CORRELATIVE INTERFEROMETRY FOR ANGLE OF ARRIVAL ESTIMATION AND SIGNAL SOURCE LOCATING

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I declare that this project report entitled "*Correlative Interferometry for Angle of Arrival Estimation and signal source locating*" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my honoured and esteemed family, friends and
all those who have contributed in this project
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ABSTRACT

Radio Direction Finding (RDF) refers to the measurement of the direction of the transmitted signal. RDF is used in military intelligence systems, public safety systems, navigation of ships and aircraft. The emitter location can be estimated based on the measured parameters, namely the angle of arrival (AOA), time of arrival (TOA) or time difference of arrival (TDOA). In this project, the square arrangements of four receivers which spaced at 5 km from the centre is considered. The configuration is determined in order to establish line of sight (LOS) and minimize losses. The measurement parameters are observed at each receiving station independently. There are two major methods to determine emitter locations: one-step positioning techniques (centralized processing) and two-step positioning techniques (decentralized processing).In this project, the one-step positioning techniques or direct method is considered. The method requires a two dimensional search which takes the advantage of simple propagation assumptions, that are usually used for radio frequency signals (RF). Direct position estimation that used to estimate angles from all receiving units and location of the emitter, is based on maximum likelihood of the signals intersection point. The triangulation and least square approximation method are then implemented to estimate the emitter positions. Finally the performance of the system was tested with various SNR and estimates emitter locations. The results were compared with the true emitter locations in order to determine the percentage of errors in the estimation.

ABSTRAK

Radio Arah Mencari (RDF) merujuk kepada pengukuran arah isyarat yang dipancarkan. RDF digunakan dalam sistem perisikan tentera, sistem keselamatan awam, navigasi kapal dan kapal terbang. Lokasi pemancar boleh dianggarkan berdasarkan parameter diukur, iaitu sudut ketibaan (AOA), masa ketibaan (TOA) atau perbezaan masa ketibaan (TDOA). Dalam projek ini, pengaturan persegi empat penerima yang berjarak 5 km dari pusat itu dipertimbangkan. Konfigurasi ditentukan untuk mewujudkan garis penglihatan (LOS) dan meminimumkan kerugian. Parameter pengukuran dipatuhi pada setiap stesen penerima secara bebas. Terdapat dua kaedah utama untuk menentukan lokasi pemancar: teknik satu langkah kedudukan (pemprosesan berpusat) dan teknik kedudukan dua langkah (pemprosesan diagihkan). Dalam projek ini, teknik kedudukan satu - langkah atau kaedah langsung dianggap. Kaedah ini memerlukan dua dimensi carian yang mengambil kelebihan daripada andaian pembiakan mudah, yang biasanya digunakan untuk isyarat frekuensi radio (RF). Anggaran kedudukan langsung yang digunakan untuk menganggarkan sudut dari semua unit menerima dan lokasi pemancar, adalah berdasarkan kebolehjadian maksimum bagi titik isyarat persimpangan. The triangulasi kaedah dan kurangnya Penghampiran kuasa tersebut dilaksanakan untuk menganggar kedudukan pemancar. Akhirnya prestasi sistem yang telah diuji dengan pelbagai lokasi pemancar SNR dan anggaran. Keputusan yang diperolehi dibandingkan dengan lokasi pemancar benar untuk menentukan peratusan kesilapan dalam anggaran.

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AOA	-	Angle Of Arrival
EEP	-	Elliptical Error Probable
RDF	-	Radio Direction Finding
DF	-	Direction Finding
TOA	-	Time Of Arrival
TDOA	-	Time Difference Of Arrival
LOS	-	Line Of Sight
AOI	-	Area Of Interest
SNR	-	Signal to Noise Ratio
RF	-	Radio Frequency

CHAPTER 1

INTRODUCTION

1.1 Introduction

Radio Direction Finding (RDF), refers to the measurement of the direction from which a received signal was transmitted. RDF is used in military intelligence systems, geolocation, navigation of ships and aircraft [1]. Numerous techniques of RDF have been used over time to determine the angle of arrival AOA, such as pseudo-Doppler DF techniques, Watson-Watt/Adcock antenna array and correlative interferometry. However, correlative interferometer has been the highest tendency of accurate measurement of AOA [2].

