Thesis Title: "Performance Analysis of DOA Estimation Algorithm in Massive MIMO Network"

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Declaration

I hereby declare that this thesis contains my own work except where specifically acknowledged.

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Certificate

This is to certify that the project work entitled "Performance Analysis of DOA Estimation Algorithm in Massive MIMO Network" is a record of original work done by Jean de Dieu MWUNGURA with Reg no: 217292585 in partial fulfilment of the requirements for the award of Master of Science in Information and Communication Technology of College of Science and Technology, University of Rwanda during the academic year 2017-2018

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ABSTRACT

This generation has seen a massive growth in the number of connected wireless devices. Billions of devices are connected and managed by wireless networks at the same time; each device needs a high throughput to support applications such as voice, real-time video, movies, and games. As solution, Massive multiple-input multiple-output (MIMO) technology has been proposed, which is a multiple access technology where a base station (BS) serves many users in the same time-frequency resource according to his very large number of antennas (distributed). Thanks to its advantages, Massive-MIMO promises as a candidate technology for next generations of wireless systems.

One of the research challenges often encountered (in the context of massive MIMO) is the problem of two-dimensional (2D) estimation (in azimuth and elevation) of the direction-of-arrival (DOA) at the BS. When 2D-DOA estimation is well done, it improves the performance of the beam-forming mechanism that helps the network to have higher signal to noise ratio (SNR) and the prevention inter-user interference (pilot contamination) which naturally leads to an increase in the total capacity and higher network efficiency of the system.

In the context of the two-dimensional estimation of the DOA, several recent research have opted different algorithms for estimation of 2D-DOA by using different antenna structures and their respective performances are compared in terms of the complexity/precision. Research conducted on this topic (2D-DOA estimation algorithms) considered a time-invariant channel that is different from the reality of Massive-MIMO systems applied in mobile communication whose channel is time-variant (Multi-path channel). Here comes the idea of my research that study comparatively the Performance of 2D-DOA estimation algorithms by considering the time-variant channel (multi-path channel) in order to recommend a suitable DOA estimation algorithm for 5G systems.

In this work, we analyze the 2D-DOA estimation algorithms that uses L-shaped antenna array structure DOA by evaluating the mean-squared error in azimuth and elevation. By analyzing the 2D-DOA estimation algorithms that uses L-shaped antenna array; we observe that PM perform better than others because of presenting lower value of RMSE, SNR and AS in different cases of simulation.

LIST OF SYMBOLS AND ACRONYMS

AOA: Azimuth of arrival

AS: Angular spread

AWGN: Additive white Gaussian noise

CSS: Conjugate symmetry based subspace

CCB: Cross-correlation based

CDMA: Code division multiplexing

CoMP: Coordinated multi point

DOA: Direction of arrival

EDGE: Enhanced Data Rates for Global Evolution

EOA: Elevation of arrival

ESPRIT: Estimation of signal parameters via rotational invariance techniques

GPRS: Generalized Packet Radio Service

GSM: Global System for Mobile Communications

HSDPA: High-Speed Down link Packet Access

i.i.d: Independently identically distributed

IMT: International mobile telecommunication

IS-54: Interim Standard 54

LTE: Long Term Evolution

MATLAB: Matrix laboratory ,

MIMO: Multiple input-Multiple output

MISO: Multiple input-single output

MUSIC: Multiple signal classifcation

mm-wave: Millimeter wave

OFDMA: Orthogonal Frequency Division Multiple Access

PM: Propagator method

PRIME: Polynomial root intersection for multi-dimensional estimation

RARE: Rapid acquisition relaxation enhanced

RMSE: Root mean square error

SC-FDMA: Single-Carrier Frequency Division Multiple Access

SNR: Signal to noise Ratio

SIMO: Single input-multiple output

SISO: single input-single out put

URA: Uniform rectangular array

ULA: Uniform linear array

WCDMA: Wide band Code Division Multiple Access

WIMAX: Worldwide Interoperability for Microwave Access

2D: Two dimension

3GPP: Third Generation Partnership Project

5G: Fifth Generation

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

Direction of arrival (DOA) estimation is useful in signal processing of various applications like wireless communications, radio detection and ranging (RADAR) communication, sound navigation and ranging (SONAR) communication, electronic surveillance measure systems and seismic exploration [1]. In wireless communication, smart antenna is an important system that is composed of an antenna array together with a signal processing unit. Smart antenna brings several opportunities in wireless communication including increase of network capacity, network security as well as an increased coverage range with reduced interference. The overall performance of smart antenna system is conditioned by both array geometry and the applied DOA estimation algorithm. In application of multiple input-multiple output (MIMO) technology in mobile wireless communication, DOA estimation is of great interest because the performance of three dimensional beam-forming of Massive MIMO [2], [3] relies on the accuracy of 2D-DOA estimation of many incident signals received on the antenna array mounted on a base station.

Since few years ago, a great work of research is oriented on development of both high-resolution and low-complex DOA estimation algorithms that can work well with Massive MIMO antenna array structures in order to enable real-time applications and other various benefits expected in 5G systems. In DOA estimation literature, various DOA estimation algorithms have been studied namely MUSIC (Multiple signal classification) [4] that search over a reduced parameter space, ESPRIT (Estimation of signal parameters via rotational invariance techniques) [5] that relies on rotational invariance property of the antenna array, Propagator Method(PM) [6] that is used in L-shaped antenna array structure and does not involve eigen-value decomposition, cross-correlation based estimator(CCB)[7], conjugate symmetry based estimator [8]. These DOA estimation algorithms are applied in various antenna array geometries like uniform linear array (ULA), uniform rectangular array(URA),Uniform circular array(UCA), cylindrical array, spherical array and L-shaped antenna arrays. In order to overcome the computational complexity challenges faced by many high-resolutional DOA estimation algorithms, different solutions have been developed.

In [1], esprit and closed-form 2-D angle estimation with planar arrays [5]. The use of ESPRIT-based techniques in beam-space has been proposed and brought the idea of Unitary ESPRIT that estimates DOAs by performing real-valued computation, the solution that reduces significantly the computation load. An interesting research has been done demonstrating that we can farther reduce the computation complexity in L-shaped array based DOA estimation methods by dealing with vectors rather than matrices [9].

URA based DOA estimation methods show a good performance but their computational complexity is higher to be used in Massive-MIMO where we will be dealing with hundreds of base station antenna serving tens of mobile user running real-time applications.

In this thesis the purpose of comparative review of L-shaped antenna array based DOA estimation algorithms is to have a suitable algorithm that can be proposed as candidate in 5G system. Throughout this research a MATLAB simulation of L-shaped antenna array based 2D- DOA Estimation algorithms: Propagator Method(PM), Cross-correlation based(CCB) method, Conjugate symmetry based subspace (CSS) method is used to analyze comparatively performance by observing the variation of RMSE against AOA (Azimuth of arrival) and EOA Elevation of Arrival). Computational complexities (run time) and the robustness of both method against the variation of SNR and angular spread (AS) will also be compared.

1.2 Research frame work

Throughout this research thesis, my first task is to understand the need of 2D-DOA estimation and its applications attaching much interest on mobile wireless network by exploring the technological trends of mobile network together with respective challenges as well as solutions proposed to circumvent them. A brief review on Massive MIMO proposed as the key technology up on relies the future generation of mobile communication network technology is provided by focusing on full dimension MIMO that will be exploited in 5G network System.

In this thesis, I will describe high competitive DOA estimation algorithms encountered in literature of DOA estimation and I will analyze L-shaped based DOA Estimation algorithms in MATLAB. To conclude, I will compare the performance of implemented algorithms on basis of computational complexity efficiency, DOA estimation precision, and variation of RMSE with SNR and angular spread.

1.3 Research objectives

This research intends to compare L-shaped antenna array based 2D-DOA estimation algorithms like Propagator Method, cross-correlation based method and conjugate symmetry based methods by considering the computational complexity and their respective root-mean square error (RMSE) when they are all subjected to the same simulation conditions. We analyze and simulate each method and make a comparison on basis of MATLAB simulation results obtained by considering similar parameters in a multipath environment.

1.4 Contributions

Other authors conducted their research in this domain by considering AWGN (Additive white Gaussian noise) channel that is far different to the realistic mobile communication network. To approach the reality of mobile communication network; I conducted my research to study the performance of L-Shaped based DOA estimation methods in a multi-paths environment.

1.5 Research report organization

This research project report is organized in five chapters.

In **CHAPTER ONE**, we introduce briefly the concern of the whole project by introduction, research frame work, research objectives, and the contribution of this work and the organization plan of the research project report.

In **CHAPTER TWO**, we discuss briefly the need of 2D-DOA estimation in the mobile network where much emphasize is attached to new trends in mobile networks by presenting the evolution of mobile network toward 5G. Before we conclude this chapter, we shall outline key features of 5G Massive MIMO.

In **CHAPTER THREE**, Research Methodology; this focuses on simulation approach methodology that can be used on the project and the algorithms comparison gathering techniques.

The **CHAPTER FOUR** is consecrated to 2D-DOA estimation for L- Shaped array antenna structure where we present a system model in which L-shaped Method (Propagator Method (PM),Conjugate symmetry based subspace method, Cross-correlation based method) are presented and implemented.

The **CHAPTER FIVE** focused on the presentation and interpretation of simulation results comparing L-shaped array based methods implemented in the same conditions.

