Wideband Local Positioning System (WLPS) Testing in a MOUT Facility

Sponsor: TRMC – T&E/S&T
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Approved for Public Release
WLPS Program Overview

- WLPS – 5-year S&T, $1.97 million program, sponsored by TRMC.
- WLPS program developed waveforms and algorithms to track a System Under Test (SUT) in a GPS denied environment.

- The end-of-project testing took place March 7-18, 2011 at the McKenna MOUT Site, Ft. Benning, GA.
- The WLPS Receiver tracked 3-D position
  - Through as many as 4 concrete block walls
  - X, Y mean error < 0.31 m
  - Z mean error < 0.82 m
Dual PRN sequences transmitted for acquisition and tracking

- Each transmitter transmits different PRN sequences continuously.
- Different sequences will not interfere with each other in the receiver.
• A minimum of 4 transmitters deployed around the T&E area.
• Location of each transmitter is accurately determined.
• Each transmitter is self contained and stands alone.
• Laptop computer controls operation of receiver.
  – Communicates over RS232 serial link
  – Computer performs high level tracking algorithms and controls receiver PRN sequences
Most tests were performed in building B2 using four transmitters (minimum possible).

- T1, T3, and T4 transmitters are on the ground.
- T2 transmitter: On roof of B1 (10 meters above T1, T3, and T4)
- B2 (2 story building)
- A4 (2 story building)
- Clear Air Receiver Survey Points
- Black dots are receiver survey points.

McKenna MOUT Facility, Ft. Benning, GA
Difficult to determine ground truth in existing buildings.

Transmitter and receiver test positions were surveyed with theodolite for 2.5 to 5 cm accuracy.

Receiver test positions had to be surveyed through windows and doorways.
System Tests

- **Accuracy:**
  - *Static:* Receiver antenna carefully located surveyed points inside B2 and outside
  - *Dynamic:* Receiver moved around “walking” with approximate locations only
- Measurements to see how much attenuation was possible before track was lost
- Velocity tests in clear air
- General conditions for all tests
  - Acquisition started with clear signals
  - Timing offsets were set in clear air – no “room calibration” performed
  - Timing offsets differed from trial to trial
  - Live display showed received signals and estimated location
- All received data were recorded for post-test analysis
Static Accuracy Tests

Static Tests with receiver on push cart

Grid is in this room on first floor

B2

T1

A4

B2

Grid is in this room on first floor
Static Accuracy Grid Test

**Plan View of Data Points**

**Static Accuracy Results Summary**

<table>
<thead>
<tr>
<th>Receiver Antenna Ht.</th>
<th>1.12 m</th>
<th>1.87 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y Accuracy, mean</td>
<td>0.28 m</td>
<td>0.31 m</td>
</tr>
<tr>
<td>X, Y Accuracy, Std. Dev.</td>
<td>0.20 m</td>
<td>0.13 m</td>
</tr>
<tr>
<td>Z Accuracy, mean</td>
<td>0.43 m</td>
<td>0.82 m</td>
</tr>
<tr>
<td>Z Accuracy, Std. Dev.</td>
<td>0.50 m</td>
<td>0.29 m</td>
</tr>
<tr>
<td>Mean Height (Z)</td>
<td>1.55 m</td>
<td>1.94 m</td>
</tr>
<tr>
<td>Data Points Used</td>
<td>Best 12</td>
<td>Best 12</td>
</tr>
</tbody>
</table>

**3D Plot of Data Points**

Rx Ant Height = 1.87 m
Dynamic Walking Accuracy Tests

Dynamic Walking Tests on the Grid in B2

Back View of Walking Tests
- Walked along one wall, then across diagonal, etc., multiple times.
- Better tracking than expected based on static tests
- Every track point included

**Results**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (approximate)</td>
<td>1.8 m</td>
</tr>
<tr>
<td>Height, mean</td>
<td>1.32 m</td>
</tr>
<tr>
<td>Height, Std. Dev.</td>
<td>0.54 m</td>
</tr>
</tbody>
</table>
For T2, magenta for signals through ceiling and roof, and blue for signals through ceiling and front wall.

