



**5G MOBILE SYSTEM MIMO DESIGN WITH
IMPROVING DATA RATE**

Abubakr Wsu MUHAMMED

**MSc Thesis
Electrical and Electronics Engineering
Supervisor: Assistant Prof. Dr. Turgay KAYA**

APRIL-2019

REPUBLIC OF TURKEY
FIRAT UNIVERSITY
THE INSTITUTE OF NATURAL AND APPLIED SCIENCES

5G MOBILE SYSTEM MIMO DESIGN WITH
IMPROVING DATA RATE

MSc THESIS

By

Abubakr Wsu Muhammed

(162113105)

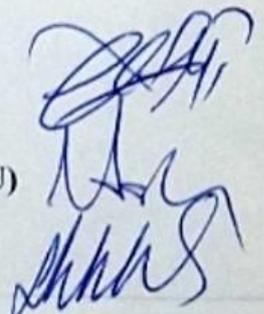
Submitted Date: 04.03.2019

Examination Date: 19.04.2019

Supervisor: Assistant Prof. Dr. Turgay KAYA (F.U)

Jury : Assistant Prof. Dr. Muzaffer ASLAN (B.U)

: Assistant Prof. Dr. Ayhan AKBAL (F.U)



April -2019

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to my Supervisor *Assistant Prof. Dr. Turgay KAYA*, for his support of my study and research, guidance, helpful suggestions, correction, and supervising my work.

A special thanks to *Dr. Jalal J. Hamad Ameen* and PhD student *Ibrahim N. Qader* that helped me during hard times when I need their assistance during my thesis.

I am especially thankful to my parents, brothers and sisters who have always provided me strength, best wishes, moral and supporting during our whole career.

I would like to dedicate and thankful to my beloved wife, thank you for helping me for everything, and especially I can't thank you enough for supporting me throughout this experience, also dedicated to my lovely kids *Diyar* and *Dima*.

Sincerely

Abubakr Wsu Muhammed

Elazığ, 2019

TABLE OF CONTENTS

	Page no.
ACKNOWLEDGEMENTS	I
SUMMARY	IV
ÖZET	V
LIST OF FIGURES	VI
LIST OF TABLES	VIII
ABBREVIATIONS	IX
1. INTRODUCTION	1
2. REVIEW BASIC WIRELESS MOBILE SYSTEM	3
3. THEORY OF THE WORK	5
3.1. Evolution	5
3.1.1. First Generation Technology (1G)	5
3.1.2. Second Generation Technology (2G).....	6
3.1.3. Third Generation Technology (3G).....	8
3.1.4. Fourth Generation Technology (4G).....	9
3.2. Next Generation Technology (Fifth Generation (5G))	10
3.2.1. Features of 5G Technologies.....	12
3.2.2. 5G Technology Challenges	13
3.2.3. Future 5G Networks	15
3.3. MIMO System	15
3.3.1. Channel Model MIMO System	16
3.3.2. Capacity of the MIMO channel.....	17
3.3.3. Advantages of MIMO system	17
3.3.3.1. Array gain.....	17
3.3.3.2. Spatial diversity gain	18
3.3.3.3. Multiplexing Gain	18
3.4. Fading Channel Model	19
3.4.1. Rayleigh Fading Channel System	19
3.4.2. Rician Fading Channel System	20
3.5. Precoding Scheme	20
3.5.1. Zero-forcing linear precoding	21
3.5.2. MMSE linear precoding	21
3.5.3. SIC Non-linear Precoding:	22

4. SIMULATION RESULTS AND DISCUSSION	23
4.1. Simulation Results for M-MIMO using (MF, MMSE, ZF and SIC precoding scheme.....	23
4.2. Simulation results for Cumulative Density Function (CDF)	26
4.3. Simulation Results for Ergodic Capacity	28
4.4. Simulation results for outage probability.....	31
4.5. Simulation results for capacity with outage probability	34
5. CONCLUSION	37
REFERENCES	38
CURRICULUM VITAE.....	42
APPENDIX	43



SUMMARY

5G Mobile System MIMO Design with Improving Data Rate

In recent years, there is still a dramatic increase in the number of mobile users who handle this system for different purposes, continuously. Thus, more and more people want to access a faster internet and better mobile services. Therefore, the demand for the internet supported services, various multimedia applications, huge number of smartphones, and laptops need reliable services with a high data rate. To achieve the required data rate and high speed, a new revolution in mobile technology is necessary.

Fifth Generation (5G) can perform very high bandwidth and a huge data rate, also it will involve all types of advanced characteristics, which make it as the most powerful net system that will be achieved in few years later. Massive-MIMO for 5G could represent a major leap in relation to the newest technology in systems and component design, also massive-MIMO can perform the 5G demand that implement multiple antenna in the base station and user equipment with a suitable coding system to decrease the errors, improve the signal quality, and transferring the data rate. The MIMO multiplexing and diversity is the key factor to focus and discuss to deliver and achieve a high sum data rate.

This study represents a brief survey of 5G technology and focuses on a Massive MIMO system as well the various of precoding schemes such as ZF, MMSE, and SIC precoder are discussed. The system has been estimated for four types of precoding scheme ZF, MF, MMSE, and, SIC pre-coding for different number of multiple antennae, which the simulation results displayed the data rate has been much improved when the SIC linear precoding was applied.

