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Through-the-Wall Sensors (TTWS) for Law Enforcement: Test & Evaluation

(Version 1.2)

DOJ Office of Justice Programs
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NLECTC
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LIST OF FIGURES

Percent detection was slightly decreased when compared to the overall results of the Xaver 400 overall SO results (Table 11: SO Results: Overall), and detection time was also slightly increased. The distance uncertainty results indicate that once a target was detected, there was almost no question as to the location of the target.

Table 49: AKELA – Exterior Wall with Vinyl Siding: SO

Characteristic	Result
Total Number of Measurements Attempted	15
Percent Detection	60%
Moving Percent Detection	83%
Still Percent Detection	44%
Detection Time (Seconds) ± Average Deviation	13 ± 8
Average Distance Uncertainty	+22% ± 23%

Percent detection of the ASTIR decreased compared to the overall result of the ASTIR (Table 11: SO Results: Overall), and detection time was slightly improved over the overall results. However, the distance uncertainty was significantly larger than the overall results.

12.2 House Garage

The barrier is an external garage wall that has brick on the outside. Drywall on the inside of the garage, is supported by wood studs, and is filled with insulation in the void spaces between the wooden studs.

Figure 24: Garage – Interior
Interior view of Garage. Far wall was barrier tested (Brick, plywood, insulation, and dry wall); See Figure 21: Foundation House – Exterior
Photo by NLECTC SSBT CoE

The garage is a two car garage with two metal garage doors and an entry door to the left of the garage doors. The remainder of the house is to the left of the garage and to the rear of the garage. Testing was done on the right side wall of the garage, the wall is perpendicular to the wall with the two garage doors. Two windows are positioned on the test wall, and testing points for ATW measurements were between the two windows, to the left of the left window and to the right of the right window. ATW tests as well as stand-off tests were performed at this site.

Table 50: Barrier Summary – Brick Wall

Barrier Feature	Details
Material Type(s)	Brick, wooden studs, insulation, drywall
Thickness	8” (estimate)
Metal Components	Window frames
Interior	Open
Openings	Two windows
Wall Dimensions	8’ x 16’ (estimate)
Other Features	Metal garage doors on perpendicular wall may cause more reflections

12.2.1 ATW – House Garage

The following tests were performed with TTWS devices in ATW mode against the brick wall:

- Target 4 m from device (Ranger-R, Xaver-100, Xaver 400),
    - Target standing still (Facing toward, facing sideways, and facing away)
    - Target walking (parallel and perpendicular)
- Target 8 m from device (Ranger-R, Xaver-100, Xaver 400),
    - Target standing still (Facing toward, facing sideways, and facing away)
    - Target walking (parallel and perpendicular)

Table 51: Range-R – House Garage: ATW

Characteristic	Result
Total Number of Measurements Attempted	30
Percent Detection	70%
Moving Percent Detection	100%
Still Percent Detection	50%
Detection Time (Seconds) ± Average Deviation	14 ± 6
Average Distance Uncertainty	+16% ± 16%

Compared to the overall ATW results of the Range-R (Table 8: ATW Results: Overall), there was a slight decrease in percent detection and slight increase in detection time; however the difference was not large. The average uncertainty is higher for the brick wall, but this may be due to reflections coming from the metal garage doors on a perpendicular wall.

Table 52: Xaver 100 – House Garage: ATW

Characteristic	Overall	Normal Mode	High Penetration Mode
Total Number of Measurements Attempted	30	20	10
Percent Detection	53%	55%	50%
Moving Percent Detection	83%	88%	75%
Still Percent Detection	33%	33%	33%
Detection Time (Seconds) ± Average Deviation	21 ± 12	25 ± 13	13 ± 10
Average Distance Uncertainty	-47% ± 31%	-71% ± 16%	0% ± 0%

Percent detection for the Xaver 100 are similar to the overall performance of the Xaver 100 in ATW measurements for Normal Mode (Table 9: Xaver 100 – All: ATW), however High Penetration mode would have been significantly more difficult for an operator to make out a target than the overall results. The amount of time to detect a target is significantly increased (over double for Normal Mode). The low detection uncertainty in High Penetration mode could be due to a lower than normal detection of still targets who happened to be measured at just the right distance. A similar argument could be made for the large distance uncertainty of the normal mode where a small number of measurements happened to be significantly off. If a statically low number of still detections were made, the uncertainty may be skewed.

Table 53: Xaver 400 – House Garage: ATW

Characteristic	Overall	Tracker Mode	Expert Mode	High Penetration Mode
Total Number of Measurements Attempted	31	11	10	10
Percent Detection	90%	100%	80%	90%
Moving Percent Detection	92%	100%	75%	100%
Still Percent Detection	89%	100%	83%	83%
Detection Time (Seconds) ± Average Deviation	11 ± 6	14 ± 11	9 ± 4	8 ± 3
Average Distance Uncertainty	+6% ± 9%	0% ± 3%	+12% ± 12%	+9% ± 12%

Percent detection of the Xaver 400 against the brick wall improved for Tracker Mode and for High Penetration mode over the overall ATW (Table 10: Xaver 400 – All: ATW), however expert mode decreased overall. This decrease in the Expert Mode performance could be due to the garage doors on the wall perpendicular to the left side of the barrier. Expert mode measurements were typically taken at the far left of the barrier, which would be nearer to the metal garage doors. This could potentially cause more reflections of the main signal.

12.2.2 SO – House Garage

The following tests were performed with TTWS devices in SO mode against the cinder block wall:

- Target 16 m from device, SO distance 12 m (Xaver 400, ASTIR)
  - Target standing still (Facing toward, facing sideways, and facing away)
  - Target walking (parallel and perpendicular)
- Target 19 m from device, SO distance 12 m (Xaver 400, ASTIR)
  - Target standing still (Facing toward, facing sideways, and facing away)
  - Target walking (parallel and perpendicular)

Table 54: Xaver 400: House Garage – SO

Characteristic	Overall	Tracker Mode	Expert Mode	High Penetration Mode
Total Number of Measurements Attempted	30	10	10	10
Percent Detection	30%	40%	50%	0%
Moving Percent Detection	33%	50%	50%	0%
Still Percent Detection	28%	33%	50%	0%
Detection Time (Seconds) ± Average Deviation	15 ± 9	16 ± 9	14 ± 8	No Detection
Average Distance Uncertainty	-27% ± 20%	-55% ± 20%	-13% ± 15%	No Detection

The brick wall proved to be a difficult barrier for the Xaver 400 in SO operation when compared to the overall SO results of the Xaver 400 (Table 11: SO Results: Overall). Percent detection, average detection time, and distance uncertainty all showed decreased performance compared to the overall SO results for the Xaver 400.

Table 55: ASTIR: House Garage – SO

Characteristic	Result
Total Number of Measurements Attempted	10
Percent Detection	30%
Moving Percent Detection	50%
Still Percent Detection	17%
Detection Time (Seconds) ± Average Deviation	12 ± 4
Average Distance Uncertainty	0% ± 0%

Compared to the Overall SO results for the ASTIR (Table 11: SO Results: Overall), the brick wall was a very difficult barrier to penetrate and detect targets. Percent detection decreased by 38% and average detection time was slightly decreased as compared to the overall SO results for the ASTIR. The highly accurate and precise average distance uncertainty may be due to a statically low number of detections of still targets which may result in skewed averages.

12.2.3 ASTIR Long Range SO (30 m) – House Garage

The surrounding terrain allowed for testing long range SO of the ASTIR, although there was a small amount of potential environmental interference from trees, shrubs and tall grass. (see Figure 21: Foundation House – Exterior)

The following tests were performed with the ASTIR against the brick wall at long range SO:

- Target 34 m from device, SO distance 30 m (ASTIR)
  - Target standing still (Facing toward, facing sideways, and facing away)
  - Target walking (parallel and perpendicular)
- Target 38 m from device, SO distance 30 m (ASTIR)
  - Target standing still (Facing toward, facing sideways, and facing away)
  - Target walking (parallel and perpendicular)

Table 56: AKELA: House Garage – 30 m SO

Characteristic	Result
Total Number of Measurements Attempted	10
Percent Detection	80%
Moving Percent Detection	75%
Still Percent Detection	83%
Detection Time (Seconds) ± Average Deviation	13 ± 7
Average Distance Uncertainty	-9% ± 7%

It is interesting that the AKELAs percent detection improved significantly at longer range. One possible reason is that the angle of the signal passing through the windows is less when the ASTIR is placed at longer ranges. This may allow a more direct path for the signal to travel into the garage instead of passing through or reflecting off of the floor, ceiling, and perpendicular walls and allowing a higher percentage of multipath reflected signals to reach the target.

12.3 Wood Siding Exterior Wall (House Porch)

This barrier consisted of wood siding on the exterior, with plywood, insulation, wood studs and drywall on the interior. The interior room was less than the standard 8 m and therefore ATW measurements only consisted of the target positioned 4 m from the barrier. The external measuring locations were accessible by a covered porch which was approximately seven feet off the ground. The porch was only a couple of meters wide which made standard SO measurements impossible.

Table 57: Barrier Summary – Exterior wall with wood siding

Barrier Feature	Details
Material Type(s)	Wood Siding, plywood, insulation, wood studs and drywall
Thickness	5.75” (estimate)
Metal Components	Door and window hardware, frames
Interior	Insulation, wood studs
Openings	Doorway and two windows
Wall Dimensions	8’ x 12’
Other Features	*None*

Figure 25: Interior view of wall with wood siding.
Photo by NLECTC SSBT CoE

Figure 26: Exterior view of wall with wood siding
Photo by NLECTC SSBT CoE

12.3.1 ATW – Wood Siding

The following tests were performed with TTWS devices in ATW mode against the exterior wall with wood siding:

- Target 4 m (~13 ft) from device (Range-R, Xaver-100, Xaver 400),
  - Target standing still (Facing toward, facing sideways, and facing away)
  - Target walking (parallel and perpendicular)

Table 58: Range-R – House Porch: ATW

Characteristic	Result
Total Number of Measurements Attempted	15
Percent Detection	80%
Moving Percent Detection	100%
Still Percent Detection	67%
Detection Time (Seconds) ± Average Deviation	9 ± 4
Average Distance Uncertainty	+2% ± 25%

Compared to the overall ATW results for the Range-R (Table 8: ATW Results: Overall), this barrier did not seem as difficult to penetrate as the average of all barriers. Percent detection is higher than the overall, and the average detection time is slightly shorter. Compared to the vinyl siding (which was the opposite wall of the same room of the wood siding) the results show a marked increase in percent detection and decrease in average detection time.

Table 59: Xaver 100 – House Porch: ATW

Characteristic	Overall	Normal Mode	High Penetration Mode
Total Number of Measurements Attempted	15	10	5
Percent Detection	53%	30%	100%
Moving Percent Detection	67%	50%	100%
Still Percent Detection	44%	17%	100%
Detection Time (Seconds) ± Average Deviation	7 ± 3	7 ± 2	7 ± 3
Average Distance Uncertainty	-13% ± 33%	-78% ± 0%	+9% ± 5%

Normal mode percent detection is significantly lower than the overall average for ATW measurements of the Xaver 100 (Table 9: Xaver 100 – All: ATW), however high penetration mode shows a significant increase in percent detection over the overall results. The high distance uncertainty may indicate that the device had difficulty isolating a target, which may be easier for an operator when presented with the HP mode data. Compared with the vinyl siding wall, the Normal mode had a significantly harder time identifying a target through wood, although HP mode was identical (100% in both cases).

Table 60: Xaver 400 – House Porch: ATW

Characteristic	Overall	Tracker Mode	Expert Mode	High Penetration Mode
Total Number of Measurements Attempted	15	5	5	5
Percent Detection	100%	100%	100%	100%
Moving Percent Detection	100%	100%	100%	100%
Still Percent Detection	100%	100%	100%	100%
Detection Time (Seconds) ± Average Deviation	7 ± 2	8 ± 2	9 ± 2	5 ± 1
Average Distance Uncertainty	+1% ± 2%	0% ± 0%	-2% ± 2%	+5% ± 2%

The Xaver 400 had an easy time detecting and indentifying a target through the barrier. Percent detection was 100% in all cases, the times are comparable to the average of the overall detection times (Table 10: Xaver 400 – All: ATW), and the average uncertainty is also better in all modes except HP. Percent detections through vinyl siding (

Table 47: Xaver 400 – Exterior Wall with Vinyl Siding: ATW) were also high (Expert mode did miss one detection out of five), but on the average it took longer to identify the target through the vinyl barrier.

