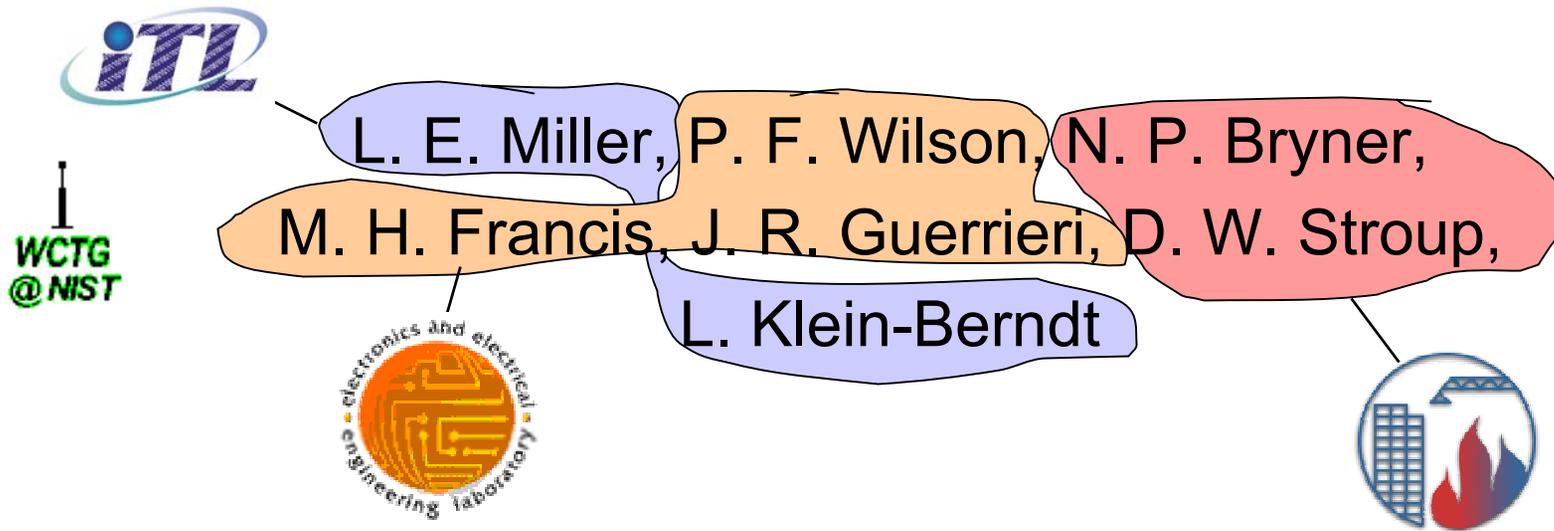


RFID-Assisted Indoor Localization and Communication for First Responders





Outline

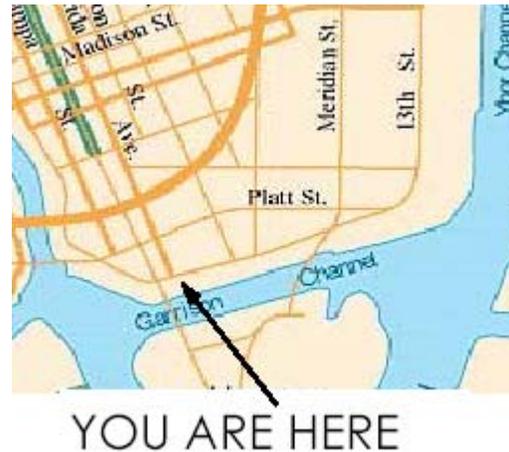
- Background and objectives
- Approach
- Project milestones
- Summary of first year results
- Second year work on this project



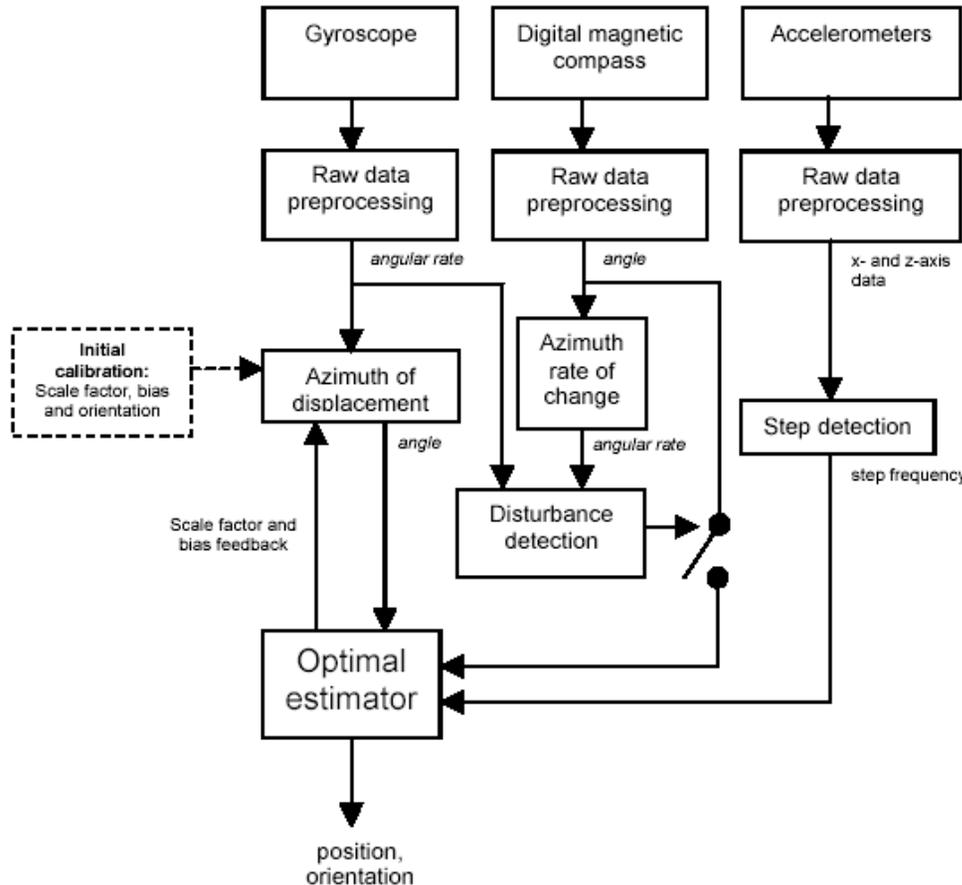
Background and Objectives

- RFID devices commonly are attached to persons or to moveable objects so that the objects can be tracked using *fixed readers* at different locations.
- We are exploring application of the “flip side” of this practice based on the concept that detection of an RFID device in a known, fixed location by a *moving reader* provides a precise indication of the reader’s location.
- The research is evaluating the exploitation of this concept to implement a low-cost, reliable means for tracking firefighters and other first responders inside buildings, where navigation using GPS is not reliable—indeed, the GPS signal may have been disabled temporarily to prevent exploitation by terrorists.[1]

