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13. ABSTRACT (Maximum 200 words)

The following report describes and defines theoretical considerations necessary for the definition of an air-to-ground opposite side bistatic imaging radar simulation. Theoretical considerations include: range resolution, maximum and minimum range as function of transmitter and receiver depression angles, altitudes, and ground distance.

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Key Techniques and Algorithms for the Development of an Air-to-Ground Bistatic Imaging Radar Simulation

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1.0 - Introduction

The following final progress report indicates those tasks completed for the development of a bistatic air-to-ground imaging radar simulation as per the requirements of the University of Nevada / Army Research Office Short Term Research Project (number DAAD19-00-1-0461).

2.0 - Geometry and Assumptions

The opposite sided bistatic situation in which a radar transmitter and receiver are located on opposite sides of the terrain area (target or clutter) to be imaged is shown in Figure 1. Assumptions underlying the simulation methods described herein include the following. 1) The transmitter is located at a sufficient distance from the terrain to be illuminated such that the wave arriving on the ground may be considered to be a Uniform Plane Wave (UPW). 2) All scattering occurs in the plane of incidence. 3) A timing link (direct communication or synchronized clocks) exists between the transmitter and receiver such that the receiver is signaled when a pulse of energy is transmitted by the transmitter.

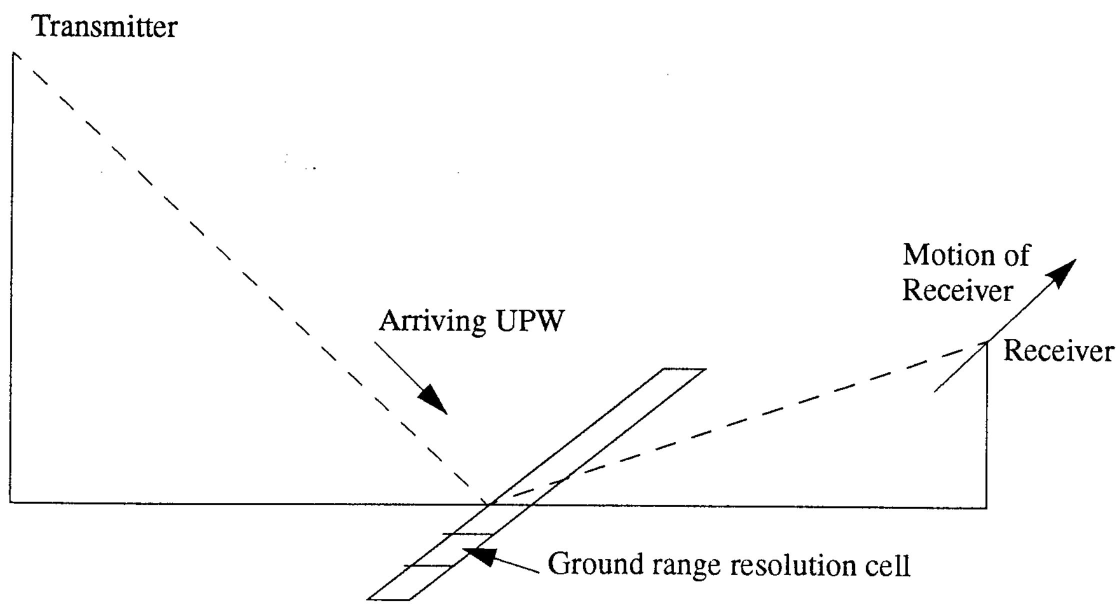

Figure 1 - Basic Opposite Sided Bistatic Geometry

With these assumptions the geometry for the simulation takes the form shown in Figure 2 where θ_{NT} is the complement of the near range transmitter depression angle, θ_{NR} is the complement of the near range receiver depression angle, h_T is the altitude of the transmitter, h_R is the altitude of the receiver, e is the elevation of a scattering center, s_i, located a distance d_1 along the ground from nadir of the transmitter and a distance d_2 from nadir of the receiver. The distance that a transmitted wave must travel to reach the receiver is $R_{Ti} + R_{Ri}$ where

$$R_{T_i} = ((h_T - e)^2 + d_1^2)^{1/2}$$

$$R_{R_i} = ((h_R - e)^2 + d_2^2)^{1/2}$$

Due to distance, time, velocity considerations the two way range of the scattering center (R_{Ti} + R_{Ri}) ,can be written as a function of time. For simulation purposes however, it is the distance, R_{Ti} + R_{Ri} , that we must compute to determine the location of the scattered energy in a particular two way range resolution bin or cell.