The **CHAPTER SIX** closes this research project report by conclusion and future works.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Mobile network is a fast growing career and adopted as key elements in all aspects of life. However, its operating frequency band does not expand [10].This brings many challenges regarding spectral efficiency, network capacity and quality of service. Nowadays, we face another tremendous challenge of global warming occasioned by carbon emission that has some of their roots in fast evolution of mobile communication network specifically in signal transmission power. So, on top of the aforesaid challenges, energy efficiency is added [3]

As a solution, on the physical layer, MIMO antenna technology [11] is proposed to overcome the continuous challenge of spectral efficiency in mobile wireless networks. The latest version of MIMO, Massive MIMO in its variety called Full dimension MIMO will be exploited to enable 3D-beam forming in 5G [12] whose performance depends on accuracy of 2D-DOA estimation. In the following section, I discuss in this chapter DOA estimation principle that will be extend to 2D-DOA estimation in FD-MIMO by use of the antenna structures of Massive MIMO.

2.2 New trends in mobile networks

Nowadays, the world enjoys a mobile technology, a long journey to the smart life that has started in years 1950 in Europe and rapidly evolves both in time and space [13]. Evolution of mobile networks is termed Generations. From 1980 up to date, four generations have been in service whereas a fifth generation is expected to be in use in 2020. 5G is expected to offer low latency, always on connectivity, cost-effective secure communication systems. In the next section, a journey made by mobile network is summarized before presenting the technological innovations that will take us to the 5G [14]

2.2.1 Evolution of mobile network towards 5G mobile networks

In year 1980,the World experienced an analog communication mobile systems classified as first generation 1G of mobile networks that could only allow to communicate voice in 900 Hz frequency at speedy of 2.4 kbps. There was many drawbacks namely wastage of radio resources that lead to lower capacity of the mobile network, poor voice quality, high cost and big sized user equipments and lack of interoperability of 1G mobile network systems of different network operators companies. Soon after in 1980, came an improved mobile network systems that provided solution to these aforesaid problem suffered by 1G mobile network systems [14].

The world wide knew Global Mobile system (GSM) classified as the second generation of mobile networks 2G. GSM is a digital mobile system that uses circuit switched technology to communicate digitized voice at rate of 9.6Kbps in frequency band of 900 Hz and 1800Hz band [13].GSM solved the problems of lack of interoperability (roaming) that suffered by 1G mobile network systems, it was able to improve the voice quality, to provide increased data rate up to 9.6kbps, increased network capacity and GSM users could communicate both voice and data (SMS). GSM (European standard) and IS-54 (US standard) both used TDMA as their multiple access technique to serve an increased number of user equipments.GSM that is best known as $2G$ evolved in General Packet Radio Service (GPRS) classified as 2.5G by some authors that uses two different switching technology namely packet switching for data and circuit switching for voice, and then after it farther evolved to EDGE that can be viewed as 2.75G for the sake of increased data rate [13]. On the other side, Americans adopted IS-95, that was based on Code division multiple access technique (CDMA) [15]

For the need of improved management of radio resources(bandwidth efficiency) and data rate, we experienced the arrival of 3G best known as Universal Mobile Telecommunication System(UMTS) that is enabled by introduction of robust multiple access techniques WCDMA and T-CDMA which allowed 3G to be viewed as a platform for multimedia services thanks to its high data rate. 3G overtakes 2G both in service quality(voice, Image and video) and increased data rate up to 384kbps [13].The third generation of mobile network evolved in High Speed Downlink packet Access (HSDPA) that evolved to HSDPA+ by integration MIMO antenna technology. On USA side, IS-95 evolved to IS-95B that turned into CDMA2000 that became CDMA2001XEV-DO to evolve to CDMA2001XEV-DV.The last mobile network system classified in 3G is WIMAX [16]

Although was that great development of mobile networks, there was still many issues to handle. Among them was the data rate that was still low compared to the data traffic generated by multimedia applications, latency that still needed to be minimized to meet requirement of smart applications that need real-time communication, Optimization of radio resource management, there was still a need for increased systems capacity, capability to support multiple-antenna technology that would lead to optimization of the transmission power, backward compatibility with existed mobile network systems [13].

All these challenges urged 3GPP to start the development of a new mobile network system in what they called long term evolution. The first mobile network system released in long-term evolution is known as (LTE release 8) and was compatible with the existed systems and employed OFDMA in Down link and MC-CDMA in up-link [32] . LTE release 8 supported Massive MIMO and could provide up to 150 Mbps and 75Mbps respectively in down link and up link. However, LTE release 8 did not meet criteria of 4G mobile network [17].

The first 4G system launched was called LTE (Long Term Evolution) advanced and could offer up to 1Gbprs in Down link and 500Mbps in uplink. Main technologies used by LTE-A include OFDM technology, OFDMA multiple access technology, COMP and many others. The future of mobile network,5G that is expected to be on the market in 2020 is supposed to take the world to a higher level of smartness by providing seamless mobility, high quality of multimedia services, low latency that will enable real-time applications in all domains. Among key technologies enabler of 5G, we have Full dimension MIMO that is also known as 3D-MIMO [12] COMP and non Orthogonal multiple access (NOMA) [18].Different telecommunication platforms as well as informatics based ones are collaborating to step the world in this incredible communication system that will take our planet at a new higher level of smart life. Among other the platforms partners of 5 mobile network is Internet of things (IoT), Software defined networking(SDN),cloud computing, as well as network function visualization [19]

2.2.2 Key features of 5G mobile network

The fifth Generation mobile is expected to provide 1000 times network capacity and 100 times throughput of 4G network systems [18] through the federation of the different robust data processing technologies, networking and telecommunications technologies like Massive MIMO, cognitive radio networks, network densification, millimeter-wave [20], green communication and radio access technology association. Also, in 5G the use of Edge-coaching will lead to significantly reduced backhaul as well as backbone load that will result in non detectable latency with human senses that is supposed to be less than 1ms.Apart from mobile communication,5G will be integrated in all area of life, and will include all precedent technologies to provide smart platform for business, health services, and environmental management by use of heterogeneous networks [19].The air interface will be improved by the use of FD-MIMO where the vertical spatial beam forming is exploited for user scheduling and transmission consequently, the more degree of freedom.

2.3 Multiple input-Multiple Output (MIMO) Overview

In wireless communication, Multiple-Input Multiple-Output (MIMO) is an antenna technology that uses many antennas at the transmitter and/or receiver and profit multipath propagation and scale up the capacity of a radio communication link. MIMO techniques has been adopted in modern wireless communication systems among them is HSPA+ (3G),Long Term Evolution (4G), WiMAX (4G), IEEE 802.*11n* (Wi-Fi) and IEEE *802.11ac* (Wi-Fi). Furthermore, the use of MIMO techniques leads to the improvement of symbol rate of systems or performance without purchasing additional spectrum resources [21]

We classify wireless systems according to the antennas number used at the receiver and at the transmitter as single input single-output (SISO), single-input multiple-output (SIMO), multiple-input single-output (MISO), and MIMO architectures as illustrated in figure 1.

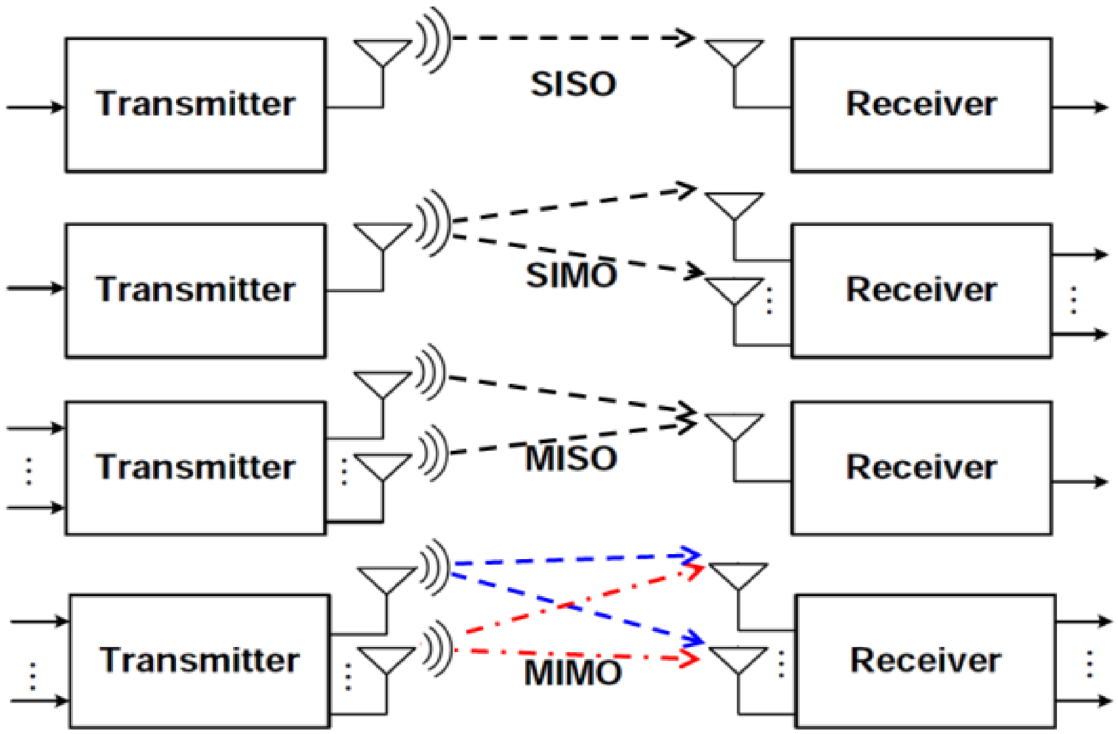

Figure 1: Multiple-antennas system configurations.

2.3.1 Operating principal of MIMO

MIMO uses a very simple and very advantageous principle that is to provide an increase of bandwidth efficiency simply by using more than one antenna in transmission as well as in reception. Apart from that MIMO allows reduction of the transmission power so it enables to improve both spectral and energy efficiency. MIMO depends the number of antennas deployed at receiver and transmitter provide incredible performance thanks to array gain, diversity gain, diversity multiplexing and interference reduction [22].

