Proposed Geo-Location Amendment

IEEE P802.22 Wireless RANs **Date:** 2011-05-04

Authors:

Name	Company	Address	Phone	email
Russ Markovsky	InvisiTrack, Inc.		(410) 991-8529	rmark@invisitrack.com
Upkar Dhaliwal	InvisiTrack, Inc		(858) 926-5839	upkar@invisitrack.com

Abstract

This presentation describes proposed enhancements to the most recently approved version of the IEEE 802.22 standards. The presentation will also demonstrate how the proposed enhancements can support advanced geo-location techniques for determining location in difficult indoor environments.

Precision Indoor Location:

The InvisiTrack Solution

Presented to 802.22 Group

May 5, 2011

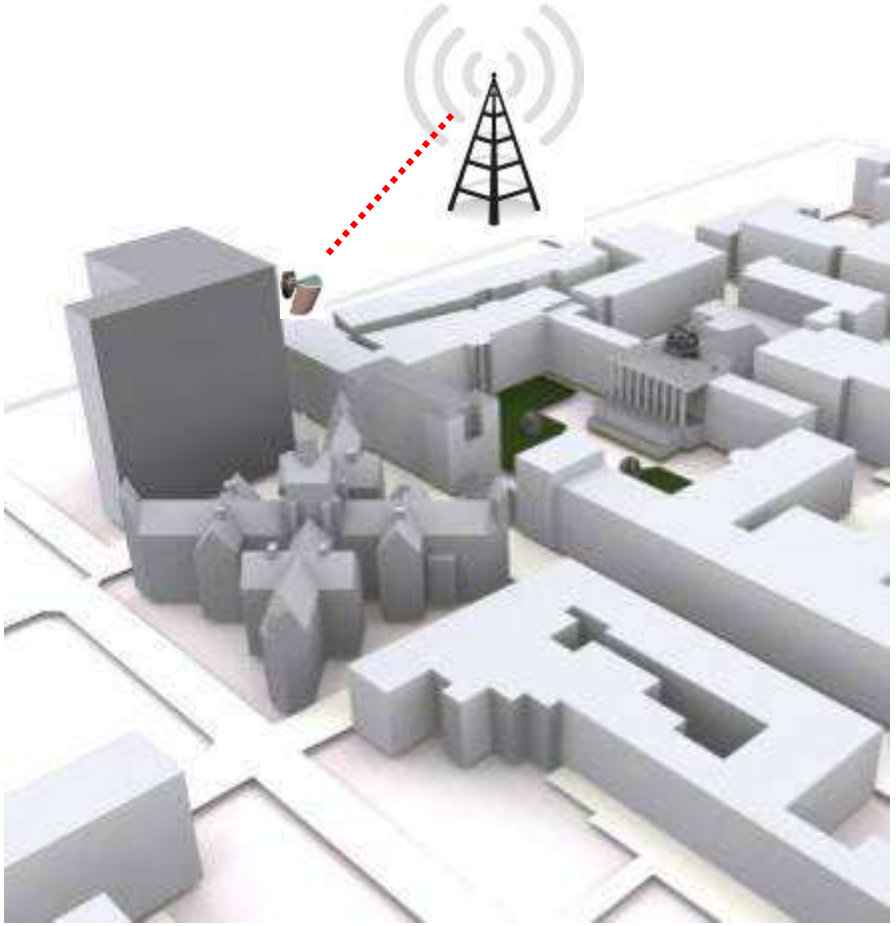
InvisiTrack Solution Overview

- **Developed for indoor and challenging outdoor environments**
  - Dense multipath environment
- **Low computational intensity multipath mitigation algorithms**
  - Can be executed in software by a nomadic CPE/ mobile terminal
- **Developed for mobile environment**
  - Allows simultaneous tracking of several hundred terminals
- **Supports one-way and transponder distance measurements**
- **Same multipath mitigation can be used for determining DLOS distance and DOA/ AOA (direction/ angle of arrival)**
  - Supports geo-location by a single position reference (e.g. BS or CPE)
- **Compatible with the existing IEEE 802.22 Standard protocols/ infrastructure**
  - No changes in HW required
  - No changes in PHY

Suggested Amendment: Transponder Mode Option

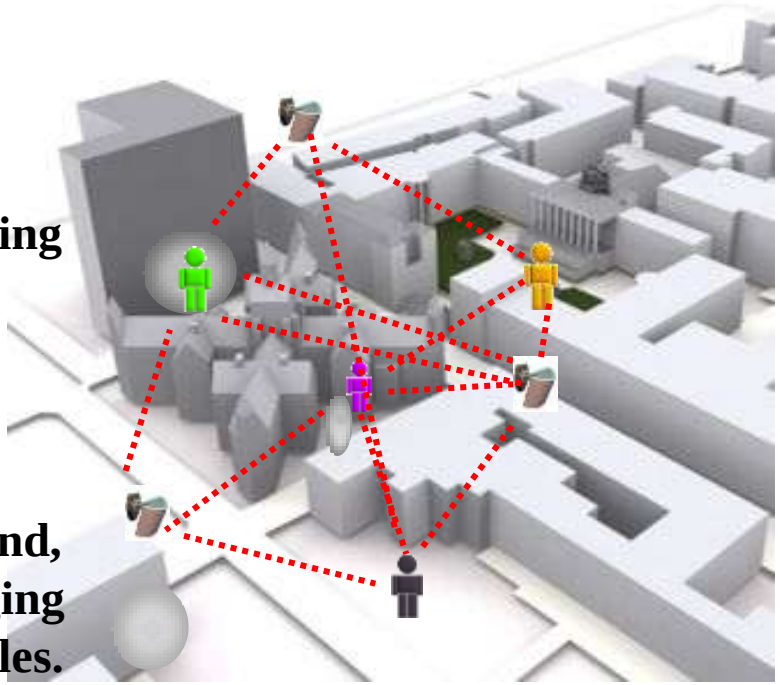
Existing 802.22 Geo-Location Capability

- **Geo-Locate over long distances**
  - **Needs Base Station**
  - **Relies on one way OFDM coherency**
    - **(Coherency affected by multipath)**

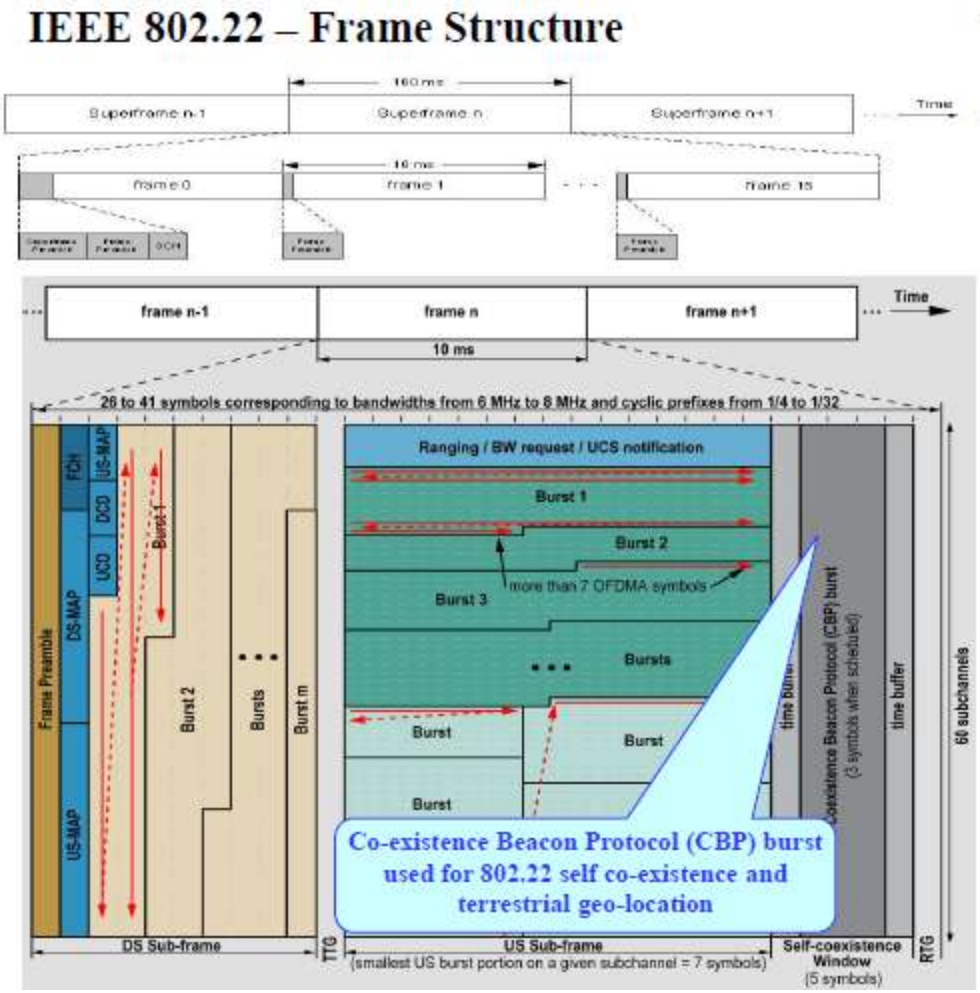


Addendum 802.22 Geo-Location capability (Transponder Mode)

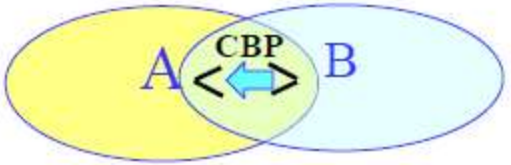
- **Improved Indoor closer range Accuracy**
  - **Does not rely on OFDM system coherency.**
  - **Either a terminal or base station/ fixed CPE will originate the ranging signal (fully compatible with the 802.22 signaling, e.g. OFDM)**
  - **The receiving terminal will then store the DFT output (samples) and, will re-transmit (repeat) the ranging signal from the stored DFT samples.**



Transponder Mode, continued



- 802.22 supports Time Division Duplex (TDD) frame structure
- Super-frame: 160 ms, Frame: 10 ms
  - Each frame consists of downlink (DL) sub-frame, uplink (UL) sub-frame, and the Co-existence Beacon Protocol (CBP) burst
  - Lengths of DL and UL sub-frames can be adjusted .
- Self Co-existence Window: BS commands subscribers to send out CBPs for 802.22
  - self co-existence – CBP bursts contain information about the backup channel sets and sensing times
  - terrestrial geo-location and
  - whitespace device identification as required by the regulatory domain rules.