Direction information from two or more receivers that are properly spaced is used to estimate position of the source of that transmission through a process called triangulation method. Difficulty in emitter location attracts great interest in the signal processing, underwater acoustics literature and vehicular technology, this has been witnessed since World War I, researches have been conducted, some of the early ones are mathematics of emitter location, using AOA [3], a paper by Torrieri a "Statistical theory of passive location systems" [4] and a lot more publications were followed, also comprehensive review journals were presented, like antenna array processing for location by AOA by Krim and Viberg [5] and the one by Wax[wax]. Recently, Nikhila et al have published a paper "Simulation on emitter location algorithm" [6].

1.2 Problem Statement

- Existing RDF systems have an increased directional error due to weak signal and multipath.
- High needs of processing ensue from the execution of enormous data base of all possible directions.
- Errors due to geometry of the receiving unit.

1.3 Objectives

Objectives of this research work are as follows;

- To evaluate a square configuration of four receivers for signal source locating using the process of triangulation.
- To use Correlative Interferometer algorithm to estimate AOA of the received signals.
- To compare the AOA and emitter locating estimate using Monte Carlo simulation for various SNR.

1.4 Scope

This research project is implemented with no use of hardware, it is solely on MATLAB® implementation and scopes of this research work are as follows:

- Square setup of four receivers is considered (for symmetry) where the separation of 10 $\times$ 10 km is considered which is known as area of interest (AOI) for the provision of line of sight (LOS) between receivers for communications and minimize number of losses.

- One step positioning techniques (centralised processing) method was employed, because this method takes advantage of rather simple propagation assumptions that are usually used for radio frequency (RF) signals.
- The process of triangulation is employed to locate the position of signal source (emitter) in space and the emitter is assumed stationery within the period of observation.
- The performance of the system is tested (verified) by Monte-Carlo simulation to determine the effect of variance in the AOA estimate and the position of emitter.

1.5 Research Methodology

This research work methodology, start with the introduction of signal reception, AOA and signal source estimations. Then, literature review on numerous angle estimation and emitter location, where emphasis were given to the emitter location or position of signal source estimation techniques for aims and objectives of this research to have proper or appropriate solution.

Initially, signal source and frequency coming from a direction is considered and a square setup of four receivers is also considered, received signals will be down converted to base band frequency components and phase differences will then be estimated where the minimum phase differences will correspond to the AOA of the received signals, process of triangulation was employed to estimate the signal source location where least square approximation was used to solved four equations with two unknowns, results of this estimation are the coordinates corresponding to the x and y axis positions of the emitter and finally the performance of the system was tested (verified) by Monte Carlo simulation to determine the effect of variance in the AOA estimates.

1.6 Organization of the Project

This research project is separated into five chapters. Every chapter discussed on dissimilar subjects of the project. Discussions are as follows:

Chapter 2: This chapter starts with the introduction of RDF and emitter locating where a brief background of it and signal source locating were presented in details and least square approximation method was also highlighted.

Chapter 3: Chapter three was the details methodology required to set a square arrangement of four receivers and determine the AOA of each of the receiver and estimate signal source location. This chapter further elaborated on parameters needed to set up this arrangement and method used in signal source estimation.

Chapter 4: Delivers AOA estimates and presented the signal source locating using the process of triangulation. Deliberations for these results were included. The percentage errors between the true and estimated locations were also highlighted sources of errors and errors were presented in plots.

Chapter 5: This chapter conclude this research work with recommendations for further research.

1.7 Summary

This chapter discussed the introduction of this project, shadowed by brief explanation on radio direction finding and signal source locating. Problems where stated, objectives and scope of this project were presented.

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