Design and Analysis of Passive Multi-static Radar System

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Abstract — *This project presents the design and implementation of simulator focusing on multistatic and netted radars. This project examines the problem of target detection in passive multi-static radar. A review of the theory and history of passive radar is presented. The state of the art is addressed and analyzed, and some existing detection algorithms are implemented, along with discussion about specific implementation details. A novel new approach, Range-Doppler transformations, is proposed. This approach relies on a large number of radar receivers, and processing targets in the Range-Doppler domain. These targets are then transformed into the spatial domain, resulting in a number of ellipses that are intersected to determine the location of targets. This algorithm is accurate, robust to synchronization errors, and has better time complexity than current methods.*

Keywords — Algorithms; hardware; imaging; multistatic; netted radars; Passive radar; radar systems;

1. INTRODUCTION

Radar simulators can be divided into a number of categories depending on the type of results they are intended the produce, and the expectations of the end user. Broadly defined, the categories of radar simulators are: Result simulators produce a simulation of the results, after processing, which could be expected when a radar system is run in a particular environment. These types of simulators are useful for training both humans and machines in result Interpretation. These types of simulators can run extremely efficiently, as they do not need to model the actual operation of a radar system — only the expected results.

Simultaneously, the rise of computing power and communications technology has lead to increasing interest in the application of the ideas of sensor networks to radar systems, greatly increasing the system level complexity, and hence difficulty of analysis, of radars. Simulation can provide an invaluable tool to radar researchers, engineers and operators.

So if passive radar has all of these advantages over active radar, why isn't it more widely used? Why is it not standard?

There are 2 main reasons for this. Firstly, as you would expect, passively detecting targets is a very computationally expensive exercise. Only recently have the digital signal processing technologies become available to quickly and accurately implement a passive radar system up to the standard of active radar. Secondly, for passive detection to work there needs to be a strong broadcast signal, an Illuminator of opportunity.

The recent advent of digital television broadcast has made passive radar detection more viable as it provides many wideband, high strength, high frequency signals. These DVB-T signals are perfect for passive detection. Previously FM radio, cell phone base stations and digital audio broadcast were possibilities for use in passive radar and have been shown to have detection ranges in the order of several 10's of kilometer's. With the higher signal power from digital television broadcast, this range can be vastly extended.

Apart from the obvious current military applications, passive radar has also been used for civilian applications. Also passive radar is used for collision warning of wind power plants. It employs a passive radar system that uses the DVB-T illuminators to detect aircraft approaching wind farms and also to reduce the collision of birds. So we can see that passive radar detection is a superb technology, but how does it work?

2. EXISTING SYSTEM

A Passive radar system is a type of radar system that exploits the transmitters of commercial broadcast or communication systems as their source of target illumination. Passive radars do not have a dedicated transmitter, and they are based mainly on a high performance receiver. Compared to conventional active radars, passive radars are more resilient to jamming, easier to fabricate and lower in cost. Passive radars have witnessed developments in the last decade.

The geometry is bistatic in nature, due to the separation between the transmitter and the receiver. Signal processing depends on the cross correlation between the direct signal from the transmitter and the scattered signal from the target.

Passive radars have been shown to be appropriate in various applications. For example, in passive coherent radar systems are investigated based on FM radio, cellular phone base stations and digital audio broadcast (DAB). Passive radar detection is the problem of locating unknown targets using only static radar receivers. It uses unknown signals broadcast by non-cooperative parties.

3. NEW TECHNIQUE

The main motivation behind a new approach for passive radar detection systems from the fact that the cost of radar receivers is beginning to fall, as antenna and receiver technology gets cheaper and more efficient [5,6]. This means that it is starting to become reasonable to have large networks of cheap receivers working together as a detection system. With this scalability in hardware, comes the need for a massively scalable algorithm for detection.

The large scale of such a system presents its own problems that current detection methods will struggle with, such as Greater timing and synchronisation issues due to the larger number of receivers, the need to merge all the data at a centralized location for processing, the computing power to calculate the PPI map using all of the received data.

The current methods all require that the raw received data be sent and synchronized to a high degree of accuracy to the same place for processing. The main focus is to develop an algorithm that is robust to the factors mentioned above and very efficient, as it must scale well.

3.1 Range-Doppler Map

RD maps can facilitate these requirements; received signal is correlated with itself at each receiver. Gives a measure of how likely a target is to be at a certain range (difference between the Tx-Rx and Tx-Target-Rx paths) or frequency (velocity). Shown in Fig :-1

3.2 Range-Doppler Transformation

Each target in the RD map represents an ellipse with foci at the Rx and Tx locations.

1. Find all ellipses for all receivers

2. Intersect ellipses and vote

3. Intersection point with highest consensus is a target

4. Remove target ellipses and repeat consensus step until threshold reached

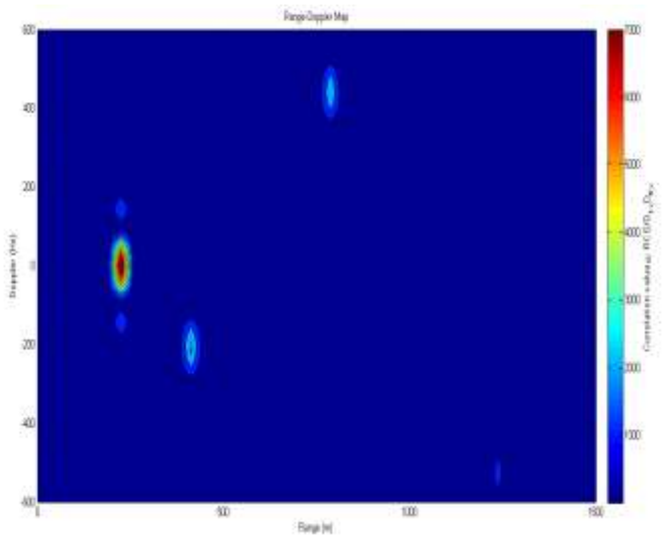

Fig-1: Range-Doppler Map with 4 targets

3.3 Methodology

Research and develop algorithms for the signal level simulation of radar systems using Coding Language and IDE Matlab. The algorithms required must support the simulation of systems with arbitrary numbers of receivers, transmitters and targets.