2.3.2 Advantages and Challenges of Massive Multiple Input-Multiple Output

Massive MIMO that some people call it large scale Multi-user-MIMO, Hyper MIMO, full dimension MIMO, very large MIMO and very large Multi-user- MIMO to refer to a system of hundreds of antennas on base station that communicate to tens of users terminals in the same frequency band [11].

The rate of data traffic generated by smart phones and tablets, the qualities of service required by communication based applications that do not cease to increase with time, predicts the need of a thousand times increase in network capacity in the next five years [3], [10]. MIMO is proposed as a potential array antenna technique that claims to allow a significant improvement of spectral efficiency (support an increased number of users on the existing frequency band) by limiting the transmission power and maintaining the same bandwidth .In [23], the numbers of antennas at base station tends to infinity; both the effect of additive noise and small fading vanishes. Communication in millimeter waves allows to pack a big number of antenna elements on base station so it is exploited in massive MIMO systems [24]

Another attracting utility of Massive MIMO is the improvement of energy efficiency that leads to the reduction of carbon emission in the environment. Future digital society infrastructure like internet of things, cloud computing will be enabled by Massive MIMO as a solution of processing complexity. Massive MIMO technology is an extension of MIMO technology that came to enable the multiplexing gains for the sake of improved reliability. However, a number of significant challenges came along with this emerging antenna technology namely channel state information acquisition, channel feedback, hardware impairments, architecture, statistic reciprocity and instantaneous reciprocity [2]

Massive MIMO increases 10 times or more the capacity of the system thanks to the spatial multiplexing, and simultaneously improve 100 times the energy efficiency by focusing in a very reduced region of space a well-shaped signal resulting from superposition of many wave fronts [3]. Massive MIMO is built with very cheap components, hundreds low-cost amplifiers that operates in mil-watt range are used in Massive MIMO to replace ultra-linear 50Watt amplifiers employed in conventional systems. Apart from that, Massive MIMO also offers more degree of freedom than its precedent antenna array techniques. On the air inter- face, Massive MIMO by help of its big number of antenna arrays and it three dimensional beam-forming, offers significant reduction of the latency, a high solicited requirement in future technology [25]. Massive MIMO simplifies multiple access-layers by allowing channel hard-ening. Massive MIMO improve the robustness to both accidentally man-made interference and to non desirable jamming. It can easily happen in Massive MIMO implemented in a multi-cell environment that orthogonal pilot sequence be exhausted, a re-use of pilot sequence from one cell to another result in negative effects that is best known as pilot contamination. A good number of solutions had been proposed to circumvent pilot contamination among other we can say adaptively pilot allocation; use of pilot contamination pre-coding, use of clever channel estimation algorithms. Apart from pilot contamination, another limiting factor encountered in massive MIMO is channel reciprocity [2]

In massive MIMO systems, there is a great burden of signal processing; therefore, the orientation of research in the domain of the massive MIMO is to optimize signal processing algorithms and their implementations. However, low-complex algorithm is not performing as well as high complex algorithms. For example the use of more accurate CSI results in improved performance however the processing complexity increases prohibitively. In multi-cells environment, the use of low-complex linear channel leads to limited performance by pilot contamination that is circumvented by employing complex channel estimation algorithm [12]

In the frequency band less than 2GHz massive MIMO antenna arrays are bigger sized enough to fit the size recommended by User equipment manufacturer. To satisfy the size requirements, massive MIMO propose to operate in millimeter-wave band. The solution proposed to achieve the high data rate as well as good coverage is to use massive MIMO in ultra-dense small cells that will be operating in millimeter-wave band. Massive MIMO in millimeter-wave band still imposes many different issues about which a research is needed among other we can say hardware impairments, pilot contamination, cost of reciprocity calibration, channel characterization, new deployment scenarios, prototype development, challenge of low cost hardware [2].

2.3.3 Special case of FD-MIMO

A full-Dimension MIMO [26] can be viewed as a particular implementation of Massive MIMO systems that allows deploying up to 64 antennas at the base station and operating at recommended frequency. In FD-MIMO system, the considered active antennas are disposed in two dimension configuration and able to process the signal propagation in azimuth and elevation what is not the case in the conventional Massive MIMO system where the active antennas are only considered to process signals in horizontal plane [26]

This particular antenna array technology that exploit in maximum the capacity of base station antenna allows to handle the base station form factor constraint and increase the gain in cell capacity at up to 3.5 times and boost the cell edge as well. In a full dimensional MIMO, spatial three-dimensional channel model described in equation 2.1 are considered. FD-MIMO is viewed as the expansion of Massive MIMO antenna technology it will be deployed in next generation of mobile network system [2].Assume that we have N path and that each path has M sub path, the channel model in a full-dimensional MIMO is given by [2]

$$\boldsymbol{hu,s,n(t)} = \sqrt{\frac{P_n \sigma_{SF}}{M}} \sum_{m=1}^{M} \begin{pmatrix} \sqrt{G_{BS}(\theta_{n,m,AoD}, \beta_{n,m,AoD})} \\ \times exp(j[kd_s \bar{r}_s . \bar{\emptyset}_{n,m} + \emptyset_{n,m}]) \\ \sqrt{G_{MS}(\theta_{n,m,AoA}, \beta_{n,m,AoA})} \\ \times exp(jkd_u \, sin(\theta_{n,m,AoA})) \\ \times exp\begin{pmatrix} jk\|v\| cos\, \beta_{n,m,AoA} \\ cos(\theta_{n,m,AoA} - \theta_v)t \end{pmatrix} \end{pmatrix} \quad (2.1)$$

For $\bar{r}_s . \bar{\emptyset}_{n,m} = x_s \cos\beta_{n,m,AoD} \cos\theta_{n,m,AoD} + y_s \cos\beta_{n,m,AoD} \sin\theta_{n,m,AoD} + Z_s \sin\beta_{n,m,AoD}$

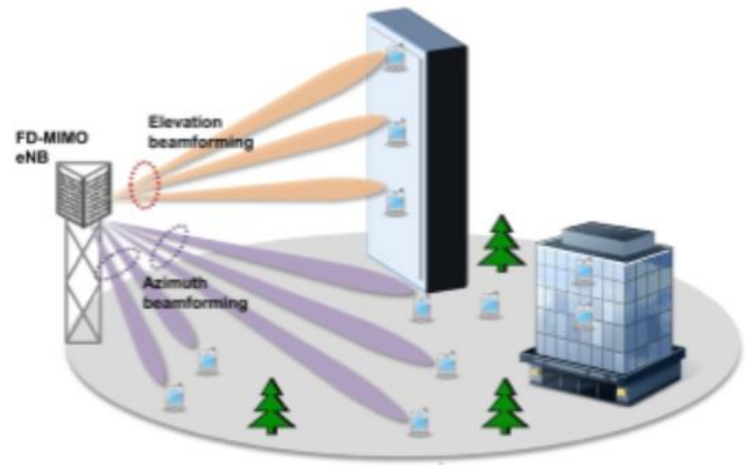

Figure 2: Beam forming in Full dimension MIMO [14].

Where:

$\beta_{n,m,AoD}$: Elevation domain angle of departure (E-AoD) for the m^{th} subpath of the n^{th} path at the BS with respect to the BS broadside

$\beta_{n,m,AoA}$: Elevation domain angle of arrival (E-AoA) for the m^{th} subpath of the n^{th} path at the MS with respect to the MS broadside

$\boldsymbol{\theta}_{\mathbf{n,m,AoD}}$: Azimuth domain AoD (A-AoD) for the m^{th} subpath of the n^{th} path at the BS with respect to the BS broadside

$\boldsymbol{\Phi}_{\boldsymbol{n,m,AoA}}$: Azimuth domain AoA (A-AoA) for the m^{th} subpath of the n^{th} path at the MS with respect to the MS broadside

$\bar{\boldsymbol{r}}_{\boldsymbol{s}}$: Location vector of Tx array element s x_s, y_s, z_s: Components of $\bar{r}_s$ to x, y, and z-axis respectively

$\bar{\boldsymbol{\Phi}}_{\boldsymbol{n,m}}$: Departure angle unit vector of ray n, m P_n The power of the n^{th} path

$\mathbf{s_{SF}}$: The lognormal shadow fading, applied as a bulk parameter to the N paths for a given drop.

