DEVELOPMENT OF MIMO DIVERSITY TECHNIQUE WITH DISCRETE WAVELET TRANSFORM FOR MILLIMETER WAVE COMMUNICATION SYSTEM

BY

NAGMA PARVEEN

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Kulliyyah of Engineering
International Islamic University Malaysia

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ABSTRACT

Millimeter wave (mm wave) wireless communication systems are considered as the key feature technology for future next generation i.e. 5th generation (5G) as mm wave band has prospective to meet high data rate, mobility and less energy consumption. Spectral efficiency improvement is one of the primary requirements for future wireless communication networks. One of the major research problems is that the signal loss at the receiver because of channel propagation. The received signal becomes more sensitive when the system uses mm wave since its frequency is very high between 3 GHz to 300 GHz. To enhance the performance of wireless communication system, exploitation of Multiple Input and Multiple Output (MIMO) antenna diversity has become well known technology. Orthogonal frequency division Multiplexing (OFDM) systems are used to improve the spectral efficiency with the use of wavelet transforms. The Discrete Wavelet Transform (DWT) has superior properties compare to Fast Fourier Transform (FFT) as it eliminates the use of cyclic prefix which improves spectral efficiency. The wavelets transforms are also beneficial in many aspects such as channel modeling, data compression and interference mitigation. Hence, a MIMO antenna diversity technique is developed with wavelets transform to improve the performance and spectral efficiency of the system. The multiple antenna arrays such a Uniform Linear Array (ULA) with half-length spacing has been considered. The system is deployed at 60 GHz as it is unlicensed spectrum band and suitable for short distance propagation for both line of sight and multipath propagation channel. The QAM modulation and demodulation are performed at the transmitter and receiver. The data is converted into DWT coefficients by reshaping property. The wavelets are then constructed and reconstructed by perfect reconstruction property. Therefore, the inverse DWT at the transmitter and DWT at the receiver could improve the Bit Error Rate (BER) performance. The performance in terms of BER are carried out in MATLAB simulation software for all diversity scenarios Single Input and Single Output (SISO) DWT, Multiple Input and Single Output (MISO) DWT and MIMO DWT. Among all of them MIMO DWT is better. The performance of MIMO OFDM with different wavelets is also simulated and Haar wavelets transform performance is better when compared with another wavelet transform by 2 dB at 10^{-3}. The MIMO DWT BER results shows better improvement when compared with the benchmarking by 2 dB at 10^{-3}. The analytical results when compared with simulation results are good in agreement with minimum discrepancy.

