FAMU-FSU College of Engineering

Department of Electrical and Computer Engineering

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Needs Assessment

Team E#7

SAR Imager

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# **NEEDS ANALYSIS**

## OVERVIEW

In partnership with the FAMU/FSU College of Engineering and Northrop Grumman, the objective of the Synthetic Aperture Radar (SAR) Imager Project is to develop a low-cost weapon detection system that provides suitable imagery resolution for physical security and military force protection applications.

Current detection technologies commonly employed in the security industry such as metal detectors, Advanced Imaging Technology (AIT) scanners, and x-ray scanners can be expensive, obtrusive, and require the subject to be inside the apparatus. An imager based on SAR technology, composed primarily of commercial-off-the-shelf (COTS) components, can be implemented at a lower cost than many industry-standard scanners; it may be placed behind a barrier, out of view from subjects; and most importantly, it can identify concealed metal objects from a distance.

In environments with multi-layered physical security protocols, the SAR imager’s superior range can alert security professionals to potential threats before they reach an access control point, or before they progress further into a secure area, depending in which security layer the SAR is deployed. Some environments may be vulnerable to physical attack, but conventional AIT body scanners are too obtrusive or inefficient. An amusement park, for instance, might have high-level security needs, but their customers would not tolerate stepping into a full-body scanner.

Furthermore, random screening protocols have been widely criticized for being culturally or racially biased in practice. With SAR capability, guests can be discreetly imaged while queuing, and persons of interest can be identified for additional screening based on the presence of metal signatures rather than the caprice of a human screener.

## STATEMENT OF THE PROBLEM

While the current prototype achieved significant pathfinding targets, critical objectives regarding the electrical system, software implementation, and physical structure remain to be realized.

## OPERATIONAL DESCRIPTION

The SAR imager design uses the reflection of radio frequency (RF) waves to create an image. Much in the way a bat sends pulses of sound and listens to the reflected echoes to determine the distance of objects, the SAR emits pulses of RF, and “listens” for amplitude changes and phase shifts in the reflected signals to determine the distance and composition of objects.

Typical SAR systems are airborne, using the aircraft’s movement to synthesize a much larger antenna. The FAMU/FSU and Northrop Grumman Stationary SAR Imager uses an array of small antennas to synthesize a large virtual antenna with no moving parts. This proof of concept prototype will cast a 40 square inch imaging scene at a range of 20 feet.

# **REQUIREMENTS SPECIFICATIONS**

## REQUIREMENT SPECIFICATIONS

The 2014 FAMU/FSU College of Engineering & Northrop Grumman Synthetic Aperture Radar (SAR) Imager Project team laid the foundation for a successful radar imaging system. The 2015 team has inherited a wealth of technical documentation, including signal processing calculations; a fully-prototyped electrical system with all major components laid out for testing; and a functional, albeit simple, antenna structure. In 2014, the SAR team successfully transmitted and received a 20 ns wide RF pulsed signal at 10 GHz.

A comprehensive list of technical needs will be elaborated in the following sections, but it is worth noting for context a few of the important technical challenges this team will overcome in order to deliver on the project’s requirement specifications:

* The Voltage-Controlled Oscillator (VCO) is not currently generating sufficient frequency to meet the passband frequency of the bandpass filter (4.631 GHz of 4.875 GHz required before multiplication). This is why the 2014 demonstration had to be done using an external signal source. The prototype must be able to generate its own signal, within calculated parameters.
* The Field-Programmable Gate Array (FPGA) must provide precise, high-fidelity pulses to drive the switch that toggles between transmit and receive mode, and the switches that control which antennas are transmitting and receiving. This was also demonstrated with external test equipment in 2014.
* While the mathematical basis for signal processing functions has been set out, implementing these functions in software is quite another task. The SAR must be able to resolve the reflected signals into useful data. After this problem is solved, that data must be parsed to illuminate the pixels of a VGA display, another challenging programming problem.
* Finally, the existing antenna structure needs to be redesigned with emphasis on weight-reduction, mobility, precision and repeatability of alignment, rigidity, and practicality.