The InvisiTrack Approach to Terrestrial Geo-Location

Greater Accuracy

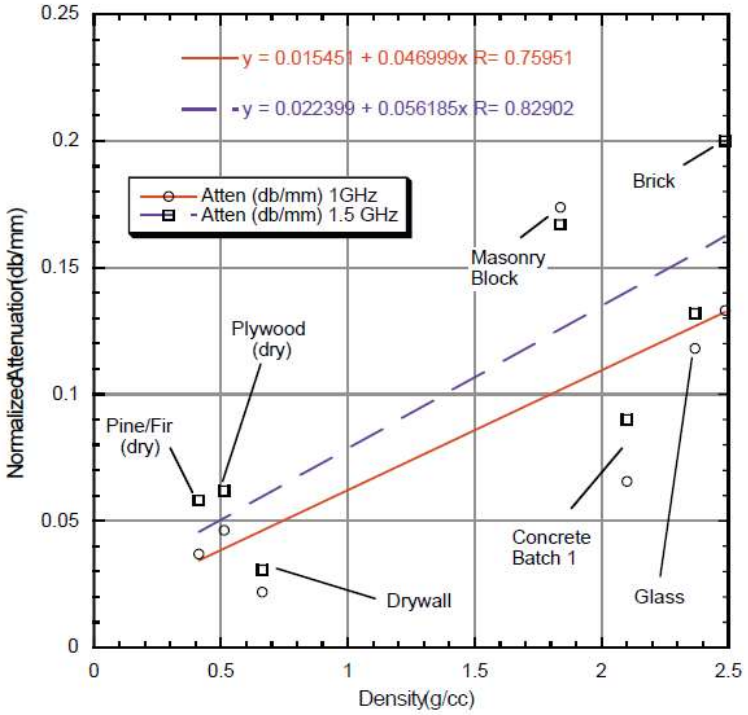


Figure 5.2: Signal loss per unit material thickness (expressed in dB/mm) as a function of the material density (g/cc). The above data represent a very small sampling of the available database at only two discrete frequencies. Attenuation increases, generally, with increasing signal frequency.

Indoor Location - Unique Challenges

- **Obstructed/Non-Line-of-Sight Environment**
  - DLOS (Direct Line Of Site) Blockage
    - Structures, walls, floors, etc.
    - Requires signals that penetrate dielectrics
    - DLOS signal is severely attenuated relative to reflected signals
- **Dispersive Propagation Environment**
  - Multipath Interference
    - DLOS and reflections are closely spaced
    - Requires signal structure to minimize effect

Signal Propagation - Background

- **Signal penetration in dielectric**
  - Loss varies as square root of wavelength
    - Lower frequencies penetrate better than higher
    - Example: with the same loss, 240 MHz penetrates 3.2 times further than 2.4 GHz or, at same distance, loss at 2.4 GHz is 10 dB greater.
  - Dispersion (multipath): inversely proportional to wavelength
    - Objects smaller than the wavelength don't reflect;
    - Objects larger than the wavelength, reflect and generate multipath dispersion.

InvisiTrack Solution Integration

- **InvisiTrack's geolocation ranging signal is < 5 MHz BW (ie, does not require channel bonding).**

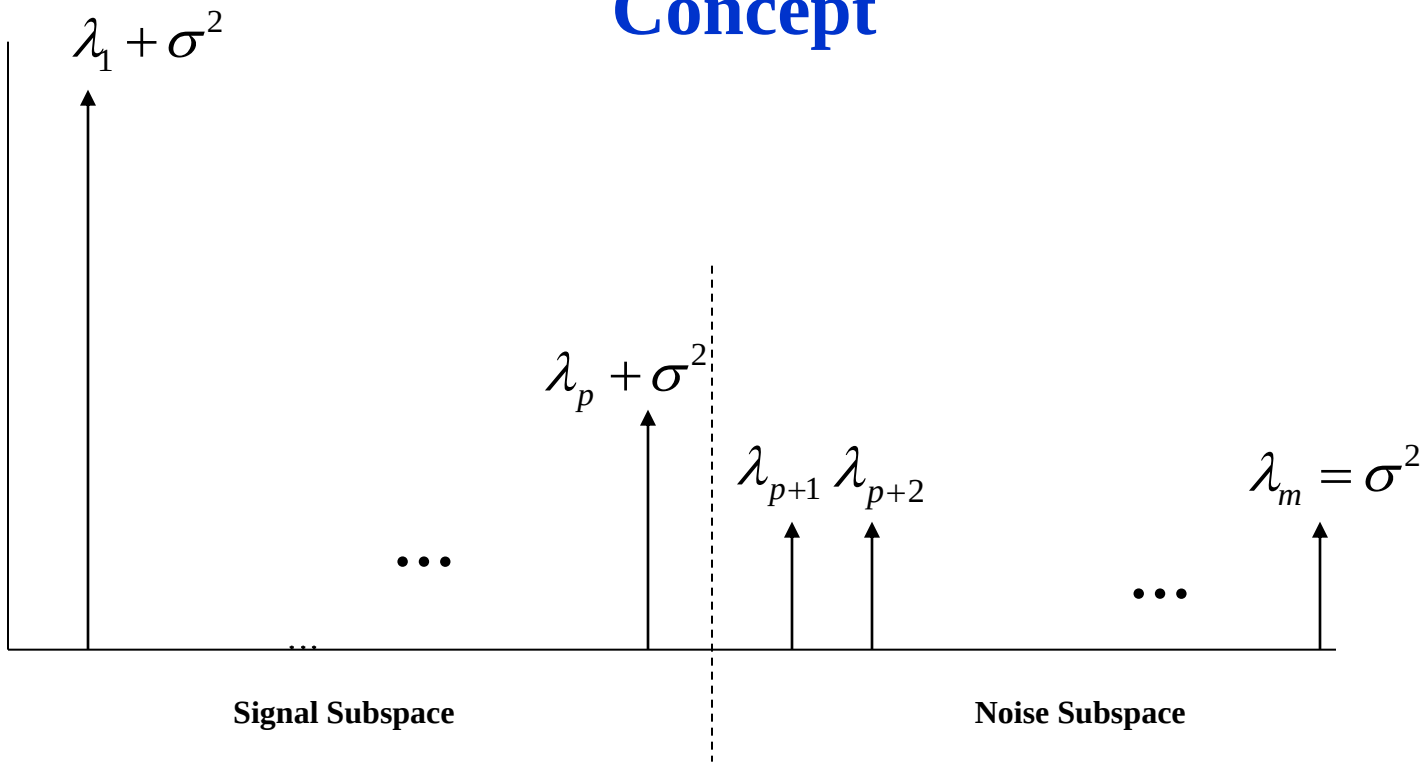
- **The ranging signal consists of:**
  - Pilot signals or subcarrier signals; or
  - A combination of pilots and subcarriers;
  - The total number of signals is 100 or less.

- **The ranging signal subcarriers do not need to be modulated; the modulation may also be applied, for example QPSK, as long as the modulation signal is known beforehand.**

InvisiTrack Multipath Processor

- **Uses highly optimized and improved high-resolution spectrum estimation analysis methods and techniques as applicable to multipath mitigation;**
  - Able to separate direct path for accurate range estimation
  - Performance
    - No “picket fence” effect
- **Methods and techniques support frequency estimations that approach the Cramer-Rao Bound (CRB).**

High-Resolution Spectrum Estimation Analysis Concept



Signal Subspace – Eigenvectors Associated with Largest Eigenvalues

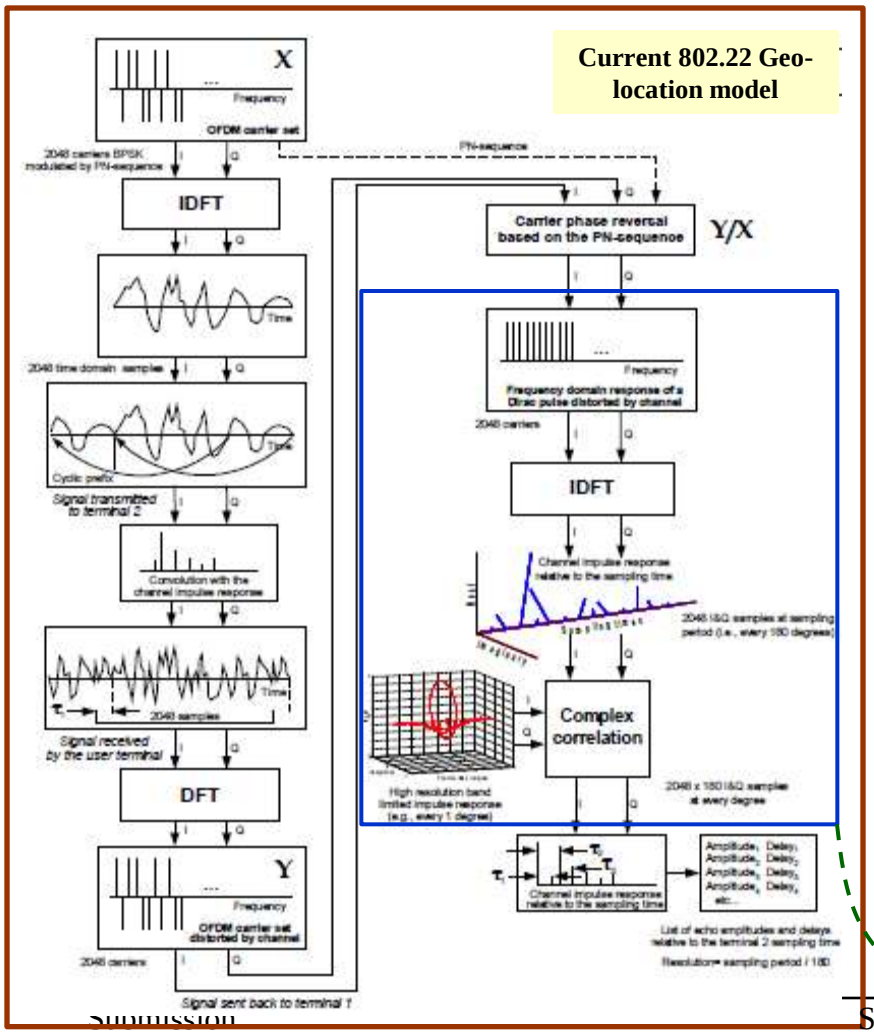
Signal Subspace – the Direct Path Plus Reflected Signals

