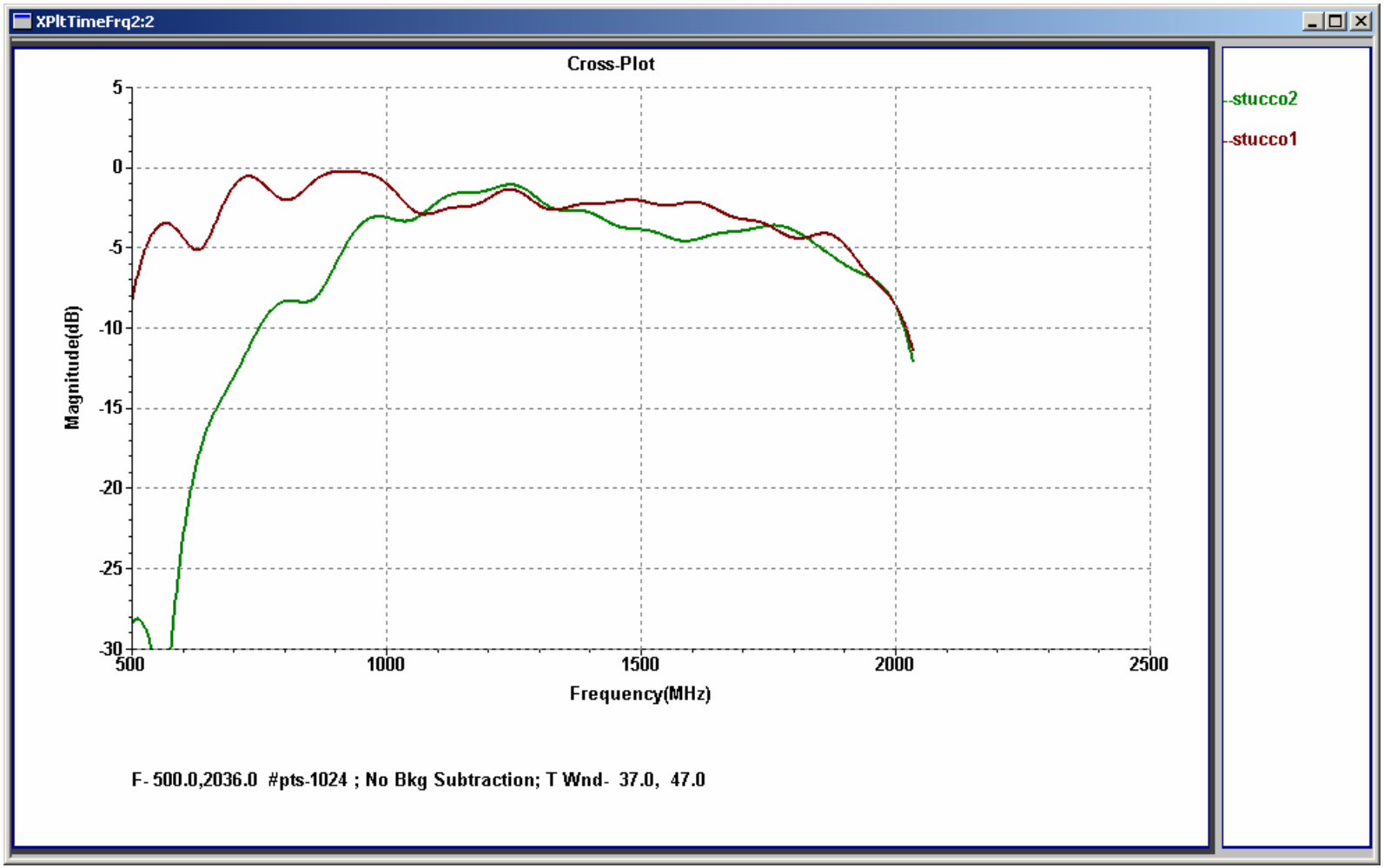
NORMALIZED ATTENUATION RESPONSE FOR STUCCO WALLS