$\mathbf{G_{BS}}$(.): The BS antenna gain of each array element

$\mathbf{G_{MS}}$(.): The MS antenna gain of each array element

K: The wave number $2\pi/\lambda$ where λ is the carrier wavelength in meters

$\mathbf{d_s}$: The distance in meters from BS antenna element s from the reference (s = 1) antenna

$\mathbf{d_u}$: The distance in meters from MS antenna element u from the reference (u = 1)antenna

$\boldsymbol{\Phi}_{\boldsymbol{n,m}}$: The random phase of the m^{th} subpath of the n^{th} path

$\|V\|$: The magnitude of the MS velocity vector

$\boldsymbol{\theta}_{\mathbf{V}}$: The azimuth angle of the MS velocity vector with respect to the MS broadside

FD-MIMO is the official terminology adopted by 3GPP to refer to enhanced MIMO systems of future generation that will use up to 64 antenna elements at the transmitter side

[1] there is a possibility of controlling a radio signal in three dimensional spaces what is referred to as 3D-beamforming

2.4 Direction of Arrival Estimation overview

In the past DOA estimation used to be applied in RADAR, SONAR, seismology and in electronics surveillance domain. By the evolution of radio mobile communications, they include of angle and time of arrivals statistics in radio multipath channel modeling made DOA estimation an important area of research [27]. An accurate estimation of DOA helps adaptive antenna to orient the main beam in a specific region of interest that has the target user mobile equipment and suppress side lobes that would cause interference. Direction of arrival estimation is possible to use a fixed antenna but this approach is very limited and not flexible as the resolution would be constrained by the main lobe of the antenna which varies inversely with the physical size of the antenna. With this traditional approach, we are supposed to increase the accuracy of the angles by varying the size of antenna. Also this can't allow the distinction between multiple incident signals. As a solution, DOA are determined by use of array antenna system and application of a suitable signal processing that provide a desired angular resolution. Different array antenna have been presented in literature namely Uniform linear array (ULA),uniform rectangular array (URA),circular arrays and many others [1], [4], [28]. DOA estimations algorithms are classified in four categories namely Conventional DOA estimation methods, Subspace based DOA estimation methods, Maximum likelihood techniques and Integrated DOA estimation methods. Conventional methods rely on classical beam forming mechanism and they need a great number of antenna elements to reach a high resolution. Subspace methods are sub-optimal but high resolution that profit from eigen structure of input data matrix. Maximum likelihood methods are optimal and their performance is good even at low SNR, however their computational complexity is prohibitive. Integrated methods separate the multiple incident signals by use of property restoral based techniques and perform the estimation of spatial signature of different incident signals from DOAs are determined by use subspace techniques [27]. To present the problematic of DOA estimation, we will start with a very simple case where K signals that impinge on a Uniform Linear array made of M antenna elements as show in figure 2.3 in the next section.

2.4.1 Principle DOA estimation (for ULA)

The received signal vector on the uniform linear array is constructed according the relation follow as [12]

$$X(t) = \sum_{k=1}^{K} S_k(t) \sum_{j=1}^{N_k} \gamma_{k,j}(t) \boldsymbol{a}\big(\theta_{j,k}(t)\big) + \boldsymbol{n}(t) \epsilon \mathbb{C}^{M\times 1}\big) \qquad (2.2)$$

where $\boldsymbol{S_k(t)}$ is the complex-valued signal transmitted from the user terminal, $\boldsymbol{\gamma_{k,j}(t)}$ denote the complex-valued path gain, $\boldsymbol{a}(\boldsymbol{\theta_{j,k}(t)})$ is array manifold or the response of the array and $\boldsymbol{n}(t)\epsilon\mathbb{C}^{M\times 1}$ denote the complex-valued additive noise the array response is give by

$$\boldsymbol{a_x(\theta)} = \begin{bmatrix} \mathbf{1} & e^{j2\pi/\sin\theta_k} & \dots & e^{j2\pi(M-1)d/\lambda \sin\theta_k} \end{bmatrix} \qquad (2.3)$$

DOA estimation consists in use of received signal data vector x (t), t = 1, 2, ••• , T to determine estimates of 0_k and standard deviations of $0_{k,t}$ (t) that are referred to as angular spreads ^0 k.

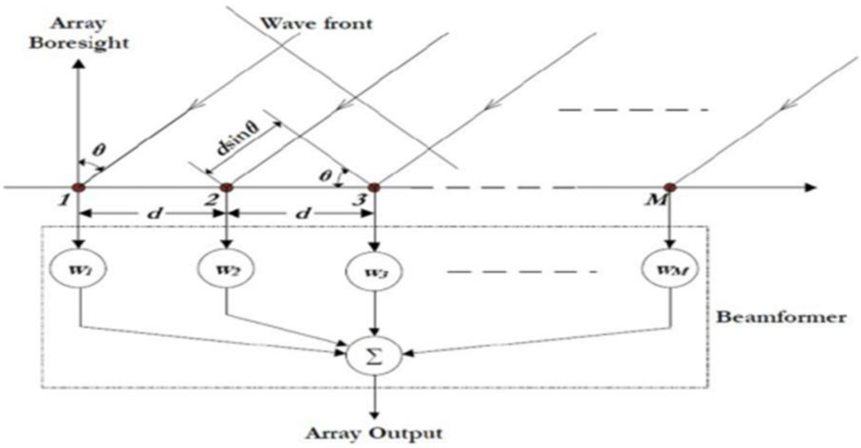

Figure 3: ULA antenna array.

2.4.2 2D-DOA estimation for FD-MIMO

Full-Dimensional MIMO performs with planar antenna arrays [2], ULA cannot be applied in DOA estimation of full-Dimensional systems. Planar arrays like URA [5], [28], and L-shaped arrays [7], [29], [30] can only be used to jointly determine angular position from which multiple incident signals are transmitted. full-Dimension MIMO exhibits a great computational load, so we care much not only on the resolution of the 2D-DOA estimation method but also on its computation complexity. This last criteria excludes some high resolution URA based methods like MUSIC [4]. In chapter four we discuss a variety of 2D-ESPRIT techniques [28] proposed to deal with the planar disposition of array antenna elements in Full dimension MIMO

$$a(\phi,\theta) = \begin{bmatrix} 1 \\ e^{ju} \\ \vdots \\ e^{j(M_x-1)_u} \end{bmatrix} \otimes \begin{bmatrix} 1 \\ e^{jv} \\ \vdots \\ e^{j(M_y-1)_v} \end{bmatrix} \qquad (2.4)$$

Where : Φ: azimuth angle

θ: elevation angle

$u = 2\pi/\lambda$

$M = M_x M_y$, M is the number of antenna

$a(\Phi, \theta)$ is the array manifold that is the response of the array corresponding to the azimuth and elevation

2.5 Major antenna structures for Massive-MIMO

A configuration of antenna array significantly affects the properties of a channel model. As an example, antenna size is taken into consideration in modeling both mutual coupling and correlation matrix. In nowadays antenna arrays have equidistant antenna elements. The technology of antenna array configuration has evolved to maximize performance and reduce overheard. In the traditional passive antenna arrays, there was a radio frequency cable to connect the physical antenna to the radio frequency circuit. After, passive antenna arrays are optimized to avoid loss induced by radio frequency cable and gain in installation and maintenance overheard. A remote radio unit (RRU) is separated from the base band Unit and a digital base band signal is communicated via optical fiber from RRUs to BBUs. In active antenna arrays system, there is no radio frequency cable. There is one circuit board that integrates all antenna elements that allows to realize massive antenna arrays. Linear antenna array is classified in one dimensional antenna array and it allows signal propagation in two dimension plane [3].

Usually, linear antenna arrays are used either in theoretical analysis or realistic measurements of massive MIMO systems. Rectangular antenna arrays, spherical antenna arrays, and cylindrical antenna arrays are classified as two dimensional antenna array and they allow signal propagation in both elevation and azimuth plane of space. To meet size requirements for both eNB and UEs, cylindrical, rectangular and spherical antenna array are employed in practical systems whereas distributed antenna array find their application inside building and in outdoor corporation [11].

2.5.1 Channel model in massive MIMO

The propagation characteristics of radio waves are modeled by the channel models that are highly affected by antenna array configuration [2].In Massive MIMO, when designer of antenna array must care much on the spacing between adjacent antenna elements as we desire to suppress side lobes that cause directional ambiguity. The number of antenna elements in antenna array is also a very important parameter in design as the increase in number of antenna elements in array lead to a narrower beam so the array gain increases via spatial diversity. However, the number antenna elements in array is constrained by the cost of implementation as well as the physical size limitation [3]

The different effects of wireless communication on the physical layer are mathematically represented by channel model. Below different features and categories of MIMO channels models are described.

Table 1: Features of channel models

Modelling Method	**Category**	**Features**
CBSM	i.i.d Rayleigh channel model	Elements of fast fading are i.i.d. complex Gaussian variable
	Correlation Channel model	count the correlation between transmit antennas or/and receive antennas
	Mutual coupling channel model	count antenna impedance, load impedance and mutual impedance
GBSM	2D channel model	Propagate beam on 2D plane it includes Linear array
	3D Channel Model	Propagate beam on 3D plane , it includes rectangular array and cylindrical array

2.6 Conclusion

As has been described in previous section, two dimensions DOA is viewed the cornerstone of important technology upon which lies the next generation mobile network system. That is the reason all research works on DOA estimation come to contribute in the success of Massive MIMO technology that enable 5G systems. We are considering the specifications of antenna array structure in full-Dimension MIMO that imposes the need for low-complex and high resolution 2D-DOA estimation algorithms required by FD-MIM

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides an overview the methods, techniques and approaches that used in this research thesis. This research has adopted correlation research design. A correlation study is a study concerned with determining if a relationship exists between two or more variable, and Mainly scientific methods for conduction research will be used, Furthermore descriptive research approach was also considered and analysis and simulation results using Matlab14a as simulation tool.

3.2 Development Research approaches

This part describes the overview of the research approaches and the steps involved in system development from the step of gathering the ideas to the final step of simulations and getting the result. This research thesis will use associational model that is developed into two distinctive phases that are development approach model. Waterfall model is a relatively linear sequential design approach.