### Functional Requirements

* REQF-001: Frequency Range
  + The frequency range of the imager should be within FAMU-FSU College of Engineering policies. The SAR will emit 10 GHz X-band energy at low power levels.
* REQF-002: Operating Range
  + The range from the imager to the target needs to be 20 feet.
* REQF-003: Extent of the Scene
  + The area that must be imaged should be the width of a normal sized person.
* REQF-004: Cross Range Resolution
  + The cross range resolution must be enough to discern whether there is a possible threat by showing there is large scatter on a specific portion of the body, but it need not be sharp enough to outline the particular type of weapon. The designed pixels size to divide the scene into would be 2.5 inches x 2.5 inches.
* REQF-005: Down Range Resolution
  + Down range resolution will be a future capability. For ethical reasons, the down range resolution should not be so high as to be capable of producing a high-resolution image of the human body.
* REQF-006: Pulse Width
  + The pulse width is nominally 20 ns since target (20 feet away) round trip is 40nS away as pulse travels 1nS per foot leaving 20nS for system to switch to receive mode at the end of the transmit pulse to detect the reflected pulse .
* REQF-007: Voltage Controlled Oscillator
  + The VCO used for converting the signal must be functional at 5 GHz.

### Non-Functional Requirements

* REQN-001: FCC Rule and Regulation
  + The Radio Frequency (RF) emitted from the SAR imager must be within ANSI/IEEE C95.1-1992 guidelines and FCC Rules and Regulations 47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093 regarding safe RF exposure for humans.
* REQN-002: Components Interference
  + The Radio Frequency (RF) from the SAR imager should not affect communication between any other electrical components in the design.
* REQN-003: Interference
  + The Radio Frequency (RF) from the SAR imager should not interfere with common communications systems in the environment.
* REQN-004: Logic Implementation
  + The programing language used to communicate with the FPGA should be VHDL.

## Implementation Considerations

* ICON-001:
  + The SAR imager should primarily use commercial-off-the-shelf (COTS) components to facilitate production cost effectiveness.
* ICON-002:
  + The final prototype should be evaluated using National Institute for Occupational Safety and Health Work Practices Guidelines (NISOH) and/or U.S. Military Standard 1472 F to determine a recommendation for safe manual lifting.
* ICON-003:
  + All purchases should not exceed the allocated budget amount of $10,000.

## Design Deliverables

The team will deliver a functional SAR imaging prototype that fulfills the requirement specifications as well as all appropriate supporting documentation including a user manual with troubleshooting flowchart(s) and component specifications.

## Preliminary System Test Plan

* TEST-001: Power Test
  + Supply power to verify the components functionality. Using voltmeter to validate the radar’s calculated power output.
* TEST-002: Operating  Signal Test
  + Using a spectrum analyzer to verify the RF signal output of the antenna.
* TEST-003: Receiver signal test
  + Receiver should be able to pick up scattering wave of various Amplitude and Phase. This test will involve checking the receiver synchronous operation in order to pick up the returning signals.
* TEST-004: Data analysis
  + Testing the amplitude and phase of known signals in order to check the performance of the phase detection algorithm.
* TEST-005: Data output
  + Computer image should be generated from the signal picked up by the receiver.
* TEST-006: Scene Extent
  + Using a Radio Frequency meter at different locations around the targeted area to test the power levels at these locations.
* TEST-007: Cross Range Resolution
  + Place a detectable object at a known location and validate if the radar system accurately identified the object.
* TEST-008: Down Range Resolution
  + Test Radar system with an object of known parameters and compare the image process with the known dimension.
* TEST-009: Phase Centers
  + Determine the number of phase center as well as measuring the distance between each antenna phase centers.
* TEST-010: Pulse Repetition Interval
  + Implement a Code that records the repetition intervals and counts all the pulse repetitions.
* TEST-011: Receiver Noise Figure
  + Measure the Noise Figure using appropriate measurement tools.
* TEST-012: Image Frame Rate
  + Reconfigure the program that conduct signal sampling.
* TEST-013: Antenna Precision Test
  + Use laser beams to verify the antennas are pointed at target with precision.