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Through the Wall Standoff Detection and Tracking of Individuals

NIJ RRA Final Report

AKELA OJP Grant No: 2009-SQ-B9-K113

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This AKELA Final Report is submitted to the OJPs Office of the Comptroller describing DOJ NIJ RRA Activities during the Period of Performance August 2009 – April 2012 for OJP NIJ Cooperative Agreement 2009-SQ-B9-K113

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ABSTRACT

Through a grant from the National Institute of Justice (NIJ) and continuation Cooperative Agreement funding provided by the American Recovery and Reinvestment Act (RRA), AKELA Inc. developed a sense-through-the-wall (STTW) standoff radar imaging system for law enforcement use. The underlying technology of the imaging system is a multiple antenna, continuous wave, frequency stepping radar in a portable case that can be positioned at standoff distances of up to 30 m away from a building of interest. Radar information is processed in real time on a laptop computer to allow detection and tracking of stationary or moving individuals within a building structure.

The project goals were to provide an easy to use, battery operated, FCC compliant, portable system weighing less than 15 lbs, at a total system cost of less than $5,000, that detects personnel behind an eight inch thick concrete block wall at a range of 30 meters, is capable of being controlled by a wireless Ethernet connection allowing remote deployment and operation, and produces images identifying stationary and moving individuals within building structures. Major program objectives include: 1) leveraging NIJ and DOD investments to produce a standoff radar sensor system for personnel detection and movement through building structures, and 2) developing an FCC compliant standoff radar system to provide situational awareness for Law Enforcement operational use with a focus on size, weight, cost, power, and performance.

AKELA leveraged radar technology currently being developed for military platforms and adapted it to specifically fulfill the needs of Law Enforcement and at the same time, navigate technical constraints and requirements particular to FCC approved operation in an urban environment. On a previous NIJ grant, a baseline laboratory prototype system operating between 500 MHz and 2000 MHz was extensively tested (using simulated personnel movement) both in the laboratory and on a challenging (realistic) structure which has 26.7 cm (10.5 in) thick double-reinforced (both vertical and horizontal reinforcing bars) concrete walls and metallic clutter objects located within the structure. Both stationary and moving objects have been successfully detected and tracked within the structure. On RRA program initiation and after IRB review, NIJ approved human subject testing for AKELA and its radar sensor device. Subsequently, human subjects replaced personnel simulation in all testing, providing greater performance assessment realism while yielding improved detection results.

Obtaining an FCC license to operate the radar in the baseline frequency band proved to be a challenging task, requiring major task replans, even when use of the device is restricted to Law Enforcement agencies and first responders. To address FCC constraints, analysis of the technical and practical advantages of changing the frequency band of operation was conducted. Based on analysis and laboratory test data, a decision was made, in concert with NIJ and AKELA's FCC legal consultants Fletcher, Heald & Hildreth, to proceed with development of a version of the

system operating in the 2900 MHz to 3600 MHz band. This radar device modification required application for a FCC Part 90 waiver in or around the 3100-3500 MHz band, and subsequent FCC certification under Part 90 rules. AKELA requested a waiver for this high frequency radar system and after FCC review and successful emission testing, received FCC approval. As this effort concludes, final FCC certification testing and LASD user performance evaluation will be conducted under a subsequent NIJ FY 2012 grant. With LASD device performance feedback and product improvement interactions, a first generation NIJ AKELA standoff radar sensor prototype will be available for further law enforcement evaluation, potential LE procurement, and operational application.

1.0 Executive Summary

AKELA has developed for NIJ a sense-through-the-wall (STTW) standoff imaging system, AKELA Standoff Through-the-wall Imaging Radar (ASTIR), for use during law enforcement operations. The system transmits and receives on single frequencies over a selected frequency range. Analysis of the returned signals provides information to determine the presence, location, and tracking of personnel movement behind building walls. Real time processing of personnel movement information provides the capability to detect and track moving individuals within a building structure. Unlike existing through-the-wall systems which must be placed in direct contact or close proximity to a wall, AKELA's ASTIR system provides the ability to place the system at a standoff distance up to 30 meters. The standoff distance significantly decreases the likelihood of system operator and law enforcement personnel being placed in harm's way when positioning and using the system. Additionally, the standoff radar provides a wide viewing angle, allowing personnel movement detection on multi-level structures from a single position.

NIJ and DOD have sponsored AKELA's development of ultra-wide band radar systems to produce an imaging sensor capable of both mapping the internal structure of building, and locating personnel inside the structure. This capability provides increased situational awareness, in both peace keeping and law enforcement operations, where there is a need not only to determine if there is someone inside a building, but also determine their location and movement. These situations arise during searches for suspects, hostage and barricade incidents, and tactical surveillance. While, in many cases, the object is to make contact with a suspect to defuse a potentially violent situation, unfortunately, most operations conclude with physical search and LE personnel are subject to a high possibility of physical harm.

Through these efforts, AKELA demonstrated the capability to image the interior of a building, and detect the motion of both stationary and moving individuals through multiple internal walls and reinforced concrete exterior walls. Under a previous NIJ grant, a small, portable imaging laboratory prototype system based on this technology has been configured that weighs 17 lbs., can be operated remotely through either a wired or wireless Ethernet link, and can operate under battery power for two hours. This standoff detection system has demonstrated detection ranges of 30 meters through concrete block and steel reinforced concrete walls. The sensor control and display functions are performed by an off-the-shelf laptop computer. The system is portable and quickly deployed.

The current NIJ RRA engineering prototype system shown in Figure 1 is packaged in a small (22"Lx17"W x 9"H), light-weight (18 lbs.) hermetically sealed case. It is deployed by placing the system in front of a building on a stationary object such as tripod, table or vehicle roof, and orienting the system towards the building of interest. Control of the system is accomplished

using software running on a laptop computer, connected to the device through either a wireless or wired Ethernet connection.

Figures 1 NIJ RRA AKELA Engineering Prototype TTWS System

The control software allows full control of the system operation, signal processing, and user graphical display. Upon starting the system, a display of detection results will begin within a few seconds. The use of multiple antennas provides the ability to not only detect individuals, but to also determine an individual's approximate location in both range and cross-range without the need to move the system to other locations. A demonstration of the system's detection capabilities is shown in Figure 2, with the colored area of the computer display output showing the location of detected motion behind a wall 15 meters from the system. The system is capable of running for up to 2 hours on standard double AA batteries or continuously when connected to a power source (e.g., vehicle cigarette lighter). AKELA's radar sensor operates in a stepped frequency, continuous wave (CW) mode. All of its operating parameters are digitally controlled and configurable through the software interface. The radar sensor has a demonstrated operational frequency range of 380 – 3600 MHz.

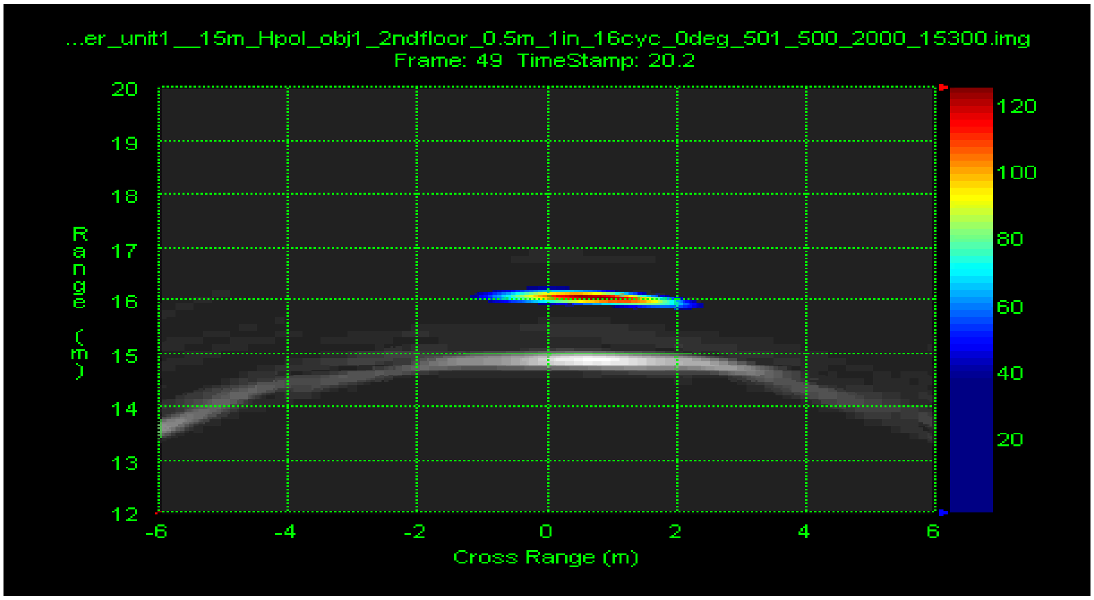


Figure 2 Computer Display of Detected Stationary Individual (Colored Oval Object) Behind a Wall 15 Meters from the NIJ RRA AKELA Radar System

Throughout the course of AKELA's NIJ RRA effort to remotely locate and track individuals through walls, compliance with FCC requirements for AKELA's radar technology has proven to be a programmatic and technically challenging, and time-consuming process. Due to difficulties obtaining FCC experimental licensing, user field test evaluation and subsequent feedback for product operational readiness improvements were delayed. To address these FCC concerns and mitigate programmatic risks, AKELA assessed a dual technical approach: 1) determine technical solutions for FCC testing modifications, and 2) modify the baseline radar sensor by increasing the frequency bands of operation to permit higher emission levels and potential FCC certification.

Due to FCC compliance testing rigidity, to modify the current test procedures, if successful, could take 2-3 years. With this expected schedule information and NIJ's concurrence, path 2)was selected to modify the baseline radar sensor frequency range. To deal with FCC compliance risks and issues, a Washington DC law firm, Fletcher, Heald & Hildreth was retained to provide a FCC interface. Their experience in FCC filings with similar STTW devices, and direct experimental licensing and waiver application interactions played a key role in final FCC compliance. Subsequently, experimental license requests were modified (AKELA radar high frequency modification) and a FCC waiver application filed for device emergency Law Enforcement applications. After FCC review, device emissions test data was requested, emission tests conducted at a FCC approved laboratory, and results provided to the FCC. Post emission data submission and FCC review with government and commercial spectrum users, a waiver was granted to AKELA for emergency LE application. FCC Waiver submission, experimental emission test report, and FCC approval documentation are attached to this final report. Final certification testing and associated documentation at a FCC validated lab remains before final FCC certification. A FCC test facility has been selected for Certification, and test execution will be conducted under a FY 2012 NIJ AKELA grant.

2.0 Introduction

2.1 Program Background

Current U.S. military operations in the Middle East have served to reinforce the importance of being able to conduct surveillance and reconnaissance on combatants in urban settings with the goal being to recapture the situational awareness advantage by denying adversaries the use of cover. Law enforcement faces the same kind of disadvantage while conducting operations for hostage rescue, building surveillance, building clearance, and building search. While early development of through-the-wall detection and imaging systems was supported by the intelligence community, most of the recent technology development has been supported by the National Institute of Justice (NIJ), U.S. Army, DARPA, ONR, and JIEDDO.

The ability to detect and locate stationary and moving individuals through building walls from significant standoff distances provides a tactical advantage to law enforcement personnel. Knowing that there is someone inside a building, where they are inside, and what the internal layout of the building is, can completely change the operational tactics used and increase the probability that an operation will successfully conclude without casualties. However, because law enforcement agencies have limited budgets for technology, practical implementation of through the wall technology for law enforcement application requires that careful attention be paid to design in order to make this capability affordable for all levels of law enforcement.

The overarching goal of AKELA's development was to: 1) develop a small transportable affordable system package suitable for operational law enforcement use, 2) perform system evaluations in concert with law enforcement agencies to identify improvements, 3) incorporate those improvements into the system design, and 4) address the issues that need to be resolved in order to ensure that the system can be certified by the Federal Communications Commission for civilian Law Enforcement use.

AKELA's NIJ standoff STTW sensor system development efforts are to provide an easy to use, battery operated, FCC compliant, portable system weighing less than fifteen lbs, at a total system cost of less than $5,000, to detect personnel through an eight inch thick concrete block wall at a range of 30 meters, to be capable of being controlled by a wireless Ethernet connection allowing remote deployment and operation, and to produce images identifying stationary and moving individuals within building structures. AKELA's approach: 1) leveraged NIJ and DOD investments to produce a standoff radar sensor system for personnel detection and movement through building structures, and 2) develop an FCC compliant standoff radar system to provide situational awareness for operational LE use focusing on size, weight, power, cost, and performance.

NIJ and the DOD have sponsored AKELA's development of ultra-wide band radar systems to produce imaging sensors capable of both mapping the internal structure of a building, and locating personnel inside the structure. This capability provides increased situational awareness, in both military peace keeping and law enforcement operations, where there is a need not only to determine if there is someone inside a building, but also to track their location and movement within the building. These situations arise during searches for suspects, hostage and barricade incidents, and tactical surveillance. While, in many cases, the object is to make contact with a suspect to defuse a potentially violent situation, unfortunately, most operations conclude with physical search and Law Enforcement personnel subject to a high possibility of physical harm.

Under previous NIJ sponsorship, a small, portable laboratory imaging prototype system based on this technology was been configured that weighs 18 lbs., can be operated remotely through either a wired or wireless Ethernet link, and can operate under battery power for two hours. The sensor control and display functions are performed by an off-the-shelf laptop computer. Through these efforts, AKELA demonstrated the capability to image the interior of a building, and detect the motion of stationary and moving individuals through multiple internal walls and reinforced concrete exterior walls.

2.2 Potential ASTIR LE and First Responder Applications

The ASTIR (AKELA Standoff Through-the-wall Imaging Radar) system provides a capability to detect and locate personnel behind building walls, from significant standoff distances. This capability provides LE, firefighters, and first responders knowledge of personnel presence and location inside a building. While providing greater situational awareness, this standoff information (up to 30 meters) provides an increased critical safety factor, as personnel location can be identified without LE personnel exposure to close building structure proximity, promoting responder officer safety. The deployment of ASTIR will directly promote responder safety and potentially save responder, hostage and general public potential injuries and fatalities.
The capability to detect and locate stationary and moving individuals behind building walls, from significant standoff distances, provides LE, Department of Homeland Security (DHS) personnel an advantage in personnel safety, with increased situation awareness and tactical advantage. Knowledge of someone's presence inside a building, and their location will help protect LE personnel and the public, while promoting a successful outcome. Similarly, a first responder (LE officer or Firefighter) ability under certain conditions, to precisely locate even unconscious

victims within a building, prior to entry, raises the probability of life saving operations, promoting a timely and successful outcome.

The ASTIR system device provides information critical to public safety and law enforcement and homeland security operations that may not be available in any other way. It provides detection and location of personnel in building structures from standoff distance up to thirty meters. Four scenarios are presented that demonstrate potential applications for personnel from LE, first responders, DHS, and Fire Fighters:

1. Prior to serving warrants to high risk and potentially dangerous individuals, the ASTIR can be deployed and incrementally moved at street standoff distances, within a complex of structures, to determine presence, and location, and number of personnel inside within the building complex. This significantly increases situational awareness as to tactics to identify, and isolate persons of interest to serve warrants. Standoff distance operations promote safety for LE and innocent building occupants and provide covert operations and tactical surprise prior to LE building entrance to serve warrants.

2. On police SWAT call out for hostage and/or barricaded situations, the initial tactics include : 1) threat definition of number of personnel present, 2) classification of personnel present and building wall construction, 3) locate, track, and isolate threat personnel within the building structure, 4) establish voice contact with individuals within building, and if contact is made, any response to communication, and 5) develop strategy for plan of action on information received, including potential forced entry. To support this plan, the ASTIR device can accurately locate and differentiate moving and breathing (unconscious or restrained personnel). This information provides decision makers the number and position of personnel and their movement inside a building without exposing first responders to building hostile fire or friendly line of fire. ASTIR set up will take approximately 3 seconds and produce image data continuously one second after device turn on.

3. Post SWAT building entry, a building search and clearance operation is conducted. This presents one of the most dangerous situations for SWAT members. Attics, basements, crawlspaces, and confined hiding places are prevalent in many buildings -- with only occupant suspect knowledge. The deployment of ASTIR can provide locations of hidden suspects. Multiple ASTIRs at 90 degrees or the movement of ASTIR across multiple positions can provide greater detailed detection and location of suspects hiding behind metallic structures or shields (e.g., refrigerators). Additionally, building clearance operations can be monitored for SWAT member location and tracking along with any suspect detected in close proximity to his location. ASTIR information can be invaluable leading directly to decreased LE injuries and fatalities

4. Fire Fighters and first responders can detect and locate living personnel trapped within a building or collapsed structure from a safe standoff distance. ASTIR provides decision support data for additional risk of Response personnel to enter into dangerous building collapse or fire situations. Similarly, Rescue and Search teams can deploy ASTIR to detect survivors under nonmetallic building collapse rubble.

5. ASTIR can provide situational awareness data for prison riot and escapees. ASTIR demonstrated the ability to detect and locate personnel behind twelve inches of reinforced concrete walls. This ability to sense empty rooms and the location and number of personnel inside various rooms is a critical component of situational analysis and deployment tactics.

ASTIR data can be invaluable for LE and first responder emergency scenarios, providing timely detection and location of personnel inside buildings from standoff distances. Additionally, ASTIR provides situational awareness, while promoting general public safety and LE personnel safer working conditions.

2.3 Final Report Subjects and Organization

This document is the Final Report on AKELA's OJP NIJ RRA Cooperative Agreement 2009-SQ-B9-K113. This effort builds on prior AKELA NIJ and DOD technology efforts to develop a standoff Sense Through-the-Wall (STTW) surveillance and building interrogation radar sensor systems.