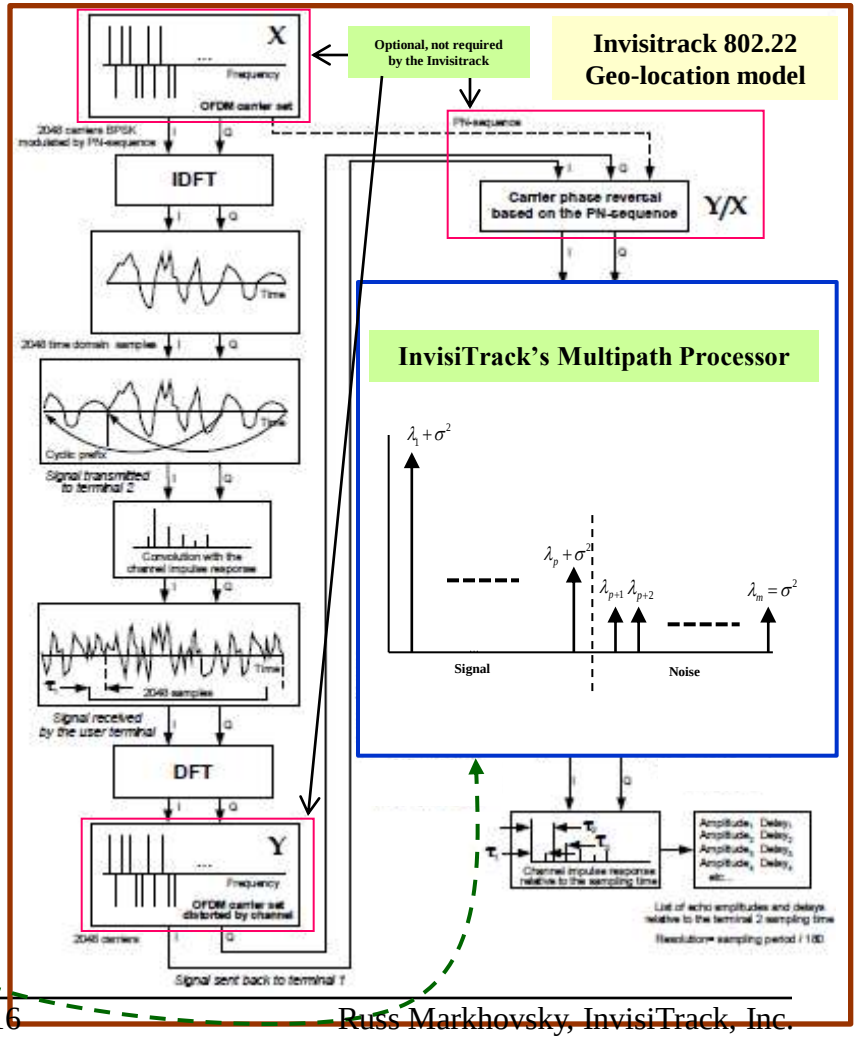
Noise Subspace – Eigenvectors Associated with m-p Smallest Eigenvalues

Noise Subspace – Additive Noise

InvisiTrack Solution Integration

- Can be seamlessly integrated into the current 802.22 geolocation model – uses complex channel impulse response in the frequency domain





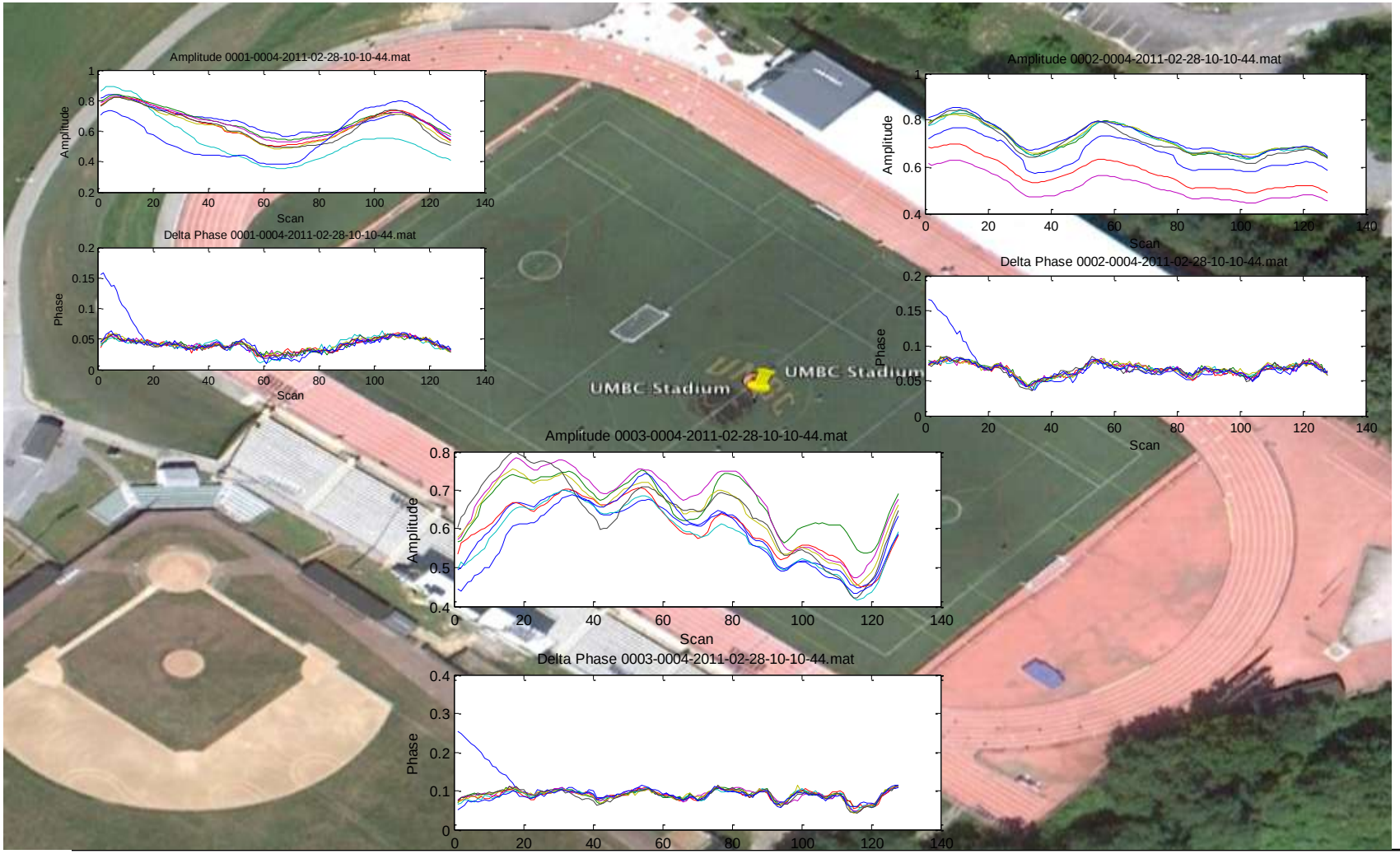
InvisiTrack Geo-location Results

- **Developed mobile, battery-operated proof of concept:**
  - Dimensions: 3x4x2 inches
  - Operating frequencies: VHF (High-band)
  - Operating bandwidth: 5 MHz
- **In all tests TX and RX antennas heights were between 0.5 meters to 1.5 meters from the ground .**

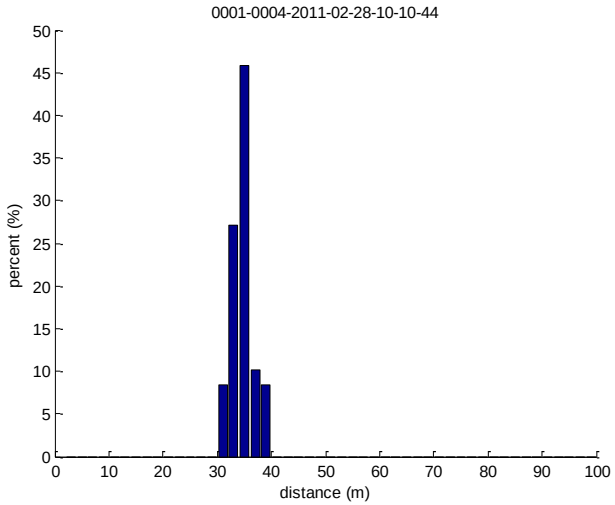
InvisiTrack Geolocation Results

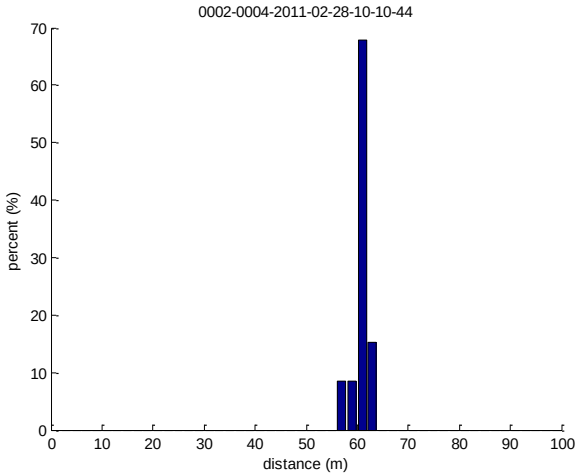
Environment	Range (m)	Accuracy (m), >=67% confidence	Accuracy (m), >=95% confidence	Comments
Coaxial cables	500 (equiv)	N/A	0.5	With multipath simulator
Analog Proof of Concept Devices				
Outdoor	350	2	3	Suburban setting
Difficult Indoor	125	4	8	Multiple floor buildings
Extreme, Indoor parking	125	4	8	Reinforced Concrete structure
Digital Production Devices				
Outdoor	350	1	2	Suburban setting
Difficult Indoor	125	2	3	Multiple floor buildings
Extreme, Indoor parking	125	2	3	Reinforced Concrete structure