[1] “Bush prepares for possible GPS shutdown,” <http://abcnews.go.com/Politics/wireStory?id=335054&CMP=OTC-RSSFeeds0312>



Concept: RFID tag provides an electronic indoor “you are here” to the first-responder.

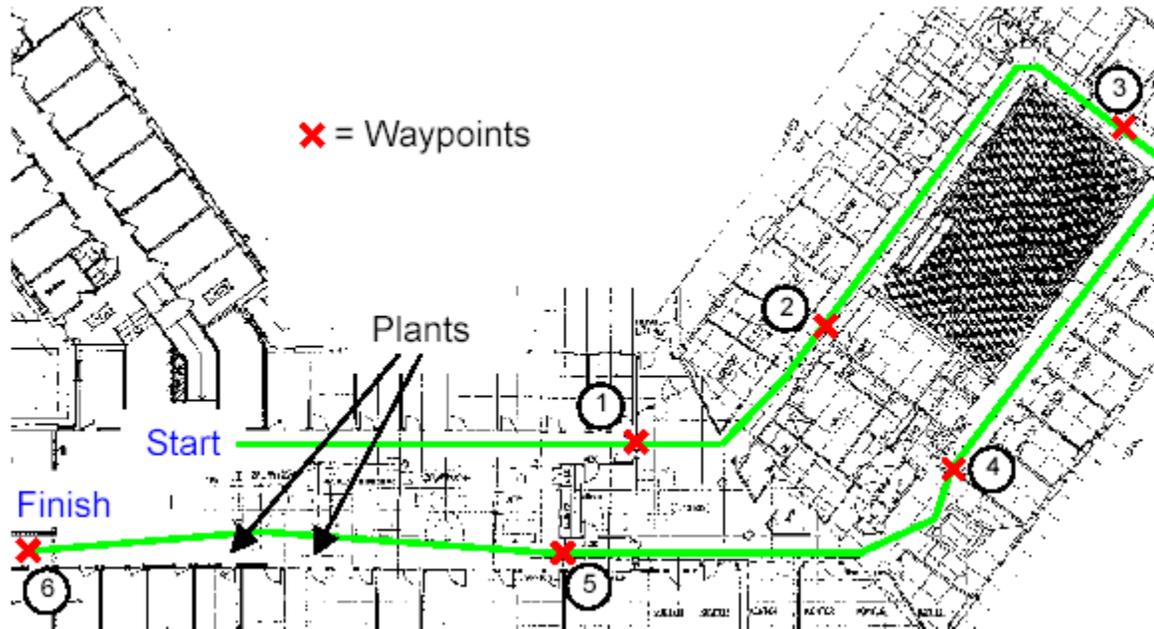


An example inertial navigation system for tracking the position of a person walking. [2]

The accuracy of such a system could be helped by RFID waypoint corrections.

Figure 1 Positioning system using a gyroscope and a compass.

[2] F. Brannstrom, "Positioning Techniques Alternative to GPS," Master's Thesis, Univ. Lund, 2002.



An example test of a “pedestrian navigation system,” from [2]. The position solution was updated manually at waypoints. An RFID reader/tag capability could provide automatic updating.

Real length	Calculated length	Error	Recalculated length	Error
20.6	0.2	-20.37 (-98.8...)	20.4	-0.16 (-0.75 %)
16.9	16.7	-0.13 (-0.77 %)	16.8	-0.06 (-0.33 %)
19.8	20.4	0.61 (3.09 %)	20.2	0.41 (2.05 %)
23.4	23.6	0.24 (1.04 %)	23.4	0.05 (0.20 %)
18.8	18.2	-0.63 (-3.34 %)	18.4	-0.37 (-1.94 %)
32.0	31.2	-0.80 (-2.49 %)	31.3	-0.70 (-2.18 %)



Background and Objectives (2)

- The system envisioned by this research is intended for a potentially “unfriendly” RF propagation environment—the in-building environment of first responders that may contain smoke, dust, or flames.
- The system does not depend upon the stability of the RF environment over relatively large distances to derive range from precision timing.
- The system leverages advances in ubiquitous RFID tag technology, along with recent advances in miniaturized inertial sensors, to develop a low-cost tracking system.



Background and Objectives (3)

- The “philosophy” of the proposed RFID-assisted system also involves reducing the dependence on RF links to external data sources by exploiting the capability of RFID tags to store critical building information for retrieval when it is needed, where it is needed.

Approach

- In addition to assessing the RF propagation environment of buildings in emergency situations, the research considers several operational scenarios consisting of
 - (1) the strategy for RFID deployment,
 - (2) the tracking method, and
 - (3) the options for presenting location information to the user and communicating this information to a monitoring station.



Synopsis of FY05 Milestones

- Define critical parameters of firefighter localization and in-building informational requirements in typical scenarios (BFRL, EEEL)
- Evaluate inertial and dead-reckoning navigation techniques and device options (ITL)
- Analyze the requirements for the number of RFID tags and their placement (BFRL, ITL)
- Evaluate options for RFID technologies—including both tags and readers—to use for location updating of a navigation system implemented on a small, battery-powered device (EEEL, ITL)



Summary of First-Year Results

- Firefighter localization parameters
- Navigation techniques and devices
- Number and placement of tags
- Options for RFID technologies

Firefighter Localization Parameters

- Firefighter location and in-building information requirements may be grouped in terms of
 - (a) building type,
 - (b) temperature environment,
 - (c) radio attenuation factors, and
 - (d) desired location resolution.
- Our study so far has collected information on these requirements, except for category (c).