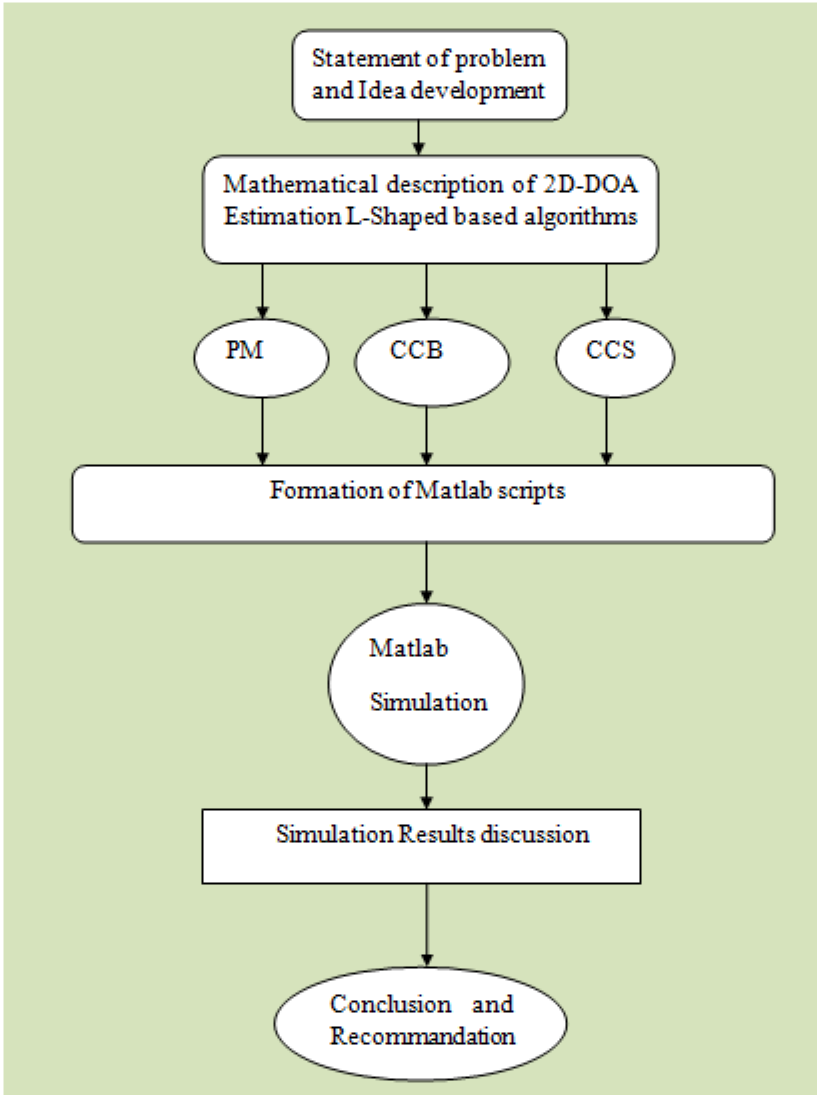

Figure 4: Overview of Research approaches development

The simulation approach in this research thesis has two types:

➢ The algorithm Descriptive approach

➢ The simulation approach.

In this research thesis, I analyzed the existing 2D-DOA estimation L-Shaped based algorithms in order to get their good understanding, then I developed Matlab scripts considering a multipath channel and compare their respective performance when subjected to then same simulation parameters.

3.2.1 Scientific research methods

A scientific method that is used to conduct this research is the analysis of mathematical formulation of studied algorithms that gives us an idea of their respective theoretical computational complexity. I began with random ideas and through the time, I came up with the objectives, statement of problem and proposed solution. In the existing schemes, we deduced knowledge about the research ideas. Currently, the existing schemes seized the opportunity to discover the existing knowledge and to propose the solution on the stated problem. To be specific, a simulation approach by use of matlab 14a was taken to evaluate different performance criteria and verify theoretical prediction upon which a comparative of study is deduced

3.2.2 Simulation approach

The simulation of this work, will be done by using simulation tool such as Matlab14a. Moreover, the simulation will be done to analyze performance of a three algorithms considering deferent performance metrics which are SNR, RMSE and AS. Under this approach, we discuss the simulation results for each performance metric. We present some figures that highlights simulation results.

3.3 Documentation

In this method, I went to the library to search for books that contain the subject related to this topic. Not only the books used but also some electronic books (from the internet), the memoirs done, class notes, different journals and papers.

3.4 Analysis

The purpose of this stage is to analyze the performance of 2D-DOA L-shaped based algorithms as detailed in chapter 2. Another purpose is to identify the best algorithm that can achieve the better performance by valuating different parameters. This involved carrying out a detailed study of the L-shaped based 2D-DOA algorithms for different values of SNR, RMSE, and AS in different ranges of Direction of Arrivals in Azimuth and in Elevation

During this analysis we run 1000 Monte-Carlo trials with 200 snapshots ,5 antennas for each branch of L-shaped antenna array, 1narrow band signal source and 20 multipath.

For this research thesis project, the requirement such as simulation parameter will be examined and analysis is done and also documentation published on relevant topics are checked and did a further development . Different aspects considered during this research project include:

- Understanding the problem of 2D-DOA estimation
- Study and developed Matlab scripts L-shaped algorithms
- Simulation and comparative analysis.
- Determine through matlab simulations the suitable algorithm of good performance according to the requirement of 5G networks .
- Redaction of the thesis report.

3.5 Proposed simulation requirements

3.5.1 Hardware and Software Requirements

Hardware requirement: The following are minimum hardware requirements for running resource efficient algorithm for Performance analysis of 2D Directions of Arrivals Estimation algorithms in Massive MIMO Networks:

1. Computer with 4,00 GB RAM
2. GB free space of Hard Disk
3. Core i5

Software requirement:

1. Windows operating System
2. Matlab14a

3.6 Simulation process

Performance analysis of 2D Directions of Arrivals Estimation algorithms in Massive MIMO Networks was very important phase after gathering the requirements and conducting the comparative study. The simulation was specifically done after analyzing the existing algorithms and then propose a good performing algorithm which was intended to meet 5G networks specifications.

3.7 Conclusion

This chapter of methodology covers the approach to carry out the research and its analysis and the processes to be undertaken analyzing and simulating of the foretold algorithms. The proposed simulation and performance analysis is going to be explained in the next chapter.

CHAPTER FOUR: SYSTEM MODEL AND ANALYSIS

4.1 Introduction

In 2-D DOA estimation, L-shaped array structure outperform other array structures like circular array, spherical array, rectangular array as it has a better performance and its implementation is easier [6]. L-shaped array can be decoupled into 2uniform linear arrays (ULAs) and the estimation of 2-D DOAs is performed from DOAs estimated from 2 independent sub-arrays. In planar array based DOA estimation methods, L-shaped based methods are distinguished by their simplicity and high performance. Propagator Method (PM) does not require eigen- value decomposition, with K incident sources, the computational complexity is of the order O(2NLK). Typically, in mobile communication, elevation angle is comprised between 70◦ and 90◦ [6].This means that the application of Propagator method in parallel shaped array signal processing leads to the estimation failure. To bypass the aforesaid problem, in spite of parallel–shape array, we use L-shaped configuration cross-correlation based (CCB) method is another high competitive L-shaped based methods is described in next section and will compare these two methods with conjugate symmetry based subspace (CSS) method . we close this chapter with simulation results that compare their computational complexity as well as the performance against the variation of SNR and Angular spread.

4.2 System model

We have considered the number K of narrow-band signals (plane waves) emitted by different mobiles users located in far-field region relatively to the position of antenna array The K plane waves impinges on each branch of L-shaped array which is ULA are made of M omnidirectional antennas spaced by distance d =λ/2.Where λ is the signal wavelength. Let us denote by $\boldsymbol{\varphi_k}$ to represent the azimuth angles (angles measured between the x-axis and the signals arrival direction), and by $\boldsymbol{\theta_k}$ to represent the elevation angles (angles measured between the z-axis and the signal arrival direction) for **k** = 1,2, ・・・,K.

The received signal vector along x and z-direction are respectively given by

$$X(t) = \sum_{k=1}^{K} S_k(t) \sum_{j=1}^{N_k} \gamma_{k,j}(t) \boldsymbol{a_x}\big(\theta_{k,j}(t)\big) + \boldsymbol{n_x}(t) \epsilon \mathbb{C}^{M\times 1}\big) \qquad (4.1)$$

$$Z(t) = \sum_{k=1}^{K} S_k(t) \sum_{j=1}^{N_k} \gamma_{k,j}(t) \boldsymbol{a_z}(\theta_{j,k}(t)) + \boldsymbol{n_z}(t) \epsilon \mathbb{C}^{M\times 1} \qquad (4.1)$$

$s_k(t)$ are the signal transmitted from the k^{th} source and $\boldsymbol{\gamma}_{j,k}(t)$ is the path gain of the $\boldsymbol{j^{th}}$ path from the k^{th} source.$\gamma_{j,k}(t)$ follow the zero-mean Gaussian distribution of standard deviation $\boldsymbol{\sigma}_{\gamma k}$, $\boldsymbol{\varphi}_{k,j}(t)$, $\boldsymbol{\theta}_{k,j}(t)$ stands respectively for elevation and azimuth angles of the j^{th} path from the k^{th} source and they are i.i.d Gaussian variables with means φk, θk and standard deviations standard deviations $\boldsymbol{\sigma}_{\varphi k}$ and $\boldsymbol{\sigma}_{\theta k}$. Both noise vectors $n_x(t)$ and $n_z(t)$ are modeled by Additive white Gaussian processes at x and z branches respectively. The array responses matrices are formed as

$$\boldsymbol{a}_x(\phi) = \left[1 \;\; e^{j2\pi d/\lambda \cos \phi_k} \quad \dots e^{j2\pi(M-1)d/\lambda \cos \phi_k}\right] \qquad (4.3)$$

$$\boldsymbol{a}_z(\theta) = \left[1 \;\; e^{j2\pi d/\lambda \cos \Theta_k} \quad \dots e^{j2\pi(M-1)d/\lambda \cos \Theta_k}\right] \qquad (4.4)$$

Elevation angles estimates are determined with z-branch and the results serve in estimation

of azimuth with x-branch.

