SYNTHETIC APERTURE RADAR IMAGER

Needs Analysis & Requirement Specifications

Group # E11

Team Members:

Cammuse, Matt

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Kim, Julia

Mock, Benjamin

Poindexter, Mark

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Stakeholder:

Consulting Engineer – Pete Stenger

Northrop Grumman Enterprise

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Date	Revision	Comments
09/17/2014	1	Original Document
09/18/2014	2	Final Revision

Table of Contents

1 Design Team Overview

Jasmine Vanderhorst

Project Manager

It is the role of the Project Manager to ensure that all deadlines are met in a timely fashion and that all milestone objectives are inherently achieved. The Project Manager will be involved with the risk/issue analysis of all design phases and coordinate with each function of the team to ensure efficient and effective work is achieved.

Technical Skill: Project Management, Integrated Production Systems, Risk/Issue Management, Quality Engineering

Benjamin Mock

Treasurer/Co-Lead Engineer (Industrial)

It is the role of the Treasurer to manage all monies and budgetary concern for the project to guarantee that the tasks are performed at the lowest cost possible to achieve the highest necessary performance as stated in the objectives of the product requirements. The Co-Lead Engineer will provide the Lead Engineer and the Project Manager with the particular specifications and limitations of the Imager as they pertain to the manufacturing and ergonomic concerns. The Systems Engineer will ensure that the product design is realized from the perspective of manufacturability.

Technical Skill: Manufacturing Systems Engineering, Production Scheduling, Quality Engineering

Patrick Delallana

Lead Engineer

It is the role of the Lead Engineer to supervise the tasks to be completed concerning the design of the Imager. The Lead Engineer will provide weekly progress reports to the design team and also be the main source between the advisors and the sponsor. The computer programmer will do the VHDL programming of the FPGA board.

Technical Skill: Computer Programming, Signal Processing, Computer Engineering

Joshua Cushion

Co-Lead Engineer (Electrical)

The Co-Lead Engineer will provide the Lead Engineer and the Project Manager with the particular specifications and limitations of the Imager as they pertain to hardware and components.

The radio frequency (RF) electrical engineer will do the budget simulations using ADS software (Advanced Design Simulation). It is also the RF electrical engineer's job to order the components along with help from the Integrated Product Team Management

Technical Skill: Computer Programming; RF/Electrical Engineering

Julia Kim

Signal Processing Engineer/Recording Secretary

The Recording Secretary shall take minutes at all scheduled meetings of the design team and make them available to all members, reviewers, advisors, and the project coordinator.

The Signal Processing Engineers will implement Fast Fourier transform type algorithms to do calibration and image formation.

Technical Skill: Signal Processing, Electrical Engineering

Mark Poindexter

Co-Lead Engineer (Mechanical)

The Co-Lead Engineer will provide the Lead Engineer and the Project Manager with the particular specifications and limitations of the Imager as they pertain to design and structure the Imager and its components.

The Mechanical Engineers will design the antenna configuration and the structure to hold the antenna as well as the electrical components. Using CAD software, the Mechanical Engineers will produce precise models and drawings. Sole responsibility for the material used to produce the structure will fall among the Mechanical Engineers. They will work in close proximity with the Antenna Engineer to make sure the system is physically working properly.

Technical Skill: AutoCAD

Malcolm Harmon

Assistant Project Manager (Mechanical)

The Assistant Project Manager will work directly with Project Manager and the Co-Lead Engineer to ensure that the deadlines for each task are being met. The Mechanical Engineer will provide all drafts and renderings of the product for the design team.

The Mechanical Engineers will design the antenna configuration and the structure to hold the antenna as well as the electrical components. Using both CAD and Professional Engineering Software, the Mechanical Engineers will produce precise models and drawings. Sole responsibility for the material used to produce the structure will fall among the Mechanical Engineers. They will work in close proximity with the Antenna Engineer to make sure the system is physically working properly.

Technical Skill: ProE, AutoCAD

Matt Cammuse

Assistant Project Manager (Electrical)

The Assistant Project Manager will work directly with the Project Manager and the co-Lead Engineer to ensure that the deadlines for each task are being met.

The aperture analysis will be the responsibility of the antenna engineer.