In previous tests, a concrete block wall (6-inch) provided a delay of 0.12 meters greater than clear air.
• Walked around perimeter of room
• Some outliers in height
• Every track point included

Results

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</tr>
<tr>
<td>Height, Std. Dev.</td>
<td>1.03 m</td>
</tr>
</tbody>
</table>
• Tracking was occasionally lost, during walk-around tests, when walking between rooms.
  – Only four transmitters, so a single loss made tracking impossible.
• Height is a weak point
  – Large propagation delay through 6-inch floor of solid concrete with reinforcing bar for first floor to Transmitter 2
  – GDOP was not good.
  – Additional transmitters at elevated positions need to be present
• Height (as well as horizontal position) could be improved through room calibration (only clear air calibration was made).
• Leading-edge tracker is rudimentary, could be improved.
• Standard tracking, e.g. Kalman filtering, could be beneficial.
• Some receiver glitches remain, making testing more difficult, but can be fixed, and will improve performance.
Tests from Transmitter 3 to A4
- Walls tested in A4 are nearly normal to Transmitter 3
- T3 is 33 meters from the exterior wall of A4
- Tracked T3 through one exterior wall and two interior walls
- Obstruction attenuation measured at 45 dB (excluding free air transmission loss)

Tests from Transmitter 4 to B1
- Walls tested in B1 are nearly normal to Transmitter 4
- T4 is about 4 meters from the exterior wall of B1
- Tracked T4 through one exterior wall and two interior walls
- Obstruction attenuation measured at 50 dB (excluding free air transmission loss)
Methods to Improve Maximum Obstruction Attenuation

<table>
<thead>
<tr>
<th>Improvement Method</th>
<th>Affect RF Emissions</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease Noise Figure of Receiver and install sharper band pass filter</td>
<td>No</td>
<td>5 dB</td>
</tr>
<tr>
<td>Limiting the FFT Search Window</td>
<td>No</td>
<td>5 dB</td>
</tr>
<tr>
<td>Utilize more directional antennas for the WLPS Transmitters</td>
<td>Yes</td>
<td>10 dB</td>
</tr>
<tr>
<td>Increase WLPS Transmitter Power</td>
<td>Yes</td>
<td>30 dB or more</td>
</tr>
</tbody>
</table>

- WLPS maximum obstruction attenuation could be doubled if all of these improvements were performed.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position Resolution</td>
<td>0.16 m</td>
<td>Mean Std dev: 0.08 m 0.08 m</td>
</tr>
<tr>
<td>Position Accuracy (x,y)</td>
<td>0.17 m Std dev = 0.25 m</td>
<td>Mean Std dev: 0.31 m 0.20 m</td>
</tr>
<tr>
<td>Position Accuracy (z) (one transmitter at height of &gt;15 m and range to receiver &lt;25 m)</td>
<td>0.28 m Std dev = 0.42 m</td>
<td>Mean Std dev: 0.82 m 0.50 m</td>
</tr>
<tr>
<td>(height of T4 was 10 m and range to grid was &lt;20 m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## WLPS Specifications and Performance

### Continued

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<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Target Speed</td>
<td>5 MPH</td>
<td>10 MPH</td>
</tr>
<tr>
<td>Maximum Obstruction Attenuation</td>
<td>60 dB</td>
<td>50 dB</td>
</tr>
<tr>
<td>Maximum Acquisition Time</td>
<td>7 s</td>
<td>52 s</td>
</tr>
<tr>
<td>Update Rate</td>
<td>0.11 s</td>
<td>0.30 s</td>
</tr>
<tr>
<td>Receiver Battery Life Without Charging</td>
<td>9 hours</td>
<td>&gt;9 hours, demonstrated</td>
</tr>
<tr>
<td>Physical Size of Receiver</td>
<td>5.9” x 11.0” x 2.5”</td>
<td>5.6” x 11” x 1.7”</td>
</tr>
<tr>
<td>Weight of Receiver</td>
<td>5.4 lbs</td>
<td>4.38 lbs</td>
</tr>
</tbody>
</table>
Accuracy Performance Improvements

- WLPS accuracy could be improved by a factor of 2 or more
  - Room calibration to remove differences in propagation delay for transmitter paths
  - Improved leading edge tracker
  - Kalman filtering to improve track
  - More transmitters than the minimum (4 are minimum for 3 dimensions)

- Z-axis accuracy could be improved by a factor of 2 or more
  - Additional transmitters above test area (only one was used in this testing)
  - Better GDOP for Z-axis
WLPS has demonstrated sub-meter accuracy going through 3 and 4 concrete block walls at a typical MOUT Facility.

Ultra Wideband demonstrates promise in GPS-denied environments:
- Utilized with INS systems to remove drift
- When operating with INS, reacquisition is much quicker
- When operation with INS, outlier tracks can be easily discarded
The authors would like to thank the Test Resource Management Center (TRMC) Test and Evaluation/Science and Technology (T&E/S&T) Program for their support.

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