The NIJ AKELA RRA Cooperative Agreement effort had four objectives and associated tasks:

1) **ASTIR Design and System Optimization**
   - Optimize baseline design for LE operational robustness
   - Integrate baseline design into LE Prototype for FCC certification
   - Document baseline design and laboratory prototype for LE user evaluation
   - Provide a simple and friendly User interface for LE application with minimal training
   - Obtain user feedback for Product Improvements requiring baseline design software modifications
2) **FCC Compliance**
   - FCC Requirements
   - Legal Representation and FCC interaction (FH&H)
   - FCC Experimental Licenses
   - FCC Waiver
   - FCC Certification
3) **Law Enforcement User Evaluation**
   - IRB review and approval for human subject testing

- LE Agencies demonstrations and feedback
- LASD interactions and user evaluation test: planning, execution, and reporting
- LE user interface requirements

4) **Law Enforcement User Evaluation**
   - Modify User Interface to respond to LE user evaluation and feedback
   - Modify device to respond to LE user evaluation and feedback on operational deployment and maintenance issues
   - Minimize time for ASTIR setup, calibration, and personnel detection data acquisition
   - Provide individual detection data to decision maker(s) in less than 5 seconds after setup

As initially proposed, the NIJ RRA effort built on a previous NIJ grant that AKELA demonstrated a baseline laboratory prototype to meet performance goals of detection and tracking of simulated humans behind eight inches of reinforced concrete. The prototype also met SWAP goals of human transportability, size (rifle case), power (50 mW) and could operate for two hours with 8 AA battery pack, and weight (18 lbs.). A computer laptop provides signal and data processing in real time and operates in either a wireless or hardwire Ethernet mode. The original NJI AKELA standoff STTW target weight and fabrication cost goals were to reduce the large military vehicle mounted unit from 120 lbs and $115K to 15 lbs and $5 K per unit; the current laboratory prototype weighs 18 lbs and costs, with wireless and integrated battery, approximately $10-12 K to fabricate.

As the NIJ RRA 2009 effort progressed, meeting the FCC compliance requirements became the driving factor in technical, schedule, and scope in all tasks. In the design and optimization task, the baseline low frequency design would not meet FCC requirements using current FCC test procedures to test pulsed radar systems. A number of “work arounds” were evaluated; however, they all involved modifications to current FCC test procedures and test data acquisition. Any FCC test change requires a long and difficult process, that takes 2-3 years with no guarantees of success. LE user evaluation could not proceed without experimental licenses for LASD locations. After an initial six month experimental license for the baseline low frequency system, attempts for a renewal and new license were not approved. This inability to legally test the AKELA device curtailed both the LASD user evaluation and AKELA testing at local test sites.

The FCC compliance requirements drove: 1) LE user test and evaluation schedules, 2) operational readiness and potential deployment issues, and 3) rework of technical tasks to modify the baseline radar system to operate in a higher emission frequency band. To address schedule and technical FCC compliance risk, a Washington D.C. law firm (Fletcher, Heald & Hildreth) with FCC experience was put on retainer by AKELA to provide direct FCC interactive communications for both experimental licensing and waiver request submission and FCC approval. In response to the pursuit of an FCC waiver to allow for unlicensed operation, and after both in-depth analysis and laboratory testing, the system’s radar operating parameters were modified. System packaging and user interface was also modified after feedback from LE practitioners during NIJ Technology Working Group forums, tradeshows, and meetings with Los Angeles Sheriff's Department (LASD) personnel. The sensor and antennas were enclosed in a hermetically sealed box, weighing approximately 18 lbs. with size reductions (large bread box).

The final report has two major technical sections, 3.0 Technical Approach and 4.0 System Test Performance. These two section document all activities related to: 1) system design description, 2) compliance with FCC regulations, 3) system operation modifications related to FCC compliance and certification efforts, and 4) system performance test and evaluation. In addition to FCC discussions, two important technical program developmental efforts will be described in some detail: 1) antenna design and 2) user interface displays. The antenna design discussion documents the major change in antenna design as a direct result for system modification required to meet FCC compliance waiver and application. The second technical area, user interface display, is important, as it can be a source of user perceived device performance, operational value added, and successful LE field operator acceptance and use.

3.0 Technical Approach

3.1 System Design Description

The radar sensor hardware and data acquisition and signal processing software used to implement the prototype portable imaging system has benefited from seven years of government development and AKELA internal investment. It is a stepped CW system operating over a frequency range of 500 MHz to 2 GHz, has fourteen user selectable hopping rates that vary from 20 to 90,000 frequency points per second, and has a nominal power output mid band of 50 mW (17 dBm). System operating parameters are all controlled by the operator through the radar control software which includes provisions for data storage and playback and an open interface allowing users to develop, test, and operate special signal processing algorithms optimized to user selected radar system operating parameters. The radar and its enclosure weigh 0.5 kg (1.1 lb) and measure 10.8 cm (4.25 in) wide, 19 cm (7.5 in) long, and 3.8 cm (1.5 in) high. Communication with the radar control program is accomplished over a 100 Base T Ethernet connection. It has demonstrated an MTBF of 150,000 hours.

The modular nature of the radar design has allowed it to be configured into a variety of system implementations. Figure 1 shows a composite set of photographs of vehicle, robot, and small systems that have been configured using the radar. Each was assembled using the common, low power and low cost radar module shown in the center of the Figure. The maximum range of each system is a function of configuration, with the large vehicle mounted system having demonstrated the capability to detect and locate a stationary person in a concrete block building at a distance of 100 m (328 ft.). This distance is greater than most law enforcement requirements and the cost of the system used to achieve it is out of the affordability range of most LE agencies.

This AKELA radar module has been used to implement the current NIJ AKELA ASTIR prototype portable system for law enforcement as shown previously in Figure 1. A special antenna switch interface board was developed to allow the radar to operate with an initial array of four planar Vivaldi antennas in a MIMO mode. Each of the antennas can act as a transmitter or receiver but just a single pair is active at a time. In practice the antenna array is scanned end to end sequentially through all of the transmit/receive antenna pairs with a complete frequency sweep taken for each antenna pair. The result of scanning the array is a set of data from each antenna pair that produces a high-range-resolution profile of all the scatterers in the field of view of each pair used to perform an image reconstruction of the illuminated scene. A complete image frame is the image constructed from the data associated with scanning through all the transmit/receive pairs in the array a single time.

The prototype system shown in Figure 2 weighs 7.7 kg (18 lb.), is a totally integrated hermetically sealed package that produces images at 4 frames per second, detects targets through a 20 cm (8 in) thick concrete block wall up to a range of 30 m (98 ft), and is controlled by hard wired Ethernet or wireless radio to allow remote deployment.

3.2 Hardware and Software Development

Modifications to the system's operating parameters were made to improve the likelihood of FCC certification of the system. The main change was an adjustment of the system's operating frequency range from 500 – 1000 MHz to 3100 MHz – 3500 MHz. To allow the radar to operate over the higher frequency range, modifications were made to the radar hardware. Initially, temporary changes were made to the hardware to allow for a quick assessment of the performance impacts of the changes. However, subsequent to assessment, the parameters were finalized. This allowed AKELA to optimize the system components for the final operating parameters. Additionally, based on feedback from LASD officers, efforts were made to improve the software detection and display algorithms. The table in Figure 3 summarizes major hardware and software tasks and associated activities conducted during the NIJ RRA effort.

Objective	Activity	Results
System hardware modifications	Update radar hardware to optimize performance for final operating parameters	• Modifications resulted in significant improvement in noise reduction
	Replacement of system antennas (Vivaldi to Adv. Horn)	• Replacement antennas resulted in an 8 dB improvement in system's signal-to-noise performance
System software modifications	Improvements to motion detection algorithms	• Modifications to the detection algorithms resulted in a 10% improvement in detection accuracy
	Improvements to image thresholding and display	• Automatic threshold algorithm for imaging implemented • Improved display of detection results

Figure 3 Summaries of Technical Activities and Results

In pursuit of FCC compliance, a number of system operating conditions were reassessed. The assessment identified components that would require radar hardware modifications to allow for a wide range of options to be assessed. The trade-off for this flexibility was that overall performance was diminished. However, following the finalization of the operating parameters for the FCC waiver, AKELA was able to finalize the modifications to the radar hardware, and in the process, optimize performance for the specific operating parameters that were specified in the FCC waiver request. The optimization primarily involved the replacement of selected RF components initially selected for specific operating parameters of the baseline (lower frequency) radar to components more applicable to higher frequency operating parameters. Additionally, with the ever changing RF electronic component performance improvements, it provided an opportunity to upgrade sensor hardware. The result of the changes was an approximate 9 dB improvement in noise performance.

Initially, Vivaldi antennas were used for the higher frequency system prototype, due to their broadband characteristics, and size. However, upon finalization of the system operating specifications, standard gain horns were identified as providing superior performance in a number of key areas, while still meeting size, weight, and cost requirements. The key areas of improvement are antenna isolation, beamwidth (the angle between the half-power (-3dB) points of the main lobe), and side and back lobes.

The Vivaldi antennas suffered from poor isolation, limiting the SNR performance of the system. Ideally the largest signal a system detects will be that of a target; however, due to the poor isolation between the Vivaldi antennas, the largest signal source was the direct path signal between the antennas. This limited the system's SNR performance due to necessity that the receiver gain amplifier operate at lower power to compensate for the large direct path signal. The isolation between the standard gain horns is an 8 dB improvement over the isolation of the Vivaldi. This improvement in isolation translates directly into an 8 dB improvement in SNR performance due to increased gain applied in the receive path.

In addition to improved isolation, the standard gain horns also have a wider beamwidth than the Vivaldis. This is important for making detections at close proximity. The beamwidth of the Vivaldis antennas was approximately 25 degrees. The narrow beamwidth of the Vivaldis limited the area of detection at close range. By comparison, the standard gain horns have a beamwidth of approximately 55 degrees, more than doubling the effective detection area of the system. A diagram showing the increase in coverage area for the close range detections is shown in Figure 4. Typically, the beamwidth of an antenna is inversely proportional to the gain of the antenna. However, the gain of the standard gain horns and Vivaldis are essentially equivalent at 11 dBi and 10 dBi, respectively. The standard gain horns are able to have twice the beamwidth, while having the same gain due to their superior efficiency (A measure of the electrical losses that occur throughout the antenna).

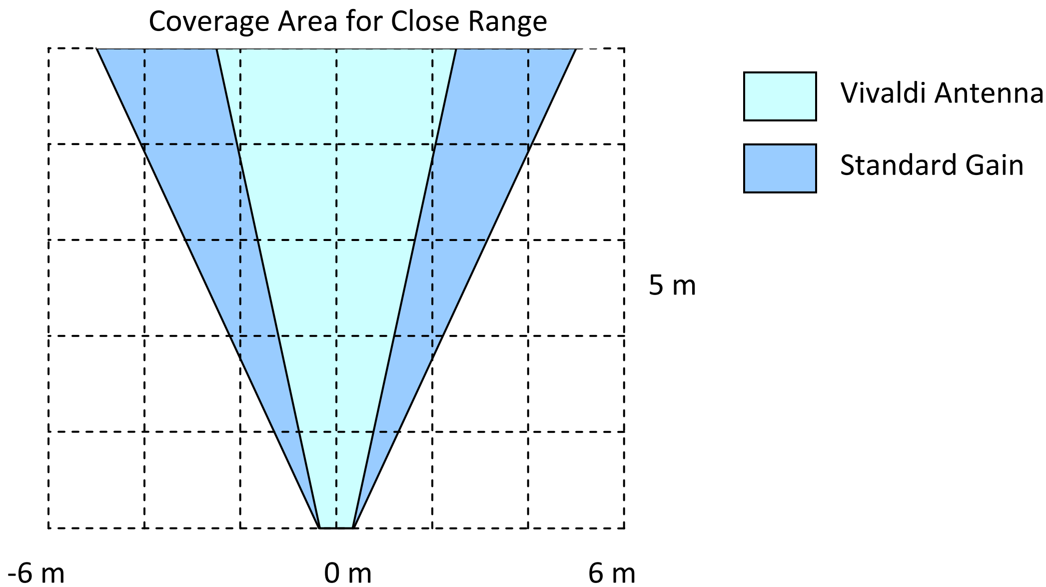


Figure 4 – Comparison of detection coverage area for two antenna models

The replacement of the Vivaldi with the horn antennas directly reduced size of the side and back lobes. For the law enforcement application of through the wall surveillance, it is important to accurately determine the number and location of detected individuals. The size of the lobes is critical as large lobes can cause targets adjacent or behind a system to appear as if they are in front of this system due to radar image formation. Radar images are formed by mapping a collection of range profiles onto an image map. For each range bin in a range profile, there is an elliptical band of cells that the range bin maps to in the image map. By summing a set of radar images from non-coincident antenna combinations the location of a target becomes apparent from the intersection of the elliptical bands from each image in the set. For the ASTIR system, the elliptical bands actually produce two intersection points; one at the location of the real target, and another directly opposite in range of the real target. Figure 5 shows an example of how the ellipsoid bands from the range profiles work to generate a real and mirror target. In the figure, the colored lines represent the ellipsoid for a given target range, with a target present in front of the system off to the left. For normal use of the system, the second mirror target produced from a target in front of the system can be ignored since users are only looking at the area in front of the system. However, if there is a significantly large target behind the system, that target's mirror will appear as if it is in front of the system. The issue is slightly mitigated since the system's antennas have high directivity, with all lobes greater than 20 dB down from the main lobe, resulting in the vast majority of the signals propagating forward. For the application of detecting individuals through walls though, a target behind the system with an unobstructed signal path from the system has an advantage over a target that is inside of a building. Signals from a target in front of the system, inside a building, have to travel through the building walls, which may attenuate the signals significantly. This can result in a target in front of the system actually having similar signal strength to one behind the system. Additionally, this situation is more difficult in the case that a target behind the system is either closer than a target in front of the system, or is significantly larger. In this case, the target from behind the system can look just as large as the target in front, if not larger, and may show up in the radar image as if it is inside the building. Given issue criticality, any decrease in the size of the lobes is important, and the standard gain horn's lobes are approximately 3 dB lower on average than those for the Vivaldis.

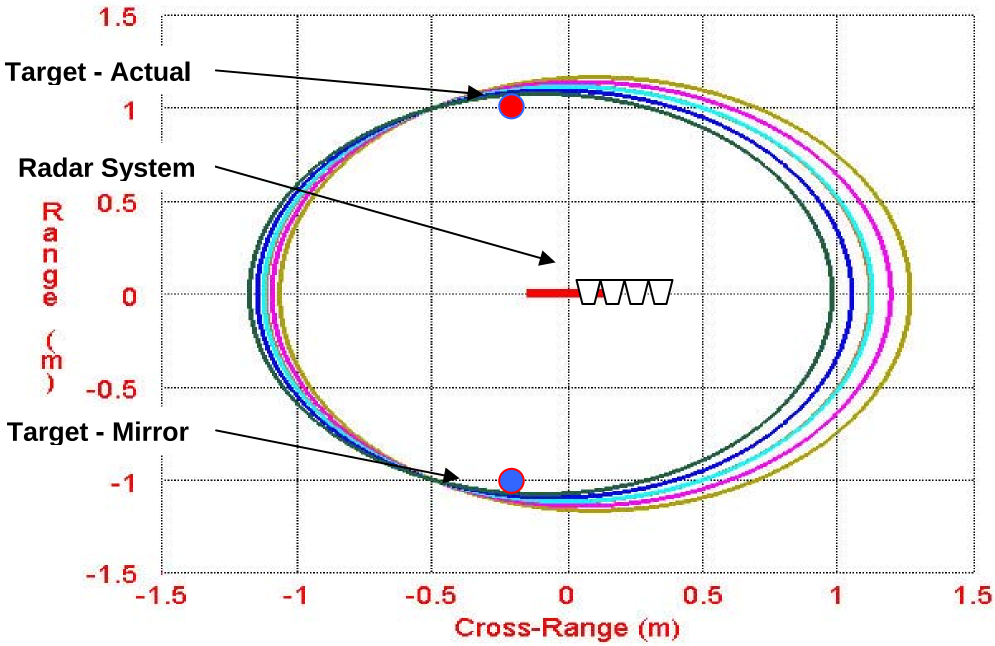


Figure 5 - Example image reconstruction with real and mirror target

After demonstrating the ASTIR system to LASD personnel, their feedback reemphasized the importance of the system to provide accurate, reliable results, and results easily interpreted by LE operators. To address this feedback, AKELA focused on improving the accuracy and reliability of the detection algorithms, improving the radar image thresholding and scaling algorithms to decrease false detections, and modifying the system display to improve overall readability of results.

The ASTIR algorithms locate individuals by detecting movement within the area of interest specified by the user. To detect the movement of individuals, there are two motion types that require detection. The first type is large motions, such as an individual walking or running through a surveillance area. The second is small motions, such as a stationary individual's breathing or other involuntary bodily motion. Different software algorithms are required for detection of these two motion types. This is due to the range resolution of the system which is approximately 0.4 meters (Range resolution = speed of light / (2 x bandwidth). For large motions, an individual will move across range cells between the capturing of successive radar images, while for small motions, an individual will stay in a single range cell between successive cycles of the radar.