Technical Skill: Electrical Engineering, Antenna Engineering

2 Needs Analysis

2.1 Overview of the Synthetic Aperture Radar Imager Project

The threat of security attacks are a big concern in today's society. A large number of people carry concealed weapons such as handguns, bombs, and chemical weaponry which increases the threat of potential attacks on public safety. The need for weapon detection systems is prevalent; however, the need for a low cost system is much greater. Existing imager systems are very expensive and provide more details of the body than is needed for most interested parties.

The objective of the Synthetic Aperture Radar (SAR) Imager project is to develop a fully-functional, low-cost detection system capable of providing a low, but useful imagery resolution so that threats to society can be identified. The design will use commercial-off-the-shelf (COTS) components wherever possible. These components will not affect the integrity or reliability of the design.

Preliminary Project Schedule

- Develop the NARS report (Milestone #1) – 1 month (09/18)
- Develop the project proposal and statement of work (Milestone #2) – 10/16
- Procure materials, components, and/or equipment – 1 month (10/17 – after project proposal is approved)
- Develop a system-level design review (Milestone #3) – 11/13
- Build and assemble prototype imager – 2 months (End of December/Early January)
- Obtain test equipment and set up tests – 1 month (tentatively around 02/09 – 02/13)
- Generate images – 0.5 month (tentatively around 02/23 – 02/27)
- Demonstration to Northrop Grumman representative – 0.5 month (tentatively around 03/23 – 03/27)
- Write final report - 0.5 month (tentatively on 04/06)

Preliminary Project Budget

A primary goal is to establish a functional budget system that adequately responds to the demands of the sponsoring company, Northrop Grumman. The overall budget for this project is $50,000. A successful design will require functioning test equipment for both the electrical and mechanical subsystems. Electrical components as well as mechanical components will need to be procured. Additional software licenses may need to be procured as well.

2.2 Statement of the Problem

Current electronic SAR Imager technology is very expensive and gives more detail than necessary of a human body when imaging. The main priority of this project is to create a low-

cost, fully-functional electronic SAR Imager using commercial-off-the-shelf (COTS) components and capital test equipment to get needed phenomenology information. Waveguide antenna structure design and RF simulation will be implemented using low-cost COTS components. The expected output of this project will be the successful development of a prototype SAR Imager that costs less to manufacture than current models and provides only the necessary amount of information to determine threats to the public safety.

Required Capabilities

- CAP-001: The radar should roughly have a range of 20 feet.
- CAP-002: The radar's operating frequency needs to exist within the standard radar spectral bands, typically around X or Ku bands.
- CAP-003: The radar should operate at frequencies safe for human interaction.
- CAP-004: The radar must be capable of detecting metal and/or threatening objects on a person's body from a distance.
- CAP-005: The radar must be operating at near real-time.
- CAP-006: The radar's width of detection should cover the narrowness of an individual person.
- CAP-007: The data from the receiver should generate an image.

Desirable Capabilities

- CAP-008: The radar should be able to detect metal objects on multiple people and determine who is in possession of a potentially threatening object.

- CAP-009: The radar should be able to detect where on the body the object is located.

- CAP-010: The radar should be able to track an object as the person in possession of it moves.

- CAP-011: The radar should be operating at real-time.

2.3 Operational Description

There are two approaches possible in tackling this project, which are the following:

1) Arrange two orthogonally-oriented switched 1-D sparse antennas which would combine images to get 2-D images. The orthogonal oriented switch configuration is shown in Figure 1[3].

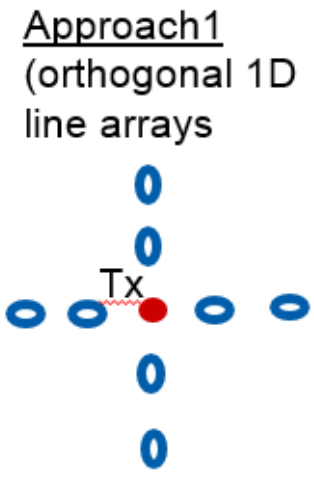

Figure 1 1D Orthogonal Array

Note: T_x (denoted as the red dot) is the target which is to be imaged.

2) Arrange antenna elements in sparse sunflower distribution across area eliminating spatial ambiguities to generate image, this is depicted in Figure 2[3].