Building Type

- Building type refers both to the building's construction, which relates to its resistance to fire, and to factors affecting communications in the building.
- The building type, along with classification of the building use (e.g., residential or industrial), is the primary parameter in the description of the fire event scenario.
- *Type I Buildings* are classified as Fire-Resistive.
- *Type II Buildings* are classified as Noncombustible.
- *Type III Buildings* are classified as Ordinary.
- *Type IV Buildings* are classified as Heavy Timber.
- *Type V Buildings* are classified as Wood Frame.

Temperature Environment

- The temperature environment of a building during a first responder event is described in terms of **zones** that correspond to degrees of exposure to **heat flux** (not just temperature) and therefore to risk of injury.

Zones	Example heat flux range
Zone I	Up to about 1 kW/m ²
Zone II	Up to about 4 kW/m ²
Zone III	Up to about 25 kW/m ²
Zone IV	Up to about 200 kW/m ²

Location Parameters

- The desired resolution of indoor location information during a first responder event varies according to scenario—residential or commercial.
- For example, the following table correlates location resolution in meters to accuracy in locating personnel and escape openings in a residential fire.

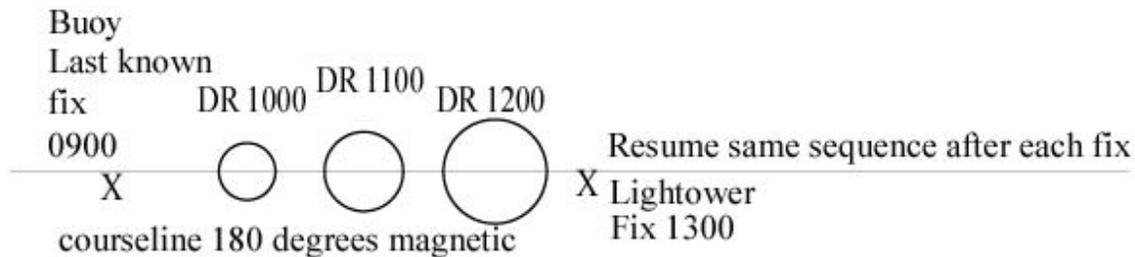
Resolution in meters	Personnel Location		Escape Openings	
	X-Y	Z	X-Y	Z
100	City block \pm	10 floors \pm		
10	Front or rear	3 floors \pm	Structure \pm	Floor \pm
1	Room	Floor \pm	Correct wall	Window/door
0.1	Location in room	Correct floor	Location on wall	Height of window/door



Navigation Techniques and Devices

- GPS accuracy could be made sufficient, but the signal strength is almost always too low indoors.
- Some systems involving triangulation of signals to/from multiple transmitters outside the building are being offered.
- At NIST, we are also investigating various indoor “active” techniques for localization (signal strength mapping, UWB, etc.)
- For this project, we focused on self-contained navigation techniques—dead reckoning, inertial or both.
- We have studied the feasibility of dead reckoning with simulated RFID waypoints.

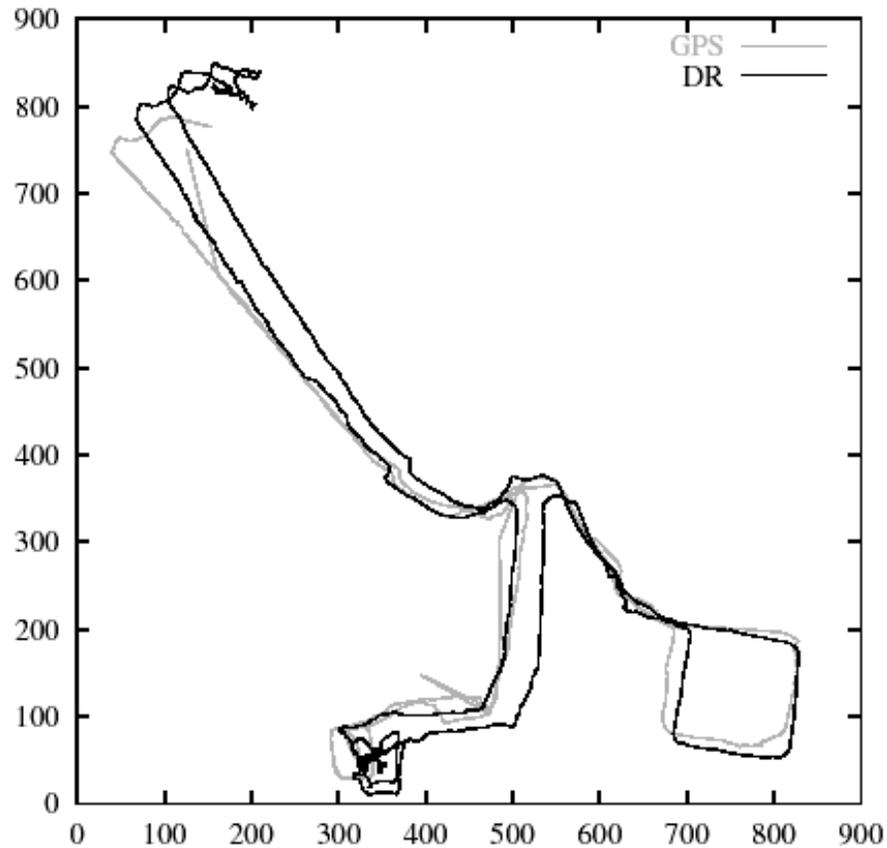
Dead reckoning: Proceed in a given direction with a constant speed. (It may be difficult to maintain a given course and speed.)



Diameter of circle increases every hour after last known fix representing increased area of uncertainty until next fix.
Actual vessel position can be assumed anywhere inside the circle.