13.0 ANGULAR DEPENDENCE OF DETECTION

The ability of the devices to detect targets as a function of azimuth angle was investigated; measurements were taken at various angles using a moving target. Two sets of tests were performed. In the Linear Angular tests (LAT), the target walked directly away from the device to the maximum detection range then straight back to the device at various angles. In the Angular Arc Tests (AAT), the target walked from 0° to 90° and back in an equidistant arc with a radius of approximately half the detection range. Barriers were not used in either of testing methodologies. The Xaver 400 and the ASTIR were tested by mounting the device on a tripod, and the Xaver 100 and the Range-R-Link were stabilized by placing them on a small table. The Range-R-Link was used instead of the Range-R (these are identical except for the addition of the wireless communication of the Range-R-Link) so that the device could be operated hands free and not have to be stabilized against a barrier.

Two sites were used for these measurements. The first site was directly behind the Allen Mollohan Office Building (Site 1). The ASTIR and the Xaver 400 were tested in this location. After testing these devices, pedestrian traffic increased at this location, and further testing of the Xaver 100 and the Range-R were done at a second location (Site 2); an empty parking area further behind the initial testing site.

Figure 27: Site 1 (ASTIR and Xaver 400)
Photo by NLECTC SSBT CoE

Figure 28: Site 2 (Xaver 100 and Range-R)
Photo by NLECTC SSBT CoE

13.1 Linear Angular Tests (LAT)

In preparation of the measurements, the device was positioned at a predetermined location and markers were placed along the target's intended path at 1m intervals for the first 20 m, 5 m intervals from 20 m to 50 m and at 10 m intervals thereafter up to 70 m as aides to determine distance during measurement. The target would walk to the maximum range of the device being tested. Measurements were initiated with the target at 5m. After the device detected the target at 5 m (or several seconds had elapsed in the case there were no detection), the target would then walk stepwise (pausing ~2 seconds between steps) to the maximum range of the device. To change the angle of the target's path relative to the device, the device being tested would be rotated to the left (away from the office building) to the specified angle. Angles tested were 0°, 30°, 45°, 60°, and 90° (0° being straight in front of the device).

In the sections below, the graphics indicate the angle of the target path and whether the target would be detected or not by the device. The angle of the target path is indicated by lines radiating out from 5 m to the maximum detection distance of the device. the color of the line indicates whether the target was detected, not detected, or may be detected along the path of the line (green = target detected, red = no target detected, orange = target detection uncertain).

13.1.1 Range-R-Link LAT Testing

The target walked from 5 m to 15 m during testing. Note that the maximum reported detection range of the Range-R is 50 ft (~15 m) (see Table 4: Range-R Usability Assessment Summary). Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

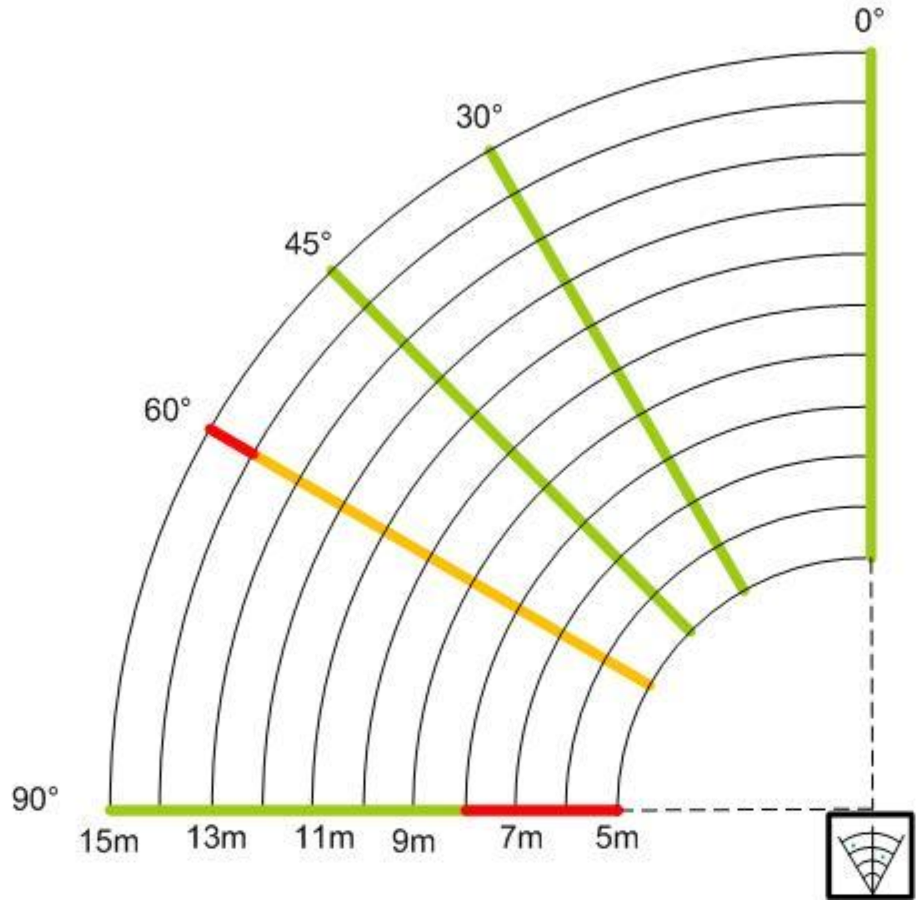

Figure 29: Angular Performance of the Range-R

Table 61: Range-R: LAT: SW: Away

Range-R Link: Target walking Stepwise (SW) away from device (5 m to 15 m)	
0°	Able to track all the way out to 15 m
30°	Able to track all the way out to 15 m
45°	Able to track all the way out to 15 m
60°	Readings were on and off several times, but able to detect to 14m
90°	Picked target up at 8 m and good out to 15m

The Range-R was able to detect the target all the way to 90°, although it began to detect/lose/redetect the target at 45°. Interestingly, the detection at 90° seemed to be more stable than either 45° or 60°.

13.1.2 Xaver 100 LAT Testing

The target walked from 5 m to 8 m during testing. Note that the maximum reported detection range of the Xaver 100 is 8 m (see Table 5: Xaver 100 Usability Assessment Summary). Measurements were taken with the device operating in both Normal mode and High Penetration mode.

13.1.2.1 Xaver 100 - Normal Mode

Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

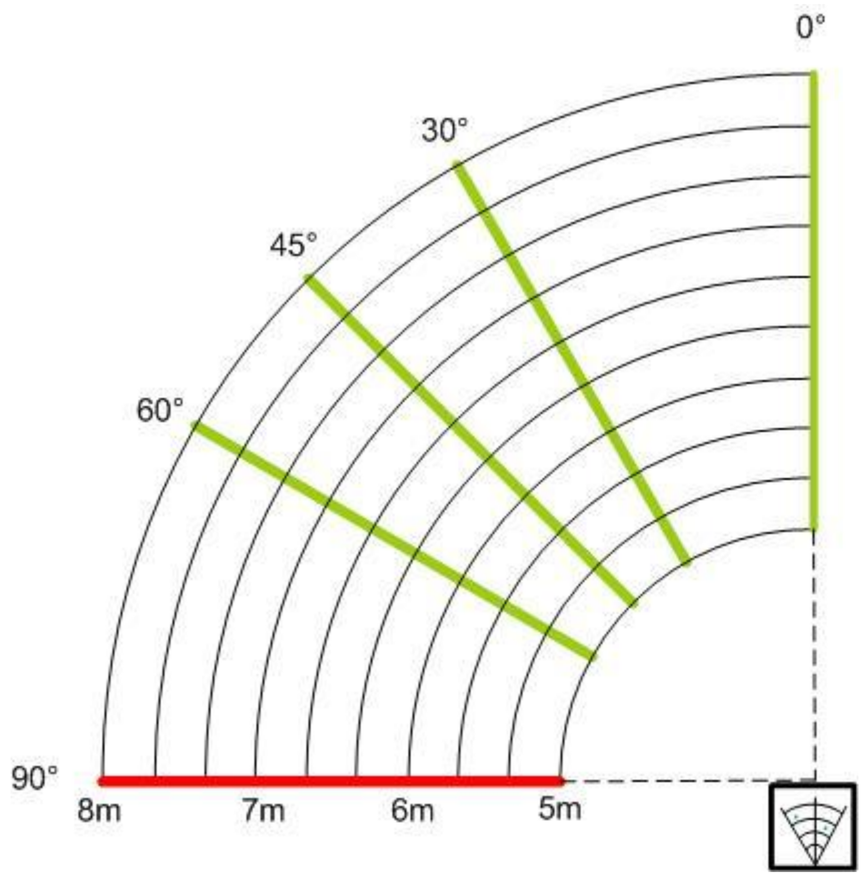

Figure 30: Angular Performance of the Xaver 100 - Normal Mode

Table 62: Xaver 100: Normal Mode: LAT: SW: Away

Xaver 100: Normal Mode: Target walking Stepwise (SW) away from device (5 m to 8 m)	
0°	Started at about 3.5 m *(5 m actual)* and fluctuated around 3.0 m to 4.0 m rest of the way out
30°	Detection was made all the way out, but measurements stayed between 3.8 m and 5.0 m most of the way (display showed 7.0 m toward the end).
45°	Detection was made all the way out, but reading fluctuated between 0.5 m and 1.8 m until target was at 7 m, then reading fluctuated between 5 m and 4.3 m to end
60°	Detection was made all the way out; reading showed 4.7 m for most of the time
90°	No Detection

Normal mode was able to detect that a target was present up to 60° from center when the target was moving stepwise; this would indicate a nominal viewing angle of 120° without a barrier. However, the distance measurements became unreliable almost immediately. At 0° when the target walked up and back at a normal pace, the Xaver 100 indicated a target was present, but it fluctuated between 1 and 3.8 m for most of the time.

13.1.2.2 Xaver 100 - High Penetration Mode

Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

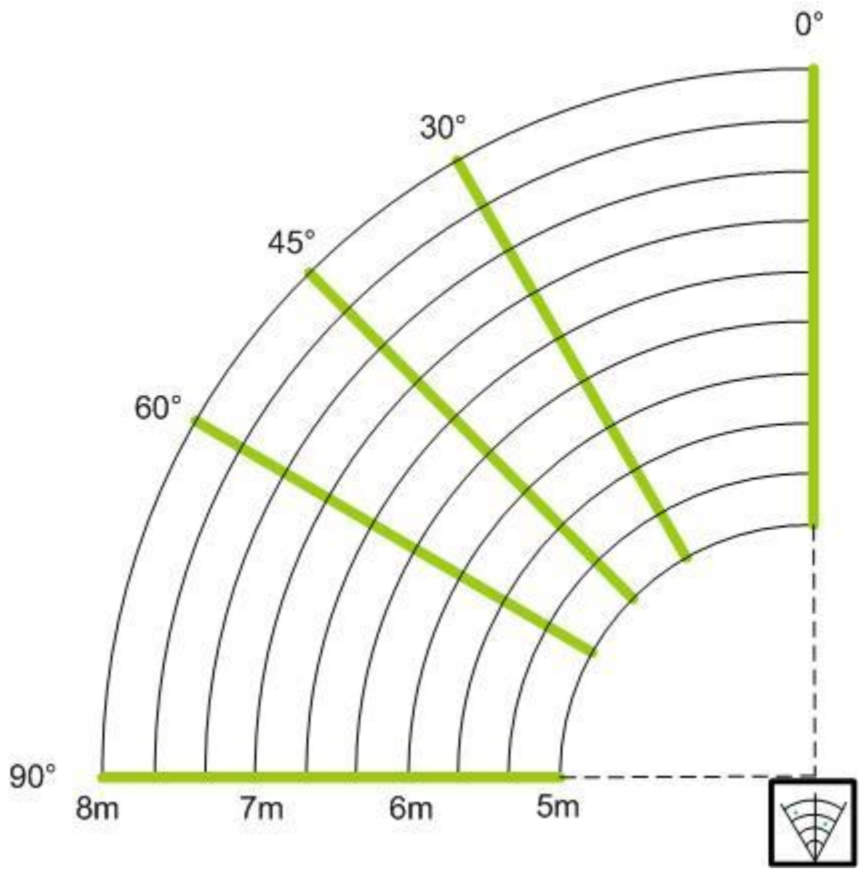

Figure 31: Angular Performance of the Xaver 100 - High Penetration Mode

At all angles, the Xaver 100 produced identifiable graphs of the moving target. The 90° angle measurement was a little more difficult to make out, but a trained operator would almost certainly conclude that a target was present, but the range may be off because of reflections.