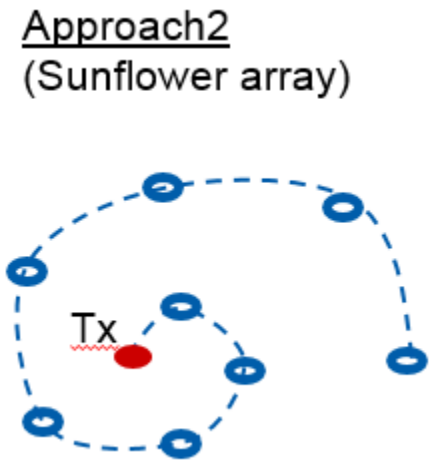

Figure 2 Sunflower Array

Note: Tx (denoted as the red dot) is the target which is to be imaged.

3 Requirements Specifications

3.1 Functional Requirements [4]

- REQF-001: Frequency Range

  The frequency range of the imager should be within FAMU-FSU College of Engineering policies. The X- or Ku- band operating frequency is preferable, which is a range of 8 to 12 GHz for X and 12 to 18 GHz for Ku.

- REQF-002: Range to target

  The distance to the scene to be imaged must be 20 feet.

- REQF-003: Scene Extent

  The area to be imaged, also known as scene extent, must be approximately the width of a person and should ideally cover the person's torso and legs. It has to be enough to image someone with a weapon or a bomb.

- 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 should not be sharp enough to outline the particular type of weapon. The optimal pixels size to divide the scene into would be 3 inches x 3 inches.

- REQF-005: Down Range Resolution

  The down range resolution must be low so that it does not take a thorough image of the body but has enough depth.

- REQF-006: Pulse Width

  Radio frequency travels at about 1 nanosecond per foot in free space. If the range to target is 20 feet, then it takes 40 nanoseconds for the signal to travel roundtrip. This means the pulse width should be less than 40 nanoseconds, and instead about 20 nanoseconds, which would give time to turn transmit off so that the pulse leaves but does not give it time to travel back yet. When transmit is turned off, there will still be 20 nanoseconds to turn the receiver on in order to receive the pulse.

- REQF-007: Safe Radius

  There must be a safe radius for power to transmit out of a horn, but it is to be determined until the antenna size is selected.

- REQF-008: Transmit Power

  There must be transmit power for the imager but will be determined when the safe radius is determined.

- REQF-009: Antenna Size

  The antenna size is to be determined.

- REQF-010: Number of Phase Centers

  The number of phase centers of the antennas depends on the antenna size.

- REQF-011: Distance between Phase Centers

  The distance between phase centers depends on the antennas.

- REQF-012: Pulse Repetition Interval

  The pulse repetition interval is to be determined.

- REQF-013: Receiver Noise Figure

  The receiver noise figure is to be determined.

- REQF-014: Image Frame Rate

  The image frame rate is to be determined.

3.2 Non-functional Requirements

- REQN-001: The Radio Frequency (RF) the SAR imager produces must be within the FCC allocations.

- REQN-002: The radio frequency (RF) the SAR imager produces should not affect communication between other electrical components.

- REQN-003: The SAR imager should be cost effective compared to existing imagers.

- REQN-004: The programming language used should be VHDL.

3.3 Constraints

- CONS-001: Antenna Amount

  Approximately 8 antennas will be needed for the SAR imager, and each antenna will be about 6 to 8 feet long. The structure must be strong enough to hold all antennas.

- CONS-002: Antenna Arrangement

  Antennas must be placed close together at equal distances apart and be precisely pointed at target.

- CONS-003: Safety

  Radiation exposure must be minimal in order to comply with safety regulations.

- CONS-004: Time

  There are only eight months to complete the project successfully.

4 Preliminary Test Plan

4.1 Capabilities Test Plan

- TESTC-0001: Physical Inspection Test

  System must be physically intact and set up exactly as specified in the design prompt.

- TESTC-0002: Power Test

  Supply power to the system to verify whether or not the system works at any specified functionality.

- TESTC-0003: RF safe test

  RF wave must not be negatively affecting humans in the surrounding. This can be done through testing.

- TESTC-0004: Operating signal test

  Antenna must output an RF wave and verify whether or not RF wave has the correct magnitude, phase, etc. This is to make sure that the antenna is receiving power in the first place and actually outputting a signal.

- TESTC-0005: Receiver signal test

  Receiver must be able to pick up scattering waves in order to confirm whether or not the receiver is doing a good job. This test makes sure the receiver in is able to turn on at the correct time and actually receive signal.