خلاصة البحث

تُعتبر أنظمة الاتصالات اللاسلكية ذات الموجات المليمترية (موجة mm تُعتبر أنظمة الاتصالات اللاسلكية ذات الموجات المليمترية (موجة mm) بمثابة تقنية الميزة الرئيسية للجيل القادم ، أي الجيل الخامس (G5) حيث أن نطاق الموجات المليمترية لديه القدرة على تلبية معدل البيانات العالي والتنقل واستهلاك أقل للطاقة. يعد تحسين الكفاءة الطيفية أحد المتطلبات الأساسية لشبكات الاتصالات اللاسلكية المستقبلية. واحدة من المشاكل البحثية الرئيسية هي أن فقدان إشارة عند المتلقي بسبب تأثير انتشار القناة. تصبح الإشارة المستقبلة أكثر حساسية عندما يستخدم النظام موجة mmلأن تردده مرتفع للغاية بين 3 GHz إلى 300 GHz. لتعزيز أداء نظام الاتصالات اللاسلكية أصبح استغلال تنوع الهوائي متعدد المدخلات والمخرجات المتعددة (MIMO) تكنولوجيا معروفة. تُستخدم أنظمة مضاعفة تقسيم التردد المتعامد (OFDM) لتحسين الكفاءة الطيفية باستخدام تحويلات المويجات. يتميز تحويل المويجات المنفصل (DWT) بخصائص أكثر تفوقًا مقارنة بتحويل فورييه السريع (FFT) لأنه يلغي استخدام البادئة الدورية التي تعمل على تحسين الكفاءة الطيفية. تعد تحويلات المويجات مفيدة أيضًا في العديد من الجوانب مثل نمذجة القناة وضغط البيانات وتخفيف التداخل. وبالتالي ، تم تطوير تقنية تنوع الهوائي MIMO مع تحويل الموجات لتحسين الأداء والكفاءة الطيفية للنظام. تم أخذ صفائف الهوائي المتعددة في الاعتبار مثل المصفوفة الخطية الموحدة (ULA) مع تباعد نصف الطول. يُنشر النظام عند 60 GHz لأنه نطاق طيف غير مرخص ومناسب للانتشار على مسافة قصيرة لكل من خط البصر وقناة الانتشار متعددة المسيرات. يتم إجراء التشكيل QAM وإزالة التشكيل في المرسل والمستقبل. يتم تحويل البيانات إلى معاملات DWT عن طريق إعادة تشكيل الخاصية. ثم يتم بناء وإعادة بناء الموجات بواسطة خاصية إعادة الإعمار المثالية. لذلك ، فإن DWT معكوس في المرسل و DWT في المتلقي لديها الفرصة لتحسين أداء BER. يتم تنفيذ الأداء من حيث معدل البت للخطأ (BER) في برنامج محاكاة MATLAB لجميع سيناريوهات التنوع المدخلات سواء المدخل فردي والمخرج فردي DWT (SISO) وإدخال متعدد ومخرج فردي DWT (MISO) و MIMO DWT. من بينها جميع MIMO DWT أفضل. كما يتم محاكاة أداء MIMO OFDM مع موجات مختلفة ، كما أن أداء تحويلات Wavelets يكون أفضل عند مقارنته بتحويل المويجات الآخر بمقدار 2 dB. تُظهر نتائج MIMO DWT BER تحسنا أفضل مقارنةً بالمعيار بمقدار 2 dB. النتائج التحليلية عند مقارنتها بنتائج المحاكاة جيدة في توافقها مع تناقض أقل.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Computer and Information Engineering).

…………………………………..
Khaizuran Bin Abdullah
Supervisor

…………………………………..
Md. Rafiqul Islam
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Computer and Information Engineering).

…………………………………..
Huda Adibah b. Mohd. Ramli
Internal Examiner

…………………………………..
Che Zalina Zulkifli
External Examiner

This thesis was submitted to the Department of Electrical and Computer Engineering and is accepted as a fulfillment of the requirement for the degree of Master of Science (Computer and Information Engineering).

…………………………………..
Mohamed Hadi Habaebi
Head, Department of Electrical and Computer Engineering

This thesis was submitted to the Kulliyyah of Engineering and is accepted as fulfillment of the requirement for the degree of Master of Science (Computer and Information Engineering).

…………………………………..
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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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In the Name of Allah, the Most Compassionate, the Most Merciful

Allah - beginning with the name of - the Most Gracious, the Most Merciful Most Auspicious is he in whose control is the entire kingship; and he is able to do all things [67:1]. All Praise to Allah, the Lord of the creation, and countless blessings and peace upon our Master Mohammed, the leader of the Prophets.

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LIST OF ABBREVIATIONS

4G	Fourth Generation
5G	Fifth Generation
BER	Bit Error Rate
BPSK	Binary Phase Shift key
CA	Approximate Coefficient Vector
CD	Detailed Coefficient Vector
Cp	Cyclic Prefix
DWT	Discrete Wavelet Transform
FFT	Fast Fourier Transform
IDWT	Inverse Discrete Wavelet Transform
LOS	Line of Sight Propagation
MISO	Multiple Input Single Output
MIMO	Multiple Input Multiple Output
mm	Millimeter
OFDM	Orthogonal Frequency Division Multiplex
QAM	Quadrature Amplitude Modulation
SISO	Single Input Single Output
SIMO	Single Input Multiple Output
SNR	Signal to Noise Ratio
ULA	Uniform Linear Array

LIST OF SYMBOLS

r(t)	Channel response
$y_{\mathrm{high}}[k]$	High Pass filter
$y_{\mathrm{low}}[k]$	Low pass filter
m	Number of transmitter antennas
n	Number of receiver antennas
n(t)	Noise signal
N_r	Order of reconstruction
N_d	Order of decomposition
y(t)	Received signal
$\frac{E_b}{N}$	Signal to noise ratio
T	Transpose
s(t)	Transmitted signal
λ	Wavelength

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

This introductory chapter lays down a foundation and discusses the background of this thesis, describes broadly the problem statement which this thesis will deal and from that identify objectives to be solved Detailed methodology is discussed at the end of this chapter.