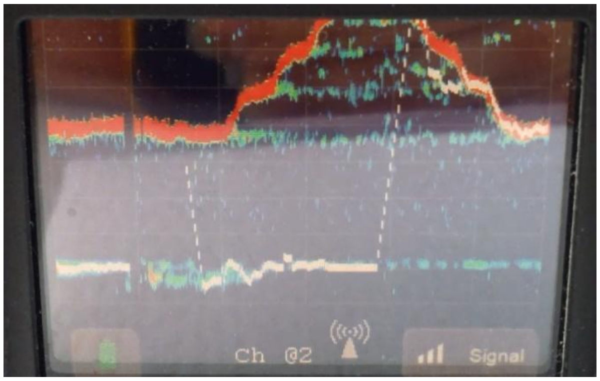

Figure 32: X100 in High Penetration mode 60° to target; target walking stepwise Photo by NLECTC SSBT CoE

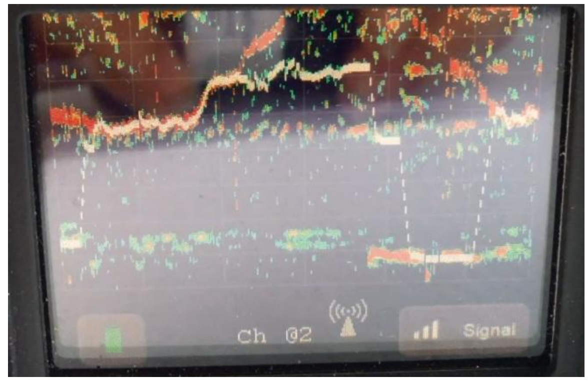

Figure 33: X100 in High Penetration mode 90° to target; target walking stepwise. Photo by NLECTC SSBT CoE

When viewed in High penetration mode, the display indicates that a target is present at every angle, however the Xaver 100 had some difficulty identifying the target in normal mode at 60° (see Table 62: Xaver 100: Normal Mode: LAT: SW: Away). Even at 90° (see Figure 31: Angular Performance of the Xaver 100 - High Penetration Mode), the CoE operators would conclude that a target was present. Normal mode did not show any detection at 90°.

13.1.3 Xaver 400 LAT Testing

The target walked from 5 m to 20 m during testing. Note that the maximum reported detection range of the Xaver 400 is 20 m (see Table 6: Xaver 400 Usability Assessment Summary). Measurements were taken with the device operating in Tracker mode, Expert mode, and High Penetration mode. Note that the performance of the Xaver 400 was exceptionally poor for this series of tests for some unknown reason. Barrier tests showed the Xaver 400 excelled in target detection in every mode and typically was the best performer of the ATW devices (e.g., Sections 10.1.1 ATW – Cubicle Material, 10.2.1 ATW – Glass, and 10.2.2 SO – Glass). However, during this series of tests (which did not include a barrier), the Xaver 400 underperformed for some unknown reason.

This was a series of tests carried out over the course of several hours with no change in the performance noted. The Xaver 400 performed well in other (barrier based) tests which were performed both before and after the angular tests. The batteries were well charged, and there were no performance issues previously noted while using low batteries until the device automatically shuts off. One possibility for the poor performance of the Xaver 400 is that the physical layout of the device and/or that the signal processing have been fine tuned to require a barrier to be present and that targets that are not behind a barrier are less likely to be detected. However this is pure speculation and the true reason for the poor performance for these tests is not known.

13.1.3.1 Xaver 400 - Tracker Mode

Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

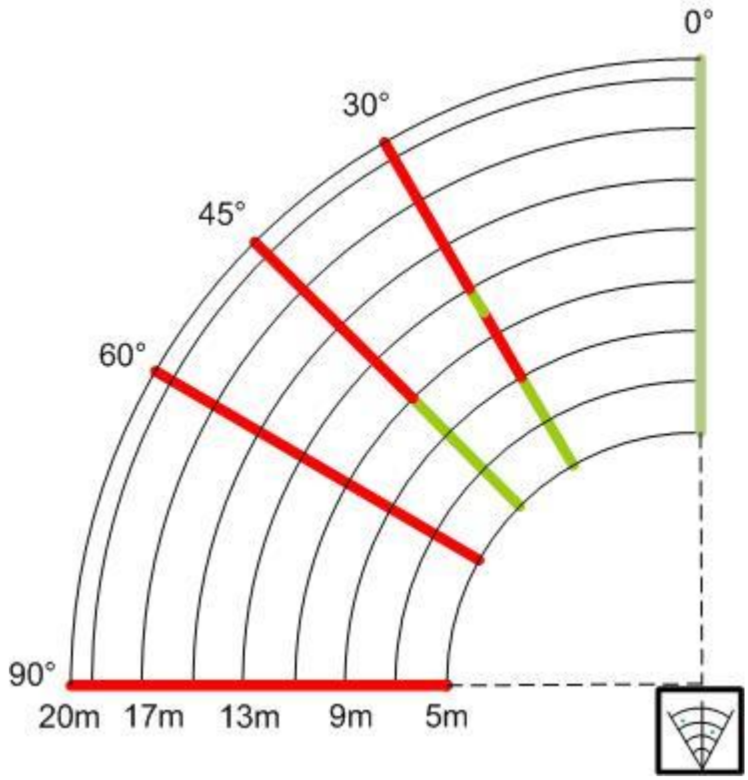

Figure 34: Angular Performance of the Xaver 400 – Tracker Mode

Table 63: Xaver 400: Tracker Mode: LAT: SW: Away

Xaver 400: Tracker Mode: Target walking Stepwise (SW) away from device (5 m to 20 m)	
0°	Tracked all the way
30°	Tracked initially to 9 m then lost; picked up at 12 m and lost again at 13m. No further detection
45°	Tracked initially to 9 m then lost. No further detection
60°	No Detection
90°	No Detection

Tracking mode was not able to detect the target beyond 45°, but even at lesser angles the device seemed to have difficulty detecting the target beyond 19m.

13.1.3.2 Xaver 400 - Expert Mode

Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

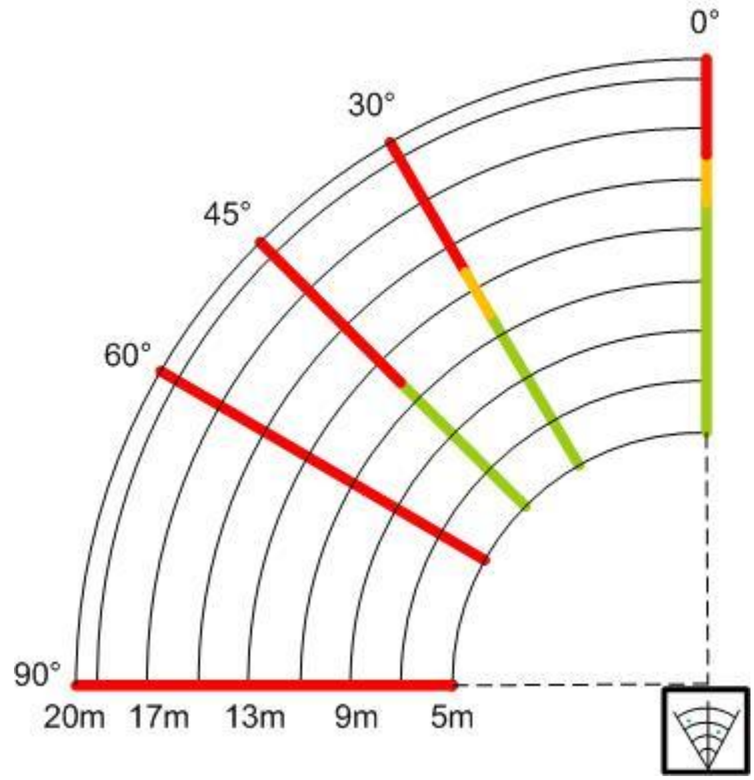

Figure 35: Angular Performance of the Xaver 400 – Expert Mode

Table 64: Xaver 400: Expert Mode: LAT: SW: Away

Xaver 400: Expert Mode: Target walking Stepwise (SW) away from device (5 m to 20 m)	
0°	Tracking initially; target signal is hard to make out around 14 m to 16 m
30°	Tracking initially; target signal is hard to make out around 12 m to 14 m
45°	Tracking initially; target signal is hard to make out around 12 m
60°	No Detection
90°	No Detection

Expert mode is similar to Tracker mode in that there was no detection at angles larger than 45°. Even then, there was no measurement that was able to detect the target at the full range of 20 m.

13.1.3.3 Xaver 400 - High Penetration Mode

Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

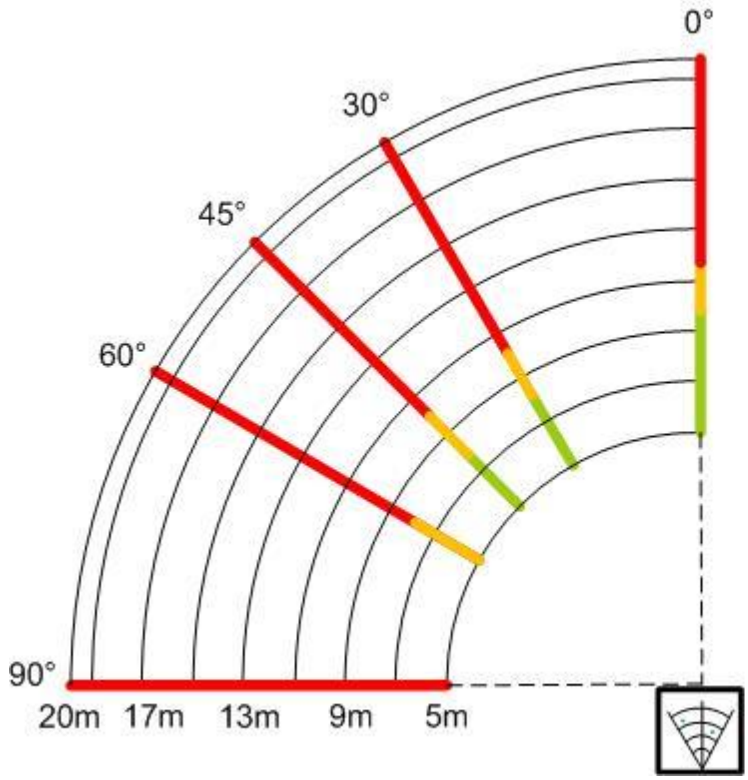

Figure 36: Angular Performance of the Xaver 400 - High Penetration Mode

Table 65: Xaver 400: High Penetration Mode: LAT: SW: Away

Xaver 400: High Penetration Mode: Target walking Stepwise away from device (5 m to 20 m)	
0°	Difficult to make out beyond 10 m – 12 m
30°	Difficult to make out beyond 8 m – 10 m
45°	Difficult to make out beyond 8 m – 10 m
60°	Seen at 5 m, No Detection beyond 8 m
90°	No Detection

While the target was able to be detected at 60° in High Penetration mode, detection was at shorter distances (about 8 m); there was no detection at 90°. In general, the detection range was shorter than the 20 m detection range of the Xaver 400; maximum distances tended to be in the 10 - 12 m range.

13.1.4 ASTIR LAT Testing

The target walked from 5 m to 70 m. Note that the maximum reported detection range of the ASTIR is 70 m (see Section 5.4 ASTIR). Device was angled at 0°, 30°, 45°, 60°, and 90°. Target path is indicated by the angles of the lines, and the detection is indicated by colors (green = detection, red = no detection, and orange = target detection uncertain).