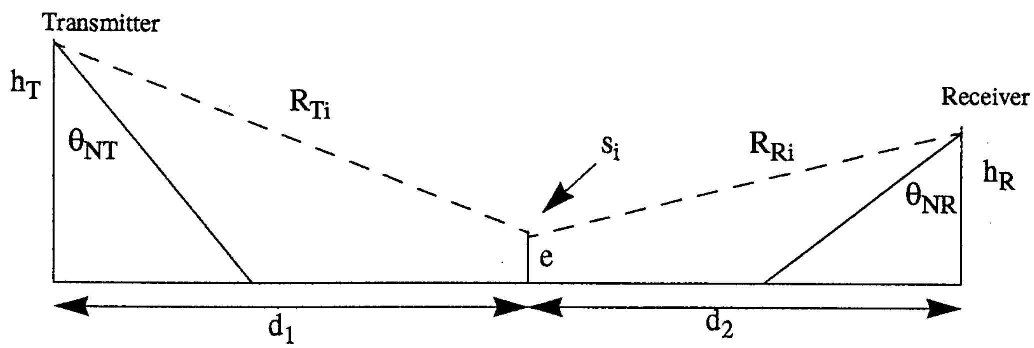

Figure 2 - Two Way Range Geometry

3.0 - Individual Task Progress

The tasks described briefly below represent the work accomplished under the current project. Based on these results it is clear that we are prepared to begin a software development stage.

3.1 - Definition of System Variables

The following variables have been defined as necessary input for simulation control: Transmitter altitude, receiver altitude, transmit depression angle, receive depression angle, illumination swath width, transmit / receive polarization combinations, operating frequency, range resolution (or signal bandwidth), and cross-range resolution. These parameters interact to define the quality and characteristics of both actual and simulated range and ground range imagery and for a robust simulation must be interactively supplied by the user.

3.2 - Definition of Physical Quantities

A detailed study and derivation of all physical quantities relating to the simulation of opposite side bistatic radar range imagery has been accomplished. These quantities include range resolution and timing(of the received signal), ground range resolution (for range to ground range transformation presentations), and two way range as a function of transmitter and receiver altitudes and antenna depression angles and beamwidths.

3.3 - Algorithm Development

Algorithms have been developed for the computation of the following quantities and data.

1) Two way range to individual scattering centers based on variable system geometry.
2) Two way differential scattering coefficient based on the local angle of incidence between the terrain and the receiver and the terrain and the transmitter.
3) Range resolution at the receiver.
4) Ground range resolution based on local angles of incidence.
5) Received power due to each scattering center
6) Two way range to each scattering center.
7) Range resolved receive power data.

4.0 - Summary

Due to the promising theoretical and practical results of this research and the importance of bistatic imaging for next generation reconnaissance and tactical military systems it is hoped that DoD sources can be identified that will provide the funding necessary to move this project into the development stage. It is anticipated that such an effort can be completed in a 12 to 18 month period and would provide the army with a real time interactive simulation capable of producing for any area for which ground truth data is available 1) Opposite Side Bistatic Range Imagery, 2) Opposite Side Bistatic Ground Range Imagery, 3) Same Side Bistatic Range Imagery, and 4) Same Side Bistatic Ground Range Imagery. User controlled parameters will include transmitter and receiver depression angles, altitudes, locations and antenna patterns, operating frequency, range and cross-range resolutions, polarization combinations, and interactive methods to visualize the system geometry and to select areas of illumination.

Based on the literature search conducted as part of the current project, the effort described in the following pages has not been attempted -- or even considered. In addition to publication, the results of such a follow-on effort will provide the ARO and its laboratories with a sophisticated and practical tool for generating and analyzing various types of bistatic imagery for various types of terrain under various imaging system constraints. Such imagery can be used for system design, mission planning, pilot briefing, threat assessment, and terrain and environmental conditions analysis. It will also provide the ARO with compelling visual demonstration materials.

With respect to the results of this effort, we again note that the air-to-ground imaging geometry, range resolution, near versus far range issues, and shadowing effects have not been dealt with in the open literature. Nor have the image formation algorithms and code developed as a result of this project been reported. We believe that a continuation of this effort will provide important scientific results and open new avenues for continued research in this and related areas.