- Comparison of one and two sided walls
- Good penetration above 900 MHz

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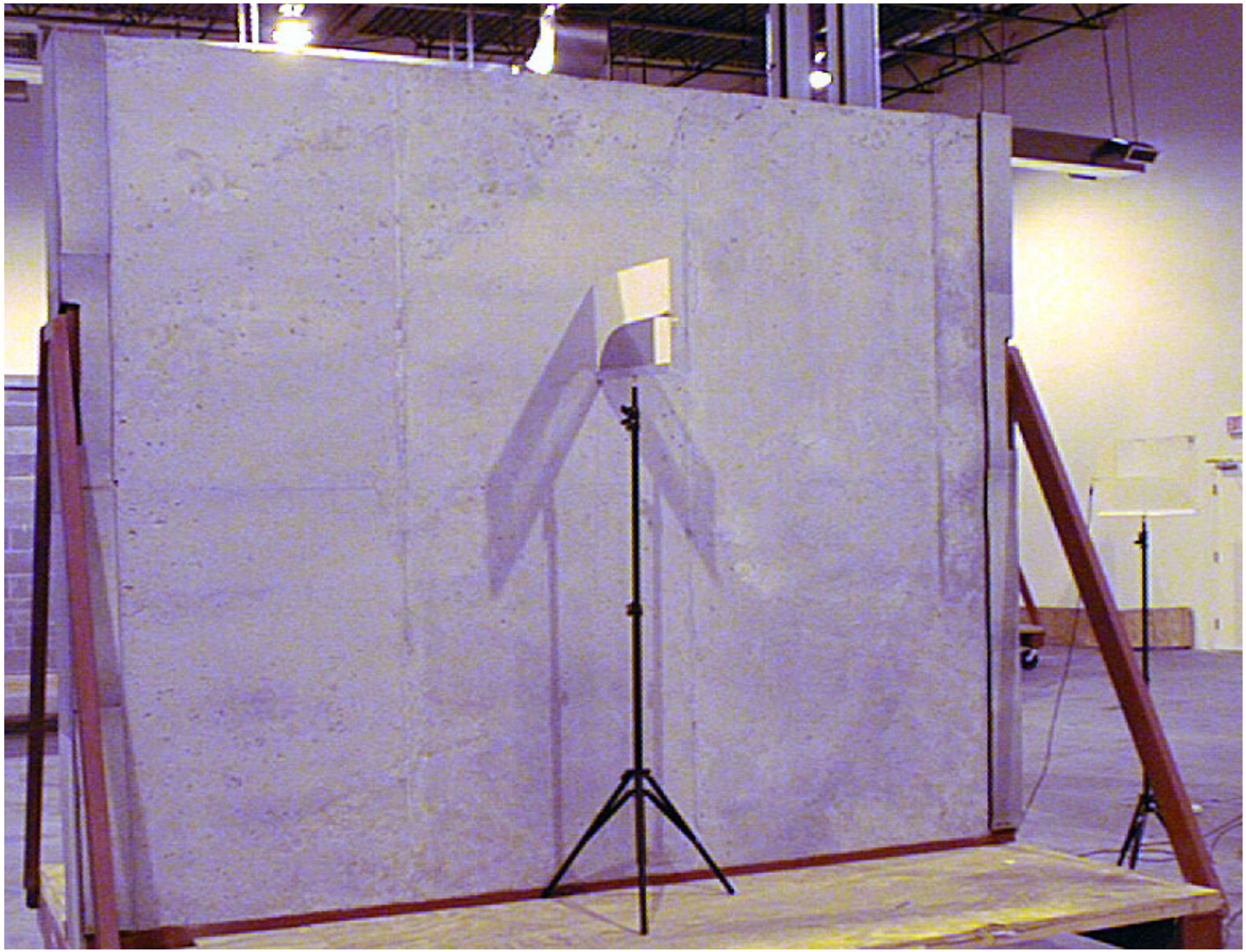
REINFORCED CONCRETE TEST WALL