The initial AKELA baseline algorithm used for detecting large motions was a differencing algorithm. The algorithm took two consecutive image images, and subtracted the first image from the second. Where there were no changes in the scene, the images would subtract down to noise; however, where there was a change, there would be a difference, causing a peak to form at the location of the change. The initial algorithm for detecting small motions also used the difference between images of the scene over time. However, for small motions, the movement of an individual between successive images would not be large enough to produce a difference that would likely be detectable. To improve the chance of detecting the small motions of a stationary individual, the algorithm attempts to detect the involuntary breathing motion of individuals. Breathing motion is detected by differencing images that are offset in time such that the displacement of an individual's chest is maximal between the images. For example, the average person breathes at a rate of 15 breathes per minute. This rate translates to one complete breath cycle every 4 seconds. To maximize the difference between images, an offset of half of 4 seconds (2 seconds) would be used to correspond to the time for an individual(s) chest to more from its more inward position to its most outward position, and vice versa. To accommodate the range of breathing rates an individual may have, a range of offsets are calculated for breathing rates from 12 – 30 breaths per minute, corresponding ranges for a person who is at rest to a person who is breathing rapidly. The images that fall within the range of offsets are averaged, and differenced with the current image to provide the detection result. In effect, this is a band pass filter, with the algorithm filtering out movements that do not have an oscillating component of approximately 0.2 Hz to 0.5 Hz (corresponding to 12 – 30 breaths per minute).

A number of software modifications to the baseline were assessed to improve the accuracy of the initial algorithms. The first modification that was assessed was cross-correlating instead of differencing images. The cross-correlation method relied on the fact that area of the image where there was no change over time would strongly correlate, while areas with change would not strongly correlate. Consequently, in the resulting image, the imaginary part of image cells would be small where there was no change, and would be large where there was change. By removing the real parts, and leaving only the imaginary parts of the image, it was suggested that motion could be detected. Unfortunately, due to signal noise degrading the cross-correlation results, the algorithm had poorer performance than the initial algorithms and was not selected for further investigation.

Another modification that was evaluated was how the images were differenced in the small motion algorithm. Instead of differencing the current image with the average of a set of images offset in time, the algorithm was modified to difference the current image from each image in the set of time offset images, and then summing the differences. It was determined that by averaging the set of images it was averaging the differences between the set of image and thus was suppressing detection. By summing the differenced images, the algorithm is additive and not suppressive, on differences, maximizing the possible capture small motions of individuals. On average, this modification improves the detection accuracy by approximately 10% over the initial baseline algorithm implementation.

In addition to modifying the initial algorithms, alternative algorithms were identified that had potential to improve the accuracy of the system. The most promising algorithms were a set which sought to extract discrete components from the radar data for the two kinds of motion using Doppler. By performing a 2D FFT on a set of radar scans over time, a set of range profiles corresponding to different ranges of Doppler frequency is formed. Large motions were detected by differencing static background, extracted from the range profiles corresponding to a Doppler frequency of 0 Hz, between scans. For small motions, range profiles corresponding to the oscillating frequencies of individuals were summed. In some cases these algorithms provided improved accuracy for detecting both large and small motions; however, the accuracy of the algorithms suffered when the movement of the individual(s) was not in-line with the orientation of the system. Additionally, the algorithms were computationally intensive limiting their application to real-time operation on low power computer systems.

To further improve the accuracy and reliability of the detection, modifications to the scaling and thresholding of the images were assessed. Previously, the scaling and thresholding factors for the image display were manually set by the operator. This was sufficient for a scene where there was little change over time. For dynamic scenes, however, where individuals often entered and exited the area of interest or multiple individuals in the area, there was the potential that an operator would be unable to easily select optimal settings for the rapidly changing scene. Additionally, in dynamic scenes, there was a propensity for the system to provide false positives when a target signal's intensity decreased or the target individual exited the area. This was caused by the inability of the image threshold to adjust to rapid changes in image characteristics. The image threshold displayed the full peak of a target signal, but when the intensity decreased or the target left the area, the threshold would not adjust for the lower maximum image intensity, allowing image peaks resulting from noise signals to appear as real targets. To improve this, an algorithm was developed to dynamically perform statistical analysis of each image to determine the appropriate threshold and not display noise signals. The automatic threshold algorithm currently calculates the mean and standard deviation of intensity of the image and thresholds the images to not display parts of the image that have an intensity that is less than the mean intensity plus three times the standard deviation. Modifications to the current threshold algorithm and additional algorithms will be evaluated based on feedback from evaluation by LE User tests.

One final assessment to the ASTIR software was modifications to the radar image display. Previously, only results of a single detection algorithm could be displayed. Given that different algorithms are used to detect large and small motions, this interface restriction had a number of limitations. A significant issue was the difficulty for an operator to track multiple individuals if individuals were stationary while the others were moving, or track an individual if the individual went from stationary to moving, and vice versa. To address this issue, software was modified to display multiple detection algorithm results concurrently in separate windows. Post User evaluation, if the User displays are inadequate for LE requirements, AKELA will investigate methods to either overlay or combine the detection results in a single window display.

3.3 Data Processing and User Interface Display

A primary objective of the ASTIR user interface has been the development of software signal processing algorithms to provide accurate performance, and incorporate feedback gathered from LE operator evaluations. With continual LE User evaluations and feedback, additional development will occur incrementally on signal processing algorithms and LE operator software interface.

To improve the signal levels of detected objects, an algorithm was implemented to correct for group delay (frequency dependent signal delay variations). The group delay algorithm development leveraged similar concurrent AKELA DOD signal processing process efforts. The group delay correction algorithm improved the system's detection performance by correcting frequency dependent signal delay variations. The variations are due to signal delays due to the signal passing through the system's components, (e.g., amplifiers, filters, cables and antennas) with dependence on signal frequency. To correct for time distortion, the phase of the signal's frequency components are adjusted to align to a known fixed point. Corrected signals allow improved signal summation, increasing signal levels for detected objects. In laboratory tests, the algorithm increased the signal levels for detection by approximately 5%. The algorithm was implemented in the ASTIR software's signal processing pathway.

Additionally, updating the underlying signal processing algorithms required the control and display functionality of the system's software user interface to also be revised. A baseline custom interface for the software environment had previously been configured for LE evaluation. Subsequent LE feedback led to the identification of areas where the imaging system's processing and display functions could be optimized for LE user requirements. The revised system interface, shown in Figure 6, has been configured to four simplified menus, two basic control windows, and one processing display window. This configuration represents a reduction of menu items by approximately 90% and of selectable windows by 80%. This reduction was accomplished allowing a minimally trained operator to quickly and effectively operate the system, while maintaining non-vital configuration options hidden under menus and not overwhelming the operator during critical operations.

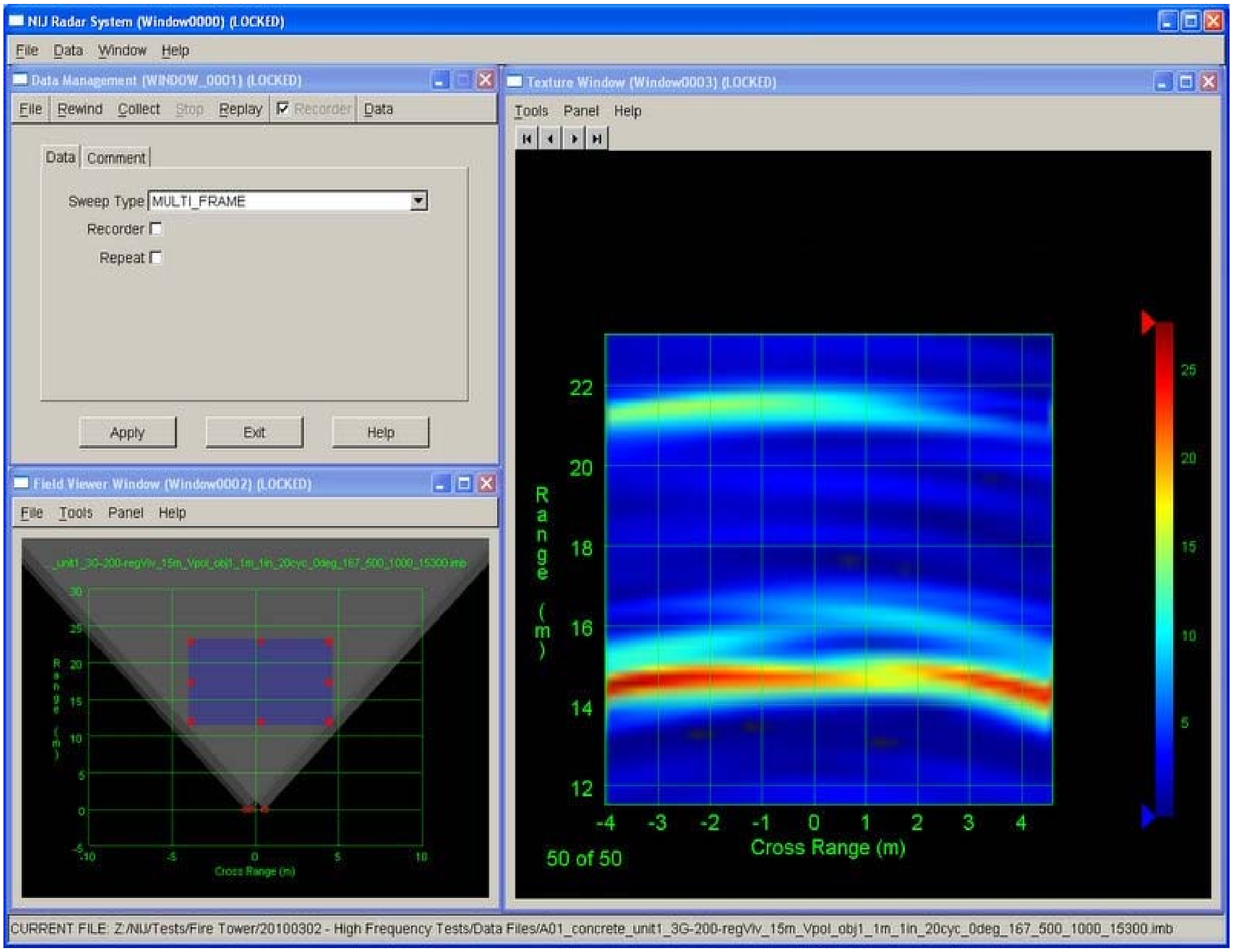
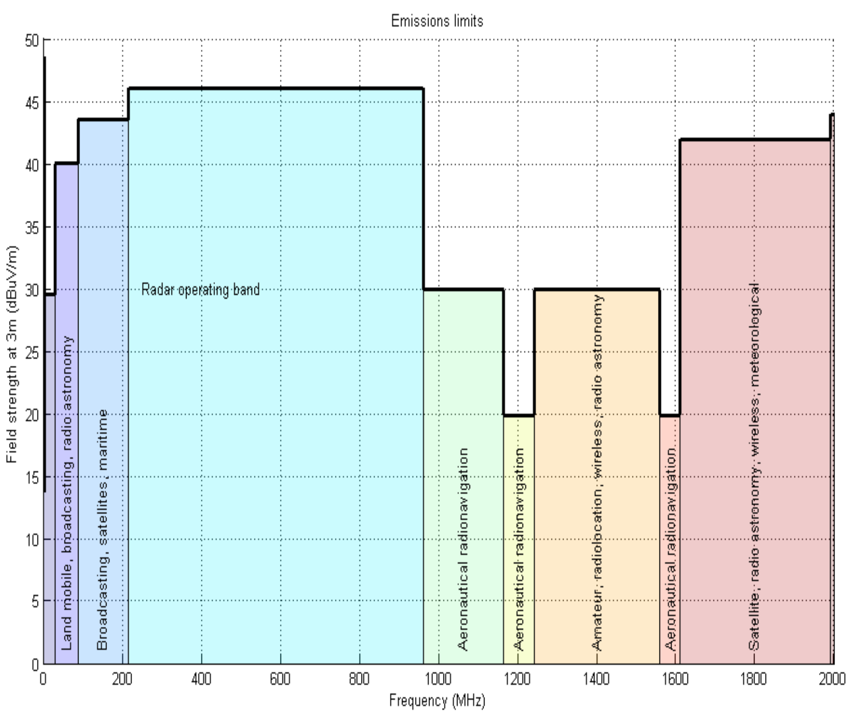


Figure 6 – ASTIR Graphical Interface for LE Operators

3.4 FCC Compliance Requirements

In order to make through-the-wall radar imaging available to Law Enforcement agencies it was necessary to obtain approval from the Federal Communications Commission (FCC). For unlicensed operation, the emission limits for ultra-wideband devices operating as through-the-wall imaging systems are specified under Part 15 Subpart F of the FCC rules. Figure 7 shows a chart and table of the allowable field strength and EIRP at frequencies from 1 MHz to 2 GHz for these systems. Unfortunately the ultra-wideband rules were not written considering frequency hopping devices. Methods used to test compliance require, for frequency hopping systems, that emission measurements be made with the device tuned to a fixed frequency. This negates the advantage of the hopping approach and for the NIJ AKELA baseline laboratory prototype system results in measured emissions 50 dB above the allowable limit for unlicensed operation. To operate as the baseline configuration required a FCC waiver to the rules allowing Law Enforcement applications.



47 CFR Part 15

Section 15.510: through-the-wall systems
Section 15.209: frequencies below 960 MHz

Freq (MHz)	EIRP (dBm)
1.705 – 30.0	-45.7
30 – 88	-55.2
88 – 216	-51.7
216 - 960	-49.2
960 – 1610	-46.3
1610 – 10600	-41.3
Above 10600	-51.3

Stricter conditions in GPS band

Freq (MHz)	EIRP (dBm)
1164 – 1240	-75.3
1559 – 1610	-75.3

47 CFR Part 90

Section 90.103: radio location service

Freq (MHz)	EIRP (dBm)
2900 – 3100	*
3100 – 3300	*
3300 – 3500	37.0 *
3500 – 3650	*

* shared use basis

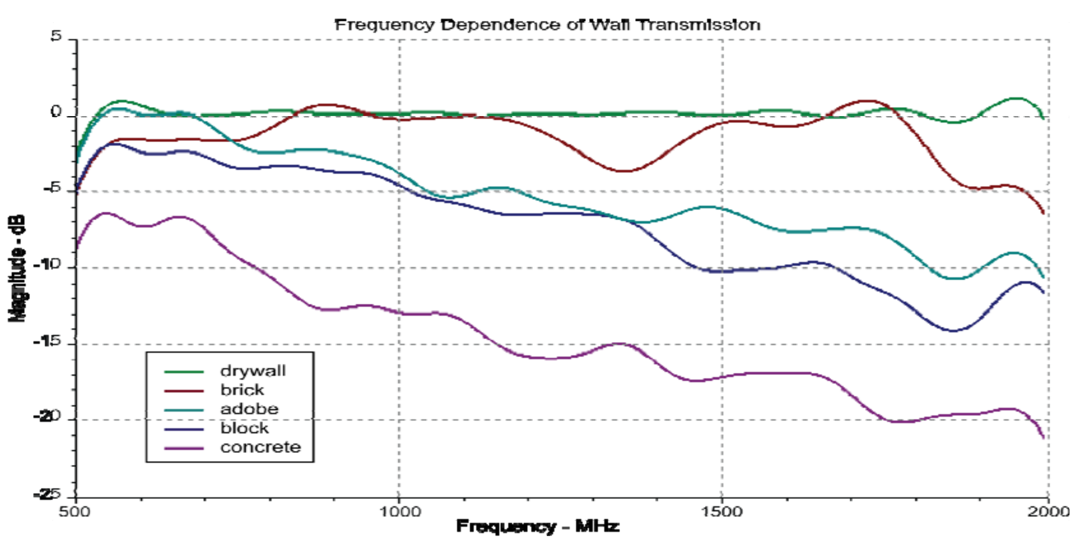
Figure 7 FCC Emissions Mask for Unlicensed Ultra-wide System Operation

To address risks associated with FCC compliance efforts, AKELA retained the legal services of a Washington, DC area law firm, Fletcher, Heald & Hildreth, with extensive experience with FCC compliance regulations. During the NIJ RRA effort the firm assisted in expediting the processing of AKELA's experimental license applications, allowing AKELA to initiate on-site evaluations with the Los Angeles Sheriff's Department (LASD). Additionally, the firm prepared a request for a waiver of FCC rules that currently prohibit the ASTIR system from being certified by the FCC for use by first responders and LE organizations.

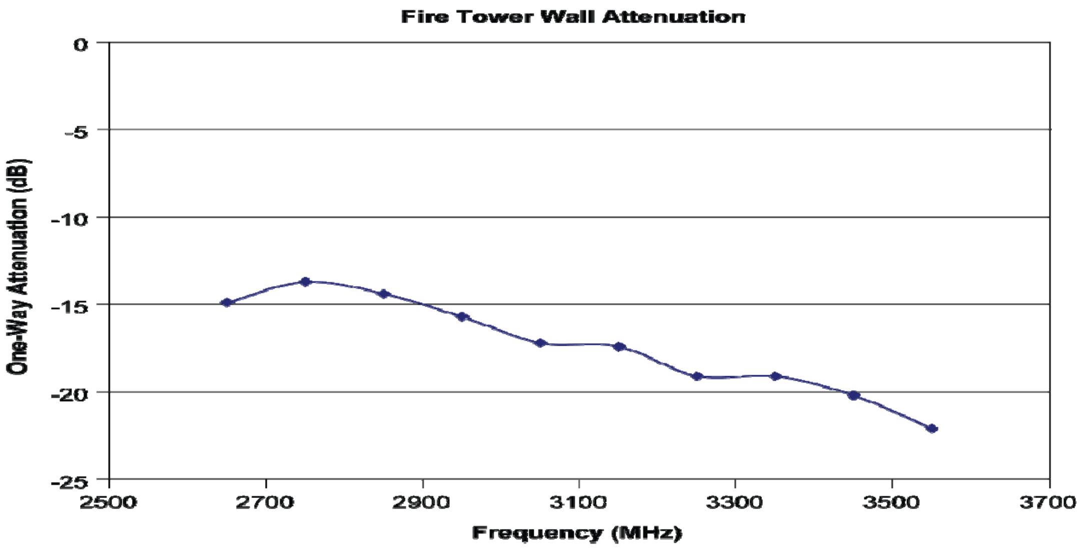
3.5 ASTIR FCC Compliance Analysis

Discussions with NIJ and FH&H (AKELA's retained law firm specializing in FCC compliance issues) resulted in two potential approaches to obtaining FCC approval for the prototype system. The first was to lower the system's emission power and submit a waiver for operation based on FCC rules for Ground Penetrating Radar (GPR) devices. The second was to modify the system's operational frequency band, moving to the higher frequency band between 2900 and 3600 MHz which is specifically allocated for radar devices. As can be seen from the table in Figure 10, the allowable EIRP is significantly greater than for the lower frequency, unlicensed operation. As with the lower portion of the frequency spectrum, there are no rules for frequency hopping devices so a waiver for operation in this mode for law enforcement application is necessary.