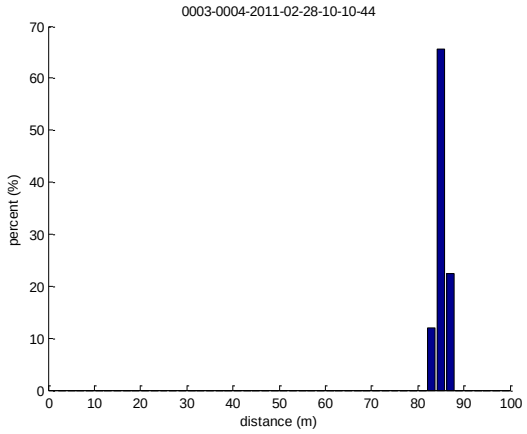
UMBC Field


Amplitude 0001-0004-2011-02-28-10-10-44.mat
Amplitude
Scan
Delta Phase 0001-0004-2011-02-28-10-10-44.mat
Phase
Scan
Amplitude 0002-0004-2011-02-28-10-10-44.mat
Amplitude
Scan
Delta Phase 0002-0004-2011-02-28-10-10-44.mat
Phase
Scan
UMBC Stadium
UMBC Stadium
Amplitude 0003-0004-2011-02-28-10-10-44.mat
Amplitude
Scan
Delta Phase 0003-0004-2011-02-28-10-10-44.mat
Phase
Scan