4. 3 Propagator Method (PM)

For the sake of reduction of computational complexity imposed by EVD or SVD, propagator method is proposed to work in conjunction with ESPRIT. However there is no dependence between azimuth and elevation angles estimated via Propagator Method in presence of more than one source. Therefore, PM needs a pair matching procedure to perform a one to one mapping that result in pair matching error or affect DOA estimation performance. The PM method evolves in two main step. PM first estimates elevation angles by using signals received by antenna elements of z-branch. Estimation of azimuth angles is performed later by use of signals received by antenna elements of x-branch. In estimation of azimuth, two sub arrays z1 and z_2 of z-branch made of first and last N −1 antenna elements respectively are constructed. The process of estimation of elevation angle is performed in four sub steps [6].

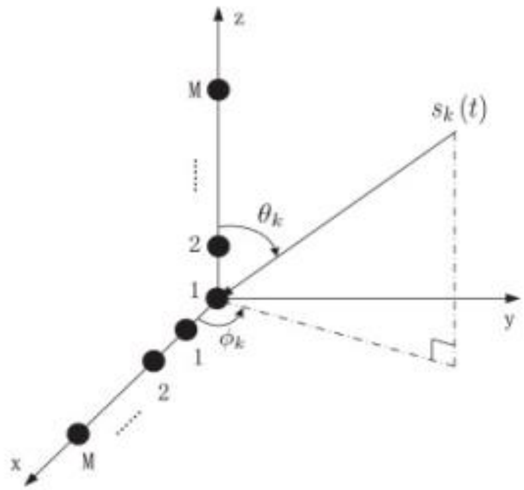

Figure 5: L-shaped antenna array [6]

Substep 1. Estimation of cross spectral matrix $\widehat{\boldsymbol{R}}$ from received signal snapshot L data vectors for（t = 1,2, ・ ・ ・ ,L） as

$\widehat{\boldsymbol{R}}=\frac{1}{L}\sum_{k=1}^{K}\boldsymbol{q}(t)\boldsymbol{q}(t)^{H}$ with $\mathbf{q(t)}=[Z_1^T Z_2^T]^T$ **(4.5)**

Substep 2. Split $\widehat{\boldsymbol{R}}$ in two sub matrices **E** and **J** respectively of dimension 2（N −1）×K and 2（N −1）×2（N −1)−K

$\widehat{\boldsymbol{R}}=[\boldsymbol{E} \quad \boldsymbol{J}]$ (4.6)

Next, we estimate the propagator matrix $\widehat{\boldsymbol{P}}$constructed as:

$\widehat{\boldsymbol{P}}=(\boldsymbol{E}^H\boldsymbol{E})^{-1} \quad \boldsymbol{E}^H\boldsymbol{J}$ (4.7)

Substep 3. $\widehat{\boldsymbol{P}}^H$ Is partitioned into 3 sub-matrix $\widehat{\boldsymbol{P}}_1$; $\widehat{\boldsymbol{P}}_2$; $\widehat{\boldsymbol{P}}_3$ respectively of dimension （N −1−K）×K, K×K, and （N −1−K）×K

$\widehat{\boldsymbol{P}}^H=[\widehat{P}_1^T;\ \widehat{P}_2^T;\ \widehat{P}_3^T]^T$ (4.8)

Calculate K eigenvalues $\xi_{\theta,k}$of sub matrix $\widehat{\boldsymbol{P}}_2$

Sub step 4. Estimation of elevation angles from eigen-values $\xi_{\theta,k}$ according to the expression

$\widehat{\boldsymbol{\theta}}_k=\cos^{-1}(\frac{\arg(\xi_{\theta;k})}{2\pi d/\lambda})$ (4.9)

First, Second and third sub step are used in estimation of azimuth angle by considering Signals received by $\mathbf{x}_1$ and $\mathbf{x}_2$ sub arrays associated with x-branch rather than $\mathbf{z}_1$ and $\mathbf{z}_2$ sub Arrays associated with z-branch. The final step of estimation of azimuth angle associated with Eigen-values $\xi_{\theta,k}$ is performed as:

$$\widehat{\Phi}_K = \cos^{-1}\left(\frac{\arg(\xi_{\theta;k})}{2\pi d\ X\left(\sin(\widehat{\boldsymbol{\theta}}_k)\right)/\lambda}\right) \qquad (4.10)$$

4.4 Conjugate symmetry based subspace (CSS) method

This method evolves in three steps, estimation of 2D−DOAs is performed in the first two steps and the final step is the pair matching of estimated 2D−DOAs [8].

Step 1. Estimation of cross-correlation matrix from L snapshots data vectors

$$\widehat{\mathbf{R}}_{\mathrm{xz}} = \frac{1}{L}\sum_{t=1}^{T} \boldsymbol{X}(t)\mathbf{Z}^H(t) \qquad (4.11)$$

Step 2. From$r^{f}_{(:,1)}$, the First column of **R**xz, we construct the column vector

$r_1^b = J.\left(r^f_{(1)}\right)^*$ .A new column vector is derived from the two previous as

$\left(r_1^b\right)^{f/b} = \left(\left(r_1^b\right)^T.\left(r_1^f\right)^T\right)^T$. Then a (2N −K) ×K matrix denoted by **R**α is constructed according to the following relation:

$$\widehat{\mathbf{R}}_\alpha = [\mathbf{r}_1 \ \ \mathbf{r}_2 \ \ \ldots \ \ \mathbf{r}_3] \qquad (4.12)$$

$\mathbf{r}_k$ is a sub vector of dimension (2N −K)×1 and corresponds to kth to (2N −K−1+k)th elements of $r_1^{f/b}$

Step 3. Use Graham-shmidit orthogonalization of **R**α to construct matrix (2N −K)×K matrix denoted by **R**oα.

Step 4. construct the cost function

$$\boldsymbol{f}\,(\boldsymbol{\alpha}) = \frac{\mathbf{1}}{\overline{\boldsymbol{a}}^{\boldsymbol{H}}(\boldsymbol{\alpha})(\boldsymbol{I}-\boldsymbol{R}_{\boldsymbol{o\alpha}}\boldsymbol{R}^{\boldsymbol{H}}_{\boldsymbol{o\alpha}})\overline{\boldsymbol{a}}(\boldsymbol{\alpha})} \qquad \text{for } 0° \leq \alpha \leq 180° \qquad (4.13)$$

With $\overline{\boldsymbol{a}}\,(\boldsymbol{\alpha}) = [1 \ \ e^{j2\pi d/\lambda\cos\alpha} \ \ \ldots e^{j2\pi(2N-K-1)d/\lambda\cos\alpha}]^T$

Step 5. The elevation angles estimates $\overline{\Phi}_K$are the K peaks of the function .

A similar process is followed by using the first row rather than first column of $\widehat{\boldsymbol{R}}_{XZ}$

4.5 Cross-correlation based (CCB) method

Cross-correlation based estimator (CCB), evolves in two major steps. Firstly, it estimates elevation angles by the use of $\mathbf{z}_1$ and $\mathbf{z}_2$ signals received respectively by 2 overlapping sub arrays of z-branches comprise first and last N −1 antenna elements [7].

Step 1.Estimation of cross-correlation matrix $\widehat{\boldsymbol{R}}_{Z1Z2}$from L snapshots data vectors

$$\widehat{\mathbf{R}}_{z1z2}=\frac{1}{L}\sum_{t=1}^{L}\mathbf{Z_1}(t)\mathbf{Z_2^H}(t) \qquad (4.14)$$

Step 2. Derive from $\widehat{\boldsymbol{R}}_{Z1Z2}$the matrix **E**z according to the relation below

$$E_z=\hat{R}_{z_1z_2}+\ \hat{R}^H_{z_1z_2} \qquad (4.15)$$

Step 3. Form four sub-matrices from **E**zas follow:

$$\begin{cases} E_{12}=\ E_z(1{:}K,\ K+1{:}2K) \\ E_{21}=E_Z\ (K+1:2K,\ 1{:}K) \\ E_{31}=E_Z\ (2K+1{:}N,1{:}2K) \\ E_{32}=E_Z\ (2K+1{:}N,K+1{:}2K) \end{cases} \qquad (4.16)$$

Step 4. Compute$\Psi_{Z1Z2}=[\Psi_1^T\Psi_2^T]^T$

$$\begin{cases} \Psi_1=E_{32}E_{21}^{-H} \\ \Psi_{1=}E_{31}E_{12}^{-H} \end{cases} \qquad (4.17)$$

Step 5. From Ψ_{Z1Z2}Form 2 sub matrices**O**and **P**that correspond respectively to First from

2(N −1−2K)−1 and last 2(N −1−2K)−1rows of Ψ_{Z1Z2}.

Step 6. Compute $\xi_{\theta,k}$,k = 1,2, ...,K eigenvalues of matrix $\boldsymbol{O}^\dagger\boldsymbol{P}$

Step 7. Elevation angle estimates are computed according equation 4.9 A similar process is adopted to estimate azimuth angle, by use of signals received along x –branch rather than Z-branch, in final step, azimuth angle estimates are given by the expression of equation 4.10.

CHAPTER FIVE: SIMULATION RESULTS

The performance of L-shaped array based DOA estimation methods is compared by considering the same number of antenna array M = 5 on each branch of L-shaped array, the same value of signal-to-noise ratio (SNR = 10dB),a low scattering environment (AS = 2◦),a same number of multi-paths (Np = 20). We compared the computational load and the impact of array size of the computational load of respective L-shaped array based DOA estimation methods. We implemented simulation in MATLAB 2014a on a personal computer (Processor: Intel (R)core(TM)i5-5200U CPU @ 2.2GHZ 2.2 GHZ ; 4GB RAM; 64 bits-Operating system)1000 Monte-Carlo trials with snapshots number L = 200. We evaluate the performance of L-shaped array based estimators in terms of RMSE Azimuth and RMSE elevation. We analyze the variation of RMSE for the SNR and AS in range of [0−20].