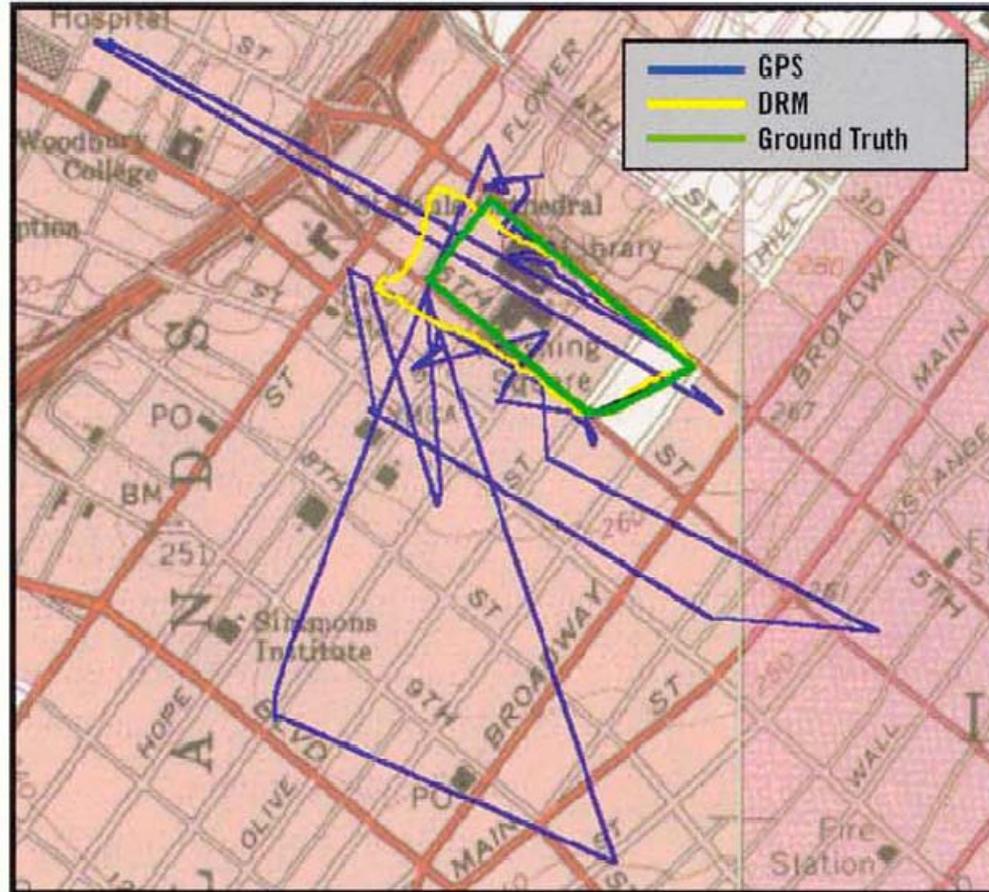
Dead reckoning in the open ocean [3]

[3] W. Newberry, "Dead Reckoning: A Skill All Navigators Should Master."



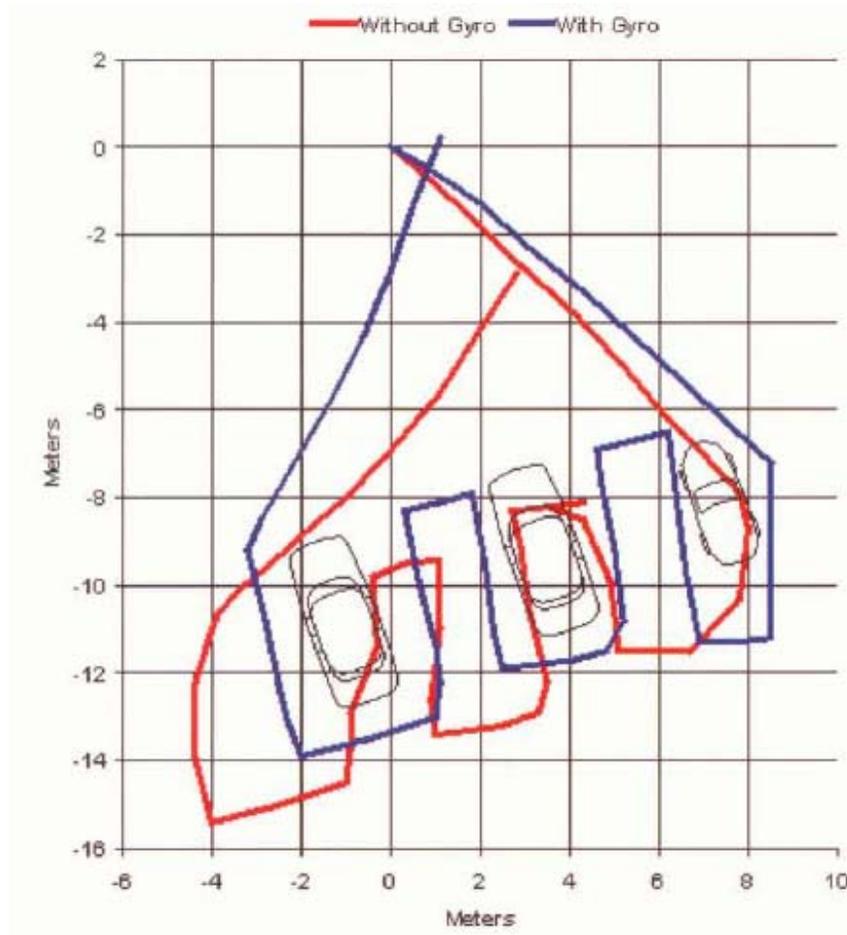
Positions developed by a DR system vs. GPS over a 4 km urban trail. [4]

[4] C. Randell, et al., "Personal Position Measurement Using Dead Reckoning," 2003.



DRM/GPS personal outdoor navigation [5]

[5] Point Research (Honeywell) data sheet for DRM III dead reckoning module.



Manufacturer's demo of gyro-stabilized DRM [6]

[6] Point Research (Honeywell) data sheet for Gyro-DRM III dead reckoning module.