1.2 BACKGROUND OF THE STUDY

Over the last few years, the subscribers of wireless communications or particularly the number of internet users has become exponential in growth. The ongoing progress in radio technology needs to provide high mobility, increase in network capacity, high data rate and excellent end-to end performance. With severe shortage of spectrum in conventional cellular bands, the range of frequencies between 3 and 300 GHz have been attracting attention for higher demand of cellular applications (Akdeniz et al., 2014). The applications such as interactive media services which use internet access for transferring data needs high-frequency band to support wireless communications system (J. Islam, 2012). Many researchers are investigating and analyzing to meet the high data rate requirement of future generation wireless communication as the data rate is increasing exponentially with the increase of demands.

The system performance is improved by diversity technique is used to counter act effect. Some of them are: frequency diversity, time diversity, polarization diversity, angle diversity, antenna/Spatial diversity. Multiple antennas are used to send signals with information to the receiver to provide multiple independent fading paths in space diversity. Spatial diversity is widely used as it is simple, cost effective, easy to implement and also reduces fast fading and inter-channel interference effects in the wireless network system (Islam, 2012). For the implementation of Multiple input and multiple output (MIMO) wireless communication systems physical diversity techniques such as time, space, frequency and polarization have been thoroughly studied (Adila et al., 2007; Patil, 2014) In wireless communication Space diversity is one of the diversity schemes which includes two or more antennas to improve the quality and reliability of the wireless link between the transmitter and receiver (Ghosh and Mehedi, 2018). Currently, the systems with four different types can be considered as diversity (input and output are considered as number of antennas).

In Single Input and single output (SISO) communication systems two antennas one as a transmitter as a source and another for the receiver as the destination are used as shown Figure 1.1. In SISO, the signal is faded more which results in high Bit Error Rate (BER) and poor communication link. The other communication system such as SIMO, MISO, and MIMO are used to mitigate the fading effect and improve the performance in terms of BER, Capacity, security and energy efficiency.

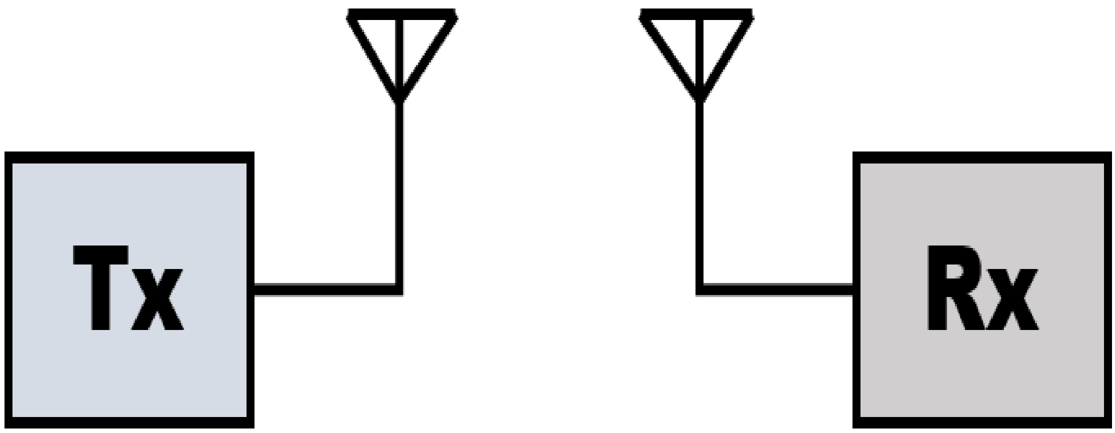

Figure 1.1 SISO communication system

In SIMO communication systems one antenna is used as a transmitter, and two or more antennas are used at the receiver as shown in Figure 1.2 which is also referred to as receive diversity. The most common used receive diversity technique include maximum ratio Combining, selection combining to enhance the framework of a receiver to various signals at the receiver to mitigate the fading effect.