Deciding which path to FCC approval required consideration of both technical and practical issues. The greatest concern, moving to a higher frequency band, is increase in attenuation associated with building structural walls of interest. Figure 8 illustrates a comparison of frequency dependent attenuation of 30 cm (12 in) thick steel reinforced concrete, adobe, concrete block, brick and drywall walls over the band from 500 MHz to 2 GHz [Hunt, A., "Image formation Through Walls Using Distributed Radar Sensor Network", Proceedings of the SPIE, Defense and Security 2005, 28 March 2005.], and the attenuation of a 26.7 cm (10.5 in) thick steel reinforced concrete wall over the band from 2600 to 3600 MHz The higher frequency attenuation measurements were made on the walls of the SB fire tower.



Wall attenuation between 500 and 2000 MHz for 12" thick walls

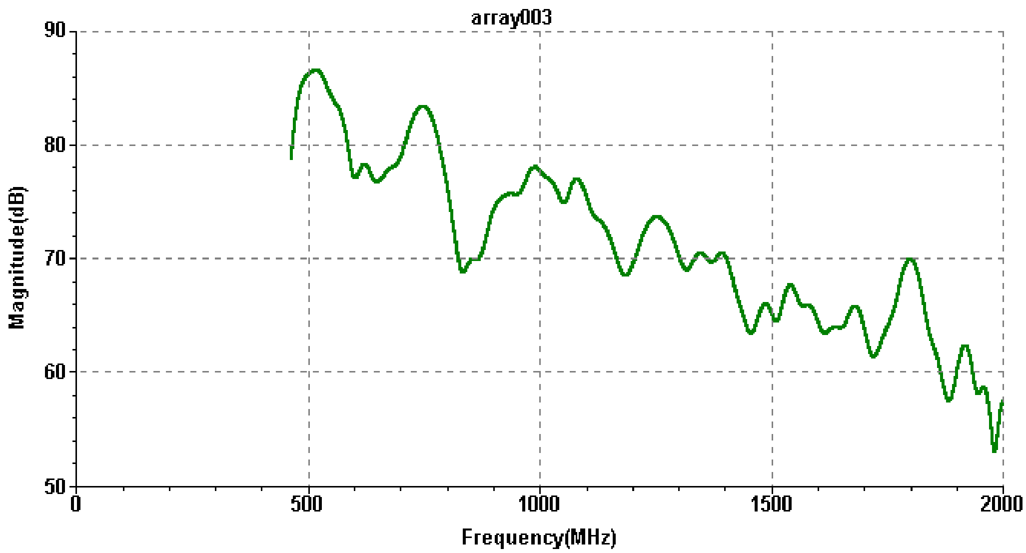


Wall attenuation between 2600 and 3600 MHz for 10.5" thick walls

Figure 8 Frequency Dependent Attenuation for Wall Types of Interest

At higher frequencies, isolation between antennas in the imaging array improves, since the direct path signal between transmit and receive antennas determines the top of the radar receiver's dynamic range. Improving isolation between antennas allows the use of either greater transmit power or additional receiver gain. Figure 9 shows the frequency dependent isolation for a typical Vivaldi type antenna similar to that used in the initial NIJ AKELA laboratory baseline prototype system.

Using this information, trade-off analyses were conducted to estimate prototype system performance for different operational frequency regions, with results shown in Figure 10. In the figure, there are three columns in the analysis; the middle column is the baseline prototype system operating over the 500 MHz to 2 GHz range. The first column is the low frequency case where the bandwidth is restricted by FCC regulations to the 500 MHz to 960 MHz range. Even though it is likely that the prototype system transmit power would have to be lowered in this regime, it was kept at a constant level of the current system to facilitate comparison. The last column is for system operation in the higher frequency band.



Frequency dependence of antenna coupling

Figure 9 Frequency dependent isolation of a Vivaldi antenna

	low, limited (500 - 960 MHz)	low (500 - 2000 MHz)	high (2900 - 3400 MHz)
Tx Power - dBm	18	18	15
Tx Antenna Gain - dB	2.7	7.3	13.5
Rx Antenna Gain - dB	2.7	7.3	13.5
2 Way Wall Attenuation - dB	-15.8	-21.9	-35
RCS	0	0	0
Antenna Switch - dB	0	0	-2
Noise Figure Improvement (allowed by antenna isolation) - dB	0	0	5
Relative Performance	7.6	10.7	10

Figure 10 System Performance Comparisons

The wall attenuation values in each column were taken at the middle of the frequency band of operation for each configuration. Values of the antenna gain are similarly taken at the mid band operating point. Radar cross section of an individual was treated as essentially constant over the entire frequency band of interest [Traian Dogaru, Lam Nguyen, and Calvin Le, "Computer Models of the Human Body Signature for Sensing Through the Wall Radar Applications",ARL-

TR-4290, September 2007]. Operation at the highest frequency band incurs a penalty because of higher frequency dependent loss in the antenna array interface switch but also benefits from the higher isolation between antennas. The results of the technical analysis indicate that the higher frequency operation should perform comparably to the existing prototype system while the lower frequency (more limited bandwidth system) performs more poorly.

The practical issues associated with which path to pursue revolve primarily around the likelihood of obtaining FCC approval. A major factor to consider is that in the higher frequency band proposed for radar operation there are multiple coincident bands, specifically allocated for radar devices with higher emission limits and fewer incumbent users than the lower frequency band. Figure 11 shows an analysis of major U.S. spectrum allocations from 2700 to 4200 MHz, and the likelihood of objections for FCC waiver approval. The spectrum allocation review indicated that operation in the 3100 – 3300 MHz and 3300 – 3500 MHz band would be more likely to be approved by the FCC, providing 400 MHz of uninterrupted bandwidth for the system to operate. In contrast, the lower frequency band identified for operation of the device under GPR rules has a large number of major primary users, and lower emission limits, which would require a reduction in radar transmit power, and subsequently result in degradation of system performance.

Band (MHz)	Non-Federal	Federal	Remarks
2700-2900	airport surveillance weather radar	AIRPORT RADARS AIRCRAFT TRANSPONDERS WEATHER RADAR military radar radio astronomy	not recommended (FAA objection likely)
2900-3100	MARITIME RADIONAVIGATION radar	MARITIME RADIONAVIGATION RADAR (MILITARY)	approval possible (may have to protect coasts and waterways and or military radar sites)
3100-3300	radar earth exploration - satellite space research	RADAR earth exploration - satellite space research	approval likely
3300-3500	radar amateur	RADAR	
3500-3600	radar	RADAR AERONAUTICAL NAVIGATION	approval possible (may have to protect a few satellite earth stations)
3600-3650	LIMITED SATELLITE DOWNLINK radar		
3650-3700	FIXED AND MOBILE INTERNET DELIVERY		not recommended (Internet provider and satellite opposition likely to be effective)
3700-4200	SATELLITE DOWNLINK		

Figure 11 Incumbent Users in High Frequency Band

Figure 12 summarizes the advantages and disadvantages of operating in the two different frequency regions. Because there appears to be no technical performance penalty for operating in the higher frequency band and there are both operational and practical advantages for doing so, development activities were refocused on implementation of a higher frequency system.

Low Frequency Operation (500 - 608 MHz, 614 - 960 MHz) FCC 47 CFR Part 15

Advantages	Disadvantages
• Lower building material attenuation	• Reduced power output to meet FCC requirements • Larger antennas, wider aperture • Long time to and low probability of FCC approval • Narrower bandwidth available • High levels of interference

High Frequency Operation (2900 - 3500 MHz) FCC 47 CFR Part 90

Advantages	Disadvantages
• Higher power output likely permitted by FCC • Smaller antennas, smaller array aperture • Short time to, and high likelihood of FCC approval • More bandwidth available • Smaller, lighter system possible • Lower levels of interference	• Higher building material attenuation • More sensitivity needed

Figure 12 Comparisons of Low and High Frequency Band Advantages and Disadvantages

Figure 13 shows a photograph of the prototype high frequency system and a display of an individual behind a wall 19 m from device. In Figure 14, a table compares the high frequency system size and weight to the low frequency prototype system. The improved antenna isolation at higher frequencies has allowed the antennas to be spaced more closely together and the entire system to be repackaged into a sealed unit half the size of the original prototype system. A waiver for operation of this unit was submitted and approved by the FCC, and final FCC certification test planning is in progress.

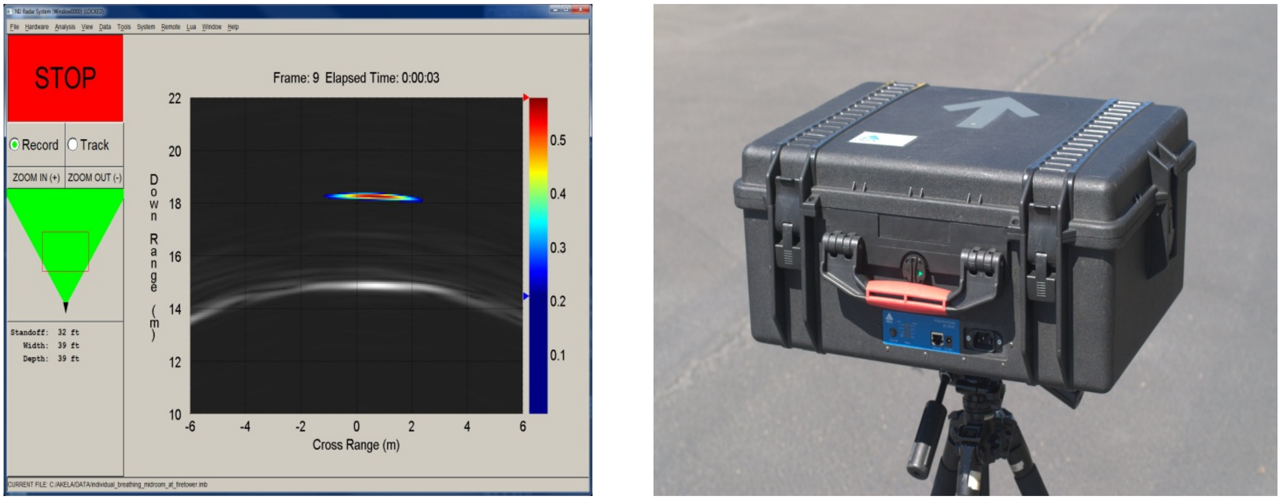


Figure 13 AKELA NIJ RRA Prototype High Frequency System and LE User Display

Feature	Low Frequency	High Frequency
Weight Size	17 lbs 54 X 15 X 5 inches	18 lbs 22 X 17 X 9 inches
Antenna Separation	16 inches	4 inches

Figure 14 High and Low Frequency Prototype System Comparison

4.0 System Test Performance

4.1 Human Subject Testing

On previous NIJ grant 2007-RG-CX-K016, AKELA had to accept a grant Special Condition that prohibited testing using human subjects. An Independent Review Board (IRB) was required to provide a determination as to the intervention or interaction with human test subjects and individual privacy violations. AKELA developed a mechanical flat plate reciprocal "breathing machine" to simulate chest involuntary movement. The breathing machine was used in both laboratory and the Santa Barbara Fire Tower testing.

AKELA had experience with military human testing, and presented this information to NIJ and eventually to an IRB as part of their evaluation. Under separate DOD contracts under DARPA sponsorship, the Army made an initial determination that the AKELA radar device did not involve research that obtained information about living individuals. Statements from their determination are included: "Requested review- - US Army Medical Research and Materiel Command (USAMRMC), Human Research Protection Office (HRPO) Applicability of human subjects protection regulations." "In accordance with 32 CFR 219.102(f), the subject ***"project is research not involving human subjects, as it does not involve living individuals about whom an investigator conducting research obtains data through intervention or interaction with the individual or identifiable private information. The project may proceed with no further requirement. . . . HRPO file will be closed".*** In parallel to this finding DARPA requested and received a waiver for human subject data to be taken in radar building data collection with the AKELA radar system.

Discussions were initiated with several academic and commercial groups that had IRB certification authority. These preliminary discussions concluded that the AKELA radar device interrogation of objects (humans, animals, and inanimate) objects did not constitute research involving information about living individuals (45 CFR 46.102(f). To meet NIJ grant testing requirements, several commercial vendors were evaluated, and Independent Research Consulting, Inc. (IRC), P.O. Box 170, San Anselmo, CA 94979-0170, Telephone: 415 485-0717, POC Dax Woods, was selected to conduct an IRB on AKELA's radar device for human subject testing. Their selection was based on references, timeliness of the determination response, and West Coast location. Prior to documentation submission, AKELA visited the IRC site and provided a background brief on the radar device and moving object imaging data taken in various field testing. At the interface meeting IRC provided a flow diagram illustrating the IRB procedure for Activity Research Involving Human Subjects Covered by 4 CFR parts 46. AKELA submitted the required documentation to IRC and the 4.06 form to NIJ for review prior to submission. IRC conducted an IRB and made a determination that the AKELA human subject testing is “research but does not involve obtaining information about living individuals (45 CRF 46.102(f)”. The IRC signed determination original and copy was forwarded to NIJ POC Dr. Frances Scott for NIJ review. NIJ accepted the findings and recommendation and lifted the Grant Special Conditions requirement.

4.2 System Testing

On the previous NIJ AKELA grant, an engineering prototype of the AKELA device (shown and described in Figure 1, Section 1.0) was evaluated and tested primarily in AKELA's laboratory. At the conclusion of the grant, to acquire performance data on more realistic operational structures, a firetower structure was selected to provide through the wall data on a complex multistory reinforced concrete structure. These laboratory and firetower tests were conducted using a breathing machine to simulate human subject breathing, as human subject testing had not been vetted or review by an Independent Review Board (IRB). The NIJ RRA effort performed system performance testing building on these tests, however, with human subjects replacing the breathing machine test configurations. For comparison purposes, previous breathing machine test results will presented along with human subject tests to provide comparison data.

4.2.1 Fire Tower Testing

To investigate the performance of the prototype standoff array radar system in real-world, complex environments, AKELA continued testing at the training facility of Santa Barbara City's Fire Department. As shown in Figure 15, the fire tower building consists of four floors, with an adjoining room on the first floor, and is 12.1 m (40 ft) wide and 6.1 m (20 ft) deep. Each story is 3.05 m (10 ft) high. The walls are 26.7 cm (10.5 in) thick, fluted on the outside, and constructed of solid poured concrete reinforced both vertically and horizontally with 1.3 cm (0.5 in) diameter #4 rebar. Vertical spacing of the rebar is 45.7 cm (18 in) on centers and horizontal spacing is 30.5 cm (12 in) on centers.

Figure 15 City of Santa Barbara Fire Tower Training Facilities

Figure 16 shows the experimental setup for data collection. The prototype system was placed on a tripod at a standoff distance of 15 m (49 ft) in front of the long side of the fire tower. The front metal door was closed during data collection. Also seen in the Figure are various clutter objects present on the first floor, as well as the metal staircase and piping that run through all four floors.

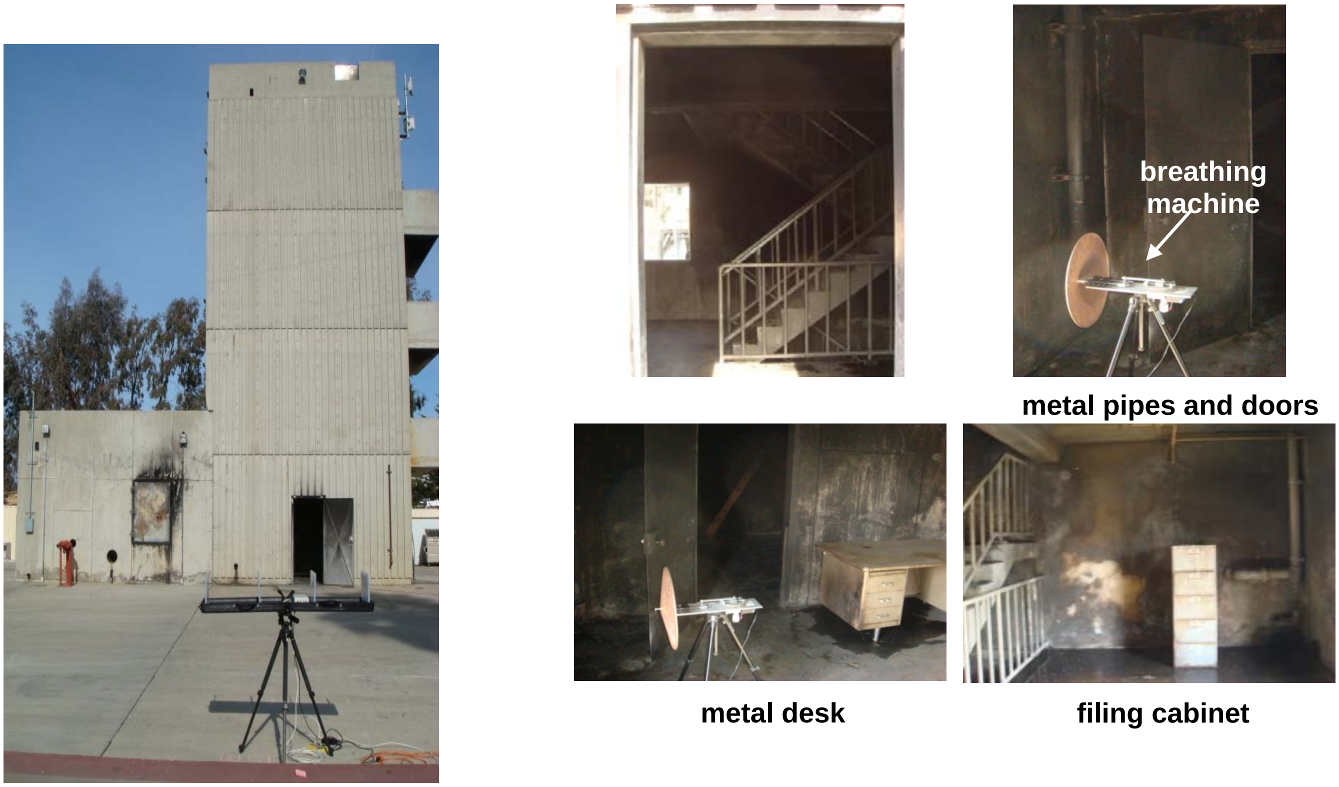


Figure 16 Performance Testing Experimental Setup

A set of tests using a breathing machine and human subjects were conducted on both the first and second floors of the fire tower. The breathing machine consists of a 0.43 m (17 in) diameter slightly convex metal plate attached to a linear bearing that is driven by an electric motor to produce a horizontal sinusoidal motion. Both amplitude and speed of the motion are variable. Typical settings for the testing were a total amplitude of 1.3 cm (0.5 in) and a period of 0.2 Hz. Figure 17 shows the real time system display from three tests with a single breathing machine placed at various locations inside a cluttered environment: 1) behind the font wall, 2) in the middle of the room, and 3) behind the front wall on the second floor. Each image shows static features of the scene in grey scale and the dynamic (moving) features in color. The breathing machine was successfully detected in each test.