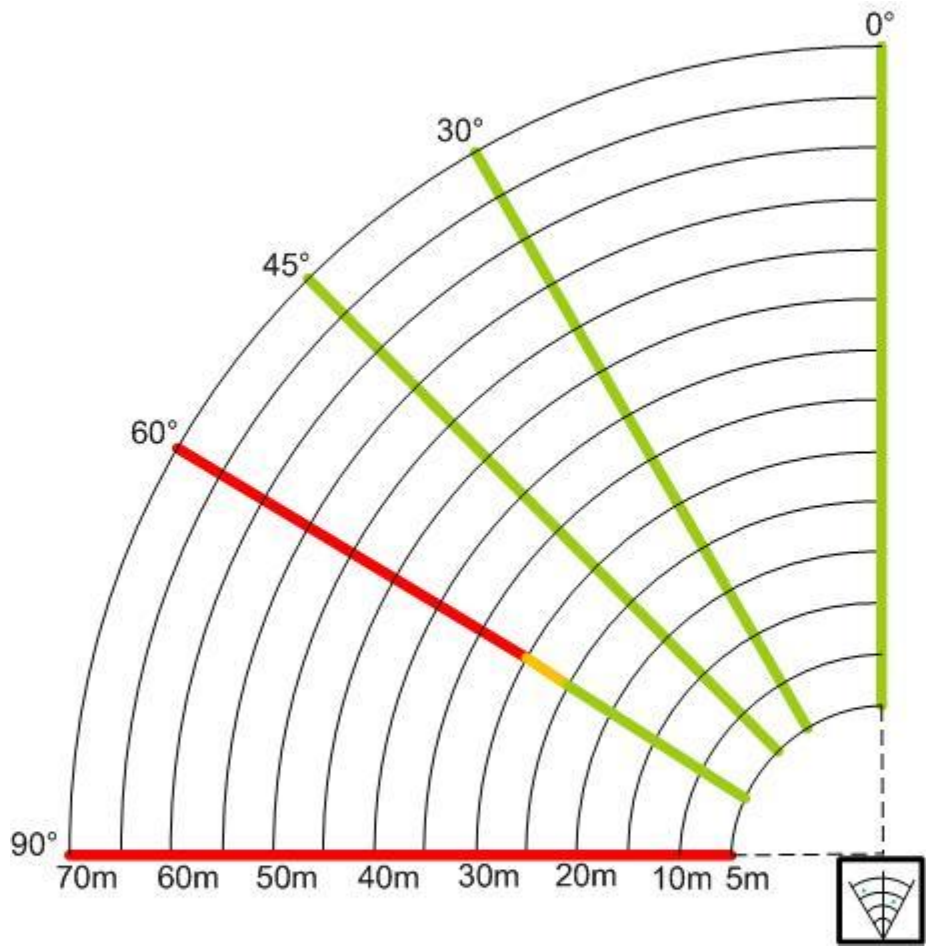

Figure 37: Angular performance of ASTIR

Table 66: ASTIR: LAT: SW: Away

ASTIR: Target walking Stepwise away from device (5 m to 70 m)	
0°	Target identifiable entire range
30°	Target identifiable entire range
45°	Target identifiable entire range
60°	Target identifiable up to approximately 25 m to 30 m
90°	No Detection

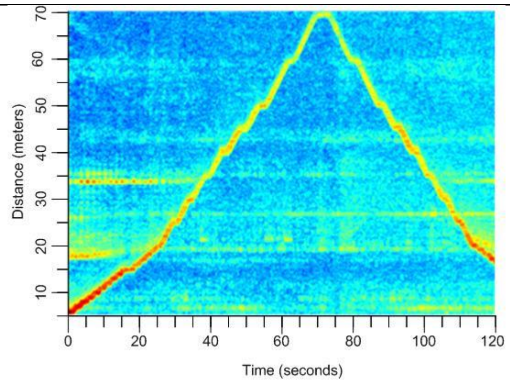

Figure 38: Target walking stepwise at 0°

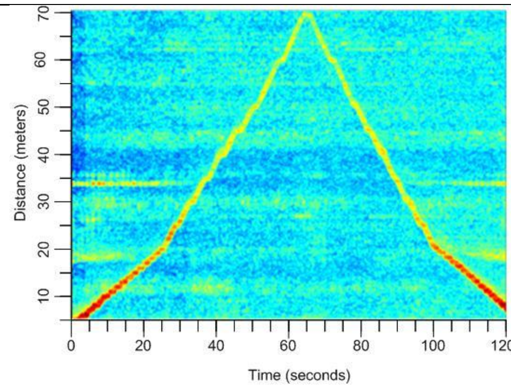

Figure 39: Target walking stepwise at 30°

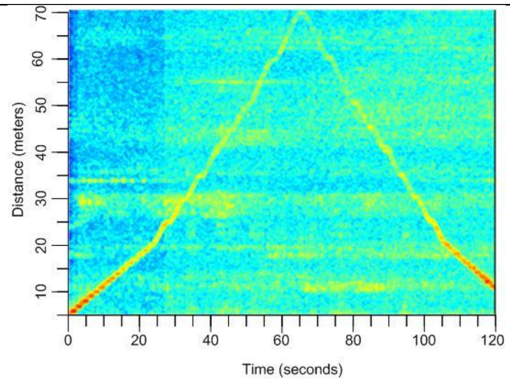

Figure 40: Target walking stepwise at 45°

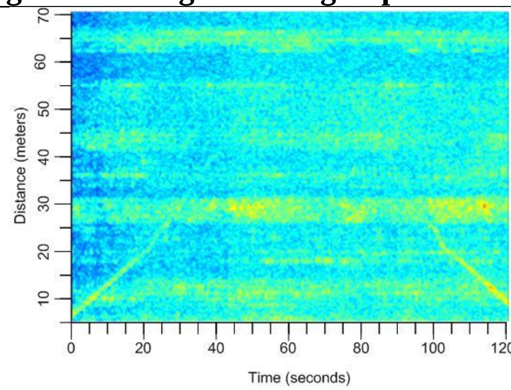

Figure 41: Target walking stepwise at 60°

The ASTIR was able to detect the target throughout the entire 5 to 70m range up to 45° without barriers. At 60° the target began to be difficult to pick out from the background at about 25 m to 30 m, and at 90° there was no indication that a target was present.

13.2 Angular Arc Test (AAT)

The angular arc test (AAT) was performed to check the ability of the devices to detect targets that were not necessarily directly in front of them but were at equal distance throughout their movements. The test consisted of the target walking in an arc (with the device at the center) at a predetermined distance. For the Xaver 100, Xaver 400, and the Range-R the distance was half the stated detection range of the device. For the ASTIR the range was less than half the detection range (20 m as opposed to 35 m) because of geographical limitations (target would have had to climb a small hillside if measurements were taken at 35 m).

13.2.1 Range-R Link Angular Arc Test

The Range-R Link measurements were taken with the target walking at a distance of 7.5 m from the device. The Range-R Link was used to provide hands free operation instead of the Range-R. The Range-R Link is identical to the Range-R with the added feature of being able to communicate to an iPod running a customized communication application. During testing, the

Range-R Link was able to detect the target throughout the arc from 0° to 90° in both directions. The reading was stable and varied from 21 ft to 22 ft during the measurement period.

13.2.2 Xaver 100 Angular Arc Test

The Xaver 100 measurements were taken with the target walking at a distance of 4 m from the device. Both Normal mode and High Penetration modes were tested. Normal mode was able to detect the target throughout the angular range 0° to 90° in both directions. The reported target distance fluctuated between 1.9 m to 4.3 m with most of the readings between 3 m – 4 m. High Penetration mode showed the target throughout the angular range in both directions, although the signal started to get noticeably weaker at angles larger than 60°, and reported distances were higher than actual distances as the angles increased to 90°. In addition, there seems to be some type of systematic distance error associated with the higher angles (when walking on an arc, the distances should be equal throughout the entire measurement).

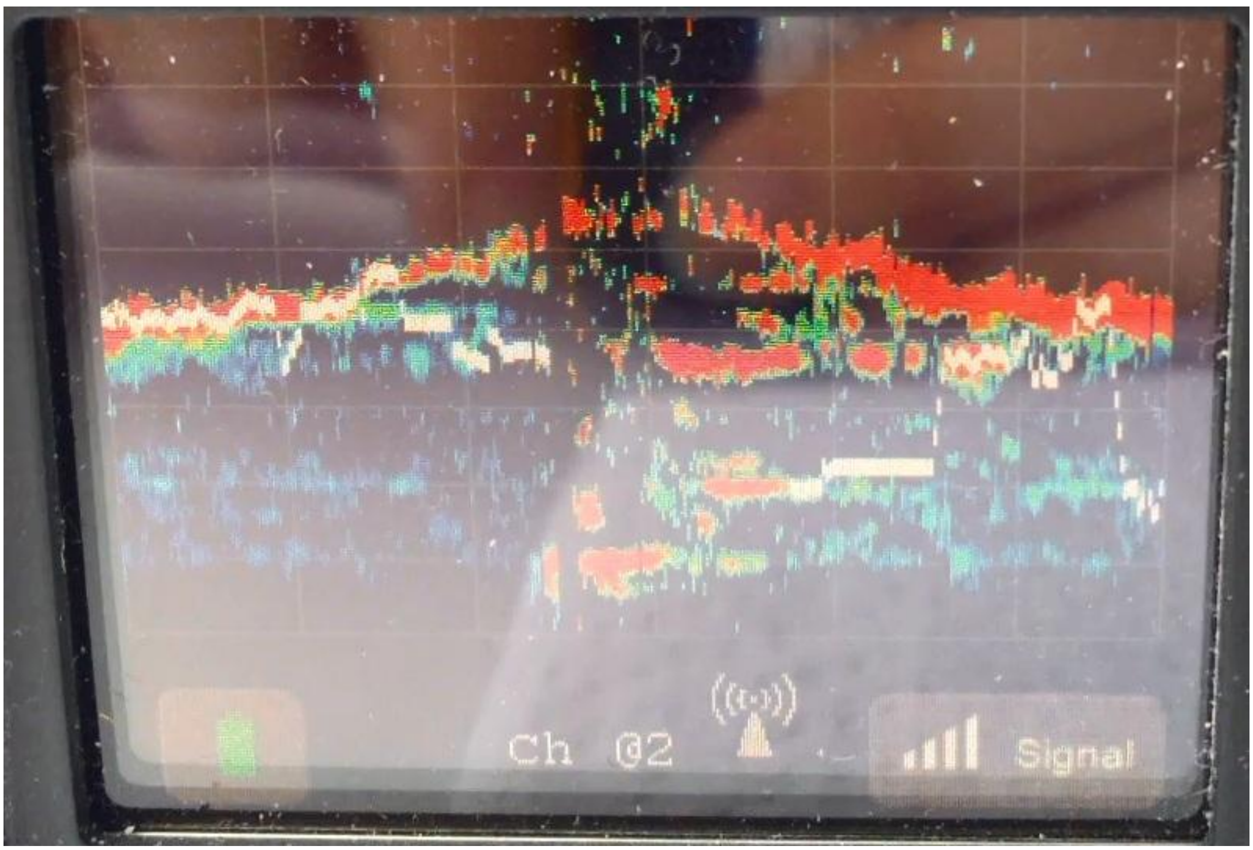

Figure 42: Target walking from 0° to 90° and back to 0° (90° in center of display)
Photo by NLECTC SSBT CoE

13.2.3 Xaver 400 Angular Arc Test

The Xaver 100 measurements were taken with the target walking at a distance of 10 m from the device. Tracker, Expert, and High Penetration modes were tested. With the target walking from 90° to 0°, Tracker mode was not able to identify the target at any angle. When the target reversed and walked back from 0° to 90° Tracker mode was able to track the target at angles less than 45°. Expert mode was able to detect the target at angles less than 30° with the target walking from 90° to 0°. When the target walked from 0° to 90° the target was identifiable up to 45°. High Penetration mode did not show that any target was present throughout the range.

Similar to the results of the LAT (see Section 13.1.3 Xaver 400 LAT Testing), these tests produced unexpectedly poor results for the Xaver 400 operating in an open environment without barriers. An explanation could not be easily determined.

13.2.3 ASTIR Angular Arc Test

Measurements were taken at 20 m instead of half the maximum detection distance because of geographical constraints. In the image below, the target starts behind the ASTIR and walks to position (diagonal line on left of image); walks along an arc to 90° and then back to 0°. The device is able to track the target strongly to about 20°, although the target can still be made out up to about 45°.

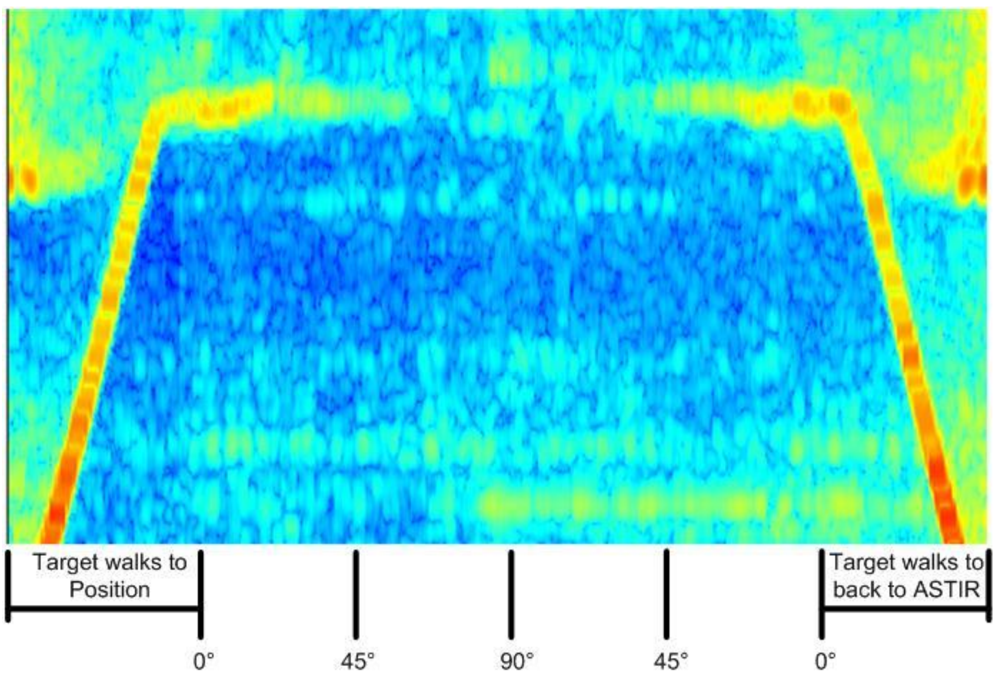

Figure 43: AKELA Angular Arc Test

13.3 Conclusions of Angular Testing

In general, the abilities of the devices to detect targets that are not directly in front of the device diminish as the angle increases – detections can be intermittent or not present and the accuracy of the distance measurements may suffer. Also, at wide angles, it is possible for a target to be missed when close to the device, but be detected when the target is further from the device. This is most likely due to what are known as lobes in the transmitted signal. Lobes are a natural consequence of antenna arrays and can create higher transmitted signal strength in areas outside the main transmitted signal. The devices generally are able to detect targets near the manufacturers' stated operational window, but keep in mind that these tests were done without barriers. The addition of barriers would presumably decrease the ability of the devices to detect targets at larger angles. The poor performance of the Xaver 400 during this series of tests is surprising, even when the target was directly in front of the device it seemed that the Xaver 400 had more difficulty detecting the target than it did when placed against a barrier.