- Used for motion testing with person

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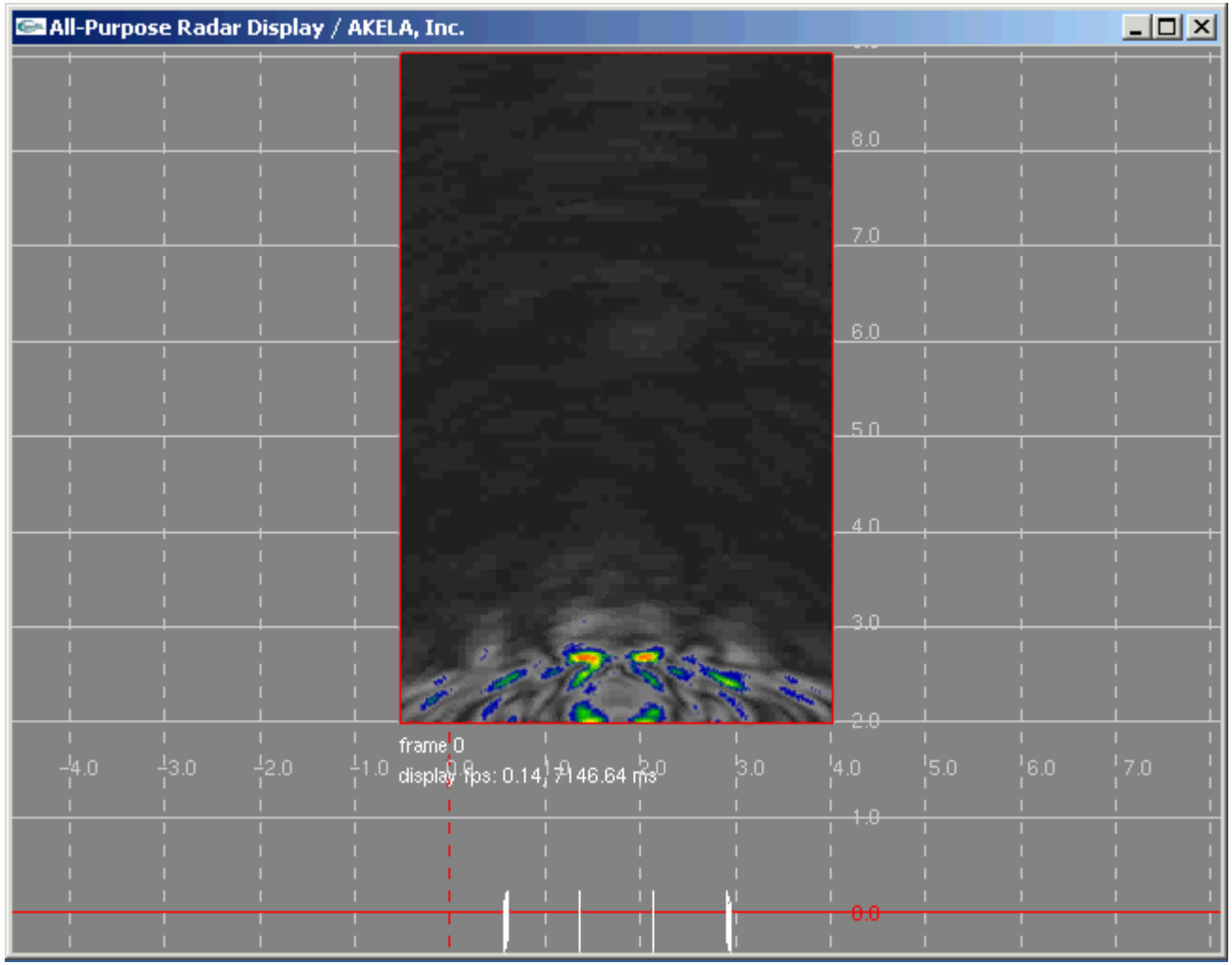
MOTION DETECTION - REINFORCED CONCRETE