A similar set of tests was performed with an individual. Figure 18 shows the results of these tests. Three of the tests duplicated the conditions of the breathing machine tests with the individual standing still on the first floor just behind the front wall and in the middle of the room, and on the second floor just behind the front wall. The last image in the figure is a single image frame from a test where the individual was walking around instead of standing still. The individual was successfully detected in all of the tests.

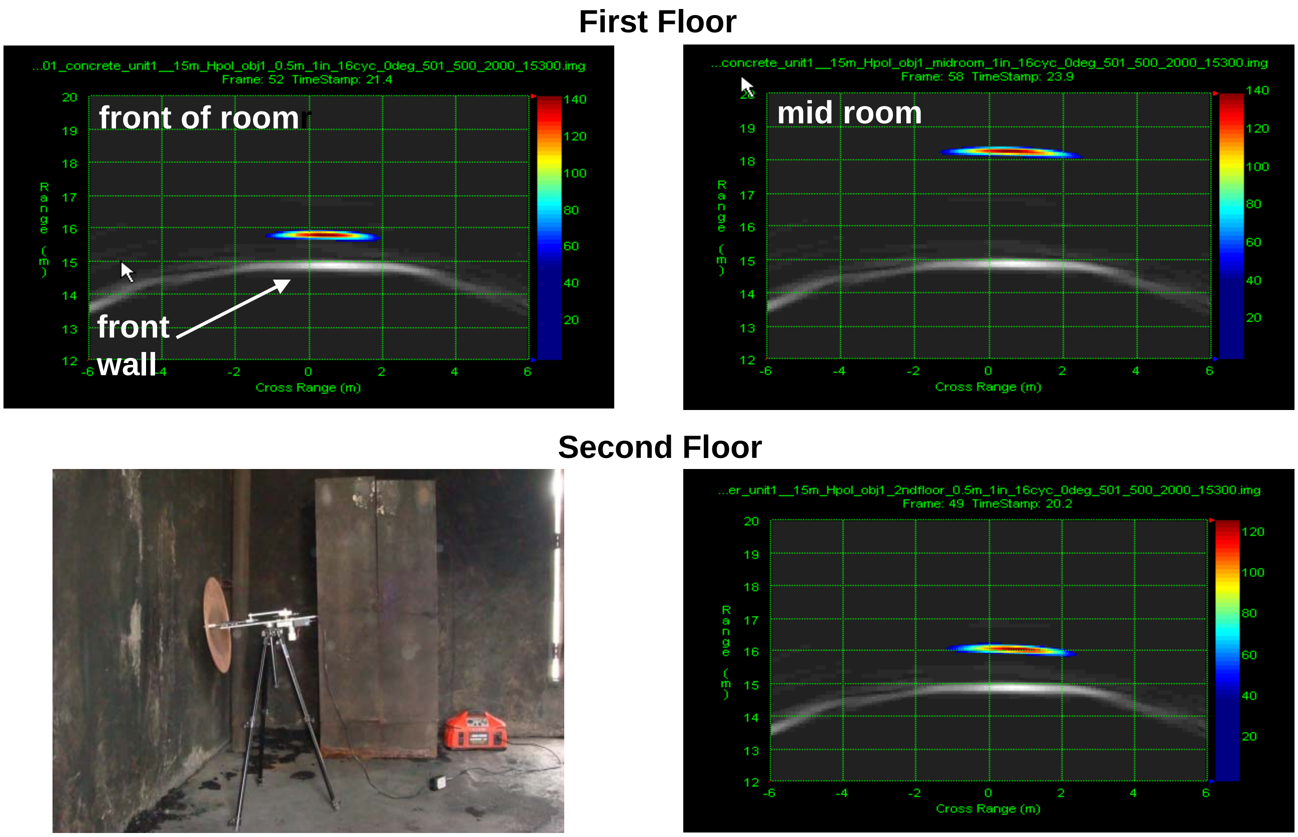


Figure 17 Breathing Machine Test Results

Being able to determine the path of motion of an individual is often important. A weighted moving average algorithm was implemented to track the peak value in the radar image as a function of time. The result is shown in Figure 19. To the left of the figure is the last single image frame in the sequence that was tracked. The right chart depicts the history of motion in range and cross range from the moving average algorithm. The algorithm used a persistence variable to allow the track history to be displayed over different lengths of time.

In order to determine sensitivity limits of the prototype system, tests was conducted with an individual standing on the other side of the fire tower while the system attempted detection. This constituted a very difficult case since the total one way thickness of reinforced concrete the system was sensing through was 0.53 m (21 in), the total standoff to the individual was 21 m (69 ft), and the movement associated with a stationary individual is quite small. Figure 20 shows both the test setup and the results. The person was successfully detected but is very near the noise floor of the system.

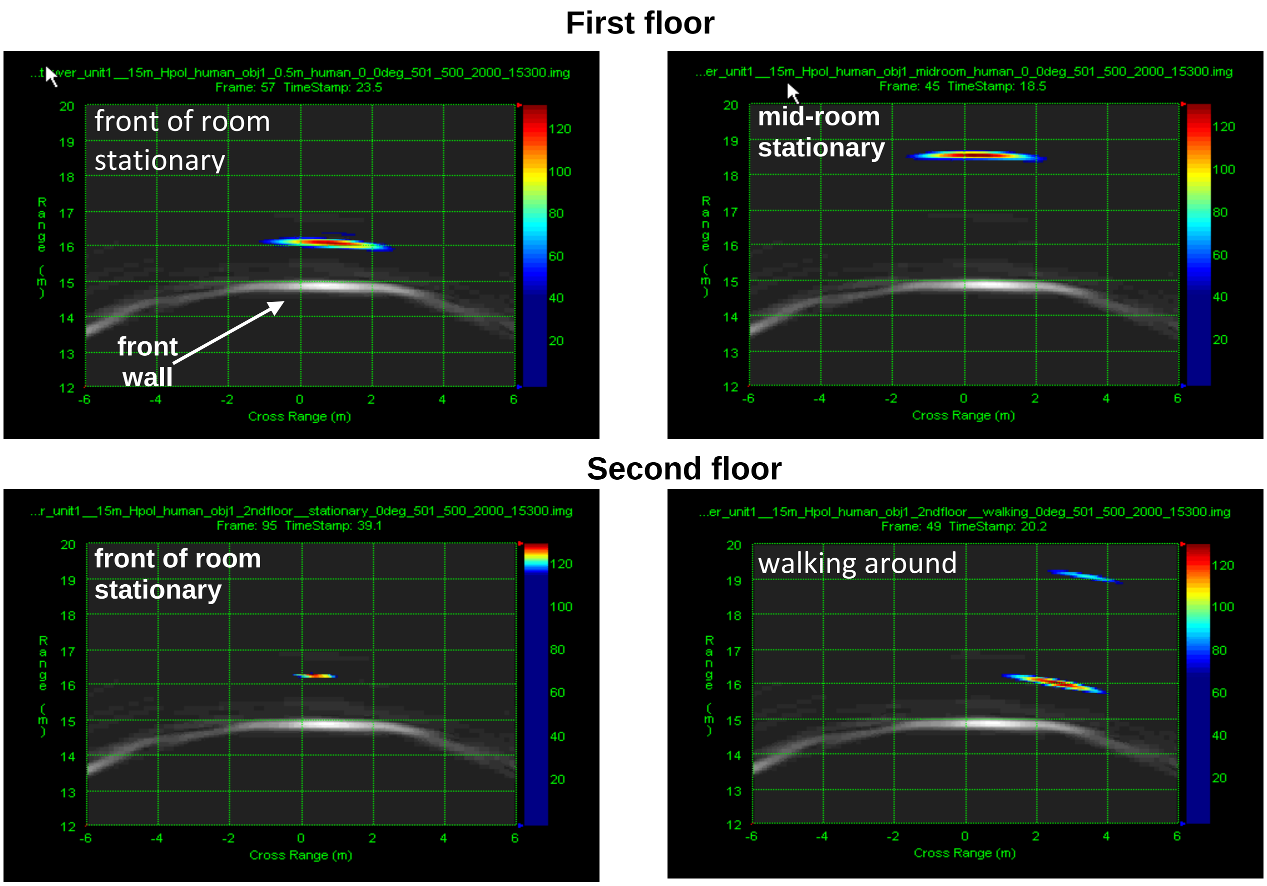


Figure 18 Human Subject Test Results

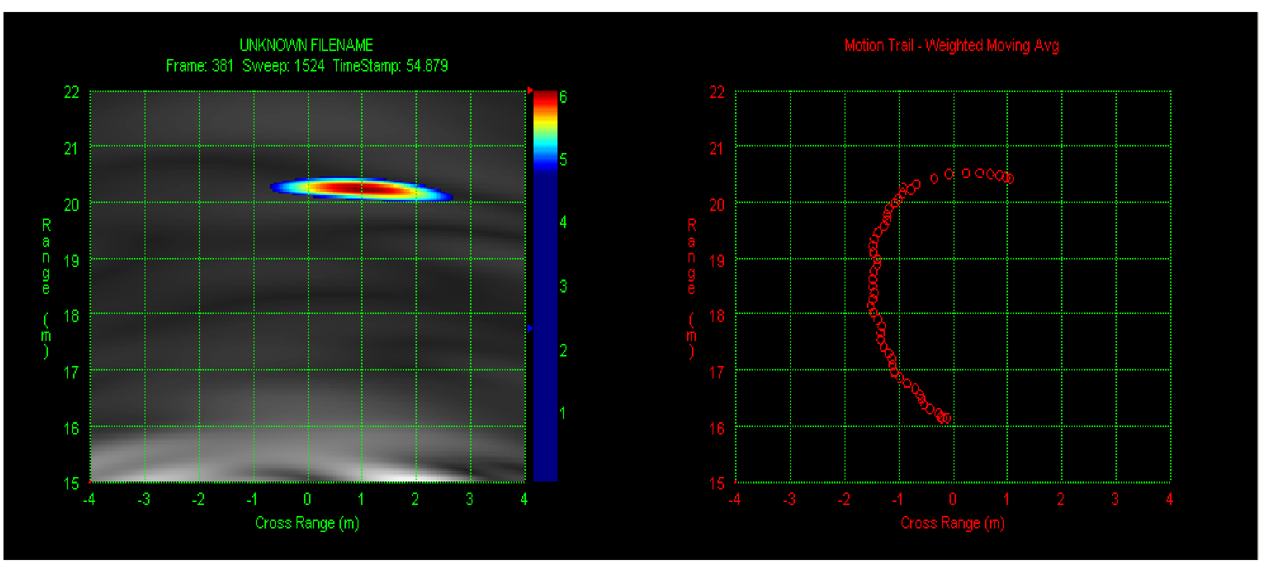
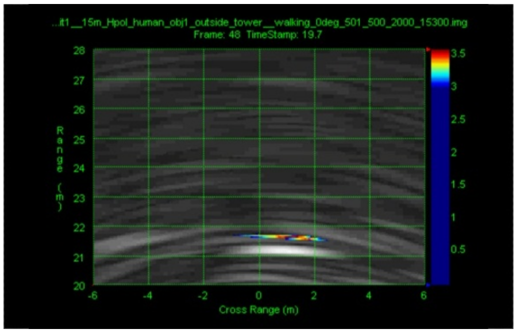


Figure 19 Human Subject Motion Detection and Tracking



standing outside tower, viewed through two walls

Figure 20 Stationary Human Detection Through 0.53 m of Steel Reinforced Concrete

Additional tests were performed that included using two breathing machines (one on each floor), placing the standoff array on top of a van, and imaging inside the fire tower with multiple arrays. In the tests with the breathing machines on both floors, both were successfully detected but since the standoff array has no vertical aperture, it was not possible to discriminate between the two machines. Two breathing machines on different floors separated by a sufficient range offset will appear as distinct detections in the reconstructed image. These tests were duplicated with human subjects providing similar results.

A final set of tests was performed to determine whether the use of multiple standoff arrays might improve imaging resolution and detection performance. For these tests a second array was placed on the east side of the fire tower and provided a view of the building orthogonal to that of the first unit. The experimental setup with two arrays is pictured in Figure 21. A person was standing inside the first floor room of the fire tower. As demonstrated in the figure, when radar returns from the two units are used to reconstruct an image over the area of interest, both exterior walls of the tower show up in the background (grey scale) of the image. The location of the person inside the building is more precisely defined, and the cross-range resolution appears improved. The results of the experiment are promising and indicate that the use of multiple standoff units may provide an advantage in some law enforcement applications as well as in mapping the interior of buildings. Throughout system performance testing of both laboratory and firetower, personnel movement (involuntary breathing) was more visible to detect than the breathing machine.

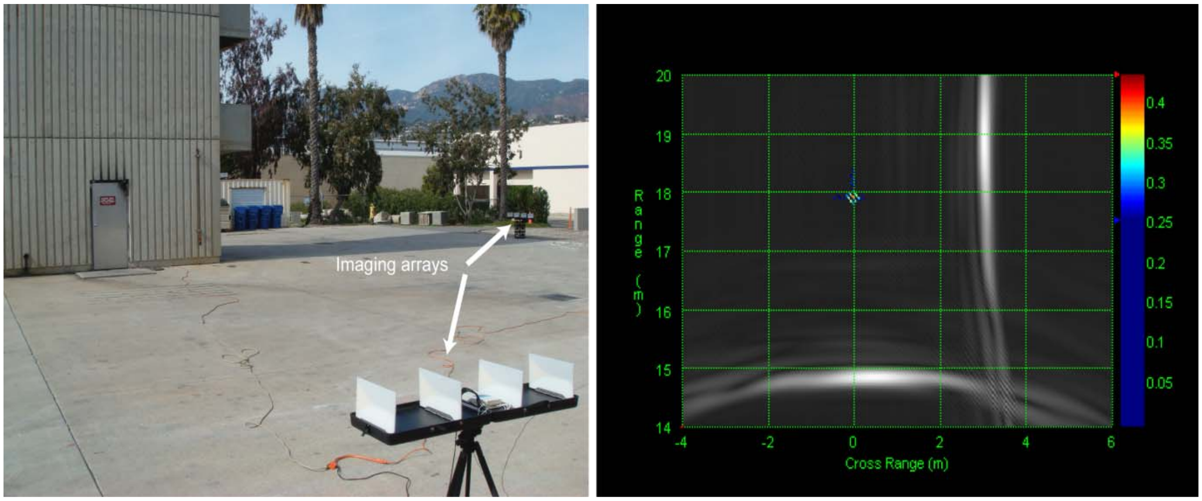


Figure 21 Target Detection Using Two Orthogonal Devices

4.2.2 Residential Home System Tests

System testing was performed using the high frequency radar system with standard gain horn antennas at a house in a residential area in Santa Barbara, California. Figure 22 depicts the overall layout of the house as well as the location of the radar system throughout this data collection. The system performance in detecting individuals at various locations in the house are also summarized and represented by icons overlaid on the same figure.