Develop algorithms for Range-Doppler Map and PPI indicator map with targets by using Matlab. Also algorithms for Target detection characteristics in the Range-Doppler domain using Matlab and for the simulation of the effects of phase noise and jitter on radar systems, and the synthesis of phase noise matching measured oscillator parameters.

Plot Spatial domain plot of all receivers, transmitters, and Range-Doppler map transformed ellipses.

Verify that the simulation results Output of the Range-Doppler Transform Algorithm Are accurate, within the bounds of the limitations of the simulation algorithms.

Simulation algorithms must also efficiently support CW radar, wideband and carrier-free radar systems.

E.g. A single transmitter located at (1000,0), receiver array centered around (0,0),Simulated a single target at (1100,500) with velocity of (200,-200) shown in Fig-2

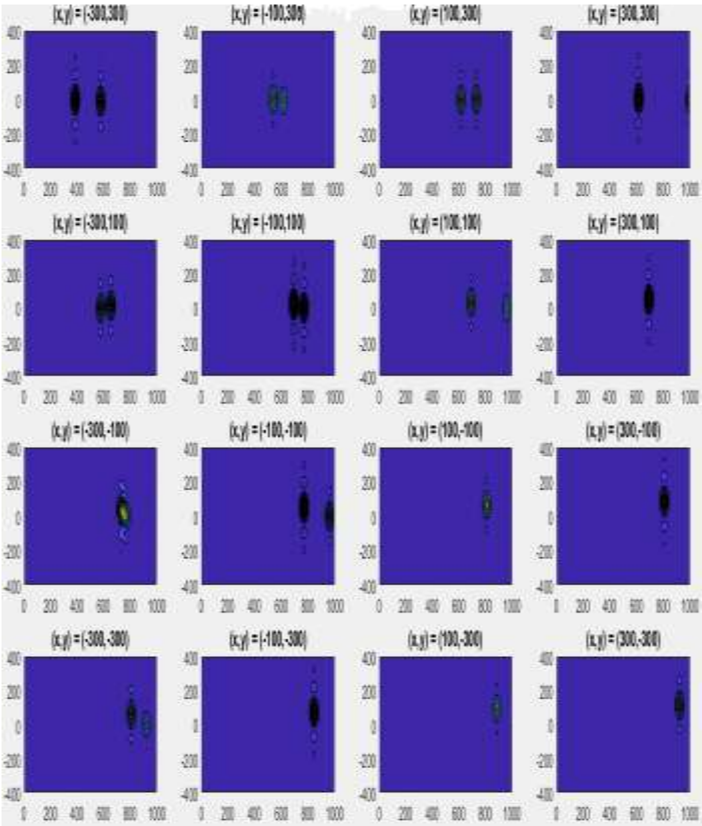

Fig-2: Collection of Range-Doppler maps for receiver array with two simulated targets

Side lobes in RD map due to ambiguity function in range and Doppler. Targets located in different spatial positions but at same range Timing and synchronisation issues become less prevalent and amount of computation decreases.

Determined that there is 1 target located at (1078, 519). Error of 29m. 8MHz sampling means 37.5m covered between samples shown in Fig-3

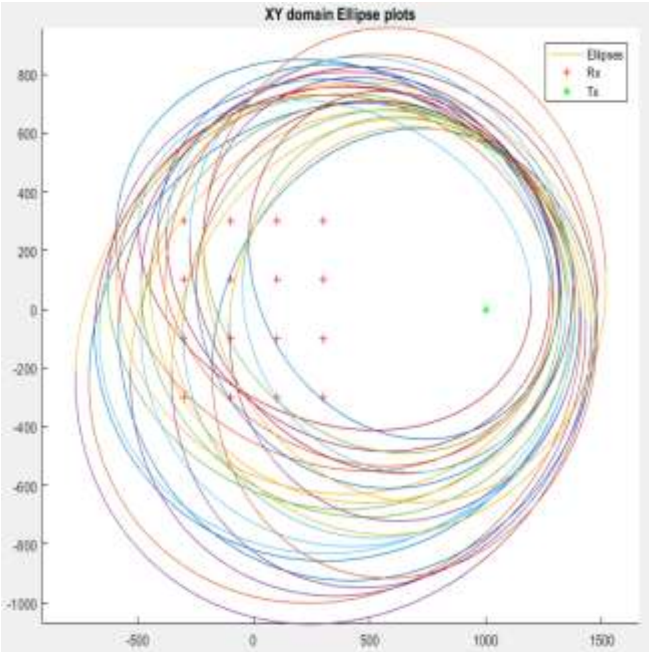

Fig-3: Spatial domain plot of all receivers, transmitters, and Range-Doppler map transformed ellipses

4. CONCLUSIONS

This project has studied the topic of Passive Radar, and proposed a new algorithm for solving the passive radar detection problem. The Range-Doppler Transformation is a novel algorithm intended for use in passive radar detection schemes with large arrays of receivers. It has shown to be successful in medium scale simulations, as well as having a very high degree of accuracy. The algorithm has been shown to be robust to many problems that outbreak current passive radar algorithms when they are implemented in the real world. It has a much better tolerance to timing and synchronization effects, meaning that it is easier to set up a live system.

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