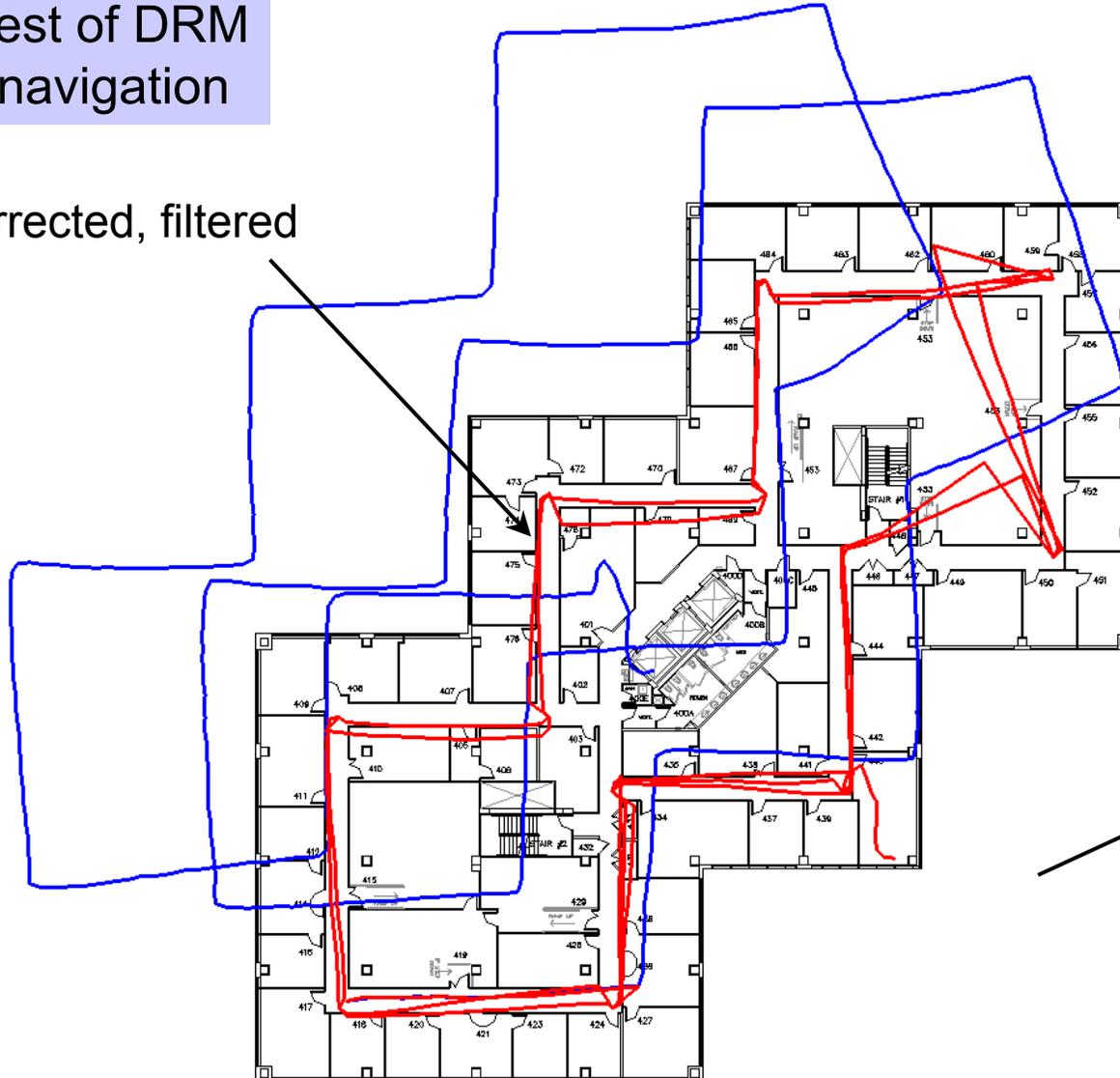
Number and Placement of Tags

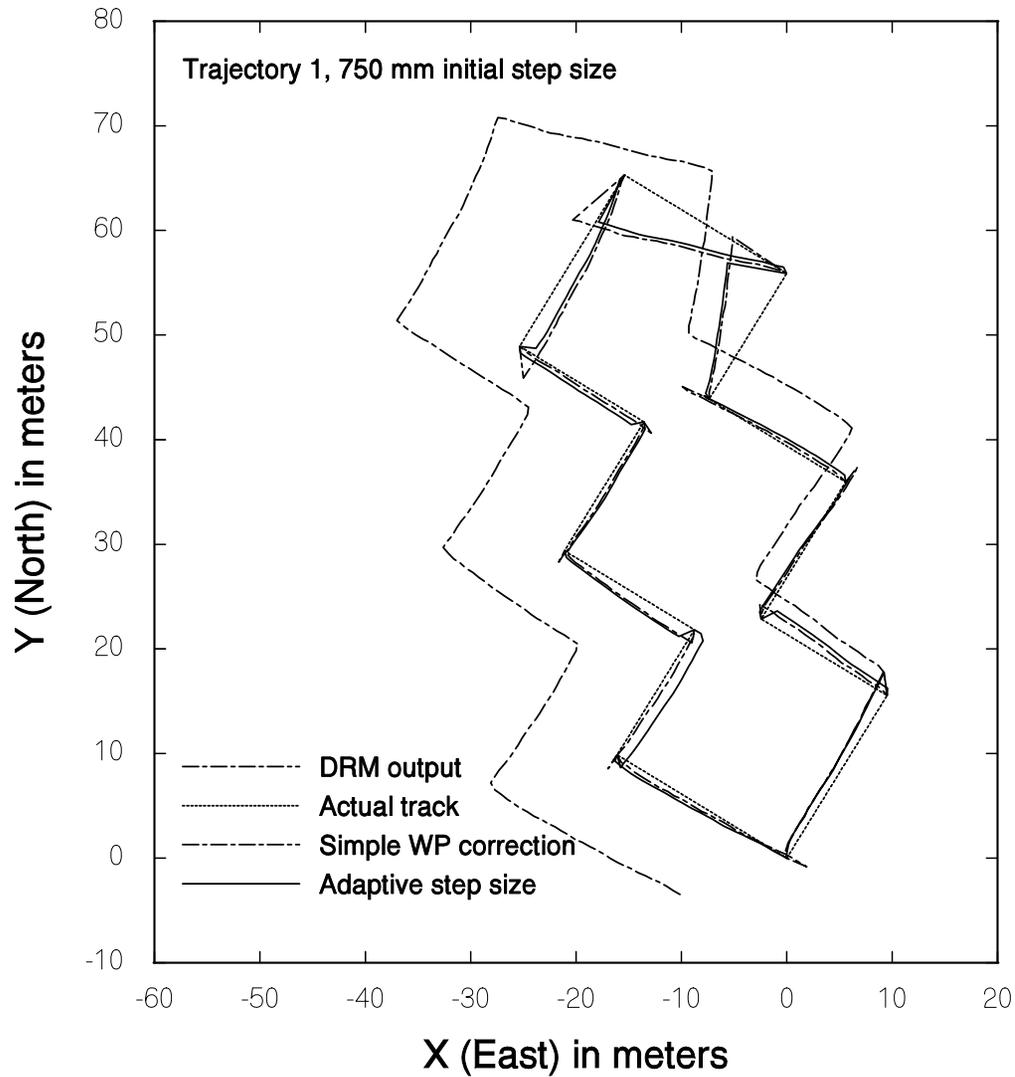
- The number and placement of tags depends on
 - desired localization resolution
 - accuracy of navigation techniques
 - read range of the particular RFID technology
- This topic is still an open question, but some recent indoor navigation test results suggest that updates can be based on an average navigation error of 5% of distance traveled.