- TESTC-0006: Receiver signal test 2.0

  Receiver must be able to accurately pick up scattering waves of varying amplitude and phase. This test makes sure that the receiver is able to pick up signal accurately.

- TESTC-0007:

  Computer image should be generated from the signal picked up by the receiver.

4.2 Requirements Test Plan

- TESTFF-001: Frequency Range

  Testing to validate that the transmitting frequency is accurate to the designs demands will require a high frequency range, radio frequency meter.

  (REQF-001: Frequency Range)

- TESTFF-002: Range to Target

  A simple measuring tool, tape measure, will validate if the distance is 20 feet.

  (REQF-002: Range to Target)

- TESTFF-003: Scene Extent

  Using a radio frequency meter, place the meter at different locations that correlate to a specific object. Test the power levels at these points to justify if the transmitting frequency reaches these locations.

  (REQF-003: Scene Extent)

- TESTFF-004: Cross Range Resolution

  Place a detectable object at a known location and validate if the radar system accurately identified the object.

  (REQF-004: Cross Range Resolution)

- TESTFF-005: Down Range Resolution

  Test the radar system with an object of known parameters and compare the image the radar system creates with actual known dimensions.

  (REQF-005)

- TESTFF-006: Pulse Width

  Establish a program code that records the times when a signal is transmitted to when the signal is received.

  (REQF-006 Pulse Width)

- TESTFF-007: Safe Radius

  Place a frequency meter at the advised safe radius and verify the frequency level at the radius end point.

  (REQF-007: Safe Radius)

- TESTFF-008: Transmit Power

  Employing a high powered voltmeter, test the transmit power to validate if the actual transmit power is relatively equal the theoretical design.

  (REQF-008: Transmit Power)

- TESTFF-009: Antenna Size

  Simple measuring tools will be used for antenna specifications.

  (REQF-009: Antenna Size)

- TESTFF-010: Number of Phase Centers

  Determine the number phase center using a relative measuring device.

  (REQF-010: Number of Phase Centers)

- TESTFF-011: Distance between Phase Centers

  Simple measuring tools to determine the distance between each antenna's phase centers.

  (REQF-011: Distance between Phase Centers)

- TESTFF-012: Pulse Repetition Interval

  Establish a program code that records the pulse repetition intervals. The program must be capable of counting all pulse repetions.

  (REQF-012: Pulse Repetition Interval)

- TESTFF-013: Receiver Noise Figure

  Measure using a noise figure meter.

  (REQF-013: Receiver Noise Figure)

- TESTFF-014: Image Frame Rate

  Establish a program that conducts signal sampling, which then will determine the image frame rate.

  (REQF-014: Image Frame Rate)

4.3 Constraints Test Plan

- CONT-001: Antenna Capability Test

  Design the structure to hold the amount of antennas needed. Must have material capable of withstand various deformations as well as its own weight.

  (CONS-001: Antenna Amount)

- CONT-002: Antenna Precision Test

  The distance between each antenna will be measured in order to verify they are placed at equal distances apart. Laser beams will be employed in order to verify the antennas are pointed at target with precision.

  (CONS-002: Antenna Arrangement)

- CONT-003: Safety Test

  The maximum radiation exposure will be verified in order to ensure safety regulations are being complied with.

  (CONS-003: Safety)

- CONT-004: Time

Deadlines will be set to specific dates, and they must be met early or on time in order to ensure the project is developing at a rate that will allow the project to be completed on time. It is important for every deadline to be met appropriately in order to test whether the design is working as it should and to make any necessary changes.

(CONS-004: Time)

5 Deliverables

The final product will be a Synthetic Aperture Radar (SAR) Imager capable of using radio frequency (RF) signals to scan and detect metal objects. The distance at which the objects can be detected will be 20 ft. with a field of view wide enough for a good detection. The SAR Imager will provide low resolution imagery; however, the resolution will be high enough to detect metal objects within both the range and field of view. The product will be designed using low-cost, commercial-off-the-shelf (COTS) components, and will be realized from a manufacturing view point.

6 References

[1] Frank, Michael, "Example Outline of Milestone #1 Written Report" - Posted on BlackBoard

[2] Fall 2012 EEL4911C Team 5, "Marine Drifters – Specifications and Requirements" - Posted on BlackBoard

[3] Stenger, Pete, "Electronic SAR Imager" – Posted on BlackBoard

[4] Stenger,Pete, "Radar Imager Performance Characteristics" – Posted on Blackboard