- **Person walking around and then sitting down detected by large and small motion algorithms**

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BREATHING SIMULATOR TEST SETUP

- **Breathing simulator used to provide repeatable test object**
  - **0 to 40 cycles per minute, 0 to 2.5´´ displacement**

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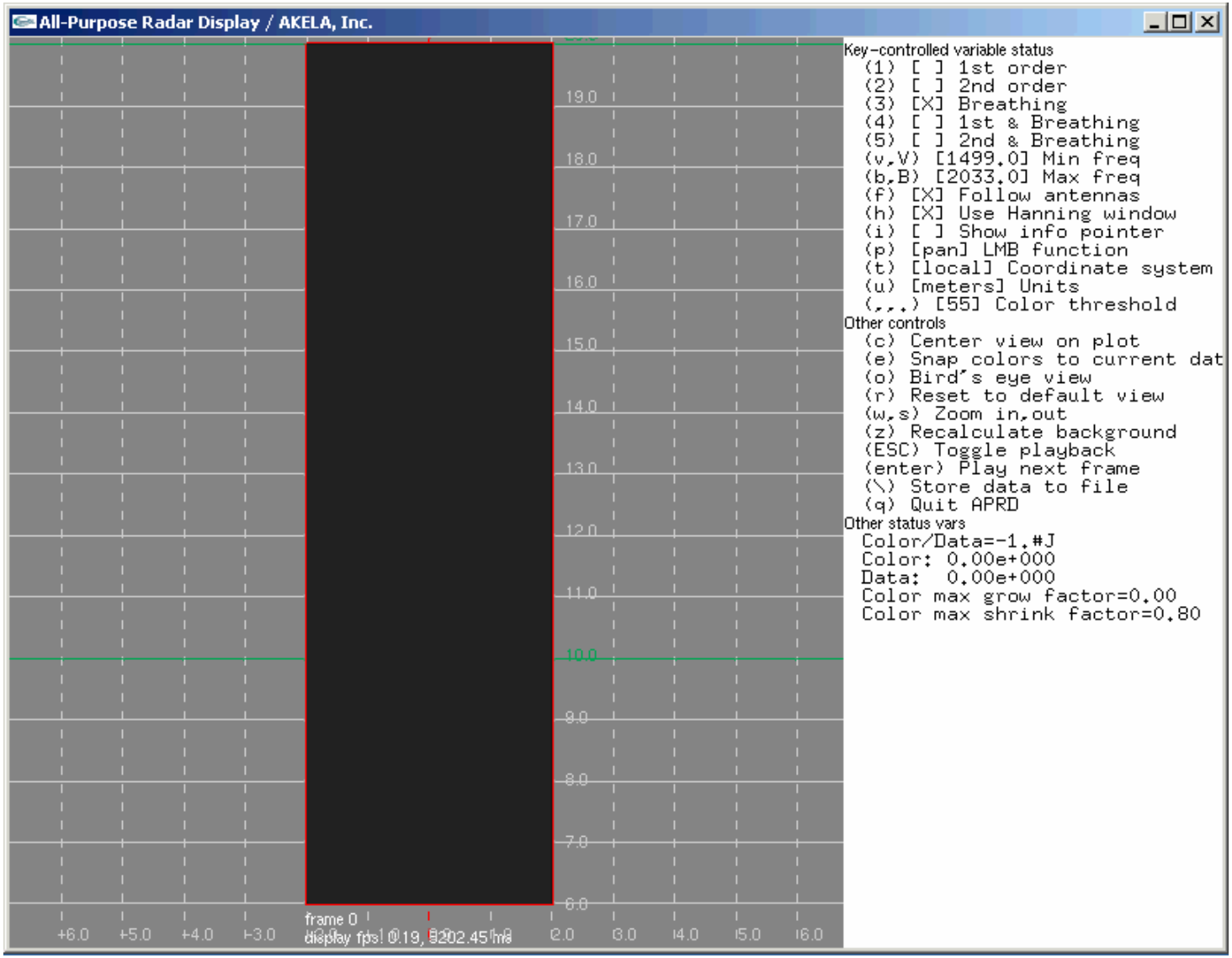
MOTION DETECTION - REINFORCED CONCRETE