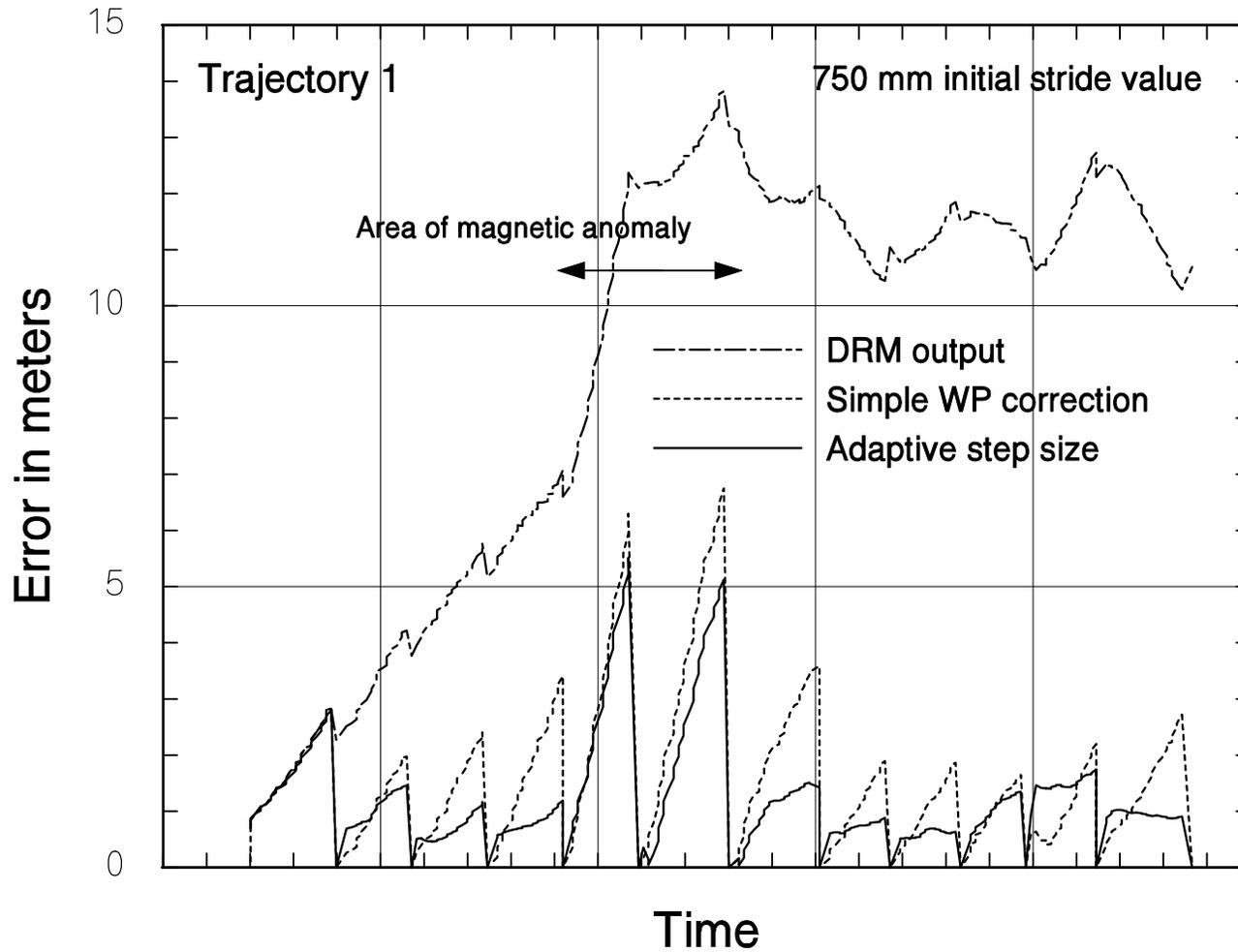
Example test of DRM for indoor navigation