The first simulation on figure 6 shows how the three algorithms are perform in the targeting angle is (70°-90°), of L-shaped array based estimators in terms of RMSE Azimuth. Where the noise is ideal Gaussian white noise, the SNR is 10dB, low scattering environment AS= 2° and the number of snapshots is 200. The simulation results are shown in Figure 6

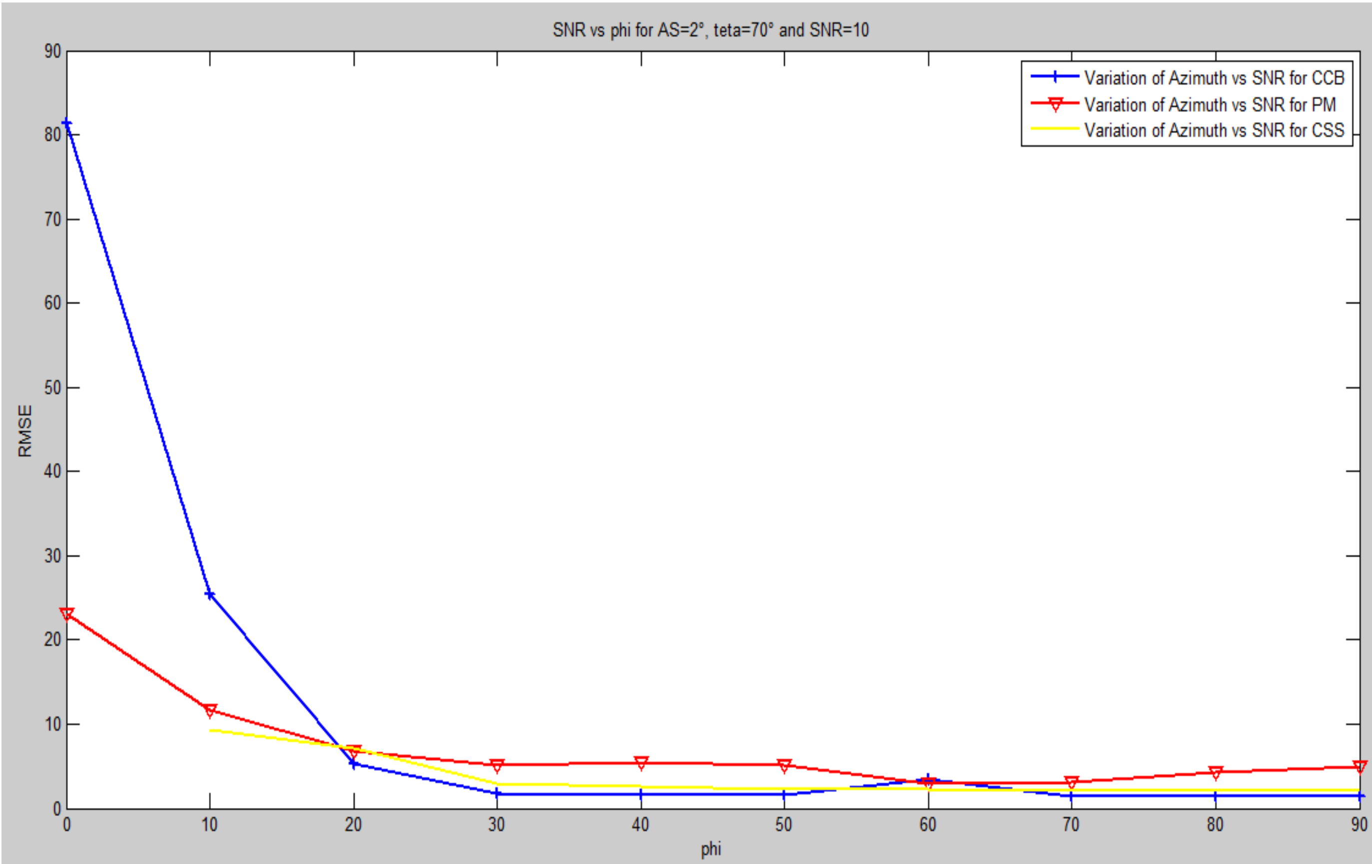

Figure 6: Comparison of performance of L-shaped array based DOA estimation in Azimuth

The comparison shown in figure 6 tells that the target angle range (70°-90°), we see the cave which is presenting the all three methods respectively. At the target angle range (70°-90°) we can classify the three methods in ascending order performance based on the value of RMSE, according to that, CCB is the first where PM is the last, but they all have an acceptable performance based on RMSE value which is <10dB for all three methods in the region of the target angle range but for the small angle there is a big difference for that three algorithms according to the variation of RMSE.

The second simulation shows how the three algorithms are perform in the targeting angle is (70°-90°), of L-shaped array based estimators in terms of RMSE elevation. Where the noise is ideal Gaussian white noise, the SNR is 10dB, low scattering environment AS= 2° and the number of snapshots is 200. The simulation results are shown in Figure 7

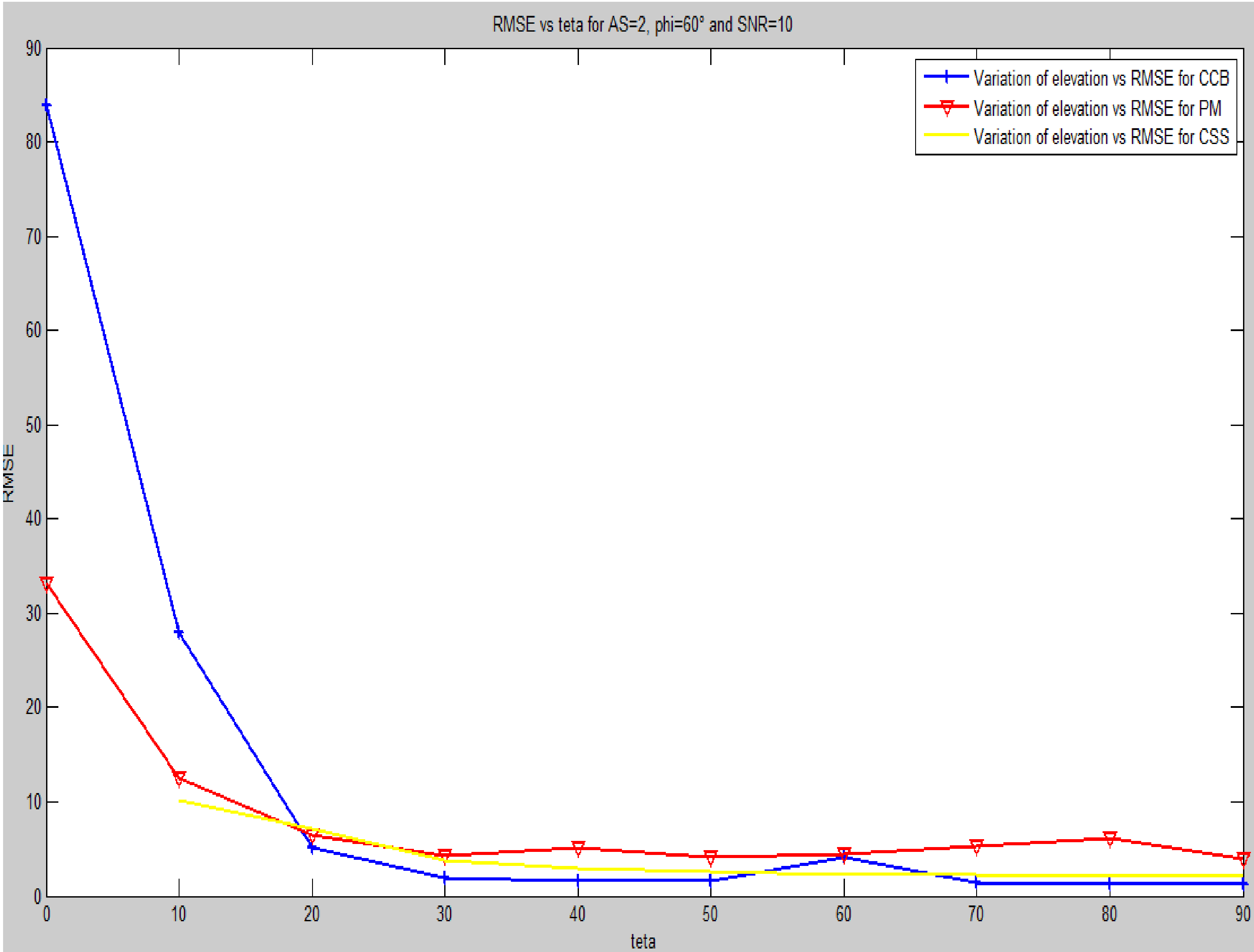

Figure 7: Comparison of Performance of L-shaped array based DOA estimation Elevation

On this figure7 the comparison is clear at lower angles where PM algorithm performs better than the two others because as we can see PM presenting lower value of RMSE but CCB performs at higher RMSE which means that its perform difficultly and CSS fails for angles less that 10°

The third simulation on figure 8 shows how the three algorithms are perform compare to the value of SNR in L-shaped array based estimators in terms of RMSE. Where the noise is variable Gaussian white noise, the SNR is [0 - 20], low scattering environment AS= 2° and the number of snapshots is 200. The simulation results are shown in Figure 8