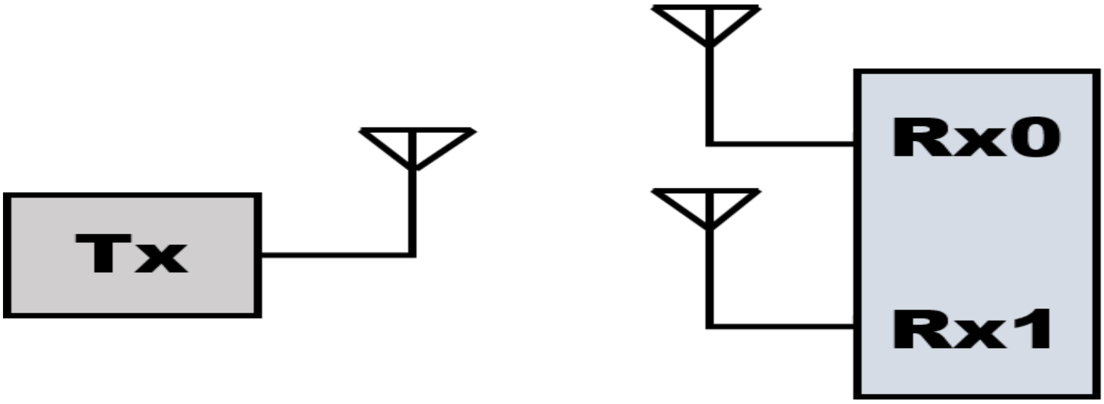

Figure 1.2 SIMO communication system

In MISO communication systems two or more antennas are used at the transmitter and one antenna at the receiver side as shown in Figure 1.3 which is also referred to as transmit diversity. Here, the same data is transmitted twice from the transmitter, and the receiver get optimized the data which results in less loss signal and improve the performance of the system. The advantage of MISO is that various signals are coded and is moved to the receiver from the transmitter.

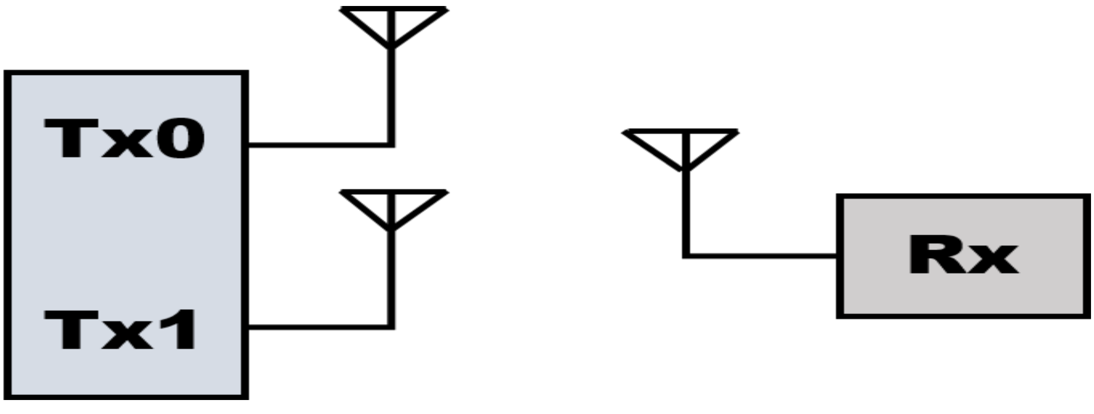

Figure 1.3 MISO communication system

In MIMO communication systems two or more antennas are used at the transmitter, and two or more antennas are used at the receiver side as shown in Figure 1.4. MIMO diversity technique provides high capacity and data rate with less loss of signal which results in a reduction of BER. Channel estimation and equalizers are used in MIMO channel to mitigate the fading effect. In mm wave communication system for a MIMO channel, a coding Technique was proposed using minimum mean square error and successive interference cancellation (Boby et al., 2019). The low correlation between the multipath channel of the MIMO system improves channel capacity and their performance in terms of BER was studied by (Adila et al., 2010).