14.0 TARGET WALKING THROUGHT STRUCTURE

The ASTIR by AKELA is listed as having a SO operation range of 30 m and has a 70 m detection range. This indicates the possibility of perhaps detecting a target throughout a small structure, such as a house. Tests such as this were performed on both the cinder block/OSB structures at the Camp Dawson Urban Training range, and at the Residential House.

14.1 Target Walking Throughout Upstairs of Building 1 at Urban Training Range

The building at Camp Dawson was constructed with cinder block, lumber and OSB. The first floor was an open room with outer walls constructed with cinder block and a wooden stairway to a second floor. The second floor was an open room with outer walls constructed of 2 x 4 lumber and OSB. To mimic a typical walking scenario in a building, the target walked into the first floor, went upstairs and walked a predetermined pattern. The target's activities were monitored at a SO distance of 30 m from the front of the structure. Once upstairs, the target walked to the wall closest to the ASTIR and stood for ~ 10 seconds, then repeated standing at the center of the room and the back of the room. Target then walked parallel to the front and back walls at three distances in the room. Target then walked from the front of the room to back of the room and returned to the front of the room before walking down the stairway and out the front of the building.

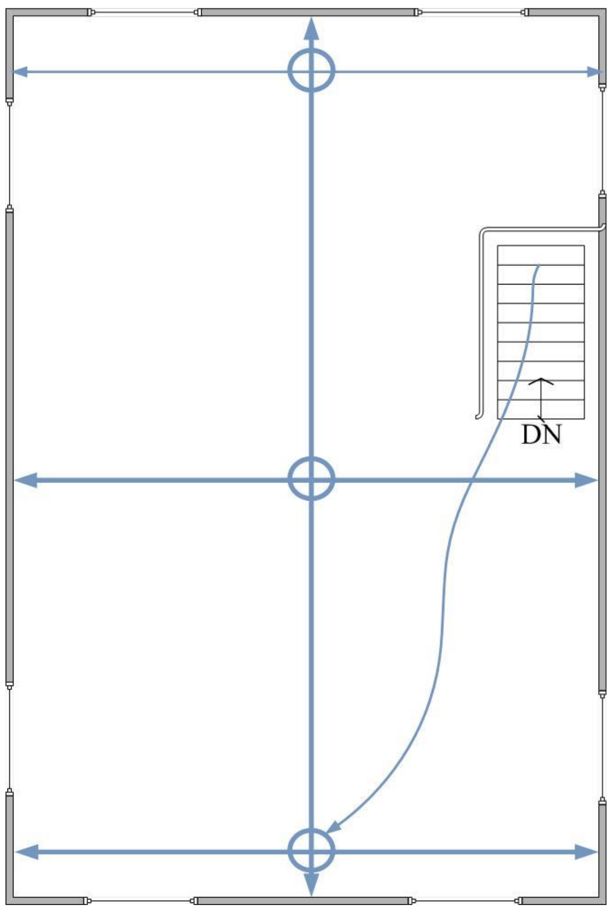

Figure 44: Building 1 second floor and target path

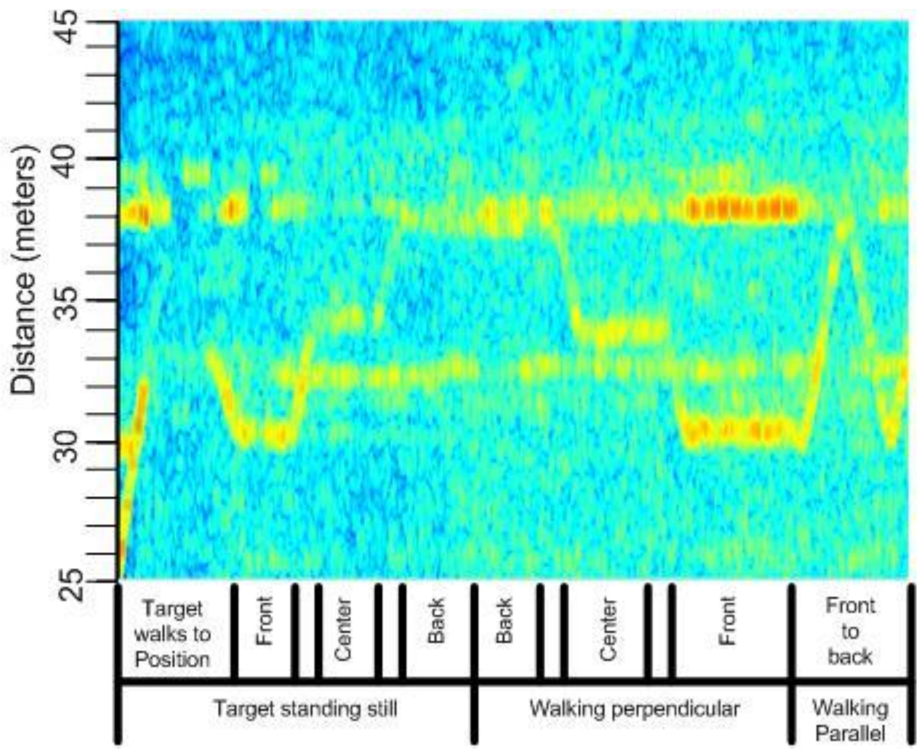

Figure 45: ASTIR 30 Meter SO
One OSB wall: Target Walking Perpendicular at Front, Center, and Back of Room

Figure 45: ASTIR 30 Meter SO shows the target entering the building (lower left) and moving toward the stairs. The target signal becomes faint as he gets behind the stairs and is not discernable as he climbs up the stairs to the second floor. The stairs are made of thick lumber and appear to be efficient at blocking most of the signal. Once on the second floor the target is seen walking to and standing against the front wall. The signal is fainter, but still visible when the target is standing in the center of the room. When the target is at the back of the room, the signal is hard to distinguish from the back wall. The transitions between each position can be seen with a slightly angled line (Approximately 10° right of vertical) with the intensity of the line decreasing as the target approaches the back of the room. When the target walked perpendicular, the signals were visible and generally more intense at each position (back, center, and front of the room) than they were when the target was standing still.

Note that when the target was at the front wall walking perpendicular, there was a strong signal on the back wall as well, in fact a stronger signal. This is due to the radar "shadow" of the target moving along the back wall. If there had been no "historical" indication that the target was along the front wall, the CoE operator would determine that the signal on the back wall was a true target, either thinking that there may be two targets in the room, or that the front target is a reflection of some type. The general unevenness of the front signal would indicate that it was not simply a wall or other reflective object.

Finally the target walked parallel (from the front to the back of the room) several times. The target's motion is indicated by the diagonal "zigzag" lines on right of the displayed image. Only one and a half cycles are shown in the image, otherwise information on the left side of the display would not be visible.

14.2 Target Walking Throughout Upstairs of Building 2 at Urban Training Range

The upstairs of building 2 was also constructed of lumber and OSB as building 1, however there was a small room in the center of the upstairs. This allowed measurements through one or two OSB walls. The ASTIR was set up 3 m from the interior wall of the upstairs room. Three meters was chosen simply because this was the farthest that the device could be placed away from the first wall. The target walked perpendicular in the room, then parallel. The target then left the interior room and went to the other side of the structure. In this location, there were two OSB/lumber walls between the target and the ASTIR. The target repeated the perpendicular/parallel walking pattern. The ASTIR was able to distinguish the target in all cases.

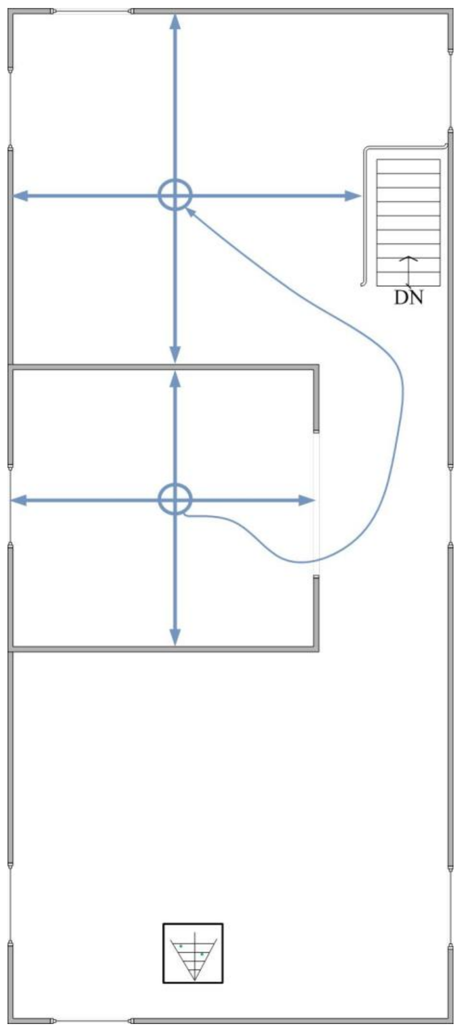

Figure 46: Building 2 upstairs and target path

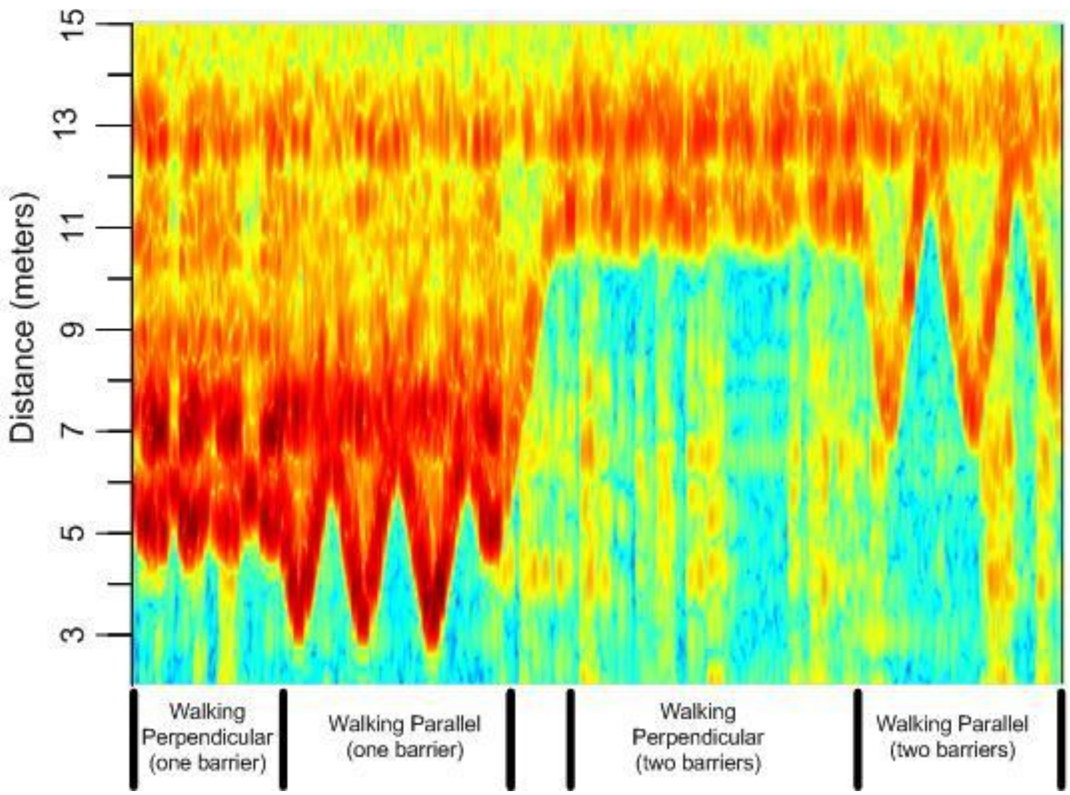

Figure 47: ASTIR 3 m SO
One and Two OSB walls: Target Walking Perpendicular and Parallel

In Figure 47: ASTIR 3 m SO, the target is walking perpendicular in the center of the room behind one OSB wall then walks parallel. Target then walks out of the room and to the center of the second room, now behind two OSB walls. The target walks perpendicular initially, then parallel. The target is clearly seen through two OSB walls; although the excess signal from shadows against the walls and even the ceiling and floors have the effect of appearing to "smear out" the signal. 3 m SO is pretty close for SO operations, and therefore the system may not be optimized for receiving the large amount of signal that would be received at this close distance.