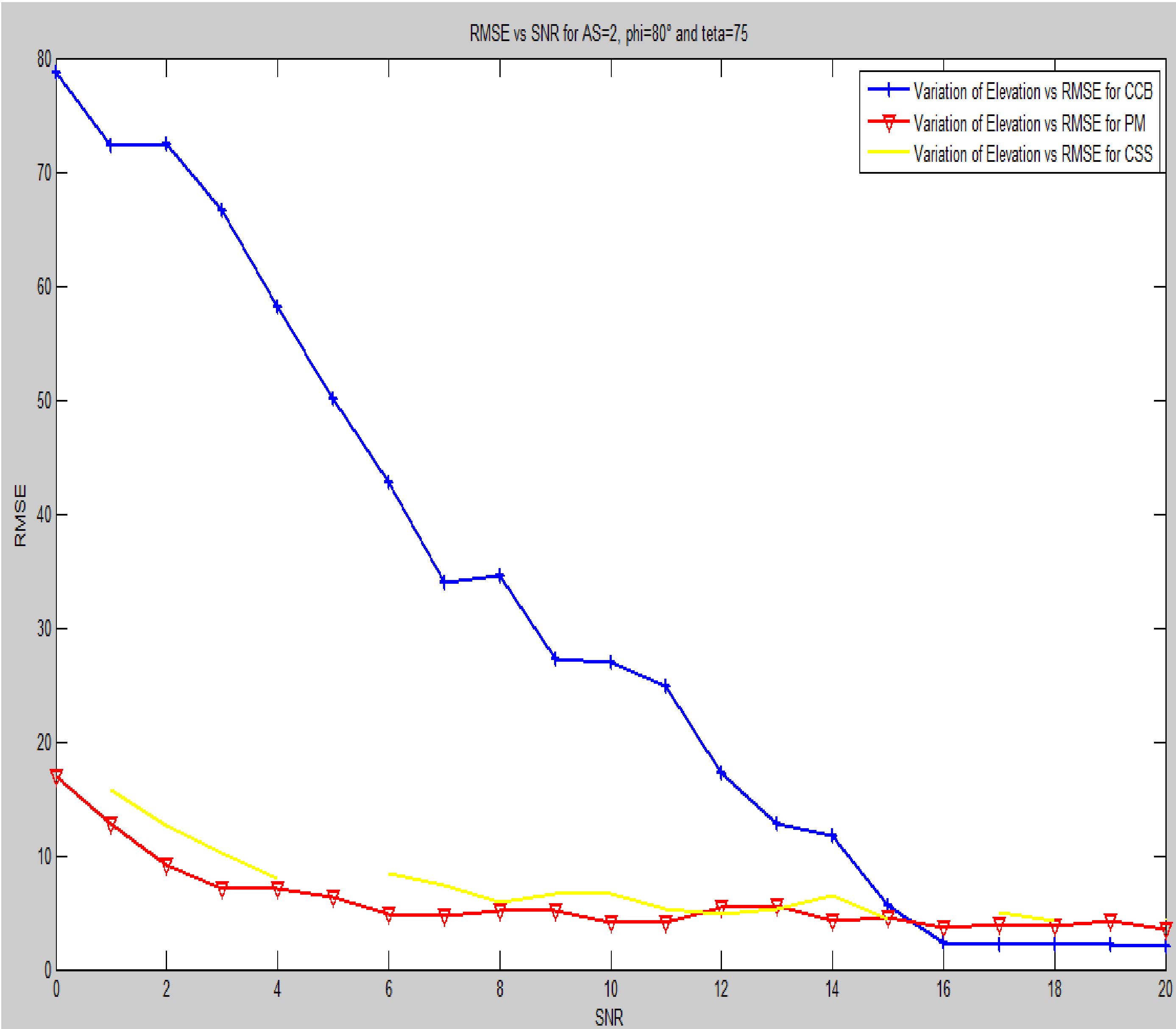

Fig. 8 Impact of SNR on performance of L- shaped array based DOA estimation methods in elevation

This figure 8 clearly shows how PM outperforms the rest of L-shaped based estimator as PM show a better trade-off RMSE vs SNR because in the performs analyzes of that three algorithms it is better to look the variation of the RMSE and SNR value means that if one of them presenting lower value for RMSE and SNR have a good performs, according to that PM Performs a both lower RMSE and SNR. CSS algorithm would show a good performance however, its fails at some values of SNR.

The fourth simulation on figure 9 shows how the three algorithms are perform compare to the value of AS in L-shaped array based estimators in terms of RMSE. Where the noise is ideal Gaussian white noise, the SNR is 10dB, low scattering environment AS= [0 - 20], and the number of snapshots is 200. The simulation results are shown in Figure 9

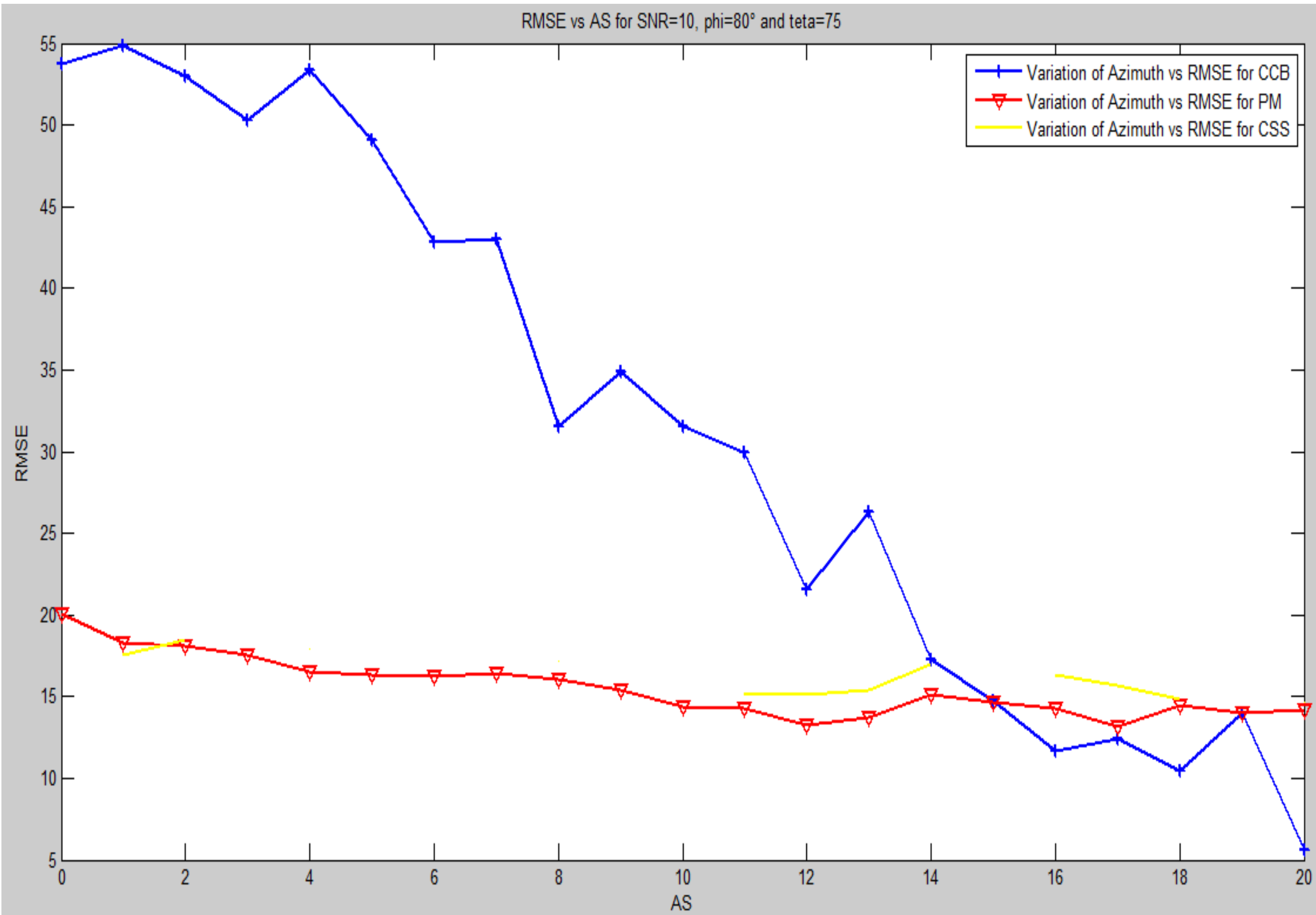

Figure 9: Impact of AS on performance of L-shaped array based DOA estimation methods

As can be seen from Figure 9 the performance of PM would be as good as that of CSS, however, CSS fails at some values of Angular spread (AS). The comparative simulation results show that CCB has the worst performance because of presenting the good performance where the RMSE is higher.

Theoretical comparison of the three DOA estimation methods shows that PM has a lower computational complexity. The computational performance are predicted theoretically in [8] by Mazlout that the computational burden of Propagator method (PM) O(2MLK) and that Cross-correlation based(CCB) method $O(2(M-1-2K)LK)$ are lower than that of conjugate symmetry based subspace (CSS) method that runs at higher computational from two origin namely subspace construction that endures the computational burden of order $O(3ML)$ and Gram-shimidth orthonormation process that runs at computational burden of Order $O(3K(K+1)(2M-K)/2)$.

CHAPTER 6: CONCLUSION AND RECOMMANDATION

6.1 Conclusion

The study conducted along this work of research which is the Performance analysis of 2 Dimensional Directions of Arrivals Estimation algorithms in Massive MIMO Networks. Simulations have been performed to evaluate the performance of the CCB, PM and CSS algorithms. Shows that L-shaped array based DOA estimation methods perform at an acceptable computational complexity. For an average number of antenna array size, however, for an exceedingly large number of antenna which is the highly demanded feature in Massive MIMO of 5G system.

The computational complexity as well as other performance metrics eliminates CCB and CSS methods. From simulation results, a subspace based method, PM show a best trade-off performance complexity.

6.2 Future works

From this work, an advanced research by considering more than one source can provide a deeper analysis and reliable results. I wish I could conduct farther research on Propagator method and analyze its performance for more than one mobile source in order to improve its computational complexity for big sized antenna arrays of full dimension MIMO system.

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