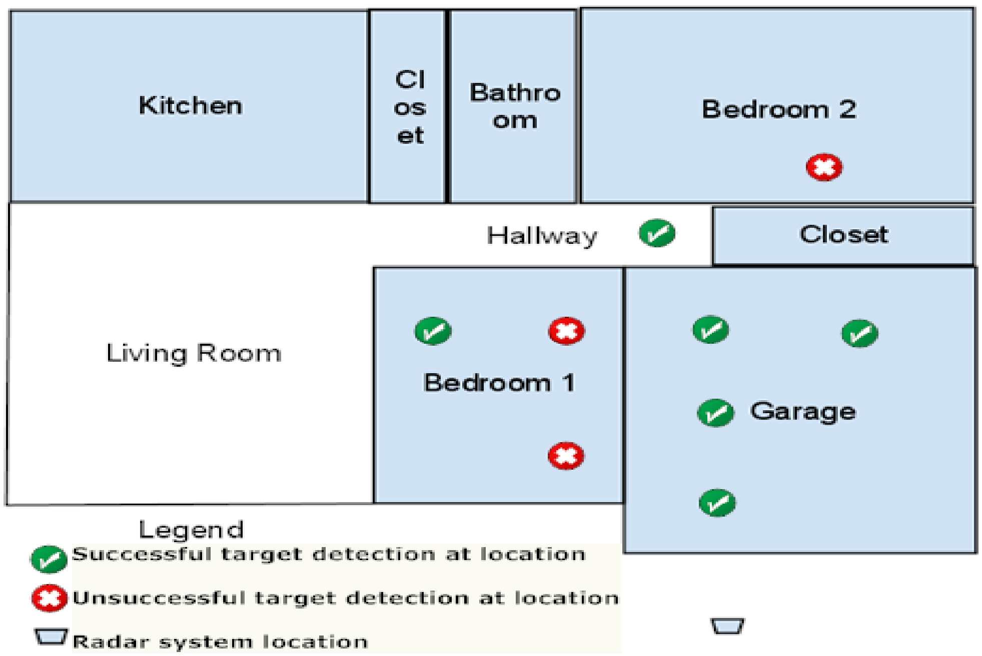


Figure 22 Test Site Diagram with Summary of Detection Results

The radar system was positioned in front of the garage, left of center of the garage door. This test location provided both unobstructed and obstructed views of locations around the garage. The test plan made use of different target locations including in the garage, the two bedrooms, as well as the hallway. These were chosen to assist in evaluating the effect on system performance when varying the number of walls, varying the distance to the target, the presence of clutter, and when the target is off axis.

Figure 23 shows the test setup with the garage door opened, revealing an interior with clutter (both metallic and non-metallic) present in the garage. Figure 24 shows the setup as the radar system testing is in progress, with garage door lowered. The blue tape on the garage door marks the center of the antenna system. Target locations in each of the rooms or hallway were also determined during test planning, and similarly marked with blue tape. During testing, a trihedral target was placed at each target location to provide a reference measurement; data files were then collected with a human target either walking or standing stationary, facing different directions with respect to the radar.

Figure 23 Radar System Location

Figure 24 House View (System Testing in Progress)

The data files collected at this house showed that the target was detectable at all locations in the garage, regardless of whether the individual was stationary or moving, and despite the presence of considerable amounts of metal clutter including refrigerators, motorcycles, workbenches and tools. A target in the hallway could also be detected. Figure 25 shows the different target locations in the garage, while Figure 26 shows examples of the significant clutter present.

Figure 25 (a) Reference Target Right of Garage (b) Target Location Markings in Garage

Figure 26 Clutter Presence in (a) Garage Center (b) Left Hand Side of Garage

By contrast, target detection in the two bedrooms proved to be significantly more difficult, due to the presence of clutter and multiple walls. Figure 27 shows the target locations in Bedroom 1 and Bedroom 2. The difficulties with detecting a human target in Bedroom 1 occurred primarily when the target locations were on the right hand side of the room. The geometry of the test setup means that the radar system has to "see" through the walls of the garage, with a full shelf of tools and metal objects and a mini-fridge, in order to detect targets on the right side of Bedroom 1. The difficulties with detection in Bedroom 2 were attributed to the significant clutter present at the front of the bedroom, which included clothes, a large dresser, and a metal safe.

Figure 27 (a) Target Locations in Bedroom 1 from Hallway (b) Target Location in Bedroom 2

While the system's ability to see into a single room in the presence of clutter has been demonstrated using detection results from the garage, it is evident that reliably detecting human targets through multiple rooms in a complex environment, such as an occupied house, maybe difficult. This is especially true if we're attempting to detect individuals in other rooms not located directly in front of the system, requiring detection at an angle to the system, through multiple walls and in the presence of clutter.

It should be noted that it was very windy on the test day, and the large palm tree next to the system position and bushes on either side were moving throughout the day. These could be detected in the absence of actual targets. This may cause some operator display interpretation confusion, especially to an inexperienced user of the system, whenever the human target has a small signal or no target present. However, when the human target signal strength is strong it dominates the display over any bush or tree movement.

4.3 LASD User Testing

Interactive discussions were conducted with the LASD over the course of the RRA NIJ effort. This interaction was primarily conducted at AKELA's on site facility. Device demonstrations and LE user feedback was accomplished with AKELA operators and LE personnel monitoring through the wall display signals. User testing and evaluation was delayed due to FCC experimental licensing approval restrictions and radar reconfiguration to be FCC compliance. In particular, the development of a test schedule of the AKELA NIJ radar system was directly dependent on LASD FCC experimental license approval. With the aid of FH&H, experimental licenses were combined and narrowly defined as to a specific location and area. Test planning continued, and when experimental licenses were finally approved, a series of calibration tests was conducted at the LASD training facility. In subsequent discussions with Special Enforcement Bureau (SEB) personnel, SEB unit commanders and potential user operators recommended that testing should be conducted at a training site that would represent greater realism in the types of structures that LASD SEB units encounter. Additionally, these units are the actual units used for SEB scenario training. With FCC waiver approval experimental licenses for the AKELA system are not necessary; however, LASD user evaluation is outside the scope and schedule of the completed RRA NIJ effort. The LASD user evaluation testing will be conducted under a FY 2012 NIJ AKELA grant.

5.0 Conclusions

A portable standoff sense through-the-wall (STTW) imaging system prototype for civilian law enforcement use has been developed and demonstrated the ability to detect stationary individuals from standoff ranges in excess of 25 m through 26.7 cm (10.5 in) thick steel reinforced concrete walls. Restrictions imposed by FCC requirements for system operation in the frequency band of 500 MHz to 2000 MHz have necessitated modification of a previous developed baseline NIJ AKELA radar laboratory prototype to a higher frequency band between 2900 and 3600 MHz. While the attenuation of walls of interest is much greater at these frequencies, differences in antenna gain and isolation suggest operation at higher frequencies are comparable to previous AKELA prototype radar systems.

Engineering prototypes have been designed and demonstrated the ability to detect personnel movement through reinforced concrete walls at distances up to 30 meters. The laboratory prototype weighs approximately 18 lbs., operates for two hours on internal batteries, and controlled with a wired or wireless Ethernet connection. A final system has been designed to meet FCC requirements, and a waiver granted for Law Enforcement application. Final FCC certification and Los Angeles Sheriff Department (LASD) user evaluation will be conducted under a FY 2012 NIJ grant to AKELA. Post FCC certification and LASD user evaluation, the NIJ AKELA device will be available for further first responder and Law Enforcement evaluation, operational application, and product acquisition.

The AKELA standoff radar sensor was successful in meeting the performance goal of 30 meter standoff detection of personnel through reinforced concrete walls of complex structures. Additional accomplishments included:

- Wireless integration into prototype units
- An engineering hermetically sealed prototype system has been manufactured, acceptance and performance tested, and available for LE practitioner evaluation
- A engineering prototype system and related performance characteristics has received FCC waiver approval, and is available for final FCC certification
- Radar system protocol has been modified along with restructured software to support asynchronous mode for wireless communication and virtual data storage. Virtual data storage was implemented and a wireless option for the array was acceptance tested
- Program SWAP goals have been met, the current engineering prototype system weighs approximately 18 lbs, can be powered continuously with AC or eight double AA batteries (2 hours), and radiates at approximately 50 mW
- The present engineering prototype system developed under the NIJ RRA cost target is approximately \$10-12K. Without a substantial technical electronic redesign effort, unit costs

may not be substantially reduced. A small unit cost may be realized with multiple unit buys, however, the anticipated number produced is too small for appreciable cost reduction

- LE practitioners' participation from LASD and other LE organizations and their feedback provided valuable input to AKELA for product improvement efforts. This feedback aided several improvements to graphical user interface, maintenance improvements, and critical input for future test planning, execution, and reporting.
- Baseline design modifications were initiated after analysis and test data indicated that moving to a higher frequency of operation, would not substantially degrade device system performance and could meet FCC requirements while meeting FCC compliance requirements.
- The time and resources required to define and respond to FCC compliance surpassed AKELA's scope, risk, and schedule expectations. Identifying FCC test requirements and obtaining FCC experimental licensing and waiver approval caused: 1) radar system redesign, retest, and re-verification, 2) delays in user test evaluation schedules, 3) reassessment of program risk and associated drivers, and 4) major system engineering tasks replanning.
- The retention of the law firm Fletcher Heald & Hildreth and associated counsel for FCC licenses and waiver interactions was instrumental in successful FCC applications, and approvals of the NIJ AKELA device.
- Leveraging prior and concurrent AKELA DOD radar sensor contracts has been invaluable for technology transfer to the NIJ RRA effort. This technology transfer and maturation has aided in reducing design and test technical and schedule risks, as well as providing significant cost reduction paths.
- A primary end goal of the NIJ RRA Cooperative Agreement was commercialization and production of the NIJ AKELA’s first generation standoff radar system product for LE field application. Product operational user evaluation and redesign modifications to meet FCC compliance requirements were major factors in task schedule delays, task replans, and scope increases. The schedule, initiation, and completion of critical user evaluation tasks were dependent on FCC experimental license approval.

The current AKELA NIJ standoff STTW ASTIR system can detect personnel detection behind non-metallic building walls of simple structures. Current capabilities are limited as a result of lack of device data on structures that maybe encountered in LE operational scenarios. This limitation is also reflected in the interpretation of device display data with no operator prior knowledge and associated training. A number of value added options are available, but were not in scope to implement as part of this RRA FY 2009 effort.

6.0 Recommendations

The NIJ AKELA ASTIR System represents a first generation product available for First Responder and Law Enforcement application. Future product improvements should focus on: 1) collecting additional LE user through the wall detection data in operational scenarios, 2) continual user training with updated data interpretation, 3) upgrades to user display interfaces, 4) integration of an adjunct optical sensor, 5) deployment and synchronization of multiple ASTIR systems, and 6) evaluation of mobile and overhead systems. Additional specific recommendations include:

- AKELA's standoff STTW device should have the ability to be used by both minimally trained and highly experienced personnel. This can be accomplished with the same device operating in a dual operational mode with a simple switch.
- On concurrent military contracts, AKELA has developed the capability for large standoff STTW systems to provide mobile "drive by capability". These mobile developments include: 1) building structural mapping, 2) standoff STTW personnel detection and tracking, and 3) multi-story interrogation. Most current advanced capabilities are not "real time" and focused on surveillance applications without *a priori* building structural knowledge, but future goals include real time information for decision makers. As these capabilities mature, they can be leveraged for direct application to the NIJ AKELA ASTIR sensor system and increase the capabilities and flexibility for LE application
- Several NIJ RRA AKELA effort key objectives were not fully realized due FCC compliance requirements. This caused an inability to have unobstructed testing feedback and interaction with LE practitioners. This feedback and interaction was expected to play a key role in the evolving standoff STTW performance effectiveness and user operational deployment and field acceptance. In future efforts, this should be a high priority task.
- Imaging data from complex targets suggest that further data analysis and signal processing could provide addition information on personnel detection and tracking. These efforts could provide valuable data and warrants further investigation.
- An optical adjunct sensor should be considered for integration into the current AKELA radar sensor system engineering prototype. Real time video data provides significant value added in interpreting external building video information in concert with internal radar sensor data.
- Multiple radar system deployment provides better cross range resolution for personnel detection and tracking data. Additional development efforts and testing should be conducted to investigate performance characteristic of integrated multi-sensors
- AKELA should continue to leverage DOD sensor system development investment for NIJ. A significant amount of synergy is evident, and to that end NIJ and AKELA's DOD

customers should interact for sense through-the-wall (STTW) surveillance technology transfer and updates

- AKELA's Santa Barbara's fire tower and residential property testing provided significant radar sensor system data for LE system performance evaluation. Additional complex building structure testing representing operational encountered scenarios with the NIJ AKELA standoff system configurations should be conducted with continual user feedback.

Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	
AKELA, Inc.,	)	No. ____________________
Request for Waiver of Part 90	)	
of the Commission's Rules	)	

REQUEST FOR WAIVER

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August 3, 2011

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Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	
AKELA, Inc.,	)	No. ____________________
Request for Waiver of Part 90	)	
of the Commission's Rules	)	

REQUEST FOR WAIVER

Pursuant to Sections 1.3 and 1.925 of the Commission's Rules, AKELA, Inc. requests a waiver of Part 90 of the Commission's Rules, subject to the conditions and limitations set out below, to permit certification and customer licensing of the AKELA Standoff Through-the-Wall Imaging Radar (ASTIR) system for public safety applications. AKELA requests an outcome that permits it to certify the device, and allows an eligible user to license the device, without further proceedings.

This is a "me too" waiver request based on a waiver granted to L-3 CyTerra, a division of L-3 Communications Corporation.[1]

The development of the ASTIR system is supported by the National Institute of Justice.[2]

A. SUMMARY

AKELA developed the ASTIR system for law enforcement, firefighting, homeland security, and other first responder applications. Set up outside a building, typically on a tripod or a vehicle, the device displays interior features of the building together with the locations of individuals inside, whether stationary or moving.

1 *L-3 CyTerra*, Order, 24 FCC Rcd 14147 (2009) (*CyTerra Waiver Order*).

2 NIJ Cooperative Agreement 2009-SQ-B9-K113.

The ASTIR device differs from other through-the-wall technologies in allowing for a standoff distance up to 30 meters away from the building under investigation. It also provides a wide viewing angle, and is often able to examine multiple levels within a building from a single set-up.

Typical applications include service of high-risk warrants, developing SWAT tactics prior to entry, searching a building after SWAT entry, and rescuing victims of building collapse and other like events.

The ASTIR device steps through the frequency range 3101-3499 MHz at 2 MHz intervals. The timing and other characteristics are chosen to maximize the utility to law enforcement, weighed against battery life and the need to protect other users of the band.

Because the technical properties of the ASTIR device are similar to those of the previously waivered L-3 CyTerra device, and are no more interfering, the ASTIR device should qualify for a "me-too" waiver. AKELA will accept the same waiver conditions the Commission imposed on L-3 CyTerra.

B. About AKELA

AKELA's primary business focus is the application of sensor and signal processing technology for military and law enforcement security applications. The company emphasizes the integration of technology and operations into hardware and software components and their rapid prototyping and verification testing. Past and current AKELA efforts include concealed weapons detection and through-the-wall imaging, IED detection, internal building mapping, security force protection, and small radar sensor development for aerospace system applications.

AKELA's research and custom product developments have been carried out for customers such as:

- Defense Advanced Research Projects Agency
- U.S.A.F. Rome Laboratory
- U.S. Army CERDEC
- U.S. Navy NFESC
- Department of Transportation
- FAA Office of Aviation Security
- National Institute of Justice
- U.S. Government Intelligence Agencies.[3]

C. About the ASTIR Device

1. General Description

AKELA developed the ASTIR through-the-wall radar imaging system for law enforcement and other first responder use. The system transmits and receives on stepped frequencies over a fixed frequency range. Processing of the returned signals determines the presence, location, and velocity of objects in front of the device, even if a wall intervenes. This enables the operator to detect and track the presence of both moving and stationary individuals within a building structure.

Unlike through-the-wall systems that must be placed in direct contact or in close proximity to a wall, AKELA's system allows a standoff distance up to 30 meters. This helps to keep the personnel operating the system out of harm's way. It also provides a wider viewing angle, often allowing detections within multi-level structures from a single position.

The system, shown in Figure 1, is packaged in a small, lightweight case: 22 x 17 x 9 inches and 15 lbs. The operator places the system outside the building to be investigated, on a stationary object such as a tripod or vehicle roof, and orients the system toward the area of

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3 For more information, see http://www.akelainc.com/

interest. Software running on a laptop computer controls the system through either a wireless or wired connection.

The provided software allows full control of system operation, signal processing, and graphic display.[4] A display of detection results appears within a few seconds of start-up. The use of multiple integrated antennas in the same unit provides the ability not only to detect an individual person, but also to determine that person's approximate location in both range and azimuth without the need to relocate the hardware. The system will be certified with all antennas in place and operating.

An example of the system's detection capabilities is shown in Figure 2. The multi-colored area just above the center of the display shows the location of detected motion behind a wall 15 meters away from the system.