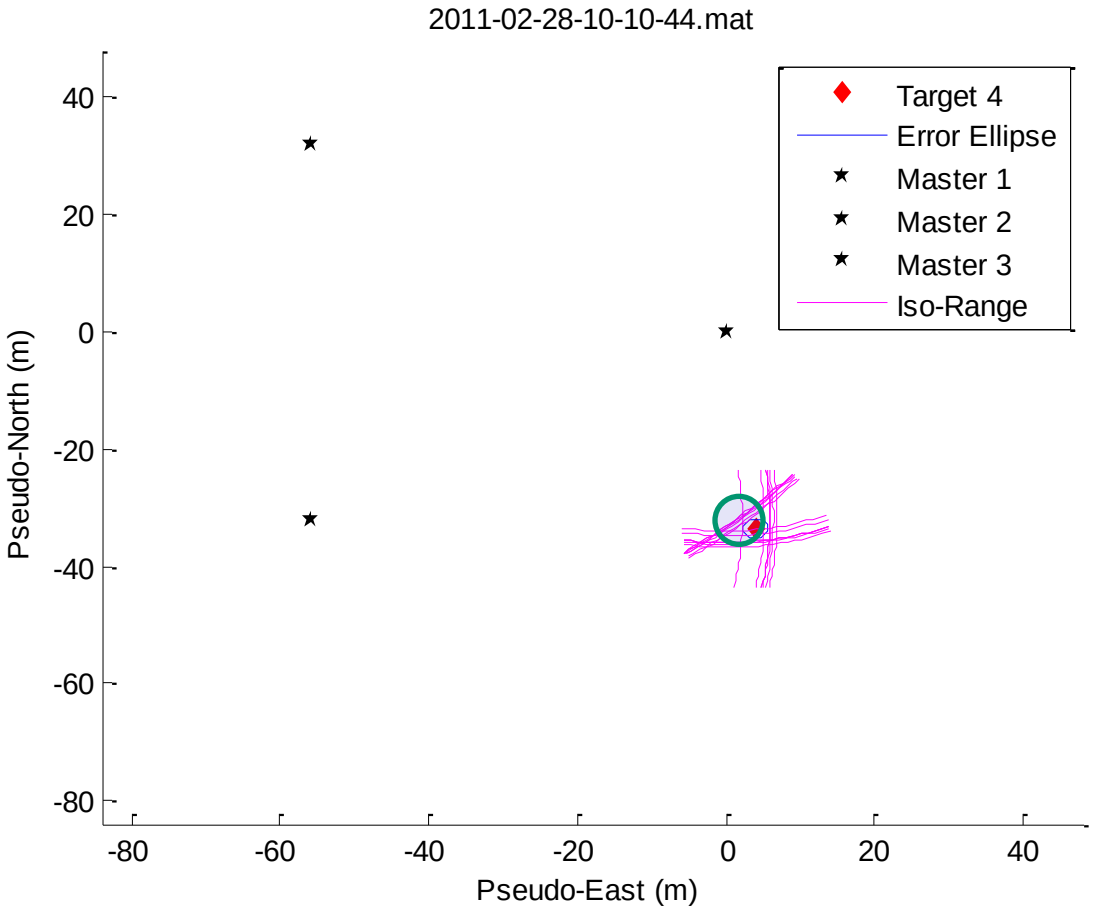
Conversion to Distance



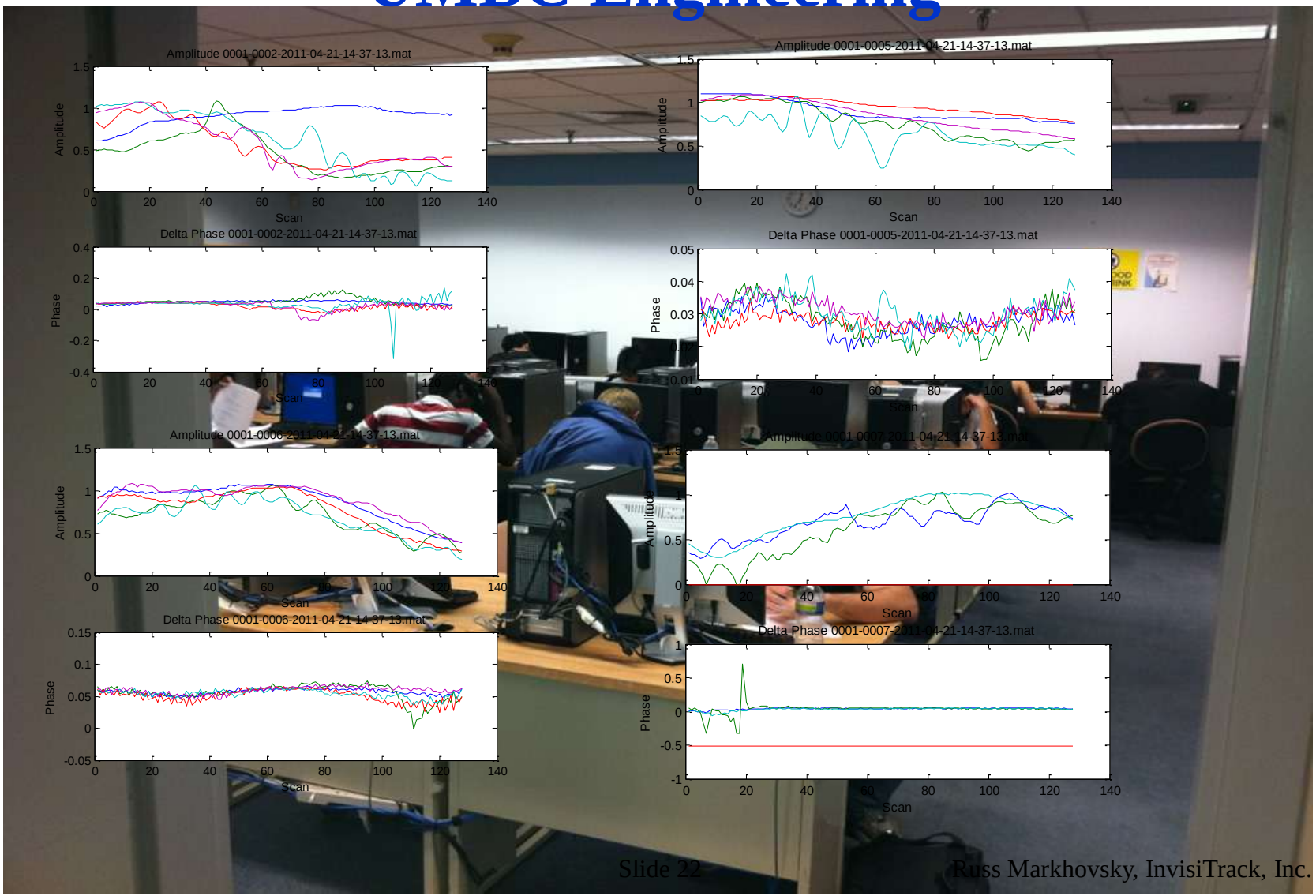




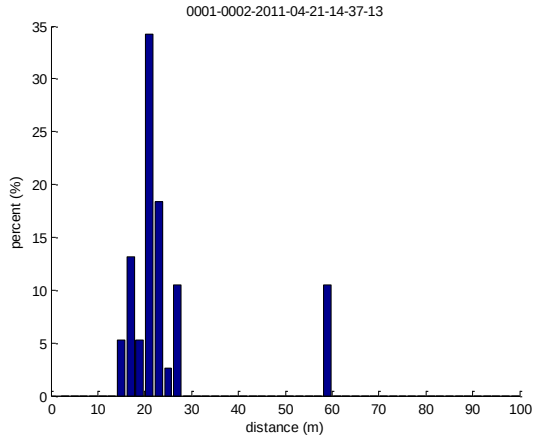
UMBC Field

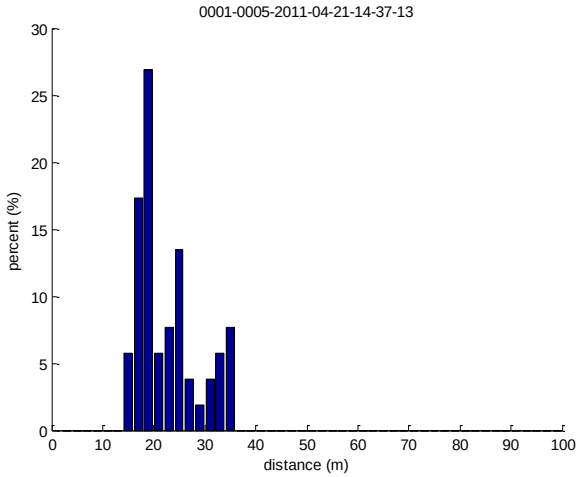

2011-02-28-10-10-44.mat
Target 4
Error Ellipse
Master 1
Master 2
Master 3
Iso-Range
Pseudo-North (m)
Pseudo-East (m)
40
20
0
-20
-40
-60
-80
-80
-60
-40
-20
0
20
40