14.3 Target Walking Throughout Residential House

At the residential house, the target started in the garage, walked through a door in the back of the garage and then walked throughout living areas of the house. The target video recorded his movements during the measurement so it would be easier to correlate his movements with the measurements. The target walked throughout the first floor and through two bedrooms on the second floor. Throughout the measurement, the target was not detected behind more than one barrier. The target was also not detected through the dining room window, but was detected through the bedroom window. In positions where there were more than one barrier between the target and the device, the signal faded beyond recognition. Descriptions of the ASTIR signal and the associated target movements are captured in the figures below for easier interpretation.

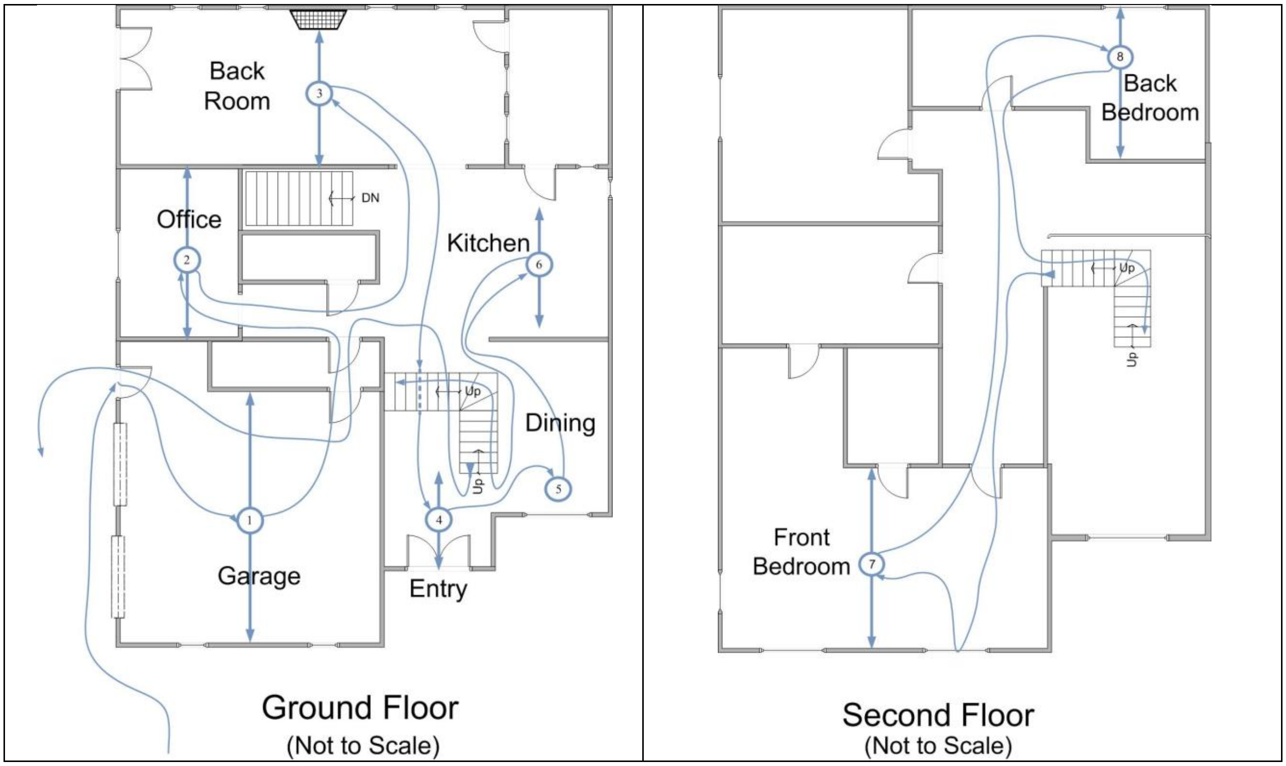

Figure 48: Schematic of Foundation House and target walking path

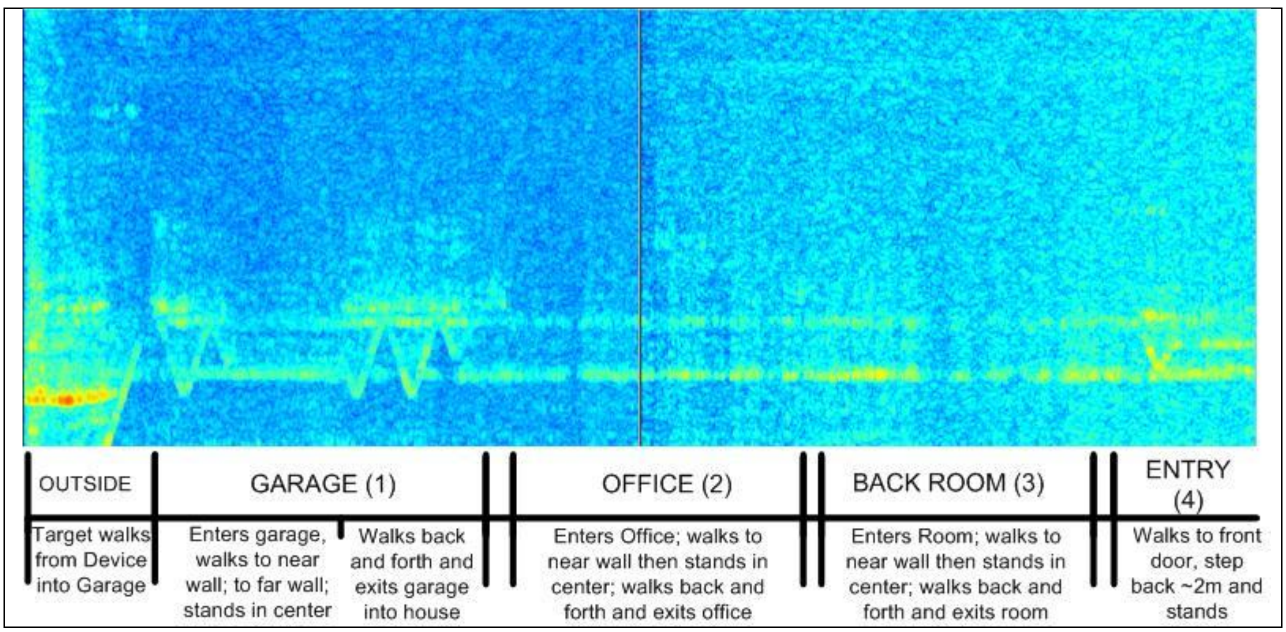

Figure 49: AKELA output during house walk through (part 1/2)

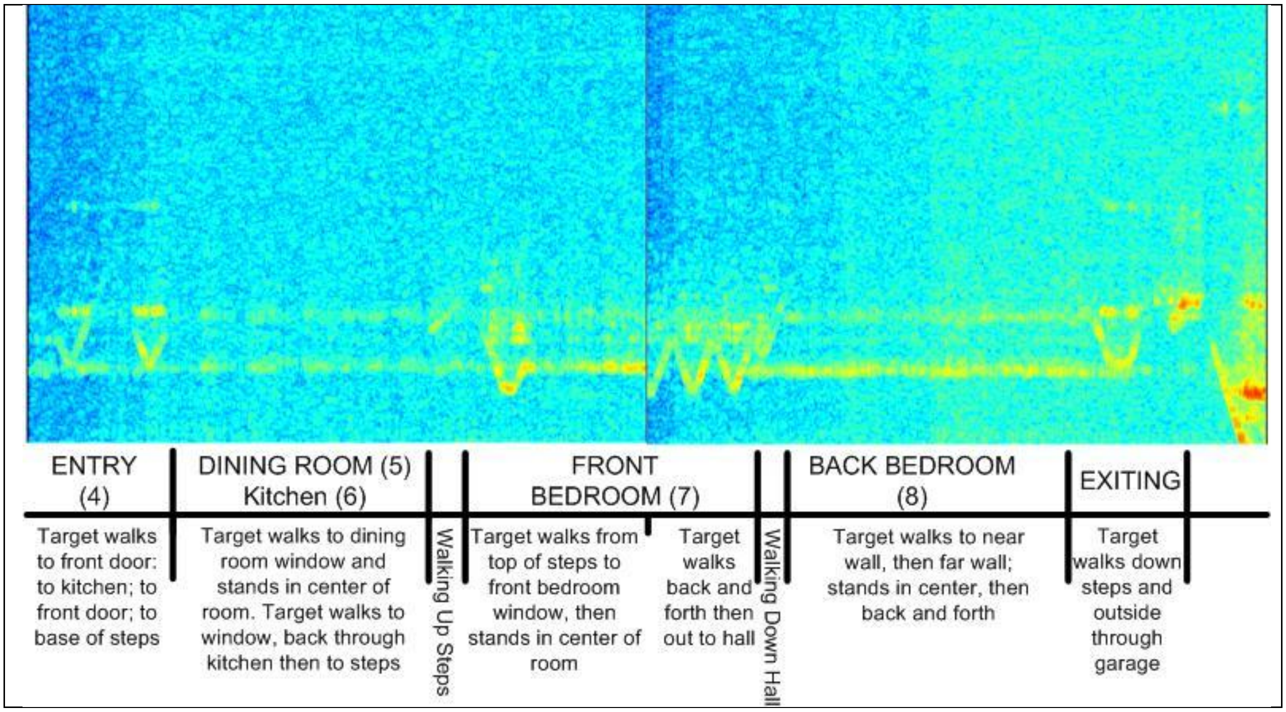

Figure 50: AKELA output during house walk through (part 2/2)

15.0 ANALYSIS

As indicated earlier, the choice of device will be strongly dependent on its intended use. The ATW hand-held devices would be most suitable for occasions where mobility is key and a minimal amount of time is available. Other situations may require extended observation and/or observation at SO distances. In these situations it may be worth the extra time to set up a device or the extra effort to maneuver a more bulky device into place so that the situation can be monitored over time at a safer distance.

Between the three ATW devices, the Xaver 400 has the highest overall percent detection, followed by the Range-R and then the Xaver 100; however the different modes of the Xaver 100 can give it an advantage over the Range-R in certain intended uses. The detection times of the devices are essentially equal when experimental error is taken into account.

The SO devices are situated further from the barrier and typically further from the target than ATW devices. They are also less maneuverable and require a support making the entire setup more bulky. During SO testing, the ASTIR was able to detect targets more often and at longer distances than the Xaver 400. The result is not surprising since the ASTIR is a dedicated SO device (and therefore specifically designed for SO operation), while the Xaver 400 is intended to operate both as an ATW device and a SO device (and not specifically designed for SO operation).

15.1 ATW Analysis

Overall, the Xaver 400 has the best ATW percent detection, the lowest average detection time, and a good distance uncertainty (+2% ± 9%). However, the Xaver is bulkier and heavier than the other ATW devices tested (The Range-R and the Xaver 100). Mobility and the performance of other operational tasks by the operator would be more hindered with this device than with a smaller device, such as the Xaver 100 or the Range-R. The larger size of the Xaver 400 is used to house additional antenna, which are able to provide better reflected signal reception and potentially better triangulation for target location. This, along with an algorithm that is able to take advantage of the additional information, is probably the main reason that the Xaver 400 has the overall highest percent detection of all ATW devices tested. This device would be best suited for instances where there is a real need for the additional information that a 2D device can provide, such as hostage or barricade situations. While it could be implemented in other situations (such as warrant serving or building clearing) the bulk and cumbersomeness of the device would be a disadvantage if fast movement through obstacles and close quarters were required.

The Range-R has the second highest overall percent detection for ATW measurements, the longest time for detection, and a low average distance error, but a medium distance precision measurement. While the Range-R is not able to directly indicate the presence of more than one target, the Range-R will cycle different distances when targets' activities change so that the reflected strength of the signal strength is changed from one target to the other. There is the potential of identifying more than one target, but the Range-R cannot detect two or more targets simultaneously. The Range-R is small and easily carried by one hand, although it seems just a little too bulky to have truly good grip on the device with one hand. With a better overall percent detection, but less ability to distinguish more than one target, the Range-R would probably be of most benefit in operations where the main question is "Is there anyone there?"

