DOPPLER METHOD FOR ANGLE OF ARRIVAL ESTIMATION

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To my esteemed and cherished family, friends and
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ABSTRACT

Radio direction finder, which utilizes angle-of-arrival (AOA) estimation, is a function in a radio monitoring system to estimate the direction of the signal. A radio monitoring system can be used to estimate the parameters of a received signal and determines its direction. The system is used in a large area of application and the major users of radio monitoring systems are regulatory bodies, law enforcement, public safety and the military. There are two types of DF techniques, multi-channel direction finding and single channel DF techniques. In this work, the single channel technique is implemented. The single channel DF systems offer several advantages over multiple channel systems, such as lower power consumption, portability and lower cost compared to the other DF technique. Basically, all DF systems are set to derive emitter location and the AOA. There are several methods of single channel DF, such as Watson Watt/Adcock method, pseudo-Doppler and correlative interferometry. In this project, the pseudo-Doppler DF techniques for angle of arrival estimation is implemented. The radio direction finder, which implement the Doppler method, consists of a circular antenna array that rotates at a constant speed. Signals received are spatially located and the rotation of the antenna introduces Doppler shift in the received signals. The Doppler method utilizes the Doppler shift and the spatial location of the receiving antenna to estimate the AOA for the received signals. The performance of the system was verified by Monte Carlo simulation to determine the effect of variance in the AOA estimation and location at various signal-to-noise ratios (SNR).

ABSTRAK

Radio arah pencari yang menggunakan sudut - of- tiba (AOA) anggaran adalah fungsi dalam sistem pemantauan radio untuk menganggarkan arah isyarat . Sistem pemantauan radio boleh digunakan untuk menganggar parameter isyarat yang diterima dan menentukan hala tuju , sistem ini digunakan di kawasan yang besar permohonan dan pengguna utama sistem pemantauan radio adalah badan-badan kawal selia , penguatkuasaan undang-undang , keselamatan awam dan tentera .Terdapat dua jenis teknik DF, arah dapatan berbilang saluran (DF) dan saluran tunggal teknik DF. Projek ini mengembangkan teknik saluran tunggal. The single channel DF systems offer several advantages over multiple channel systems, such as lower power consumption, portability and lower cost compared to the other DF technique. Basically, the DF systems determine to derive emitter location and the AOA. Saluran tunggal sistem DF menawarkan beberapa kelebihan berbanding sistem saluran pelbagai , seperti penggunaan kuasa yang rendah , keperluan mudah alih dan kos pelaksanaan . Pada dasarnya , semua sistem DF memiliki matlamat utama untuk mendapatkan lokasi pemancar dan AOA . Terdapat beberapa kaedah saluran tunggal DF : Kaedah Watson Watt / Adcock , pseudo - Doppler dan interferometri korelasi . Projek ini mengkaji mengenai teknik pseudo - Doppler DF untuk sudut anggaran ketibaan. Para pencari arah radio yang menggunakan kaedah Doppler yang terdiri daripada pelbagai antena bulat yang berputar pada kelajuan yang tetap . Isyarat yang diterima spatial terletak dan putaran antena memperkenalkan anjakan Doppler dalam isyarat yang diterima. Kaedah Doppler menggunakan anjakan Doppler dan lokasi spatial antena penerima untuk menganggarkan AOA untuk isyarat yang diterima. Prestasi sistem yang akan disahkan oleh simulasi Monte Carlo untuk menentukan kesan perbezaan dalam anggaran AOA dan lokasi pada pelbagai nisbah isyarat - kepada-hingar (SNR) .

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AOA	-	Angle Of Arrival
AWGN	-	Additive White Gaussian Noise
CRLB	-	Cramer-Rao Lower Bound
DF	-	Direction Finding
DFT	-	Discrete Fourier Transform
DOA	-	Direction-of-Arrival
FFT	-	Fast Fourier Transform
FM	-	Frequency Modulation
IDFT	-	Inverse Discrete Fourier Transform
LED	-	Light Emitting Diode
LLAC	-	Localized Lag Autocorrelation Computation
SNR	-	Signal-to-Noise Ratio

CHAPTER 1

INTRODUCTION

1.1 Background

Radio direction finder that utilizes angle of arrival (AOA) estimation is a function in a radio monitoring system to estimate the phase of the signal. A radio monitoring system can be use to estimate the parameters of a received signal and determines its direction [3]. The system is use in a large area of application which includes regulatory bodies, law enforcement, public safety, geology research and the military. In a military environment, estimates of the initial phase, phase rate (frequency or Doppler), and phase acceleration (frequency or Doppler rate) are all used to provide information about a target [2].

In practice the radio direction finder that uses the Doppler method consist of circular antenna array that rotates at a constant speed. Signal received are spatially located and the rotation of the antenna introduces Doppler shift in the received signals. The Doppler method utilizes the Doppler shift and the spatial location of the receiving antenna to estimate the AOA of the received signal. Since rotating an antenna element mechanically is neither practically possible nor desirable, several elements (dipole, monopole, crossed loops) are arranged on a circle (figure 1.1) and electronically sampled by means of diode switches (cyclic scanning). To obtain unambiguous direction finding results, the spacing between the individual antenna elements must be less than half the operating wavelength; basically, a spacing of about one third of the minimum operating wavelength is selected [3].