Figure 1 - The ASTIR System

4 The operator cannot, however, adjust the system so as to operate outside its FCC-certified specifications.

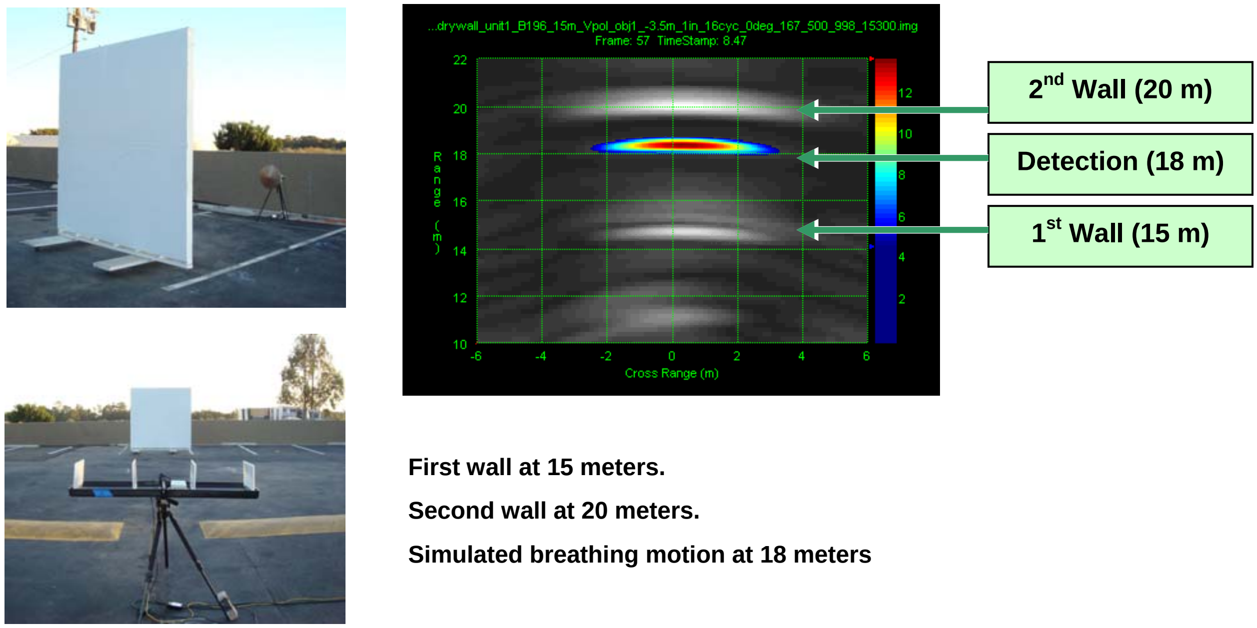

Figure 2 – Detection of breathing motion behind wall from 15 meters with an early ASTIR prototype

2. Potential applications

Standoff capabilities of the ASTIR system decrease the risk of harm in critical situations to both first responders and the public. Knowing the presence of individuals inside a building, their specific locations, and details of the internal building layout, all from a safe distance away, helps first responders to make sound tactical decisions based on fact rather than guesswork.

Outlined below are four typical scenarios in which the ASTIR system improves the likelihood of a successful outcome: service of warrants, hostage/barricade incidents, building clearance operations, and search and rescue.

- Prior to serving high risk warrants, law enforcement authorities can use the ASTIR system to confirm the presence and number of individuals in the building, thus tailoring tactics to the particular situation from a relatively safe location.
- On SWAT call-out for a hostage or barricaded situation, initial measures include determining the number and location of individuals present,

classifying those individuals, assessing the building structure, isolating and tracking threat personnel within the building structure, establishing contact with individuals within the building, and developing a plan of action based on information received, potentially including forced entry. The ASTIR system supports all of these steps, providing law enforcement with situational awareness while maintaining a safe separation from the structure under investigation. By allowing authorities to optimize entry location and timeline, and by directly confirming suspects' compliance with communications from law enforcement, use of the system decreases the risk of harm to both hostages and personnel.

- A building search and clearance operation typically follows police SWAT building entry. This operation presents one of the most dangerous situations SWAT members encounter, due to the advantage suspects have over authorities in knowing their own locations. Police can significantly reduce their disadvantage using the ASTIR system to assist in safely detecting and locating hidden suspects, particularly in building areas that are conducive to hiding and where police are otherwise most vulnerable, such as attics, basements, and crawlspaces. Clearance of buildings can also be monitored by SWAT commanders tracking personnel movements, along with detected suspects.

- In case of a building collapse or similar accident, the ASTIR system can assist first responders in detecting and locating trapped individuals from a safe distance. Use of the system allows first responders to focus rescue efforts on specific areas where survivors are known to be present.

In short, the ASTIR system protects the lives of law enforcement and first responders by providing valuable tactical information at a safe distance, before entry into hazardous situations.

3. Technical description

ASTIR operates in a stepped frequency, continuous wave (CW) mode. The transmitter emits a pure, unmodulated radio-frequency signal for 65 microseconds, repeats on a different frequency, and repeats again through a total of 200 successive frequencies.[5] All frequencies lie between 3101and 3499 MHz, inclusive, 2 MHz apart. The complete cycle through all

5 The radar transmitter employs direct digital synthesizers (DDS) as reference frequency generators to control the output of a voltage controlled oscillator (VCO). Use of a DDS allows precise control over transmitter frequency.

frequencies, including a 260 microsecond pause after all 200, takes (200 x 65μs) + 260 μs = 13.26 milliseconds.

The ASTIR device has four integrated antennas. The frequency cycle above repeats twelve times, using each possible pair of antennas to transmit and receive, respectively. The time for all twelve frequency cycles is 12 x 13.26 ms = 159 milliseconds, or just under one-sixth of a second. The system completes 15,300 frequency point samples per second, yielding approximately six complete scans across all frequencies and antenna pairings per second.

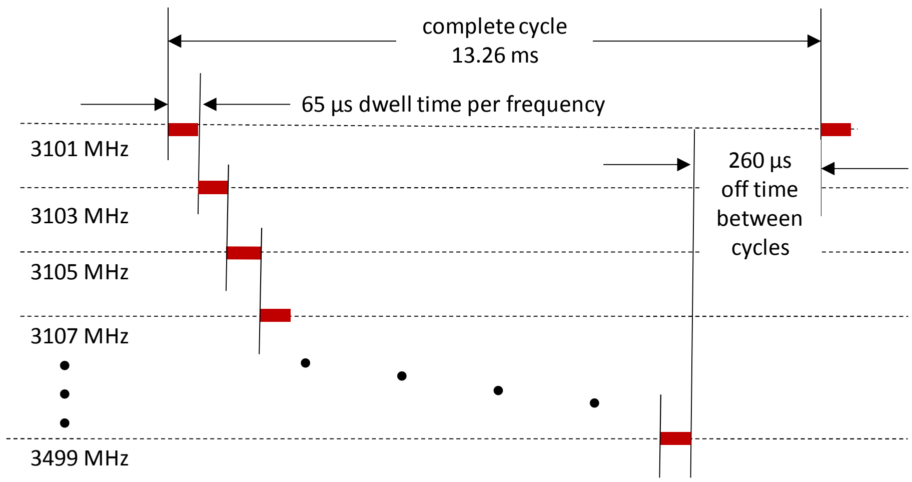

Figure 3 -- Timing Diagram

The peak output power while actually transmitting on any one frequency is 31.6 mW (+15 dBm).[6] But the average power is far lower. The transmitter steps among 200 frequencies, staying on each for 65 μs, and then pauses for 260 μs (equal to 4 x 65 μs). The duty cycle, or fraction of time on any one frequency, is thus 1/204 = 0.49 percent. The average power on any

---

6 This is the power measured at the interface between transmitter and antenna. The EIRP is 10 dB higher.

one frequency is this percentage times the peak power: 0.0049 x 31.6 mW = 0.15 mW (–8.1 dBm). These numbers are far below the power levels for typical Part 90 radar systems.

The following tables and timing diagram summarize the ASTIR technical properties.

Potential System Configuration – Operating Parameters	
Operating Bandwidth (MHz)	398
Operating Range (MHz)	3101 – 3499
Operating Scan Rates (Hz)	15,300
Frequency Step (MHz)	2
Frequency Points per Scan Cycle	200

Potential System Configuration – Operating Characteristics	
Dwell Time per Frequency (μs)	65
"Off Time" Between Scan Cycles (μs)	260
Duty Cycle on a Single Frequency Point	0.49%
Output Power – Peak Instantaneous (milliwatts)	31.6 (+15 dBm)
Output Power – Average (microwatts)	155 (-8.1 dBm)

The above parameters are chosen to balance expected law enforcement applications against battery life and the need to avoid causing harmful interference in the band, among other considerations. The sampling rate allows the detection not only of moving individuals, but also the breathing motion of stationary individuals, such as unconscious persons or restrained hostages. The 400 MHz bandwidth is needed to yield sufficient resolution for detecting multiple individuals within close proximity. The use of frequencies below about 3500 MHz is needed to achieve adequate penetration of signals through building materials. The use of 200 frequency points provides a theoretical maximum unambiguous detection range of 75 meters.[7] In practice,

[7] The unambiguous detection range equals the speed of light divided by twice the frequency step: (300,000,000 meters/second) / (2 x 2,000,000 Hz) = 75 meters.

allowing for real-world noise and losses, AKELA expects to achieve a detection range of 30 meters.

The device will comply with the out-of-band emissions limits specified in Section 90.210(c).

Power controls. The system must be activated by the user, cannot be locked on, and automatically shuts off after 60 seconds of user inaction. For extended surveillance operations the system can be put into a mode which continuously cycles the system on for 15 seconds followed by 300 seconds off time, for a maximum overall duration specified by the user. This decreases the chance of interference with other devices, and provides long term tracking capability.

4. Me-too waiver

The technical details of the ASTIR are, variously, identical or similar to those of the L-3 CyTerra device, as summarized in the table below. The few differences are inconsequential in terms of interference potential. The ASTIR thus qualifiers for a me-too waiver.[8]

[8] *Melody Music, Inc. v. FCC*, 345 F.2d 730, 732 (D.C. Cir. 1965) (error in failure to explain different treatment of similarly-situated applicants). *See also Alvarion Ltd*, Order, 25 FCC Rcd 3863 at ¶ 14 (ordering similar treatment for similar equipment); *Elastic Networks Petition for Waiver*, Memorandum Opinion and Order, 16 FCC Rcd 13974 at ¶¶ 9 *et seq.* (2001) (granting waiver on showing of similarity to previously waivered equipment).

Property	L-3 CyTerra[9]	AKELA
Frequency range (MHz)	3100-3500	3100-3500
No. of frequency steps	200	200
Size of frequency step (MHz)	2	2
Dwell time (μsec)	75	65
Off time between steps (μsec)	17.5	0
Off time between scan cycles	17.5	260
Cycle time (msec)	18.5	13.26
Duty cycle	0.41%	0.49%
Peak instantaneous power (mW)	31.6	31.6
Average power (dBm)	–8.9	–8.1

5. Limitations on marketing and deployment

AKELA proposes to:

- limit the non-Federal marketing of ASTIR to state and local police and firefighters, and to limit use to actual emergencies involving threats to safety of life, and necessary training;
- limit the number of units sold to 5,000 during the first twelve months following equipment approval, and 10,000 during the second twelve months, with no limit in subsequent years; and
- prohibit the device from being mounted on a fixed outdoor infrastructure.

These are same limits that the Commission imposed in the *CyTerra Waiver Order*.

AKELA will also accept the same Federal coordination arrangements the Commission specified for CyTerra.[10]

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[9] Data from *CyTerra Waiver Order*.

[10] "While Part 90 frequency coordination is not required, we will coordinate the applications with the National Telecommunications and Information Administration. Applicants must specify the number of units and the proposed area of operation. Applications must reference this Order by the DA number set forth above. No operation is permitted prior to license grant, and no applications will be granted until CyTerra obtains equipment authorization." *CyTerra Waiver Order* at ¶ 12 (footnotes omitted). An omitted footnote reads, "License applications in particular areas may be denied in order to protect Federal Government radiolocation facilities." *Id*. n.29.

D. REQUEST FOR WAIVER

Part 90 of the Commission's Rules does not anticipate the stepped-frequency signal used by ASTIR. AKELA requests a waiver of the rules as needed to permit certification and operation as described here. Affected rules might include the applicable technical provisions on modulation and bandwidth.[11]

The 3100-3500 MHz band sought to be used by ASTIR is variously allocated to Federal radiolocation,[12] private radiolocation,[13] Federal and private earth-exploration satellite and space research,[14] and the amateur 9 cm band on a secondary basis.[15] Private radiolocation and amateur operations both use far more power than is proposed for ASTIR, with no apparent pattern of harmful interference.[16] ASTIR should be able to coexist in the band without difficulty.

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11 *See* 47 C.F.R. §§ 90.207(k) (modulation) ("For radiolocation operations . . . any type of emission may be authorized upon a satisfactory showing of need"), 90.209 (bandwidth).

12 47 C.F.R. § 2.106 (3100-3500 MHz, primary).

13 47 C.F.R. § 90.103(b) (3100-3500 MHz, secondary).

14 47 C.F.R. § 2.106 (3100-3300 MHz, secondary). The bands 3260-3267, 3332-3339, 3345.8-3352.2 MHz are identified for radio astronomy, 47 C.F.R. § 2.106 n.US342, but we understand that very few facilities make observations in these bands.

15 47 C.F.R. § 97.301 (3300-3500 MHz, secondary). The sub-band 3400-3410 MHz is used for amateur satellite uplink and downlink operations.

16 Amateur radio stations are permitted throughout the 3300-3500 MHz band at 1500 watts PEP, secondary to Federal radiolocation. Non-Federal operations at 3300-3500 MHz are limited to 5 watts peak power into the antenna. 47 C.F.R. § 90.103(c)(13). There is no fixed power limit for radar devices in the 3100-3500 MHz band. 47 C.F.R. § 90.205(r) (requested transmitter power considered and authorized on case by case basis).

E. PUBLIC INTEREST

ASTIR can reliably locate individuals inside buildings, from a safe distance. This capability offers the potential to improve the safety and possibly save lives of first responders, fire victims, and hostages, among other members of the public. Balanced against the extremely low risk of harmful interference to other users, a grant of the requested waiver is plainly in the public interest.

F. WAIVER STANDARD

The Commission assesses waiver requests according to the standards set out in *WAIT Radio v. FCC*.[17] In that case, as here, the applicant sought to operate in contravention of the rules while explaining how it would accomplish the purpose of the rules by other means.[18] The court required the Commission to consider the request:

> [A] general rule, deemed valid because its overall objectives are in the public interest, may not be in the "public interest" if extended to an applicant who proposes a new service that will not undermine the policy, served by the rule, that has been adjudged in the public interest.[19]

The plain meaning of the passage is clear: Waiver is appropriate where the applicant maintains the public interest in the underlying rule. AKELA does so here. The waiver is consistent with the purpose of the Part 90 rules of protecting Federal 3100-3500 MHz users from harmful

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[17] 418 F.2d 1153 (D.C. Cir. 1969). *See, e.g., 2002 Biennial Regulatory Review*, 18 FCC Rcd 13620 at para. 85 n.130 (2003) (citing *WAIT Radio* as "setting out criteria for waivers of Commission rules.")

[18] WAIT Radio operated an AM broadcast station. It was limited to daylight hours so as to afford protection to "white areas" that had no local service, and that relied on nighttime skywave propagation from another station. WAIT Radio proposed to transmit at night using a directional antenna that would keep its signal out of the white areas. *WAIT Radio v. FCC*, 418 F.2d at 1154-55.

[19] *WAIT Radio v. FCC*, 418 F.2d at 1157.

interference. Equally important, the ASTIR device will directly further the public interest by enhancing the safety of first responders and victims needing rescue. The requested waiver thus fits easily within the boundaries drawn by *WAIT Radio*.

Moreover, the Court of Appeals emphasized the importance of waiver procedures as part of the regulatory scheme:

> The agency's discretion to proceed in difficult areas through general rules is intimately linked to the existence of a safety valve procedure for consideration of an application for exemption based on special circumstances.[20]

Thus, it said, "allegations such as those made by petitioners, stated with clarity and accompanied by supporting data . . . must be given a 'hard look.'"[21]

Here, too, this request fully qualifies. The "safety valve" of the waiver procedure is needed to make available an important tool for public safety. The requested waiver is in the public interest, not only in terms of benefits to the public, but also in the absence of any significant increase in harmful interference. The request is entitled not only to a "hard look" as mandated in *WAIT Radio,* but to a grant of the waiver.

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20 *Id.*

21 *WAIT Radio v. FCC,* 418 F.2d at 1157 (citation footnote omitted).

CONCLUSION

The ASTIR device will promote safety without significantly contributing to harmful interference in the spectrum. It is entirely consistent with the Commission's waiver standards. The device qualifies for a waiver both on its own terms and as a me-too waiver following the *CyTerra Waiver Order*.

Respectfully submitted,

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August 3, 2011

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445 12th Street, SW
Washington, DC 20554

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Test & Consulting Services for Commercial, Military, International Compliance
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RADIO TEST REPORT FOR A THROUGH THE WALL RADAR IMAGING SYSTEM

Manufacturer: AKELA Inc.
Model No.: ASTIR

Background
In response to a request from the FCC's Experimental License Branch of the Office of Engineering and Technology, occupied bandwidth measurements and antenna port conducted spurious emissions. The test data is to support a pending Experimental License submitted with a Waiver Request for relaxation for limits in Part 90 of the Rules.

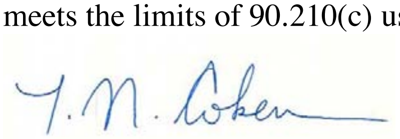
Test Date: 9 September 2011
Testing performed at:

Micom Labs
440 Boulder Court, Suite 200
Pleasanton, CA 94566

Tests were performed at three different frequencies, one near the bottom of the frequency sweep range, one near the middle of the range, and one near the top of the range:

Channel	**Frequency**
Low	3101 MHz
Middle	3300 MHz
High	3499 MHz

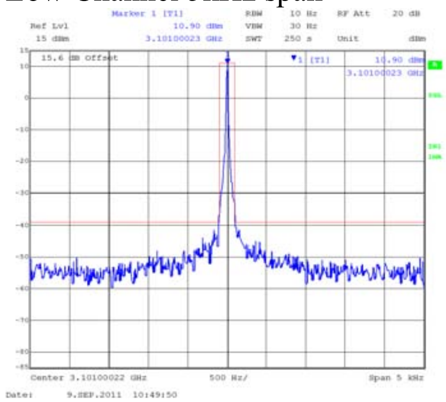
Test data spectrum analyzer graphs are presented below. Data shows the emissions be attenuated 50 dB below the peak and average power on any frequency removed from the operating frequency from 100 Hz to 10 kHz, and compliance with Section 90.210(c) on any frequency removed from the operating frequency by more than 10 kHz. The device meets the limits of 90.210(c) using peak and average limits.



