IMAGING MOVING TARGETS IN A MULTIPATH ENVIRONMENT WITH MULTIPLE SENSORS

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An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Mathematics

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

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Troy, New York

November 2010
(For Graduation December 2010)

ABSTRACT

In this dissertation we develop a method for designing a wave-based imaging system that utilizes multiple sensors effectively in the presence of multipath wave propagation.

We consider the cases where the individual transmit/receive sensors are separated by large distances. The scene to be imaged has been illuminated by direct path and multipath wave propagation. The scattering objects of interest are moving. We develop a model for the received data that is based upon the distorted wave Born approximation [?]. To model the multipath wave propagation, we introduce a reflection surface to our problem.

We derive the data models for two cases: one where the reflecting surface is perfectly reflecting and one where the reflection medium depends on frequency and take-off angle. We then develop a number of inversion formulas based on various versions of a filtered adjoint operator of the forward model. The varying inversion formulas account for the waves that have arrived via different paths. We then find the appropriate point-spread function for each case.

We perform numerical experiments by numerically simulating the forward data and reconstructing an image from that data. We test several sensor configurations of the imaging system.

In the first set of experiments we image a stationary object, we model our reflective surface to be perfectly reflecting, we use 1 receiver and up to 9 transmitters, and we simulate the forward data using a stepped frequency continuous waveform, which provides us with high range resolution. It is known from the theory in [?], [?], and [?], that multipath data contains copies of the scattering object in the wrong location. If the data can be separated according to path, then these ambiguities can be easily removed. If the data cannot be separated according to path prior to imaging, then we show that adding more sensors will minimize the ambiguities if the best path is used for backprojection.

In the next set of experiments, we image a moving object, we model our

reflecting surface to be perfectly reflecting, we use 1 receiver and up to 9 transmitters, and we use two waveforms to simulate the forward data The first waveform is a stepped-frequency continuous wave as in the stationary target case. The second waveform is a long pulse and it is known to have high doppler resolution. We again add more sensors and backproject over various paths in order find a best backprojection path and sensor configuration that will reduce ambiguities. Here we have an image of a moving object and thus we expect to find ambiguities in position and velocity. We display the image by creating a 4-dimentisonal plot made up of two dimensional slices of the image grouped together in a grid of varying velocities.

We find that we can estimate a correct velocity using the high doppler resolution waveform. We also find that using more sensors in a specific configuration minimizes ambiguities in position for the high range resolution waveforms. It is interesting to note that velocity may also be detected using a high range resolution waveform, however, the resolution in velocity is poor when compared with the high doppler resolution waveform images.

In the final set of experiments, we image a stationary object, we model our reflective surface to be dispersive, we use 1 receiver and up to 9 transmitters, and we simulate the forward data using a stepped frequency continuous waveform. We notice four distinct paths instead of three. We find results similar to those found in the multipath case for a stationary target with a perfect reflection. We see that if we add more sensors, the image fidelity is improved. In the case where the data cannot be separated by path prior to imaging, then the best adjoint is the sum of all paths.

The numerical experiments show how the theoretical results provide tools for forming images from multipath data effectively and efficiently and for analyzing these images.