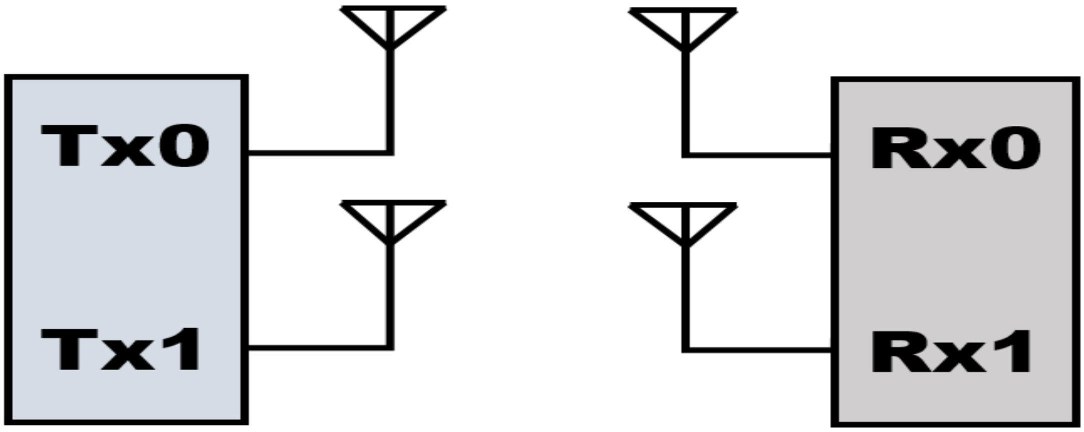

Figure 1.4 MIMO communication system

1.3 PROBLEM STATEMENT

Spectrum usage due to increase number of mobile users using services like audio, video and images is one of the challenges for wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is one of promising techniques to increase spectral efficiency. However, the conventional OFDM using fast Fourier transform (FFT) still has the drawback of reducing spectral efficiency as it requires insertion of cyclic prefix at transmitter and removal of cyclic prefix at receiver. Discrete wavelet transforms (DWT) are used as an alternative method replacing FFT to increase the spectral efficiency as it eliminates the use of cyclic prefix. Multipath fading can be one of the drawbacks for transmission wireless signal. The effect of this situation is that the signal at the receiver may be noisy and distorted. Thus, the antenna diversity i.e. with multiple inputs and multiple outputs provides an improvement in the BER performance at the receiver. Therefore, MIMO diversity with wavelets transform need to be implemented in mm wave communication system to improve spectral efficiency and reduction of BER.

1.4 RESEARCH OBJECTIVE

The main objectives of the thesis are given below

1- To study the performance of antenna diversity scenarios using uniform linear array.

2- To develop antenna diversity technique with discrete wavelet transform for mm wave communication system.

3- To evaluate BER performance for the proposed approach.

4- To compare the performance with different wavelets transform and the benchmarking:

1.5 RESEARCH METHODOLOGY

The overall in order to accomplish the objective of this research, the methodology is outlined by the following steps:

- Literature review: The first step is a review of the current state of the diversity techniques in the wireless communication to combat the fading effect and to increase the efficiency of the channel. This will give an overview and review of the researches that have been executed in this area.

- The Second step is to program and find the results using MATLAB simulation to study the performance of SISO, SIMO, MISO and MIMO diversity technique using array gain with BPSK modulation.
- The third step is to implement ULA using array gain diversity techniques at both transmitter and receiver with wavelets transform.
- The fourth step is studying the performance of SISO, SIMO, MISO and MIMO diversity techniques with wavelets transform using array gain.
- The last step is to validate our proposed results with previous work and analytical formulation. We also validate with different wavelets transform and QAM modulation techniques.

The details methodology of current work has been ordered in using the flow chart process, which as shown in Figure 1.5.