The Xaver 100 (preproduction model) had the lowest overall percent detection, the largest distance uncertainty, and a medium average detection time. The Xaver 100 preproduction model is a 1D device and does not have the performance, range, or additional operational modes of the Xaver 400. However, it is compact, easily carried, and has some ability to display movements of multiple targets. The two operational modes are Normal mode (the default mode) and High Penetration mode. Normal mode will attempt to identify a target and display the distance to the target. Normal mode will not detect multiple targets simultaneously. The ability of the Xaver 100 to switch to High Penetration mode is an advantage because during testing there were several occasions where the operator would probably identify a signal as a target from the data displayed in High Penetration mode, but the algorithm of the Normal mode did not. In addition to having better percent detection, High Penetration mode also has the potential of being able to simultaneously detect more than one target.

Different scenarios will have a greater priority on detection time. However, there does not seem to be a lot of difference in the detection times of these devices measured during testing. Table 8: ATW Results: Overall shows the average detection times of the devices to range from 8 seconds to 13 seconds, but the average deviation of the times are large and allow for significant overlap. This means that between the three tested devices, the average detection times are essentially equivalent within measured uncertainties.

Below is a table that summarizes the information presented earlier in the report for ATW devices for easy comparison across all barriers tested:

Table 67: Summary of ATW Measurements: Various Barriers

Percent Detection of ATW Measurements						
Barrier	**Range-R**	**Xaver 100**		**Xaver 400**		
	Average	**Average**		**Average**		
		Normal	**HP**	**Tracker**	**Expert**	**HP**
Cinder block	**58%**	**47.00%**		**87%**		
		35%	80%	100%	100%	60%
OSB	**80%**	**53.00%**		**100.00%**		
		40%	80%	100%	100%	100%
Cubicle	**100%**	**93.00%**		**83.00%**		
		90%	100%	80%	100%	70%
Glass	**60%**	**73.00%**		**100.00%**		
		60%	100%	100%	100%	100%
DWMS	**80%**	**61.00%**		**97.00%**		
		56%	80%	100%	100%	92%
Vinyl Siding	**67%**	**73.00%**		**93.00%**		
		60%	100%	100%	80%	100%
Brick wall	**70%**	**53.00%**		**90.00%**		
		55%	50%	100%	80%	90%
Wood siding	**80%**	**53.00%**		**100.00%**		
		30%	100%	100%	100%	100%

Comparison of the overall performances of the devices shows some interesting properties about the devices and even the barriers. The barrier that seemed to be the most difficult for the devices to penetrate is the cinder block wall. This is most likely due to the high density of cinder blocks, relative thickness, and potential moisture content (from exposure to the outside environment). The easiest barrier was the Cubicle material. The cubicle material is lightweight (not very dense), thin, and unlikely to have a high moisture content (the cubicle material is in a controlled environment).

There are significant differences between the different modes of individual devices. Typically, High Penetration mode of the Xaver 100 had a better detection than the Normal mode of the same device. This is in direct contrast with the Xaver 400, which typically had better detection in Tracker mode (the mode that most closely resembling the Normal mode of the Xaver 100) than it did in High Penetration mode. This may indicate that there is information available to Xaver 100 that could be used to improve the percent detection of the device, although it’s doubtful that the algorithm of the Xaver 100 (with two antennas) would ever be able to fully match the performance of the Xaver 400, which has four antennas.

Comparison of the modes where the device attempts to detect and identify a target (Normal mode of the Xaver 100, Tracker mode of the Xaver 400, and the Range-R) show that the Xaver 400 had nearly a perfect percent detection across all barriers, the only exception being the cubicle material. The Range-R had higher percent detection than the Xaver 100 in Normal mode in all cases except through glass where the percent detection was equal. While this gives a good indication of how well the devices are able to detect and identify a target when operated in these particular modes, a practitioner may use more than just one mode of a device (if it has more than one mode is available) to obtain as much information as possible, if time allows.

In the case that an operator has the time and training to read multiple available modes of the devices, it may be best to compare the devices based on the highest percent detection across all operational modes of an individual device. Viewed in this manner, the Xaver 400 still has the highest percent detection overall, but the Xaver 100 has higher detection than the Range-R in four cases, equal detection in three cases, and less detection in one case. This is mainly due to the high penetration mode of the Xaver 100.

In light of this, the Xaver 100 may be best utilized in HP mode and in situations where there is some length of time to allow the chart to fully develop to increase confidence in target detection and identification by the operator. Also, situations where the target would be expected to make translational movements would be the ideal scenario for the Xaver 100 operated in this manner as moving targets are more easily identifiable in HP mode. Normal mode could be used as a “second opinion” if there are any questions about the identification of a target in HP mode.

In situations where the target would not be expected to be moving (target intentionally remaining still, sleeping, unconscious, etc…) the Range-R may be a better choice since reflective clutter in a room would show up as a horizontal line on the High Penetration graph of the Xaver 100 and may mask the signal of a true (still) target. Another advantage of the Range-R over the Xaver 100 is that there is little (if any) training needed to understand the numeric display of the Range-R. The display of the HP mode of the Xaver 100 does require more thought and judgment (perhaps tempting an operator to spend more time cycling between modes and letting the chart develop more fully before coming to a decision).

15.2 SO Analysis

The Xaver 400 and the ASTIR were tested in SO operation. For comparison, the results of the percent detection are presented in the table below:

Table 68: Summary of SO Measurements: Various Barriers

Percent Detection of SO Measurements				
Barrier	ASTIR	Xaver 400		
	Average	Average		
		Tracker	Expert	HP
Cinder block	**84%**	**44%**		
		40%	60%	33%
Glass	**70%**	**80%**		
		100%	100%	40%
DWMS	**80%**	**40%**		
		60%	60%	0%
Vinyl Siding	**60%**	**47%**		
		50%	60%	30%
Brick wall	**50%**	**30%**		
		40%	50%	0%

The High Penetration mode of the Xaver 400 most closely resembles the evaluated display (historical chart) of the ASTIR. Even when comparing across all modes of the Xaver, the ASTIR was able to detect a significantly larger percentage of targets during SO operations than the Xaver 400 against all barriers with the exception of the glass barrier.

It is interesting to note the Xaver 100 also performed relatively better than the Range-R in ATW measurements against glass (see Section 10.2.1 ATW – Glass and Table 67: Summary of ATW Measurements: Various Barriers). Because the Range-R and the ASTIR use similar frequencies for their signals, and the Xaver series use ultra wide band technology for signal generation, this could indicate that the glass door tested (in both SO and ATW) was more efficient at blocking the signals from the ASTIR and the Range-R than it was at blocking signals from the Xaver series. If this is true, this would be an example of how barrier properties may cause a disproportionate absorption of signals of different frequencies (see Section 2.3 Technology Background).

The Xaver 400 is more flexible and mobile than the ASTIR and would be better suited for SO operations that would require a faster setup, and be able to be more quickly moveable to different locations at the site, or in cases where operation could benefit from a combination of SO and ATW. The ASTIR would be the better choice if there was little reason of having to move the devices once the device had been setup on site or in the case where a SO detection range of more than 20 m would be desirable.

The ASTIR by AKELA is a dedicated SO device and is able to detect targets as far as 70 m away. The device is not yet commercially available; however it shows promise for having good detection ability from long SO distances (30 m or more).

16.0 ASTIR PROTOTYPE EVALUATION

The ASTIR by AKELA is a SO motion detection device that uses an external computer to process and display data. In addition to an external computer, the prototype also requires an external power supply. The computer and power supply are required to be hard wired to the device. Once the ASTIR is up and running, control and operation are handled through a graphical user interface on the computer. The data display consists of a graphical representation of the integrated area, a historical display, and a 2D display. The historical display is easily read and interpreted and the 2D display is also set up to be easily interpreted, although AKELA personnel said that the 2D display requires more work, and their suggestion was to use the historical window for analysis. The device is able to detect movement easily, although still targets may be challenging. This is especially true if the target is close to a barrier or other strong reflector. The performance of the device is good, and it is the only device tested that is able to detect beyond 20 m (up to 70 m).

While control and operation is easy, the initial setup can be time consuming. The ASTIR prototype requires connections to an external power supply and a computer. Because it is a SO device, the ASTIR requires a stable mount or mounting surface. Although not absolutely necessary, placing the computer on a stable surface is advised. Storage, transportation, and setup can be cumbersome with all these separate components. When getting the device out of storage, it may be easy to forget something. During transportation, the device and different components required a significant amount of space in the vehicle. The time required for placing, connecting, and initializing the components was not insignificant. In addition, if the software is accidently run before the device is turned on, some system files for the software appear to be overwritten with bad parameters. Once this happens, the files had to be copied from a good copy of the software before the system could be operated.

16.1 Physical

The ASTIR requires a large number of individual components to be stored, transported, and wired together. Setup requires that the ASTIR be mounted on a stable surface, connected to a power supply, and connected to a computer. During testing, a tripod was used as a stable mount, and a 12V automotive emergency jump starter was used as the power supply. Additional pieces of equipment that are not technically required but were helpful included a small table to place the computer on and a sun shield for viewing the computer display in bright sunlight.

Having a smaller power supply within the case would reduce the number of parts that have to be transported and connected together. AKELA personnel indicated that the device could be run for about two hours with AA batteries. If AA batteries could be used as the main power source and inserted within the device, then this would reduce the weight, bulk, and number of components of the entire system. If desired, there could be an external connection that would be able to connect to a 12V external power source.

The computer used by the Center (based on AKELA's requirements) was a high end graphics notebook computer and is larger and heavier than typical laptops. In terms of logistics, setup, and physical handling, the computer was the "weak link" of the system due to it being a separate component and designed for normal mobile office use. However, the computer to be used with the ASTIR is to be furnished by the user and it would be up to the user to decide if a ruggedized computer was purchased or not. If some of the data processing could be transferred to the device itself, then a smaller, lighter, and more dedicated display device could be used (e.g., a tablet). This would help reduce the weight and bulk of the system. Of course, additional processing on the device would increase power consumption.

Having a small, foldable, and detachable stand may also be of benefit. This would reduce the number of separate components and potentially decreasing setup time. The option to be able to remove the attached stand could still be available so that the ASTIR could potentially be mounted on a more traditional stand (such as a tripod).

16.2 Software

One particular issue noted is that the software ran by the computer requires that the ASTIR device be powered up before the "Start" button be pressed. If the ASTIR is not powered up, an error occurs that shuts down the software. It also appears that some of the files used by the software are overwritten with bad parameters, which cause future operation of the software (even if the device is powered up) to not operate the ASTIR. To fix the issue, the corrupt files have to be replaced with non-corrupt files from a "good" copy of the software. The software should check the power-on status of the ASTIR before doing anything else and alert the user if a power off status was detected. At minimum a "restore defaults" or "restore last known good parameters" button or menu choice could be made available. It should be noted that AKELA personnel did say that the device must be powered on before running the software, but did not go into detail about what would occur if it did happen.

The color scheme of the charts and graphs is well suited for this application, and works well with both the historical display and the 2D image display. The 2D display seems to show the target position as more of an arc or what looks like multiple targets along a larger arc. The color scheme in the 2D window seems to be to show Doppler activity in color and non-Doppler reflections in gray shades. The additional target "blips" appear to be located at positions where the lobes of the antenna array might be expected to be stronger. An algorithm that would be able to look at the intensity changes between two "targets" displayed in the 2D might be able to help determine whether one signal is a ghost of the other or not (or perhaps give an indication of the possibility). It may also be of benefit to have an additional algorithm that would attempt to identify and track a target without the user having to interoperate whether they believe the reflected signal is a target or not.

Some improvements in data analysis by the system would be beneficial. In its current form, the 2D image display was not tremendously helpful during operation due to reasons listed in the previous paragraph. Test operators tended to focus almost exclusively on information presented in the historical display. As mentioned previously, AKELA personnel indicated that the 2D display required more work. In the historical display, the shadows of a target on walls can sometimes be used to indicate that a target is present. This is especially beneficial if the target is not able to be directly detected. Currently it is difficult to tell whether the signal is from a shadow or a target. It would be beneficial to be able to graphically view whether the displayed signal is from an increase in reflected signal (as in the case of a target) or from a decrease in reflected signal (as from a shadow).

Improvements in data display and display control would also be beneficial. Zoom options, color scheme options, and scrolling for the historical view on the front screen would help the operator focus on the analysis instead of operating the device. While there are “Zoom In” and “Zoom Out” options, the buttons only provide incremental changes. Adding buttons with preset ranges would allow the operator to more quickly adjust to required parameters. The color scheme indicates the strength of the reflected signal, but there is no easy method to change or modify the scaling factors immediately available on the user interface. The ability to easily change the scaling factors may allow the operator to bring out or highlight weaker signals. Finally, Center personnel felt that a scrolling screen for the historical view would be more intuitive and useful than the current wrap around method used for data display.