- **Breathing simulator between 17 and 18 meters**

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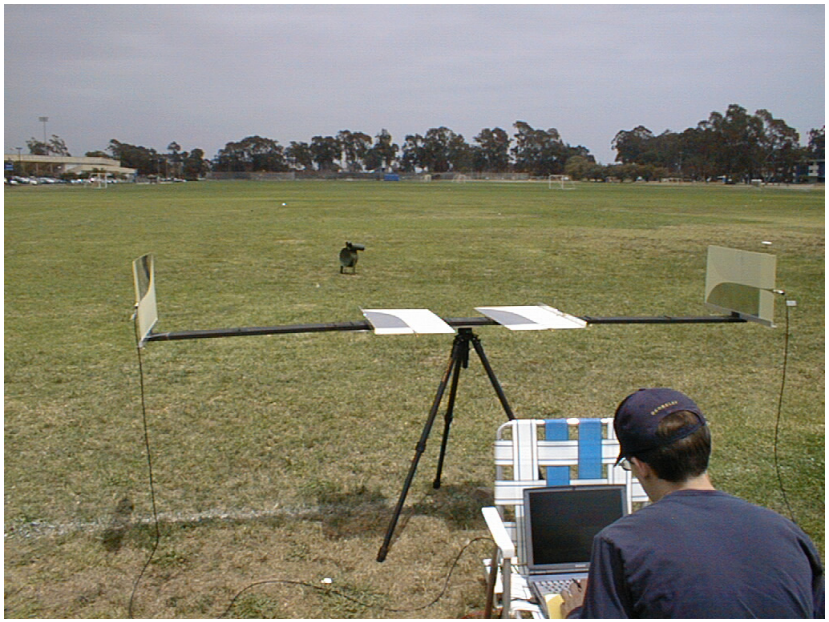
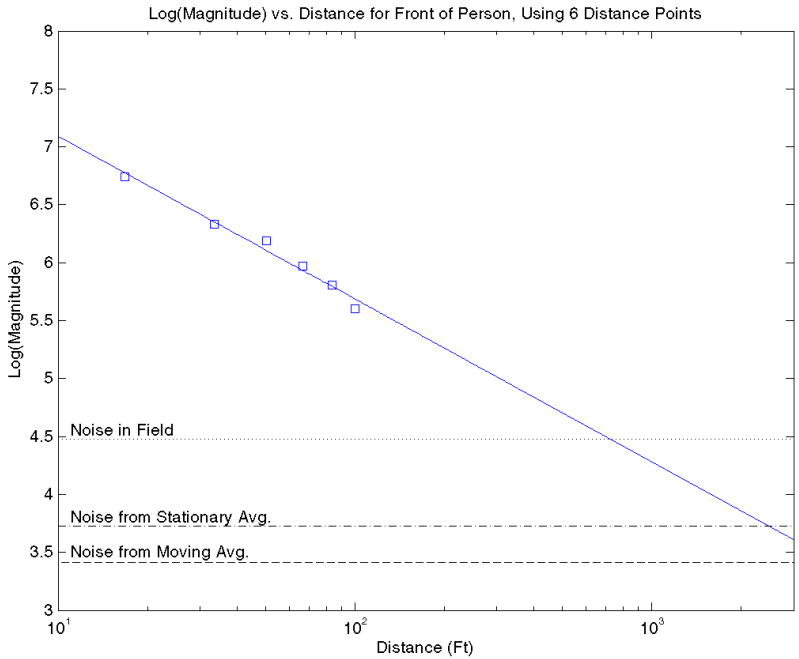
DATA ANALYSIS TO DETERMINE SYSTEM PERFORMANCE