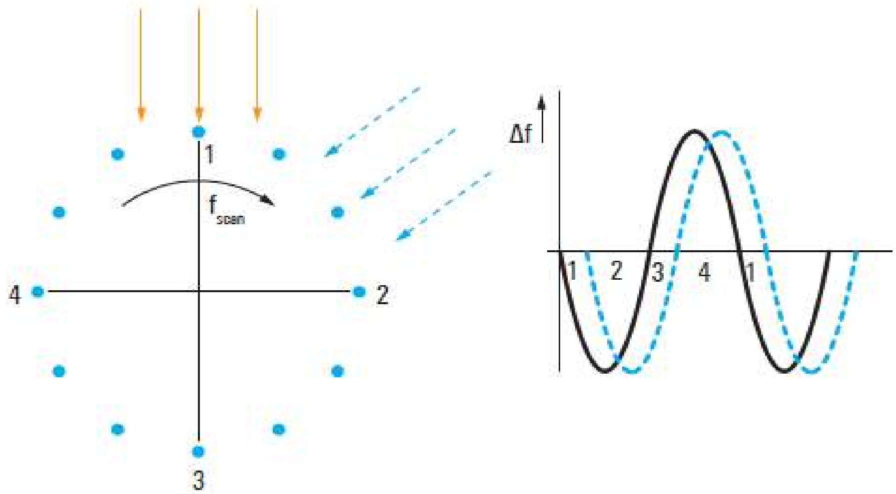

Figure 1.1: Principle of Doppler direction finder [1].

Radio direction finding (DF) techniques have classically been based on multiple-antenna system employing multiple receivers. In many scenarios (e.g., hand-held systems), multiple receivers are impractical. Thus, in this project single channel techniques are of interest. The two main categories of single channel DF are amplitude-based DF and phase-based DF system. Amplitude-based systems determine the bearing of the signal (or the AOA) by analyzing the amplitudes of the output voltages from each antenna element. Amplitude DF systems include the Watson-Watt technique using an Adcock antenna array [4]. The Phase-based systems use three or more antenna elements that are configured in a way so that the relative phases of their output voltages are unique for every wave front AOA. Phase-based DF systems include the Pseudo-Doppler technique with a commutative switch based antenna array [4].

1.2 Problem Statement

The task of a radio direction finder is to estimate the direction of an emitter by measuring and evaluating electromagnetic field parameters. Usually there is a large number of partial waves arriving from different direction and making up a more or less scattered field with noise playing a vital rule in multipath reception. The main requirement of AOA estimation became compromised resulting to:

- ❖ Several ambiguities in direction finding results with low immunity to multipath reception.
- ❖ Less accurate estimate of signal direction.
- ❖ Difficulties observed in obtaining accurate AOA using other DF approaches for phase estimation of a received signal.

The need for a robust, flexible and accuracy in detecting the AOA of a signal from multiple source or corrupted signals brought about this project.

1.3 Objectives

The objectives of this project are:

- ❖ To use the Doppler method to estimate the AOA of a signal from different directions.
- ❖ To evaluate the effect of variance in the phase estimation for various AOA at different signal-to-noise-ratio (SNR).

1.4 Scope of work

The entire project was implemented using MATLAB®. It was considered as the best tool for evaluating the simulation of this project. The Doppler method requires the arrangement of a four antennas in a circular array which are connected to a radio frequency combining circuit. The circuit combines the antenna signals in such a way it simulates the continuous rotation of a single antenna element about the axis of symmetry of the antenna array, spacing between the elements arranged in a circle is about one third of the minimum operating wavelength of the antenna. The signal was assumed to be corrupted by an Additive White Gaussian Noise (AWGN) and signal received is real which was converted to analytic form. The phase of the signal will be evaluated using cross correlation of the Doppler signal and a reference voltage of equal center frequency derived from the antenna rotation. The performance of the system will be verified by Monte Carlo simulation to determine the variance of the AOA estimated at various SNR.

The signal was assume demodulated and all processing are done at intermediate frequency, no design of antenna and receiver was carried out.

1.5 Research Methodology

The method exhibited in the process to achieve the objective of this project begins with a literature review on the DF articles that deals with robust phase estimation, this is to understand the behavior and difficulties faced in other approaches of phase estimation. Furthermore, an algorithm was derived to obtain the demodulated Doppler signal and the calculation of SNR from the received signal is done. Signal received is converted to a domain that can give the information about frequency i.e. the signal is decomposed into an intrinsic mode to obtain the instantaneous frequency. The phase of the signal was evaluated from cross correlation and several SNR are observed for different phase change. Finally the Monte Carlo simulation is performed for the evaluation of the systems performance.

1.6 Chapter Summary

The chapter covers the basic information of the project, problems associated with AOA estimation and how it plans to solve them. It also highlights the objectives, restrictions involve and all assumption made in the process of the project.

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