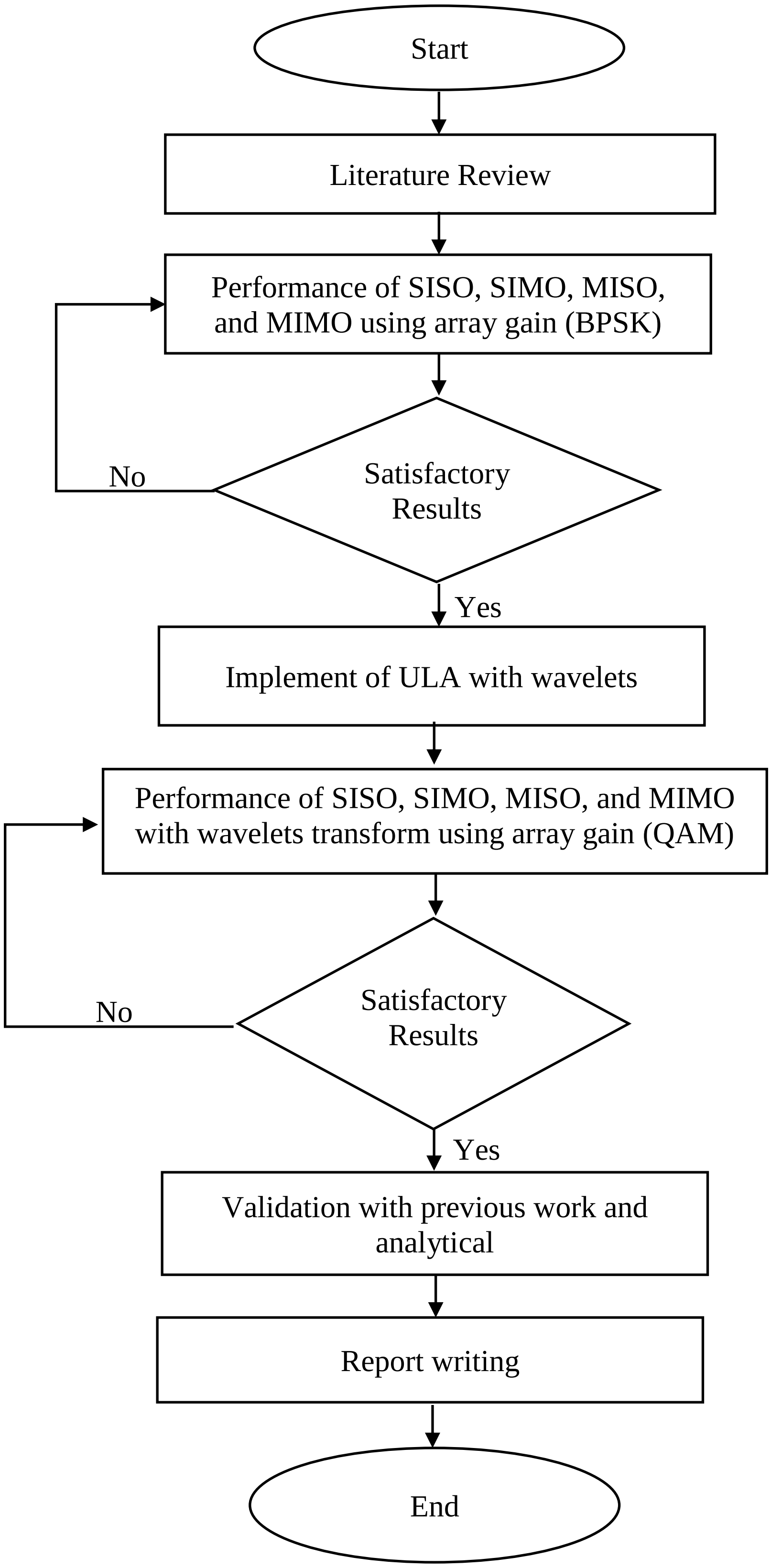

Figure 1.5 Research methodology flow chart

1.6 RESEARCH SCOPE

Increase in spectral efficiency with wavelets transform and MIMO diversity technique to improve the performance in terms of BER is the main contribution of this thesis. MIMO diversity with wavelet transform is developed and studied that significantly improves the performance for mm wave communication system. The scope of this research is given below,