Waypoint-corrected, filtered
DRM output

DRM output







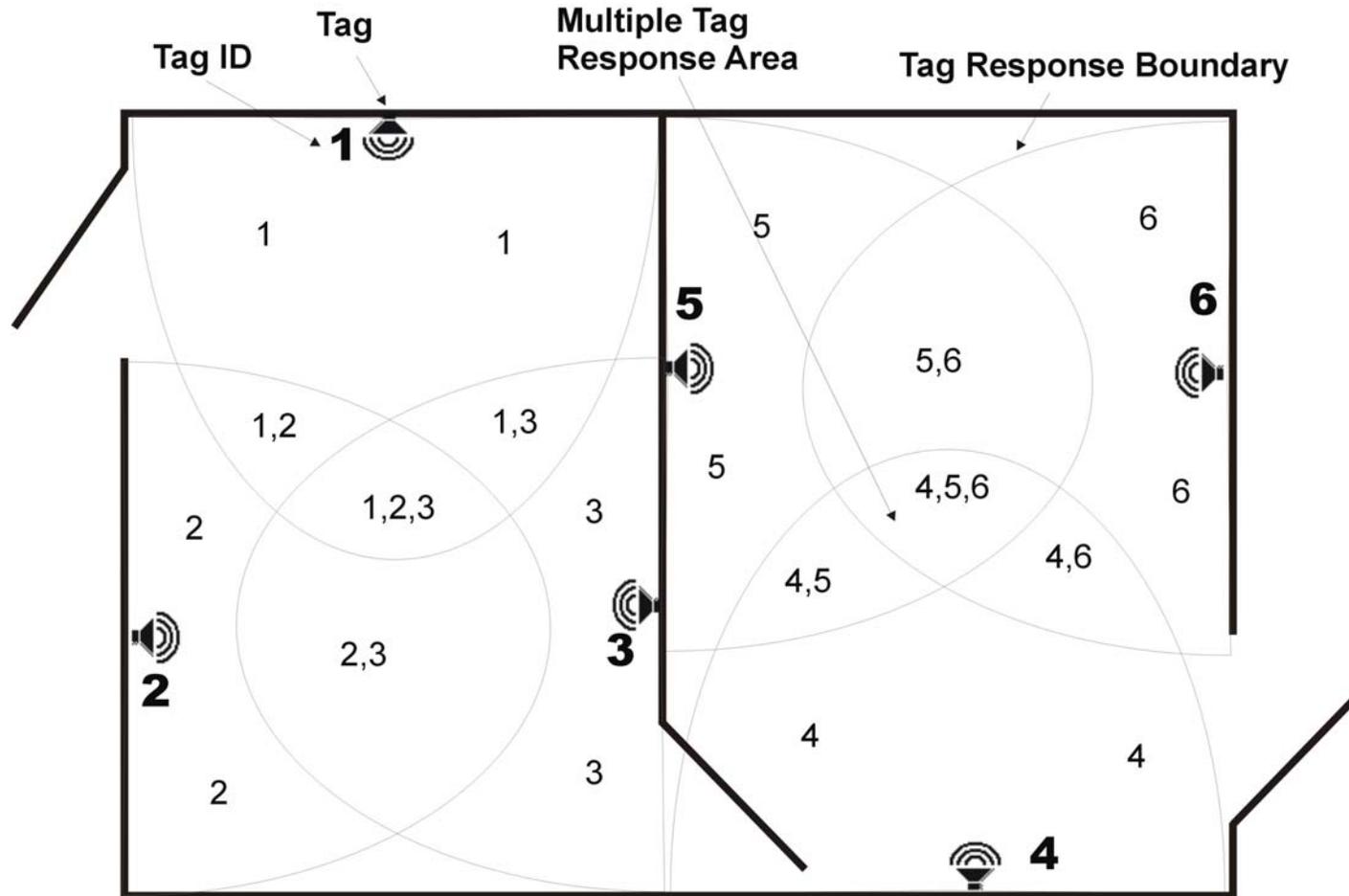
Test results are consistent with the DRM **average** error spec of 5% of distance traveled if magnetic anomalies are excluded.

Approximate distance between corrections	Error before simple WP correction	Error for adaptive step size before corr.
18 m	2.83 m	2.80 m
14 m	1.97 m	1.46 m
14 m	2.41 m	1.17 m
14 m	3.41 m	1.19 m
14 m	6.30 m*	5.52 m*
18 m	6.75 m*	5.13 m*
18 m	3.58 m	1.42 m
14 m	1.90 m	0.89 m
14 m	1.87 m	0.63 m
14 m	1.65 m	1.34 m
14 m	2.20 m	1.75 m
18 m	2.72 m	0.91 m
Average percentage of distance	20.3%	13.1%
Average excluding (*) entries	16.1%	8.9%

Options for RFID Technologies

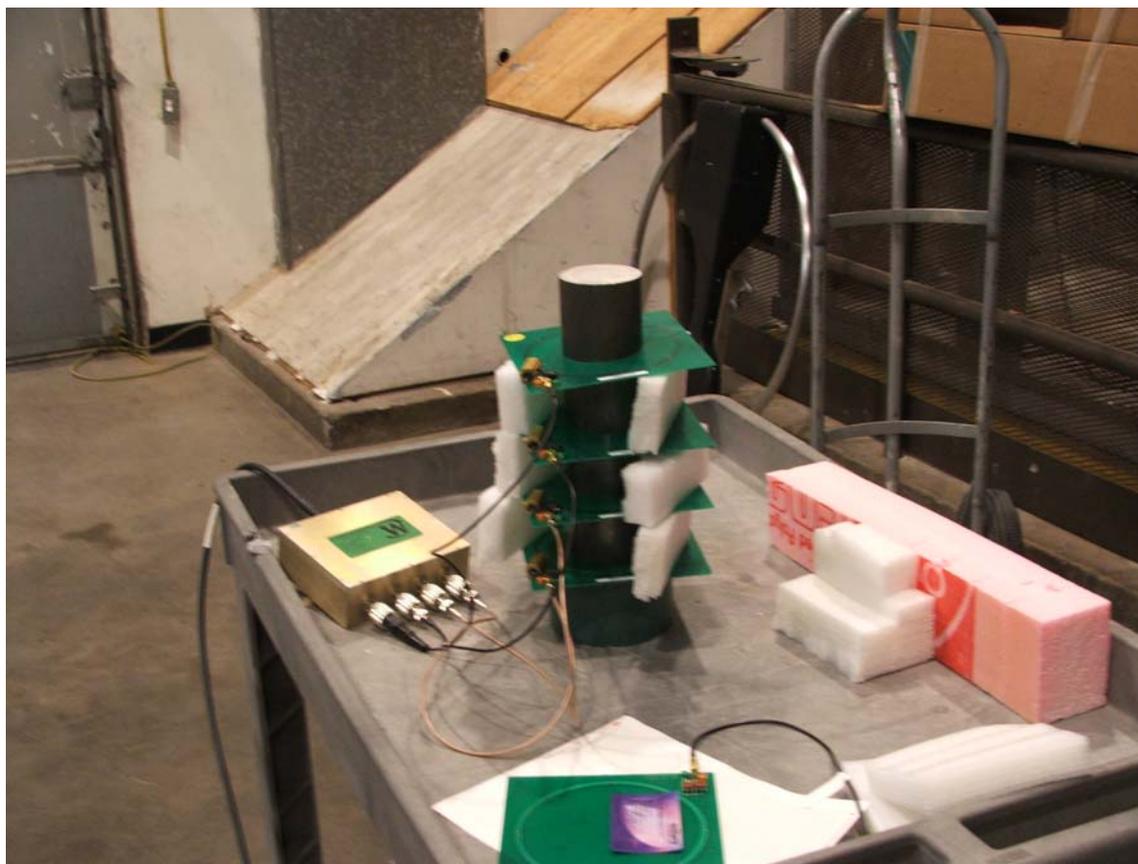
- Scope: not limited to existing RFID tag and reader technologies
- Status of our investigations
 - Measured read range, power requirements of 13.56 MHz passive tag technology
 - Started evaluating active tag technology at 433 MHz
 - Plan to evaluate 900 MHz passive tag technology