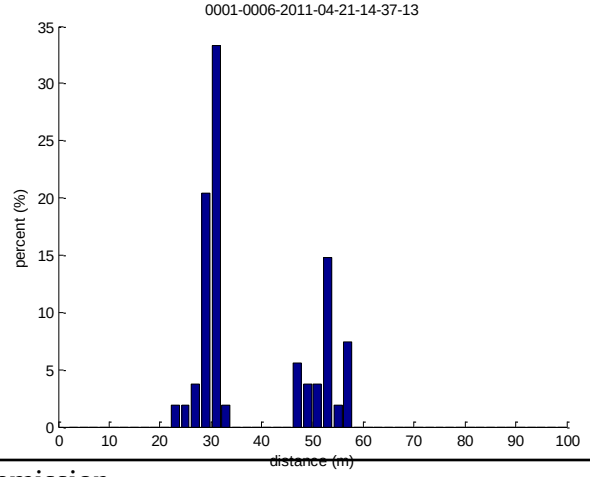
UMBC Engineering

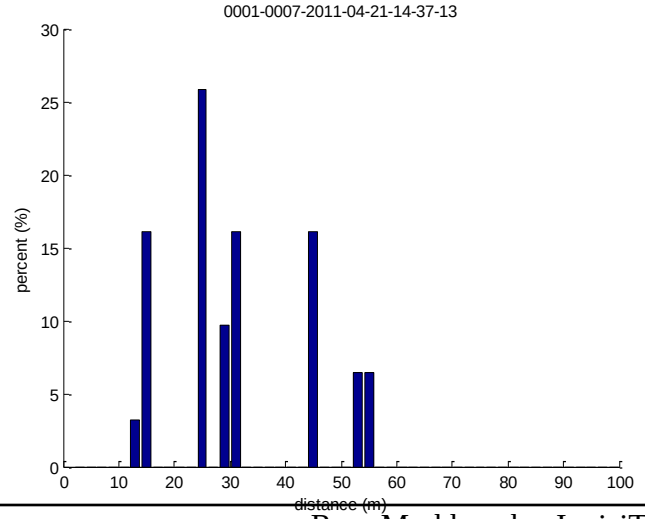


Conversion to Distance

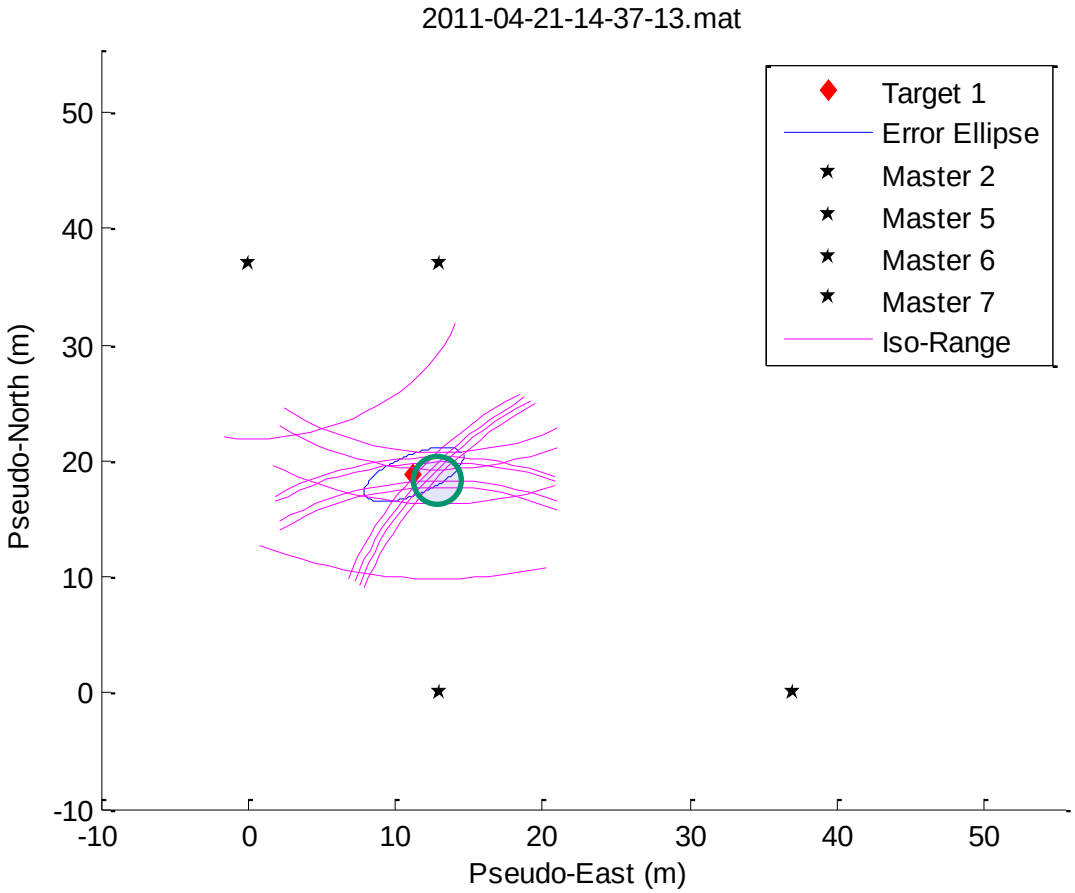




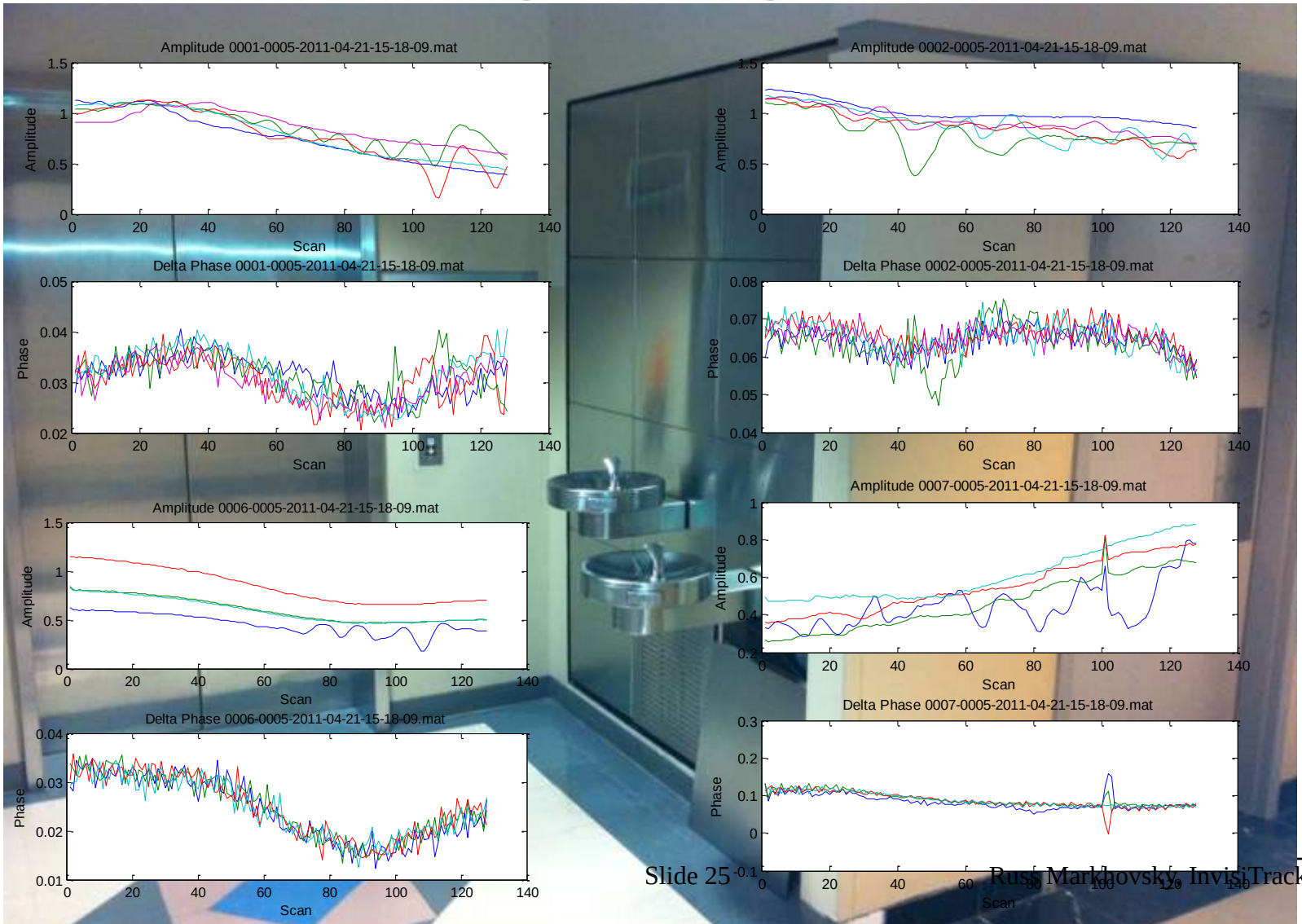




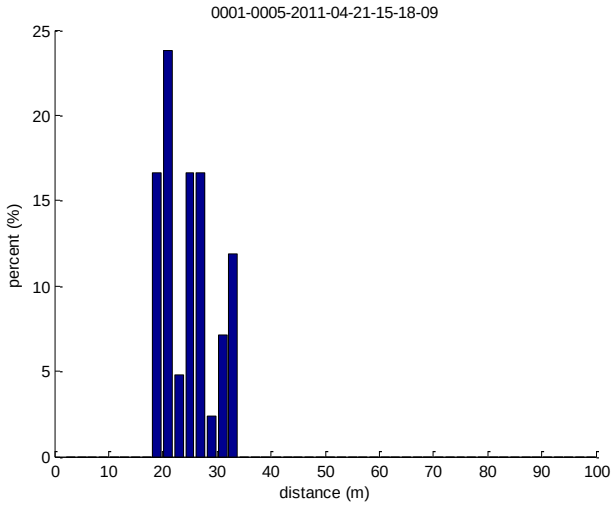
Results

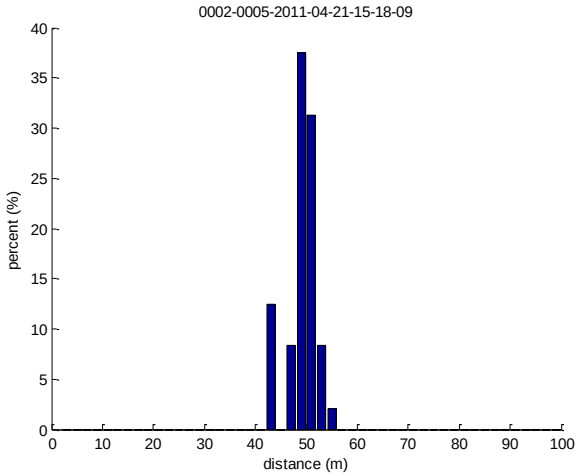

2011-04-21-14-37-13.mat
Target 1
Error Ellipse
Master 2
Master 5
Master 6
Master 7
Iso-Range
Pseudo-North (m)
Pseudo-East (m)
50
40
30
20
10
0
-10
-10
0
10
20
30
40
50

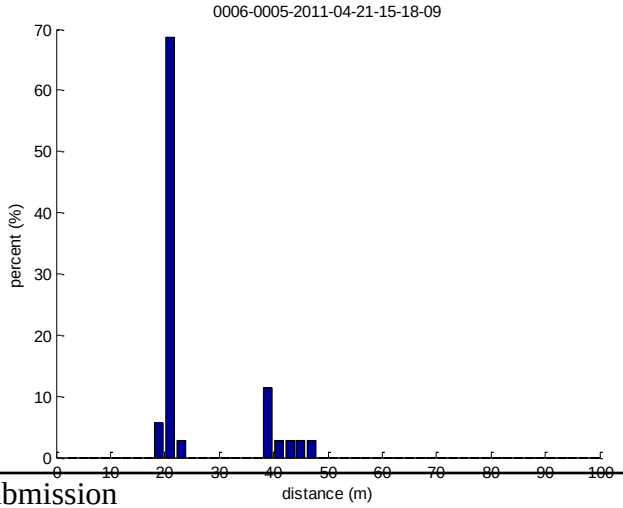
UMBC Engineering (Example 2)

