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Intelligent Automation Incorporated

Coherent distributed radar for high-resolution through-wall imaging

Annual Report

Contract No. N00014-10-C-0277

Sponsored by

Office of Naval Research
COTR/TPOC: Martin Kruger

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Coherent Distributed Radar For High-Resolution Through-Wall Imaging**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Intelligent Automation Incorporated,15400 Calhoun Dr, Suite 400,Rockville,MD,20855**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Summary

In 2010, we have kicked of the project, and made significant progress in the areas of algorithm design, simulation, hardware design, benchtop testing, and definition of the final demonstration. We will describe our progress in each of these areas below.

Kick-off meeting

On May 14, 2010, a kickoff meeting was held at the MTCSC facility in Stafford, VA. Present were Andre des Rosiers (NRL/ONR), Leon Elam (SAIC), Martin Kruger (ONR), Ted Isaacson form ITSFAC, and Eric van Doorn and Charles Abraham from IAI. We discussed progress made to date, the schedule, and expectations and intended audience for the combined demonstration of bi-static synchronized through-wall radar in FY11. At this time, integration with a third-party radar was anticipated.

Analytical synchronization algorithm and simulations

An analytical signal level description of the synchronization algorithm has been defined, and a Matlab simulation of the algorithm was implemented. The Matlab code has been used to evaluate performance under multipath conditions, hardware limitations, noise and interference. The synchronization algorithm has been refined to accommodate multipath, mobility, and multiple nodes. We have started systematic identification of error sources affecting each of our estimation steps, and are using analysis and simulations to understand the magnitude and dependencies of these errors on system and environmental parameters. We have estimated the performance of frequency estimation algorithm under varying SNR through simulations.

Hardware design

Based on the simulations, and prior experiments, we have defined the desired RF architecture and frequency plan, and other transceiver characteristics. We selected discrete components based on their low-jitter, low-phase distortion, and temperature stability performance. Using these RF components, we designed an RF frontend, and worked with vendors to manufacture the boards.

We have extensively tested the RF front-end, and characterized gain, phase, and delay linearity over the bandwidth of the transceiver, for both transmit and receive chain. We have manufactured and tested the ADC and D/A boards, both are now functional.

We are designing a final demonstration using the synchronization transceiver and in-house radar- and high-precision GPS hardware.

We have selected the radar hardware for the final demo. The figure below shows the digital processor board and plug-in transmit-receive modules developed under an on-going AFRL SBIR Phase-II (#FA8650-10-C-1737). An 8-channel, 250Msps waveform digitizer was developed to interface with a 4x2 antenna array. The goal is to directly digitize UHF frequencies without the need for analog down-conversion and still maintain high dynamic range. The digital processor board is also used by our Synchronization Transceiver. For the proposed final demonstration, we will use 5 expansion slots of the digital board, four will be used for the synchronization hardware, i.e. two for the RF frontend, one for the D/A, and one for the ADC board. One slot will be used for either transmit or receive.

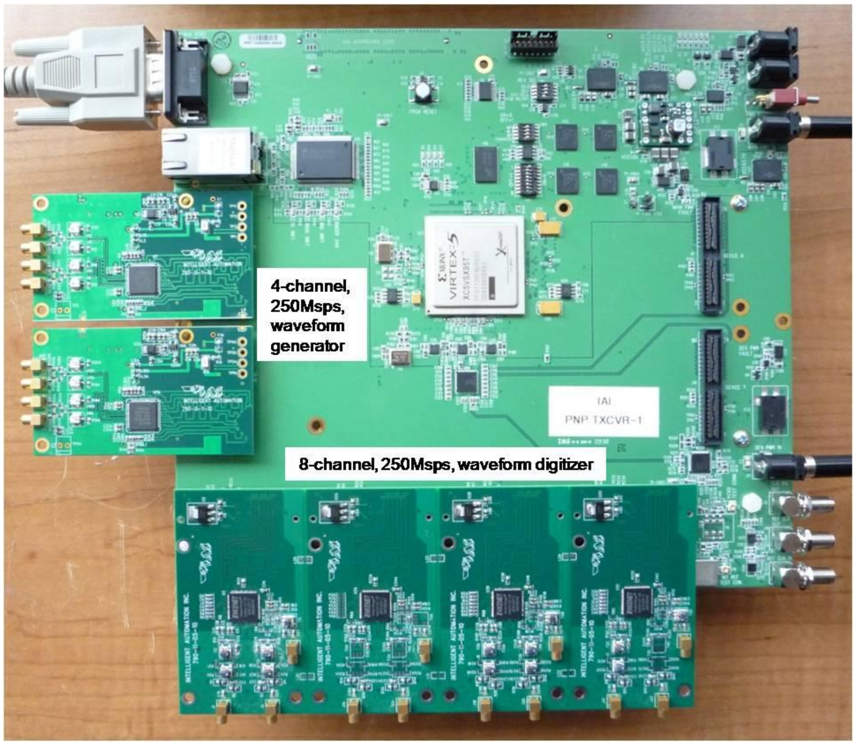

Figure 1: Digital processor and waveform synthesizer-digitizers developed at IAI

While the figure above shows a 4 channel wave generator, we will use only one transmit channel on one board, and one receive channel on a second board. Also, the board above shows the digital waveform generator. Since the clocking rate of the D/A is limited to 250Msps, we need to upconvert to get to frequencies in the 400-1000MHz range. The board below allows up-conversion up to L-band of the generated bandwidth, and is compatible with digital board.