Building with Simple RFID Tag Layout



Evaluation of 13.56 MHz Passive RFID Technology

- Technology uses magnetic coupling (near field).
- Magnetic field drops off as $1/(\text{distance})^3$
- Read range of standard tags is 10 cm or less.
- Extending read range beyond a meter requires larger **reader** loop antennas with complex tuning circuits and massive amounts of power.



Stacked 15 cm PCD loops used for magnetic field range and tag activation

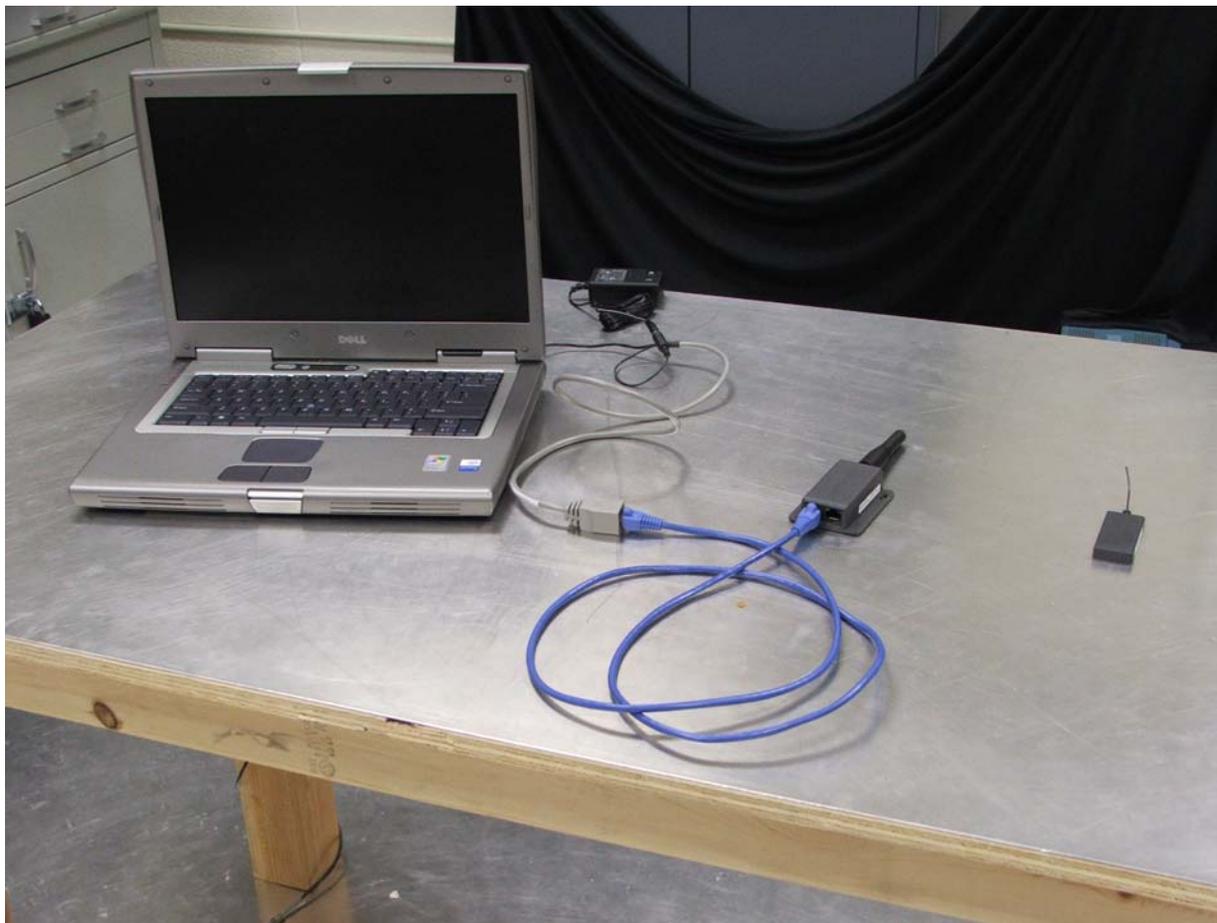
Advantages of Other Frequencies

- Wavelengths of 400 MHz and 900 MHz RFID technologies are about 30 – 80 cm, so they operate in the far field.
- Coupling is via the electric field, which drops off as 1/distance.
- Read range for passive tags is several meters.
- Best frequency band for propagation in buildings is 600 MHz to 2 GHz.



Initial Evaluation of 433 MHz Active RFID Technology

- Requires power supply (battery) for tag.
- Read range can be 30 meters.
- No longer “you are here” detection—requires strategy of identifying closest tag.



RFID system using active tags at 433 MHz.

Now evaluating 900 MHz RFID reader and tag technology.



900 MHz Developers Kit



Handheld 900 MHz reader

Second Year Work (this project)

- Select RFID tag and reader technologies and develop a prototype reader for use in this application. (EEEL)
- Develop software for acquisition of data from an RFID reader and use of that data to perform location updates and to display the location on a handheld computer as well as building information derived from RFID tag data. (ITL, EEEL)
- Conduct preliminary experiments in NIST's Large Fire Facility to evaluate the performance of RFID-assisted localization devices in structures of simple geometry. (BFRL)
- Evaluate options for interfacing the localization device with an ad hoc wireless communication network (ITL, BFRL)