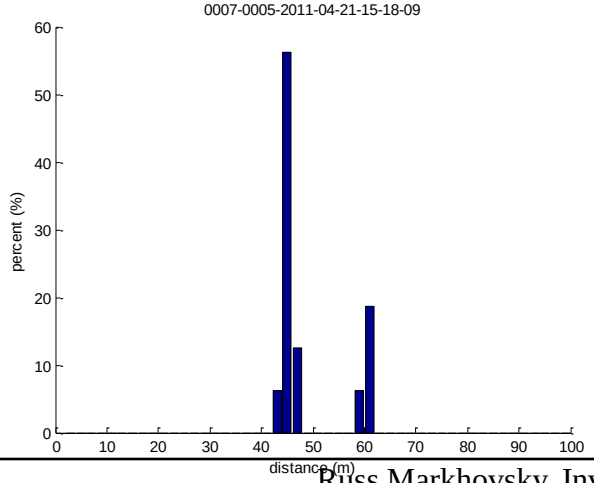


Conversion to Distance

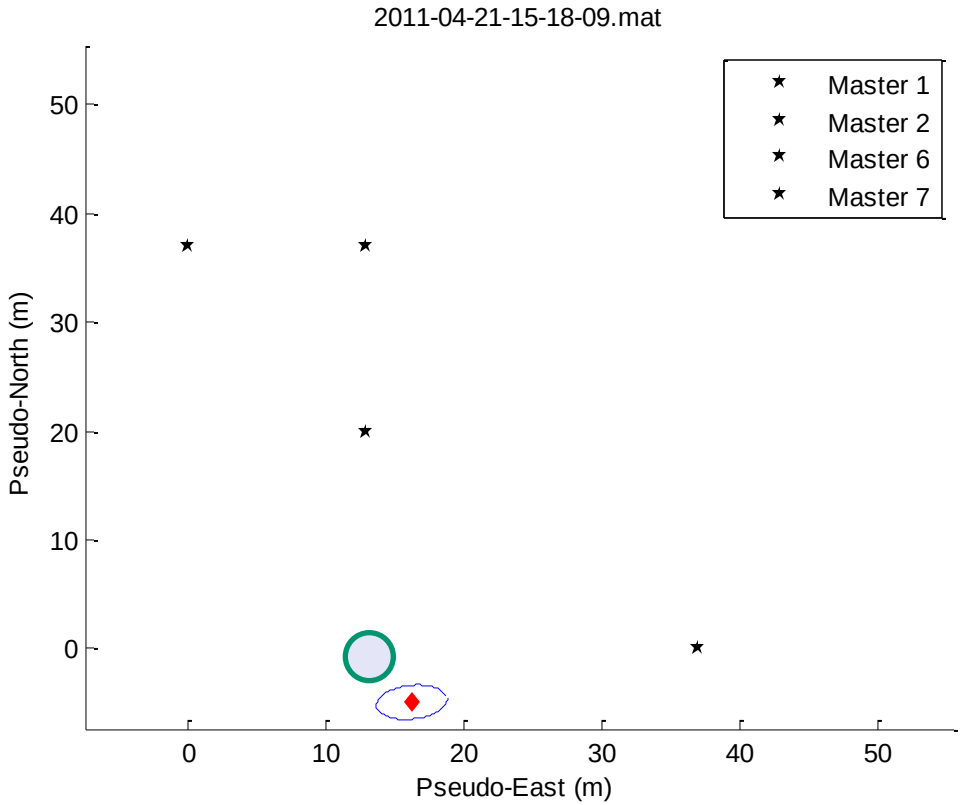




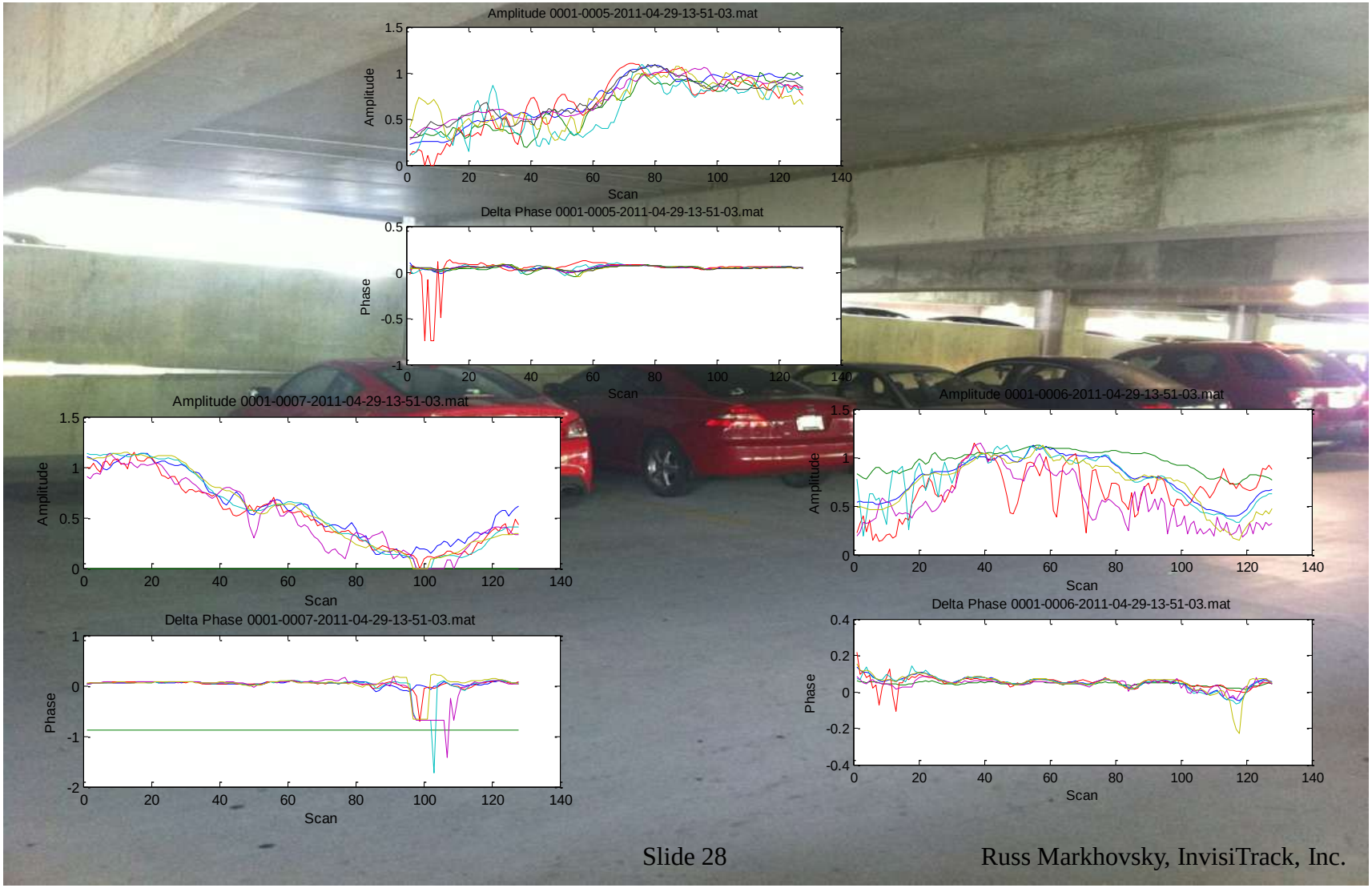




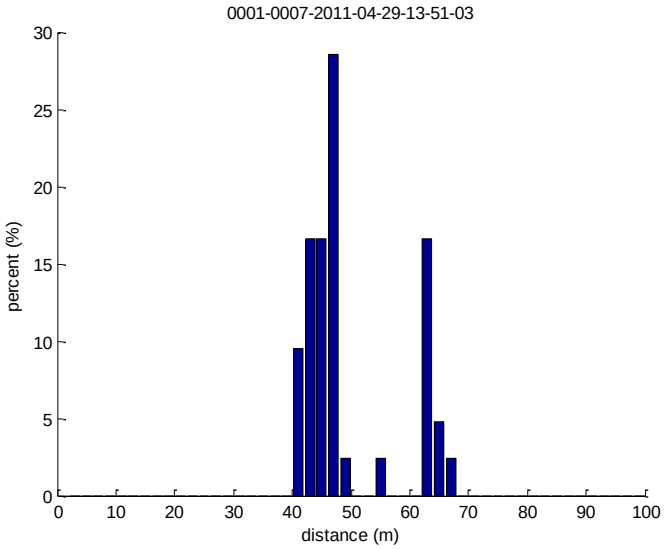
Result

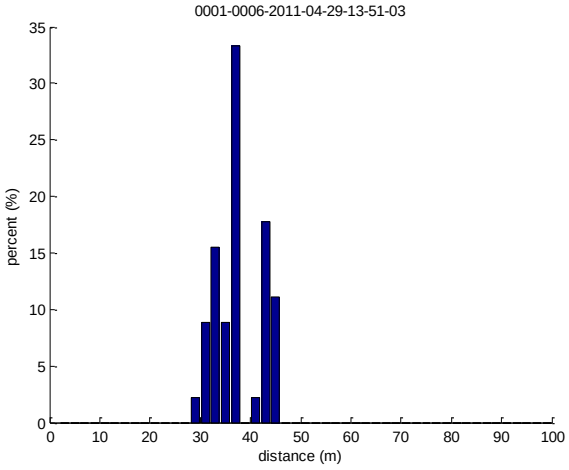

2011-04-21-15-18-09.mat
Master 1
Master 2
Master 6
Master 7
Pseudo-North (m)
Pseudo-East (m)
0
10
20
30
40
50