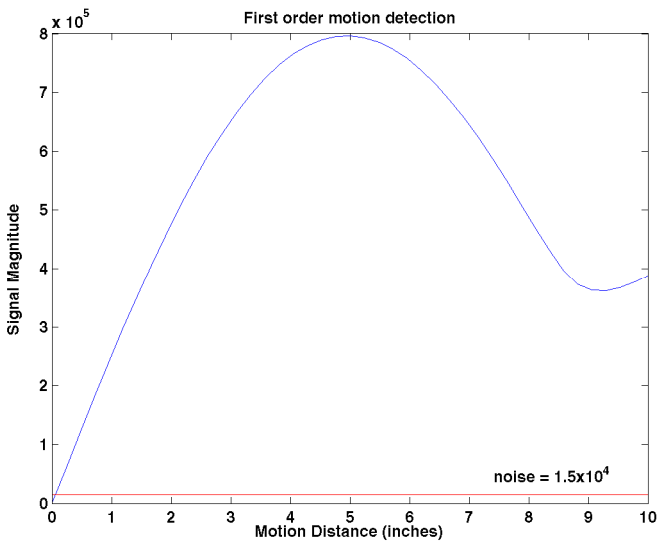
- **Data collected in open field, quiet environment**
  - **noise floor measured from field data**
  - **person detectable between 250 and 300 feet**

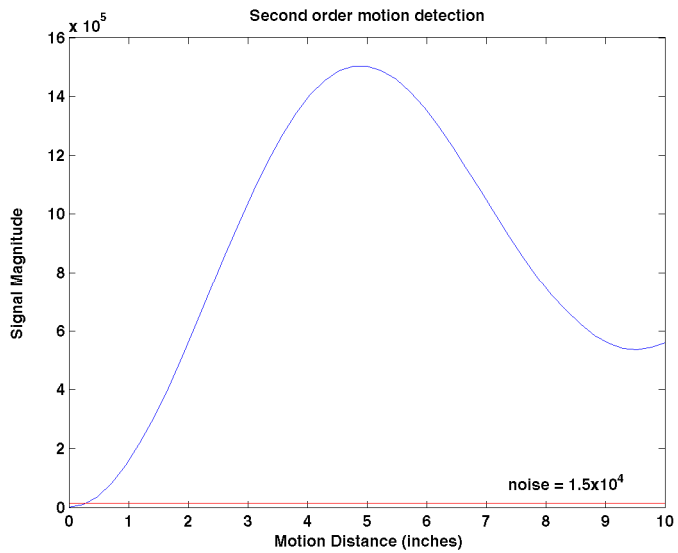
- **Adjustments required to account for attenuation of individual walls**

MOTION DETECTION ALGORITHMS PROVIDE PROCESSING GAIN

- **Sensitivity determined analytically**
  - single range profile used from person detectability test series
  - second range profile generated from original, but adjusted in distance
  - profiles used with each algorithm to determine peak response
  - result shows SNR expected with degree of movement