16.3 Operational

Wireless communication between the device and the computer would be beneficial. This would eliminate having to hardwire the device to the computer, and would allow for easier mobility. Of course, data security, decreased operational time (because of the extra power drain), and potential interference are issues that would have to be addressed before implementing any changes of this nature.

During operation, movements of the operator(s) are sometimes seen as “ghosts” in the display of the device (appears as a potential target). One potential solution would be to place a single rear facing antenna that would be able to detect any movement behind the device and try to compensate for this movement if a similar signal pattern is detected elsewhere.

16.4 Data Review

Data review is performed by loading the original data and reprocessing the data with the desired parameters. The ASTIR saves the raw data during a scan, therefore it is possible to change processing parameters for review. One improvement would simply to have the default file to open as the last data collected/saved. Other beneficial options would to have a “fast forward”, “pause”, and “reverse” options readily available.

16.5 ASTIR Evaluation Conclusion

The ASTIR is a promising technology that would need some more developmental improvements to be fully functional for use by LE and other first responder, even as a demonstration unit. The main thing would be to reduce the overall bulk and number of components of the system and to reduce the setup time and improve storage and transportation. The current 2D display has a lot of erratic and errant signals that does not really reflect the position (especially angular) of the target well. Improvements in the 2D signal processing would increase the functionality of the device beyond the historical graphical view. Improving the software so that the device attempts to identify a target would be a good addition, but not strictly necessary given the current display characteristics. Reduction of reflections or “ghosts” would also be beneficial. While improvements in data review would have been helpful during this evaluation, data review is probably not needed often in the field. Note that of all the devices tested, the ASTIR was the only one that had the capability to directly save and review the data at a later time.

16.5.1 Recommendations

The ASTIR seems to be able to detect targets well, but there are some issues with the number of components needed to operate the device and some software and signal processing that could be improved upon. Some of the main recommendations are:

- Reduce number of components needed for system support;
- Improve signal processing to remove or reduce erratic and errant signals, especially for the 2D graphical display;
- Incorporation of a target identification algorithm to specifically point out and track targets in the 2D display;
- Allow for the compensation of operator and other movement behind the device (such as using a backward facing antenna);
- Use different color schemes to indicate an increase or decrease in reflected signal (to tell the difference between a target (increased) and a shadow on a wall behind the target (decreased);
- Do not allow software to overwrite configuration file if ASTIR is not turned on;
- Incorporate wireless communication capability between device and display device;
- Allow easy real time manual scaling of signal strength;
- Allow for "on board" processing so the computer could be replaced with a smaller display (such as a tablet);
- Use scrolling display on historical chart instead of wrapping; and
- Improve data review to incorporate fast forward, pause, stop, and restart at current point.

17.0 CONCLUSIONS

TTWS have the capability to increase situational awareness in scenarios pertinent to law enforcement and other emergency responders. Like any technology, they have general limitations because of the base technologies incorporated, and specific limitations because of individual system designs. The manufacturers of the devices tested in this study have obtained certification by the FCC for operation by emergency responders and law enforcement. The devices met the manufacturer's specifications and were able to detect and locate targets behind most barriers with at least a reasonable level of probability and accuracy. Moving targets were more easily detected than still targets. The Xaver 400 was able to detect a significantly higher percentage of targets than the other ATW devices (Xaver 100, and the Range-R), but was not able to detect targets as well as the ASTIR during SO testing; nor did the Xaver 400 have the range of the ASTIR.

Overall, the Range-R was able to detect a higher percentage of targets than the Xaver 100, however when the individual modes of the Xaver 100 are examined, we notice that the High Penetration mode was able to detect more targets than the Range-R. Because of the display characteristics of the historical chart method, it is easier for an operator to detect movement than a still target, thus it appears that if a target is expected to be moving, the Xaver 100 may be the better choice, however if the target is expected to be still, the Range-R would be the device of choice.

17.1 Overall

The Xaver 400 had the highest overall performance of the ATW devices, and the ASTIR was the highest performance of the SO devices. There were some specific points noted with the devices and the technologies.

- The Xaver 400 has the highest percent detection of the ATW devices, can detect multiple targets, and has three different display options for increased confidence. The Xaver 400 is also larger than the Xaver 100 or the Range-R, not as easily stored, transported, or maneuvered on site.
- The ASTIR has the highest detection probability of the SO devices, and it has a significantly longer detection range (70 m as opposed to 20 m).
- The AKELA has the largest range of all devices, but is the largest, bulkiest, and takes the longest time to set up. It would most likely be best suited for longer term observations and/or for operations requiring larger monitoring distances.
- During testing the Xaver 100 readings seemed to jump around a lot during testing, reducing the usefulness of the distance reading, but still indicating that a target was present. (Note: this may be addressed in the final production model.)
- The UWB devices (Xaver series) seemed to show an increased amount of noise when tested in an office environment. This seemed to mainly affect the historical graph of the device, making it harder for an operator to identify a target. Detection of a target by the device (Normal mode for the Xaver 100 and Tracker mode for the Xaver 400) did not seem to suffer (at least not that it was noticeable) from the electronic environment of the

office. The ASTIR did not appear to suffer from the noise in the office environment. Nor were there any effects noted with the Range-R operated in the same environment.

17.2 Operation

Display characteristics, device setup, and ease of use are important considerations to take into account when evaluating how useful a device would be to an organization.

- Having different data display modes can helpful (e.g., Xaver 100 detecting more than 1 target in HP), but it does take additional time to cycle through and analyze the different modes.
- The Xaver 400 has three modes of operation (Tracker, Expert, and High Penetration modes). All three modes can detect multiple targets simultaneously.
- The Xaver 100 has two modes of operation (Normal and High Penetration). High Penetration mode has the ability to detect multiple targets simultaneously.
- The Range-R has one mode of operation (distance to detected target) and cannot detect multiple targets simultaneously.
- The ASTIR displays a historical chart similar to High Penetration mode of the Xaver series. It has the ability to simultaneously display a 2D chart as well, but the 2D chart requires more development. Both modes can or would have the ability to detect multiple targets simultaneously once fully developed.
- Interference was not specifically tested, however cell phones and two-way radios were in operation during testing and no interference issues were encountered.
- SO operations take longer to set up than ATW because of the necessity of a secure mount.
- Once setup, the devices require minimal manipulation to operate; usually 1-2 buttons.
- The ASTIR is the only device with direct recording capability.

17.3 Detection

In general, the devices had strengths and weaknesses that should be taken into account and evaluated in view for their intended end use.

- The Xaver 400 performed very well during ATW measurements and was the highest rated in nearly every situation; detecting a higher percentage of targets than the other ATW devices.
- The Range-R was able to identify targets better than the Normal mode of the Xaver 100.
- High Penetration mode of the Xaver 100 is able to detect targets better than the Range-R.
- The Range-R is better at detecting still targets than the Xaver 100.
- Smaller devices have fewer antennas which:
    - Allows them to be smaller and lighter.

  - Can make them less accurate at distance reporting.
  - Can make them less likely to detect a target.
- The Xaver 100 is sensitive to operator and observer movements which tend to indicate a target around the 1 m area. This could mask a true target at this distance on the other side of a barrier.
- The Range-R has a rear facing antenna that helps compensate for operator and observer movements behind the device.
- Average detection times across the devices are about equal.

17.4 Storage, Transportation, and Setup

During storage and transportation the device should be able to survive typical bumps and even accidental drops that may occur. Most devices have a protective storage case for this purpose. Setup times for ATW devices are typically very fast, but for SO devices times can increase because of the need to mount the device to a stable surface.

- The ASTIR takes the longest time to set up and it has multiple components that need to be assembled on site.
- The Xaver 400 operated in SO mode takes additional time to setup (as compared to ATW operation) as SO mode requires a stable mount.
- Devices operated in ATW mode take about the same amount of time to setup.
- Devices operated in ATW operation do not require multiple components.
- The ASTIR takes up the largest amount of space during storage and transportation.
- The Range-R and the Xaver 100 take about the same amount of space (small).
- The Xaver 400 takes up about four times the space as the smaller devices.

17.5 For Consideration

Companies and suppliers of TTWS may be willing to provide a demonstration of their devices and may even be willing to loan a device to an organization for evaluation purposes. Potential customers should try to take advantage of any offers available to better evaluate a device for their specific purposes and in typical environmental in their geographic location.

- Before purchasing a device, an organization should try to arrange for a demonstration of the devices and have them tested on a variety of barriers that are common in their locale.
- An organization considering obtaining one of these devices should compare the requirements for their intended use to the features available at a price that is within budget. For example, some questions an organization may consider are:
  - Is the typical intended target expected to be moving or still?
  - Is necessary to track a target over time, or is just an indication of whether someone is on the other side of the barrier needed?

- Is monitoring activity in an area for extended times required or would the device have to be quickly located at different barriers and locations at a site?
- Is it is expected that the typical sites would have a lot of obstacles (e.g., dense underbrush) that the operator would need to navigate before operation?

- Would typical situations include structures that hamper this technology (such as metal shipping containers, trailers, or recreational vehicles)?It is advisable to take multiple measurements at multiple locations on a barrier. This is especially true for ATW operations when localized barrier variations will have the largest effect.
- High moisture content in a barrier may hamper detection.
- Building codes and materials can change over time and can vary between different locales.
- The Xaver 400 (a 2D device) is significantly more expensive than the other (1D) commercial devices.
- The production model of the Xaver 100 was not tested during this evaluation, but company literature reports that the production model has increased the maximum range to 20 m (as opposed to 8 m for pre-production model).

17.6 Considerations for Future T&E

The testing conducted by the CoE was performed to establish a foundational evaluation of TTWS in operationally-relevant law enforcement settings. Because of the constrained resources and schedule, there are some activities that would be modified or added given an opportunity to conduct similar TTWS T&E in a more robust project environment. Below are two considerations for future T&E of TTWS in support of criminal justice or homeland security applications.

It is recognized that the operator of the device was aware of the presence of targets and their orientation and movements during testing. This is not an issue for device that automatically detects targets (i.e., Range-R, Xaver 100 Normal Mode, and Xaver 400 Tracker Mode). However, for devices and modes that rely on operator judgment, operator bias may be an issue. The ideal testing methodology would be to institute a double-blind with randomized test scenarios. This would allow the operator to be ignorant of the target(s) or lack thereof and their movements. A second approach would be conduct data collection and analysis independently, with the analyst unaware of the test conditions. Both approaches would necessity duplicate tests (including additional blanks in each wall type) and additional logistical personnel, something that the CoE testing was unable to support.

A more in depth study of potential interferences may also be worth exploring in future evaluations. Potential sources of motion such as oscillating fans, ceiling fans, and perhaps even small animals could be targets for false positive tests. Additional testing of common window coverings and coatings, including metalized coatings and aluminum foil over windows, could provide valuable information for the practitioner. Systematic investigation into potential electronic interference such as wireless networks, GPS receivers, cell phones, and other transceivers that may interfere with the operation of the TTWS or that may indicate the presence of a TTWS would be of value.

Future evaluations may also consider constructing custom barriers. This would provide barriers with exactly known materials and composition for testing. The barriers could even be varied to match local building codes or even to match historical codes. Custom barriers would also allow different thicknesses of barriers and their components to be tested. Tests of this type were considered early on in CoE test planning, but discarded due to the prohibitive level of manual labor and time required for this effort.

APPENDIX A: ACRONYMS, ABBREVIATIONS, AND REFERENCES

A.1 Acronyms and Abbreviations

ACRONYM	DESCRIPTION
2D	Two Dimensional
3D	Three Dimensional
AAT	Angular Arc Test
ASTIR	AKELA Standoff Through-wall Imaging Radar
ATW	Against the Wall
CFR	Code of Federal Regulations
CoE	Center of Excellence
DOJ	Department of Justice
DWMS	Drywall Metal Studs
FCC	Federal Communications Commission
FCCID	Federal Communications Commission Identification
FPSPA	Facing, Perpendicular, Side, Parallel, Away
HP	High Penetration
IP	Internet Protocol
LAT	Linear Angular Test
LED	Light Emitting Diode
MAX/MIN	Maximum/Minimum
NIJ	National Institute of Justice
NLECTC	National Law Enforcement and Corrections Technology Center
OSB	Oriented Strand Board
RADAR	Radio Detection And Ranging
RFI	Request for Information
SFCW	Stepped Frequency Continuous Wave
SO	Standoff
SSBT	Sensor, Surveillance, and Biometric Technologies
SW	Step Wise
TTWS	Through-the-Wall Sensors

ACRONYM	DESCRIPTION
TWG	Technology Working Group
US	United States
UWB	Ultra-Wide Band
WVHTC	West Virginia High Technology Consortium

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