- The simulation of the proposed approach is carried out in perfect channel conditions, i.e. in an indoor scenario with known distance between transmitter and receiver.
- The multipath channel is considered based on number of scatters, i.e. scattering MIMO channel with known number of scatters.
- The performance is limited to two elements of the uniform linear array with half-length spacing to achieve reduction in BER for mm wave system

1.7 THESIS OUTLINE

This thesis is mainly divided into five chapters. The outline of the chapters is given below:

- **Chapter One:** Background of the thesis study, problem statement, research objective, research scope and methodology is briefly explained and also thesis organization is discussed in this chapter.
- **Chapter Two:** The overview of 5G and advantages of both mm wave and wavelets are summarized. It also gives the brief literature of various diversity techniques developed by the researchers and how DWT is used in replace of FFT to improve the spectral efficiency is discussed.

- **Chapter Three:** The detailed methodology of the research is discussed in chapter three which includes system model, transmitter block, receiver block, channel model and analysis of the proposed technique.
- **Chapter Four:** The simulation results are discussed in this chapter. The performance of SISO, SIMO, MISO and MIMO with wavelets transform and without wavelets transform are shown. The performance for different wavelets transforms and comparison with previous results are also shown in this chapter.
- **Chapter Five:** Finally, the thesis is concluded in chapter five and future recommendation of this research is also discussed briefly. The organization of chapters is shown in Figure 1.6.

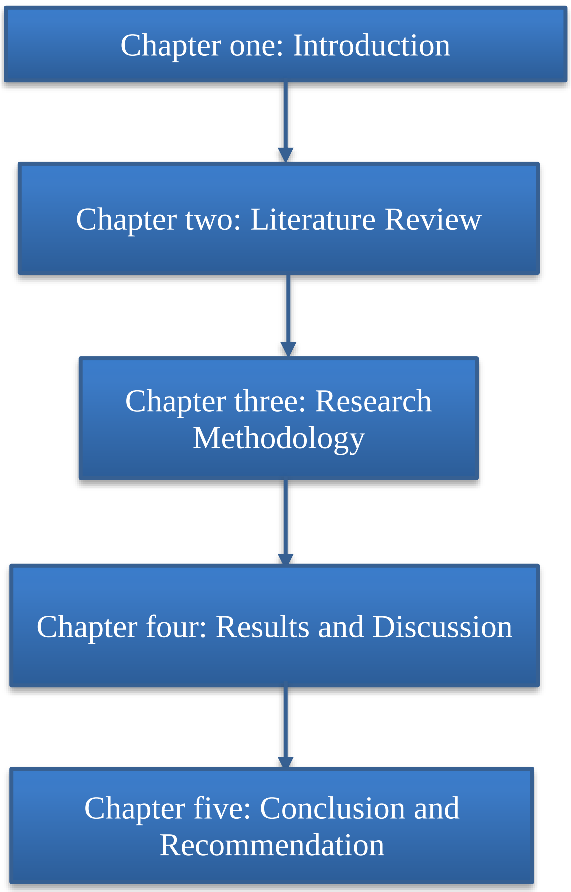

Figure 1.6 Overview of Research Methodology Flow-chart

CHAPTER TWO

LITERATURE REVIEW

2.1 EVALUATION OF 5G

The wireless communication system has become more popular due to fast revolution in mobile technology over recent years. The revolution is as there is increase in telecoms customers. The revolution is from 1G- the first generation, 2Gthe second generation, 3G- the third generation, and then the 4G- the fourth generation,5G-the fifth second generation is explained below.

2.1.1 First Generation (1G)

In 1980 first generation was emerged which was an analog system based on Frequency Division Multiple Access technique (FDMA). The highlights of the first generation were the speed was up to 2.4 kbps, it allows voice call within one country using analog signal and the capacity was 30 KHz. Some of the mobile technology’s which were used in first generation are Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS) and Push to Talk (PTT). The drawbacks of first generation are low voice quality, low capacity, the handset was heavy was not feasible to carry, battery life was poor and spectral efficiency was of lower level. The communication channel was not secure, and it utilizes analog transmission instead of digital which is less effective in means of transmitting information.