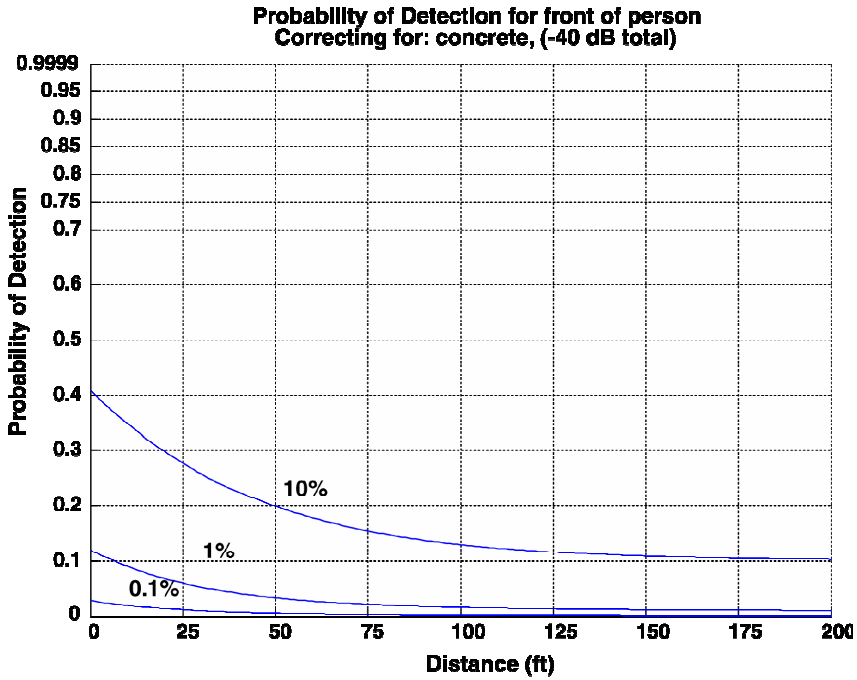
- **Second order algorithm generally more sensitive**

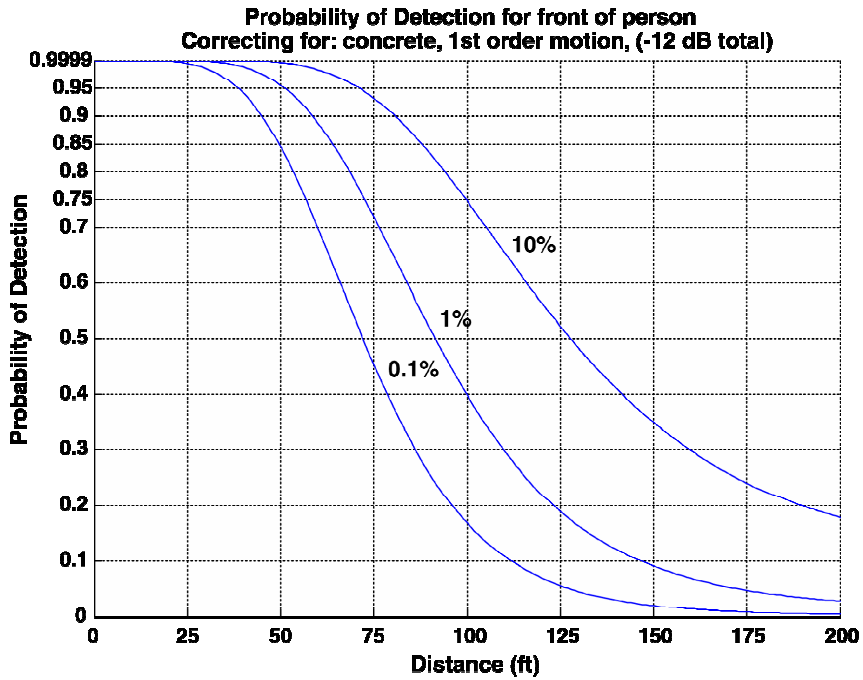




- **First order results used for P_d calculation to be more conservative**

REINFORCED CONCRETE P_d - WITH AND WITHOUT MOTION DETECTION





- **Results consistent with motion data taken with simulator**
  - **breathing detected at 57 feet through concrete wall**

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CONCLUSION

- **Physics and technology for through-the-wall imaging are well understood**
  - **no fundamental principles limit success**
  - **commercial technology exists for implementing a robust system**

- **Imaging and motion detection algorithms have been demonstrated with real data**

- **Improvements in radar operation are extending the operational range and sensitivity of through-the-wall imaging systems**