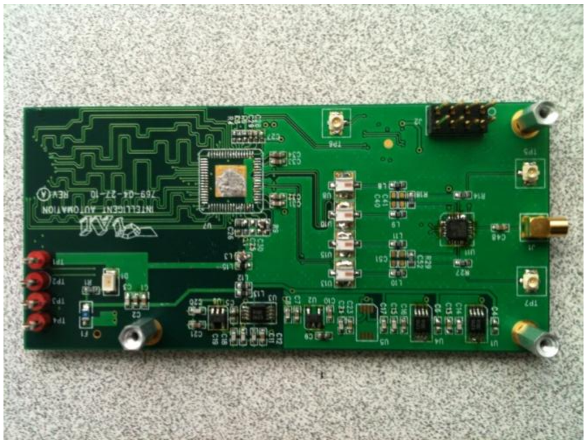

Figure 2 Waveform synthesizer with up-conversion for radar waveform generation.

To complete the radar transmit system, we will need to select a Power Amplifier, and antenna for the transmitter, and potentially a filter. For the radar receive we need to select an antenna, and a LNA. These will be discrete, connectorized components.

1.1 Preparation for final demonstration

We have further developed the final demonstration scenario. We show the demonstration scenario in Figure 3 below. We will demonstrate a bi-static through-wall radar system. Bi-static radar, while more complex and harder to deploy than traditional monostatic radar, offers covert operation of the receiver, and increased resilience to electronic countermeasures as receiver location are potentially unknown as well as possible enhanced radar cross section of the target due to geometrical effects. For our final demonstration we propose a stationary transmitter, a mobile receiver, and a GPS base station. To be able to form SAR images from the received radar scattering, positions of both transmit and receive nodes must be known and both nodes must be synchronized , to within a small fraction of the transmitted bandwidth.

The stationary node consists of a synchronization transceiver, and a radar transmitter. It will be placed at a location with excellent GPS reception within 100m of the building. The radar transmitter will transmit radar pulses with timing derived from the synchronization transceiver. The radar frequency band will be sufficiently low to penetrate the building wall, with bandwidth in the one- to several hundred MHz. For the demonstration, we will use either a signal generator with modulation derived from the synchronization receiver, or a waveform directly synthesized by the same hardware used for the synchronization transceiver.

The mobile node consists of a synchronization transceiver, a radar receiver, a differential, dual band high-precision GPS receiver, and a PC. The mobile node will move along a trajectory near the building that will allow accurate GPS-aided positioning, and detection of radar reflections from the inside of the building. A directional antenna will be used and aimed by the user at the building. Its azimuthal orientation will be tracked a recorded with a magnetic compass. The accuracy of the synchronization will correspond to a small fraction of the radar signal bandwidth. The data corresponding to the received radar scans, timestamps from the synchronization transceiver, orientation of the radar antenna and the GPS location will be transferred to the PC, and processed in to a SAR image in semi-real time.

The GPS base station is located on the roof of the IAI office. It will provide corrections to the mobile GPS receiver.

We will use sufficiently stable clocks for the radar nodes so that the synchronization link can operate at very low duty cycle (<1 signal exchange /minute). Hence, the mobile radar node is largely passive.

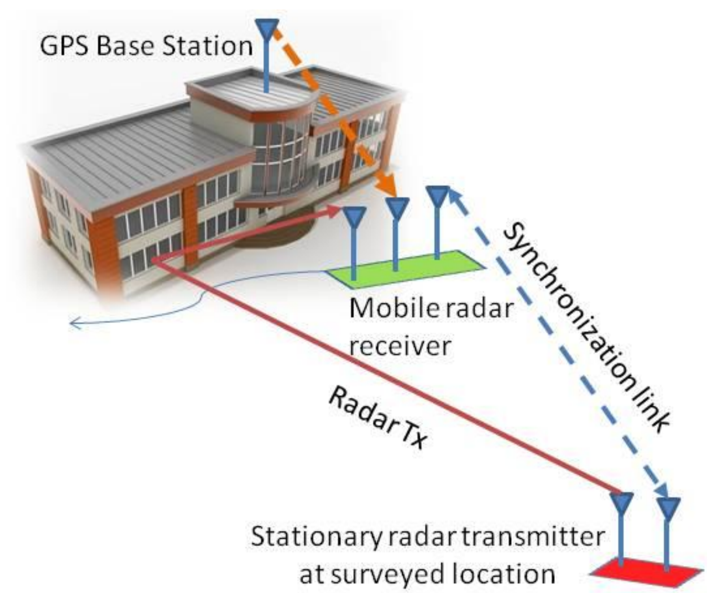

Figure 3. Final Demonstration Scenario.