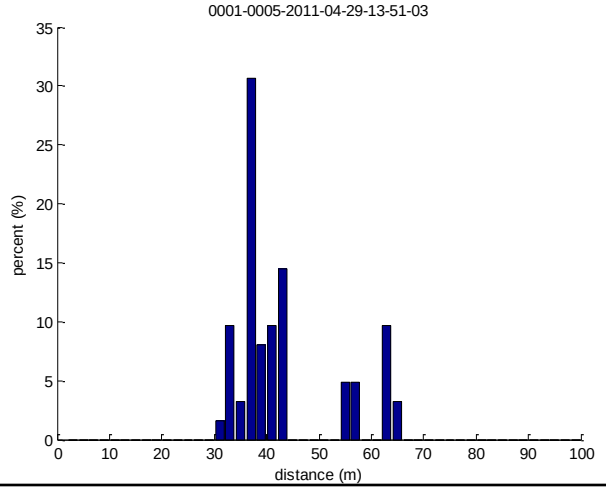
UMBC Parking Garage



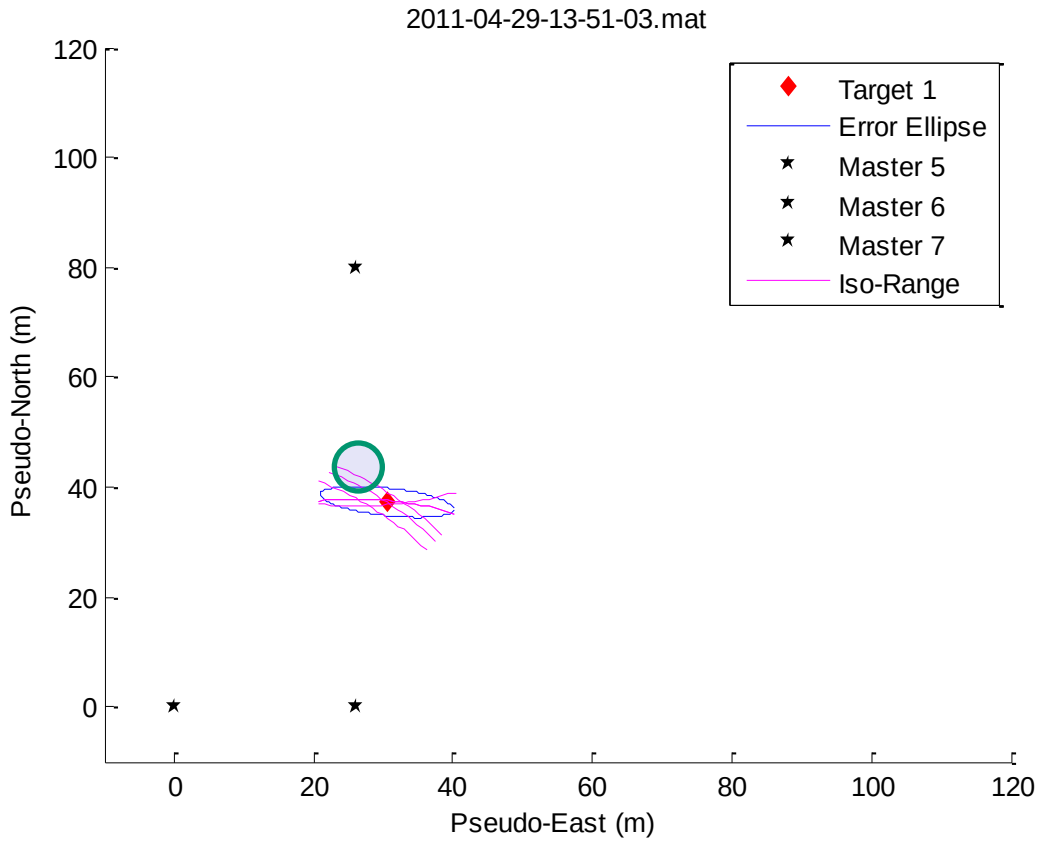
Conversion To Distance



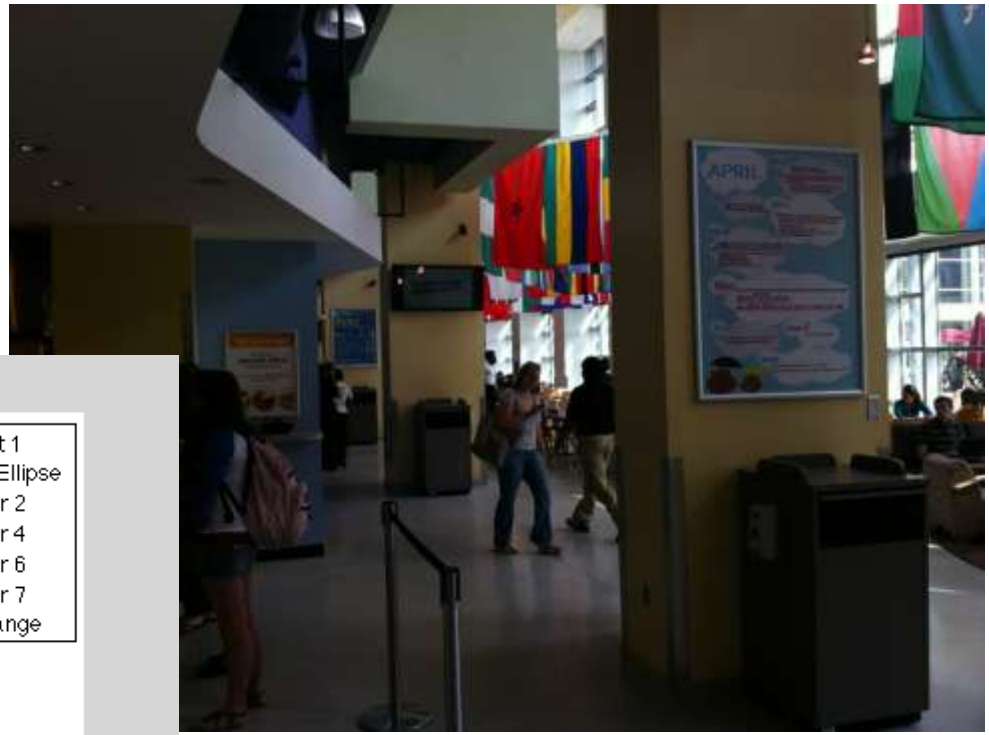


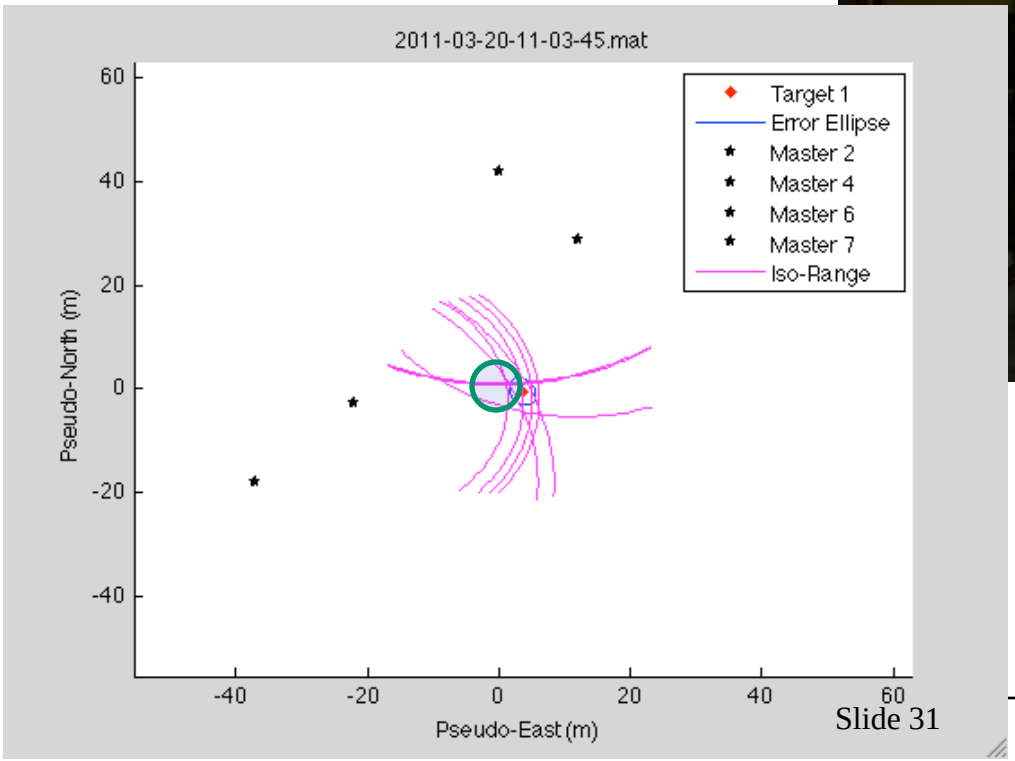


Result


2011-04-29-13-51-03.mat
Target 1
Error Ellipse
Master 5
Master 6
Master 7
Iso-Range
Pseudo-North (m)
Pseudo-East (m)
0
20
40
60
80
100
120

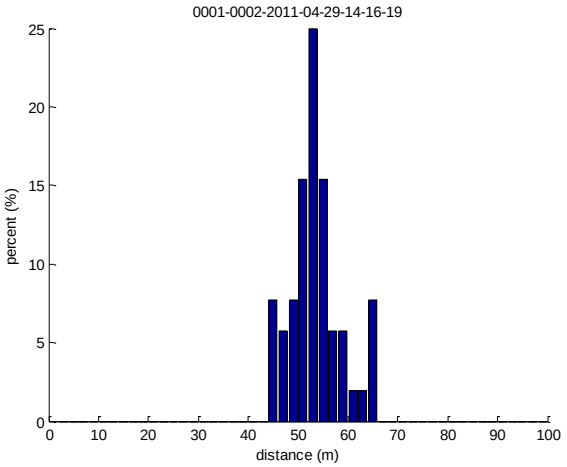
UMBC Commons

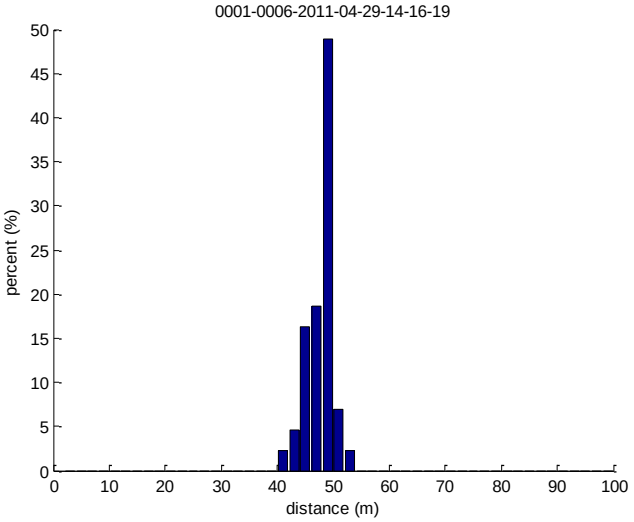


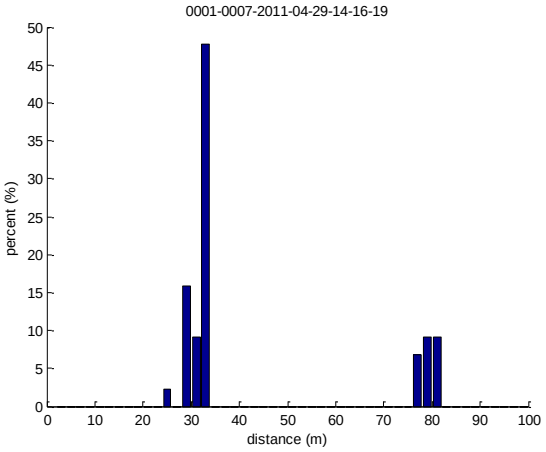


UMBC Parking Garage (Example 2)

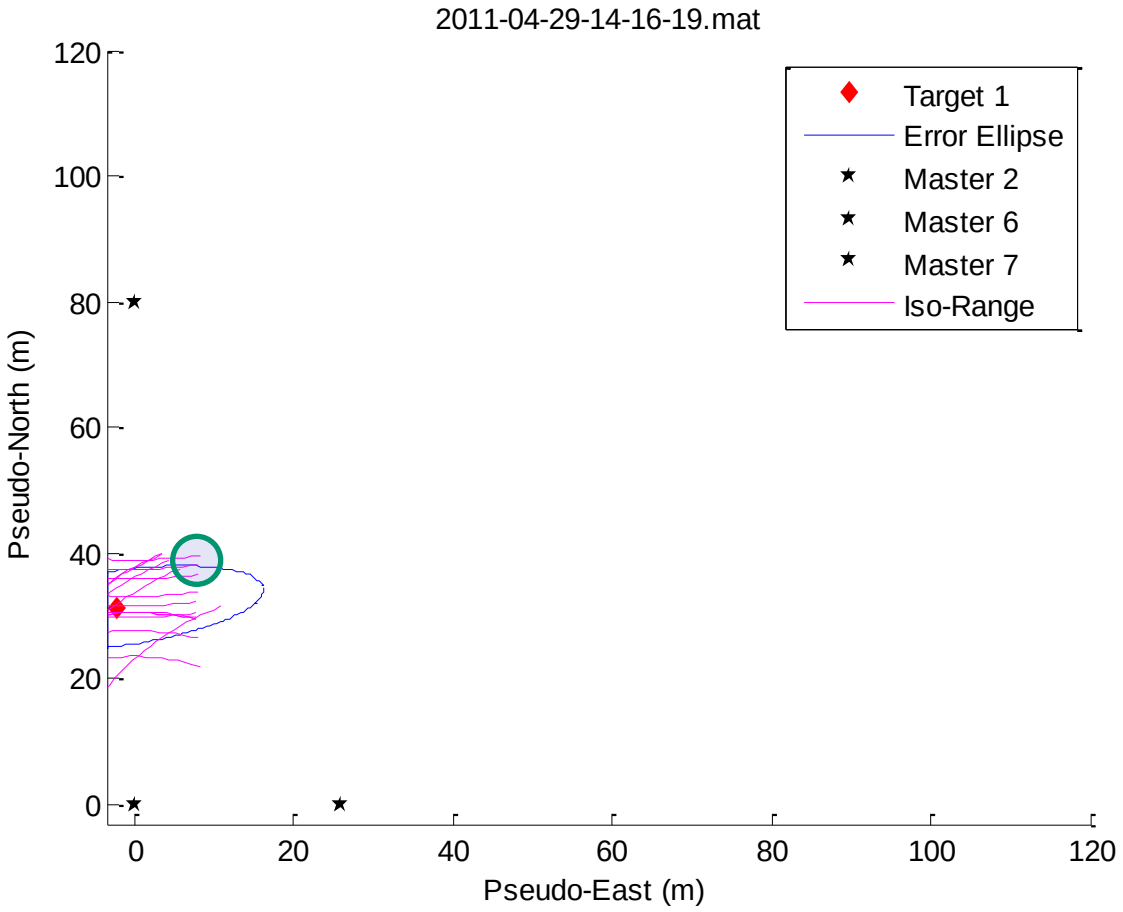
Conversion to Distance







Result


2011-04-29-14-16-19.mat
Target 1
Error Ellipse
Master 2
Master 6
Master 7
Iso-Range
Pseudo-North (m)
Pseudo-East (m)
0
20
40
60
80
100
120