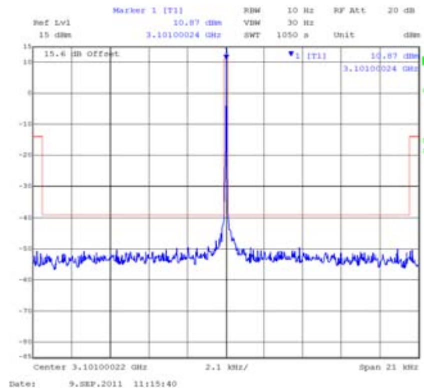
T.N. Cokenias
Consultant for AKELA INC.

Occupied Bandwidth Measurement Data

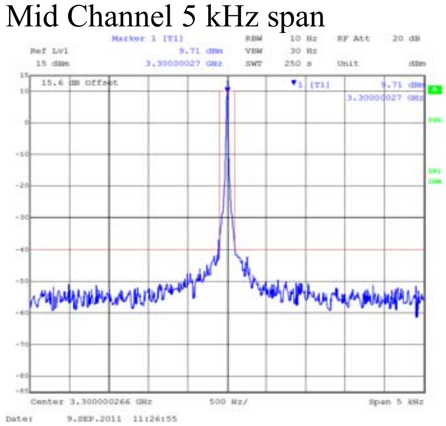
Low Channel 5kHz span



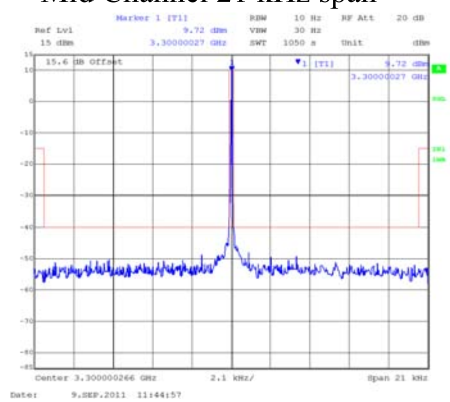
Low Channel 21 kHz span



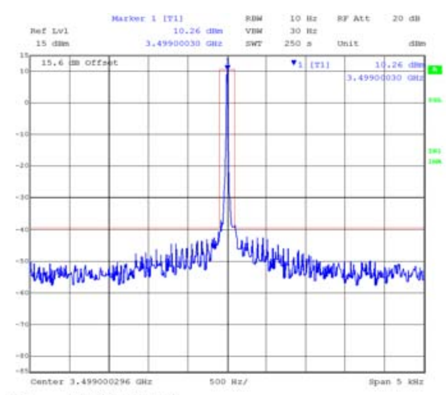
Mid Channel 5 kHz span



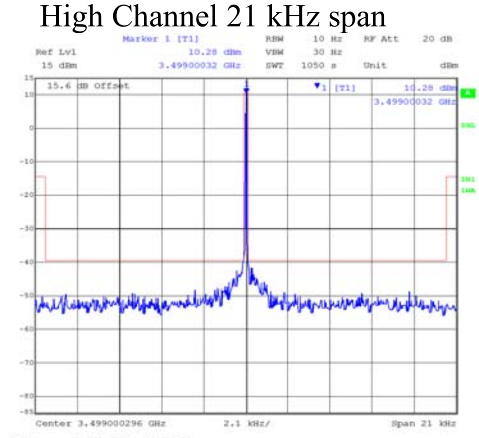
Mid Channel 21 kHz span



High Channel 5 kHz span

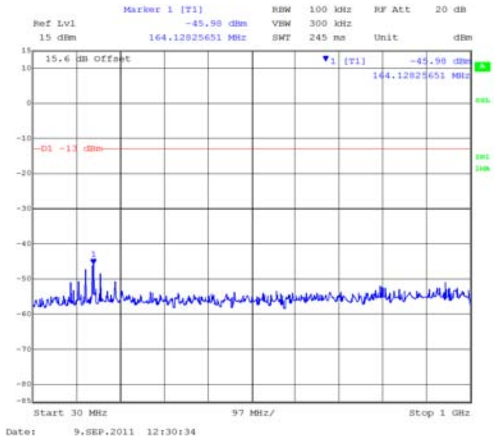


High Channel 21 kHz span

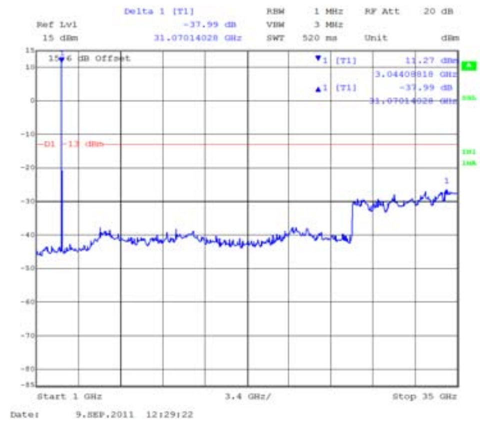


Antenna port conducted spurious emissions

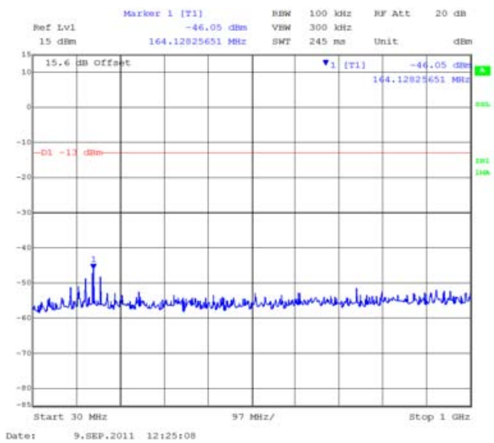
Low channel 30-1000 MHz



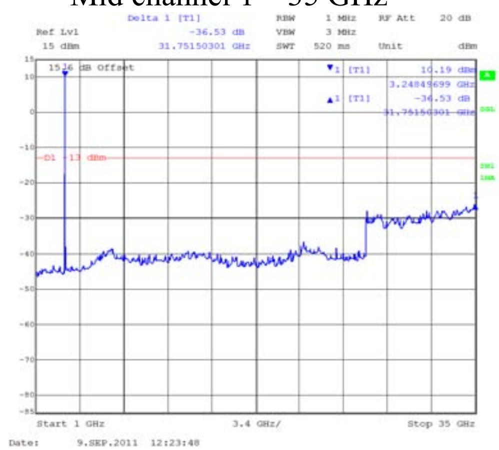
Low channel 1 – 35 GHz



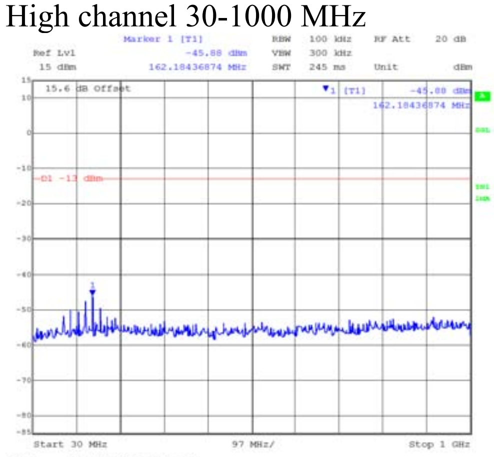
Mid channel 30-1000 MHz



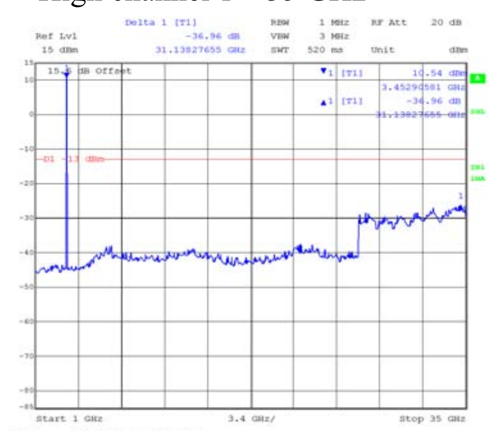
Mid channel 1 – 35 GHz



High channel 30-1000 MHz



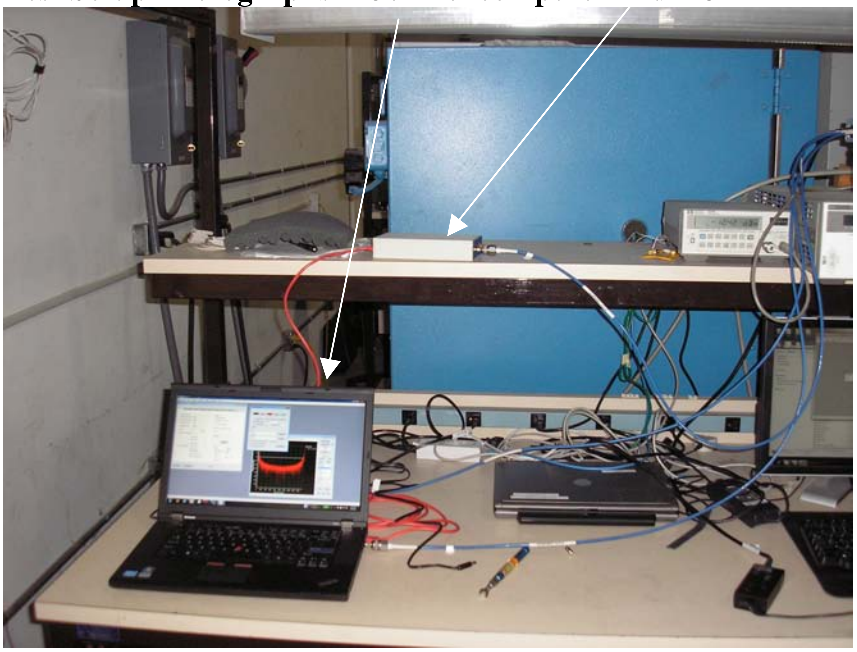
High channel 1 – 35 GHz



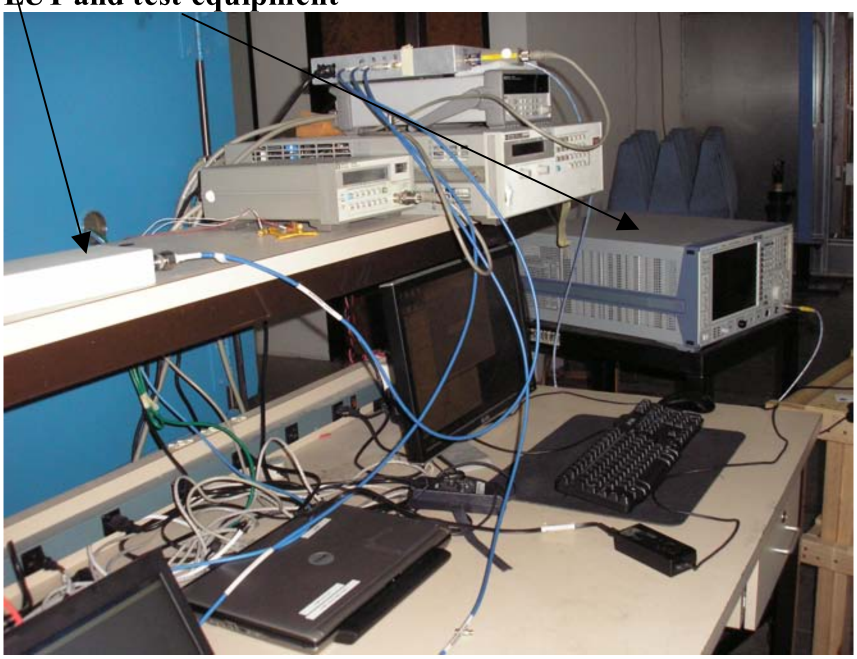
Equipment used to perform tests

Instrument	Manufacturer	Part #	Cal Date	Cal Due Date	Serial Number
EMI Receiver	Rhode & Schwartz	ESIB 40	17-Nov-2010	17- Nov -2011	100201
Power Sensor	Hewlett Packard	8485A	16-Nov-2010	16- Nov -2011	3318A19694
Power Meter	Hewlett Packard	437B	17-Nov-2010	17- Nov -2011	3125U11552

Test Setup Photographs   Control computer and EUT



EUT and test equipment



Federal Communications Commission
Washington, D.C. 20554

November 9, 2011

DA 11-1870

Mitchell Lazarus
Fletcher, Heald & Hildreth, PLC
1300 North 17th Street, 11th floor
Arlington, VA 22209

Dear Mr. Lazarus:

This letter responds to the request you submitted on August 3, 2011 on behalf of AKELA, Inc. (AKELA) for waiver of Part 90 of the Commission's Rules to permit certification and use of the AKELA Standoff Through-the-Wall Imaging Radar (ASTIR) system.[1] For the reasons set forth below, we grant the waiver request.

In 2009, the Wireless Telecommunications Bureau and Public Safety and Homeland Security Bureau (the Bureaus) granted a waiver to L-3 CyTerra (CyTerra) to permit certification and use of CyTerra's Electromagnetic Motion Detection and Ranging (EMMDAR) sensor, a handheld radar device operating in the 3100-3500 MHz band that is capable of sensing motion through walls.[2] A waiver was required because the EMMDAR's frequency usage was inconsistent with the Commission's technical rules. Specifically, rather than operating on a single frequency like most radars, the EMMDAR steps through two hundred frequencies, spaced two megahertz apart between 3101 MHz to 3499 MHz, one at a time. The Bureaus concluded that grant of the waiver request was warranted in light of the device's benefits to the public safety community, and because the EMMDAR's operational characteristics considerably reduce the potential for interference to other users. The CyTerra waiver grant subsequently was modified with respect to the emission mask.[3]

On August 3, 2011, AKELA requested a waiver of Part 90 to permit certification and use of its ASTIR system, a portable device that can be set up outside a building (up to thirty meters away), typically on a tripod or a vehicle, and displays interior features of the building together with the locations of individuals inside. On September 22, 2011, at the request of Wireless Telecommunications Bureau staff, AKELA provided additional technical information regarding the ASTIR. AKELA asserts that the technical properties of the ASTIR system are similar to those of the EMMDAR, and are no more interfering, so the ASTIR should also qualify for a waiver.

We agree, and grant the AKELA waiver request for the same reasons that the Bureaus granted the CyTerra waiver request. Grant of the waiver request is subject to the following conditions:

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[1] AKELA, Inc., Request for Waiver (filed Aug. 3, 2011).

[2] *See* L-3 CyTerra, *Order*, WP Docket No. 09-2, 24 FCC Rcd 14147 (WTB/PSHSB 2009).

[3] *See* Letter dated February 17, 2010 from Scot Stone, Deputy Chief, Mobility Division, Wireless Telecommunication Bureau to Mitchell Lazarus; Letter dated August 6, 2010 from Scot Stone, Deputy Chief, Mobility Division, Wireless Telecommunication Bureau to Mitchell Lazarus. The final version, under which CyTerra obtained its certification, requires that the emissions be attenuated 50 dB below the peak and average power on any frequency removed from the operating frequency from 100 Hz to 10 kHz, and comply with Section 90.210(c) of the Commission's Rules, 47 C.F.R. § 90.210(c), on any frequency removed from the operating frequency by more than 10 kHz. The device must also meet the limits of Section 90.210(c) using peak and average limits.

-Eligibility is limited to state and local police and firefighters, and use is limited to actual emergencies involving threats to safety of life, and necessary training.

-The number of units to be sold is limited to 5,000 during the first year following equipment approval, and 10,000 during the second year (with no limit in subsequent years).

-The device may not be mounted on a fixed outdoor structure.

-The device must have the technical parameters described by AKELA in its waiver request (*i.e.*, the ASTIR transmits with a peak instantaneous power of 31.6 milliwatts[4] on one frequency at a time for 65 microseconds and steps through two hundred frequencies spaced two megahertz apart between 3101 MHz to 3499 MHz, followed by a 260-microsecond "off time;" the device cannot be locked on, and automatically shuts off after one minute[5]).

AKELA must obtain equipment authorization for the ASTIR. A copy of this letter shall be submitted with the equipment authorization application.

Operation of the ASTIR system by eligible entities will require separate Commission authorization from the Wireless Telecommunications Bureau, using radio service code RS (radiolocation service).[6] Applicants may apply for authorization on the 3100-3500 MHz band, rather than listing each of the frequencies on which the ASTIR operates. While Part 90 frequency coordination[7] is not required, we will coordinate the applications with the National Telecommunications and Information Administration.[8] Applicants must specify the number of units and the proposed area of operation. Applications must reference this action by the DA number on the first page. No operation is permitted prior to license grant, and no applications will be granted until AKELA obtains equipment authorization.

Accordingly, IT IS ORDERED that the Request for Waiver filed by AKELA, Inc., on August 3, 2011, IS GRANTED SUBJECT TO THE CONDITIONS SET FORTH HEREIN.

This action is taken under delegated authority pursuant to Sections 0.131 and 0.331 of the Commission's Rules, 47 C.F.R. §§ 0.131, 0.331.

FEDERAL COMMUNICATIONS COMMISSION

Scot Stone
Deputy Chief, Mobility Division
Wireless Telecommunications Bureau

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[4] The device transmits an unmodulated (CW) carrier (emission designator N0N). The emission must be attenuated 50 dB below the peak and average power on any frequency removed from the operating frequency from 100 Hz to 10 kHz, and comply with Section 90.210(c) on any frequency removed from the operating frequency by more than 10 kHz. The device must also meet the limits of Section 90.210(c) using peak and average limits.

[5] For extended surveillance operations, the system can be set to cycle for 15 seconds, followed by 300 seconds of off-time, and repeat for a duration specified by the user.

[6] Ordinarily, licensees in the Public Safety Radio Services (such as state or local government entities) that already have a Commission license for a radio communications system may operate radar units without obtaining a separate license. *See* 47 C.F.R. § 90.20(f)(4).

[7] *See* 47 C.F.R. § 90.175.

[8] License applications in particular areas may be denied in order to protect Federal Government radiolocation facilities.