The system's probability is analyzed through simulation which showed the simulated results of cumulative distribution functions of the maximal achievable rate for different types of antenna configuration. And also the effect of the MIMO antenna system on the capacity of the channels for i.i.d Rayleigh fading channel was simulated.

Furthermore, the outage of the channel and outage probability were simulated by using Matlab, and the simulation results showed the outage capacity were more improved to acceptable rate, and the gain of system was also increased by increasing the number of antennas, especially on the receiver side. The results have been achieved and running was performed by using Matlab simulation.

Keywords: Mobile Generation, 5G Technology, MIMO System, precoding scheme, data rate

ÖZET

Veri Oranının Geliştirilmesi ile 5G Mobil Sistem MIMO Tasarımı

Son yıllarda farklı amaçlarla mobil sistemi kullanan kişi sayısında çarpıcı şekilde sürekli bir artış vardır. Bununla birlikte daha fazla kullanıcı, daha hızlı internet ve mobil servise erişmek istemektedir. İnternet destekli servislere, çeşitli multimedya uygulamalarına, çok sayıda akıllı telefona ve dizüstü bilgisayara olan talepten dolayı yüksek veri hızıyla güvenilir servislere ihtiyaç duyulmaktadır. Gerekli olan veri hızını ve yüksek hızı elde etmek için mobil teknolojide yeni bir devrime ihtiyaç vardır.

Beşinci Nesil (5G), çok yüksek bant genişliği ve çok büyük veri hızını gerçekleştirebilir, hatta birkaç yıl sonra çok güçlü bir net sistem olarak her türlü gelişmiş özelliği de içerebilecektir. 5G için masif-MIMO, sistemlerdeki ve bileşen tasarımındaki en yeni teknoloji ile ilgili büyük bir sıçramayı temsil edebilir, veri hızını ve sinyal kalitesini arttırmak, hatayı azaltmak için uygun kodlama sistemi ile kullanıcı ekipmanını ve baz istasyonunda çoklu anten kullanan 5G'nin talebini karşılayabilir. MIMO çoğullama ve çeşitlilik, yüksek toplam veri hızı sunmak ve elde etmek için odaklanmayı ve tartışmayı sağlayan anahtar bir faktördür.

Bu çalışmada, 5G teknolojisinin kısa bir özeti sunulmakta, masif MIMO sistemine odaklanmakta ayrıca ZF, MMSE ve SIC ön kodlayıcı gibi ön kodlama şemalarına değinilmiştir. Sistem, farklı çoklu anten sayıları için ZF, MMSE ve SIC ön kodlayıcı gibi dört tip ön kodlama şeması için incelenmiş ve SIC ön kodlayıcı kullanıldığı zaman veri hızının çok daha fazla arttığı simülasyon sonuçları ile gösterilmiştir.

Sistemin olasılığı, farklı anten konfigürasyon tipleri için elde edilebilecek azami oranın kümülatif dağılım fonksiyonlarının benzetim sonuçlarını gösteren simülasyon yardımıyla analiz edilmiştir. Ayrıca MIMO anten sisteminin, Rayleigh sönümlü kanalı için kanalların kapasitesi üzerindeki etkisi simüle edilmiştir.

Kanalın kesilmesi ve kesilme olasılığı MATLAB kullanılarak simüle edilmiştir. Simülasyon sonuçları, kesilme kapasitesinin kabul edilebilir hıza göre daha gelişmiş olduğunu ve özellikle alıcı taraftaki antenlerin sayısının artırılmasının sistemin kazancını da arttırdığını göstermiştir. Yapılan çalışmalar, MATLAB ortamında simüle edilmiş, çalıştırılmış ve analiz edilmiştir.

Anahtar Kelimeler: Mobil nesil, 5G Teknolojisi, MIMO Sistemi, ön kodlama şeması, veri hızı

LIST OF FIGURES

	Page no.
Figure 3.1. Mobile Communication: from 1G to 4G	10
Figure 3.2. The challenges of 5G system	16
Figure 3.3. Multiple Input Multiple Output (MIMO) System	16
Figure 3.4. Configuration of channel precoding and transmitter information.....	21
Figure 4.1. Achievable sum rate of an 8×8 MIMO for i.i.d. fast fading channel.....	23
Figure 4.2. Achievable sum rate of a 16×16 MIMO for i.i.d. fast fading channel.....	24
Figure 4.3. Achievable sum rate for 32×32 MIMO for i.i.d. fast fading channel.	24
Figure 4.4. Achievable sum rate for 64×64 MIMO for i.i.d. fast fading channel.	25
Figure 4.5. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 4×4 MIMO, and 8×8 MIMO channels.	26
Figure 4.6. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 16×16 MIMO channels.	27
Figure 4.7. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 32×32 MIMO channels.	27
Figure 4.8. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 64×64 MIMO channels.	28
Figure 4.9. Capacity vs. number of antennas for 8×8 MIMO, 1×8 SIMO, 8×1 MISO and SISO.....	29
Figure 4.10. Capacity vs. number of antennas for 16×16 MIMO, 1×16 SIMO, 16×1 MISO and SISO system.	30
Figure 4.11. Capacity vs. number of antennas for 32×32 MIMO, 1×32 SIMO, 32×1 MISO and SISO system.	30
Figure 4.12. Capacity vs. number of antennas for 64×64 MIMO, 1×64 SIMO, 64×1 MISO and SISO system.	31
Figure 4.13. Outage probability of the Alamouti STBC for 8×1 and 8×8 MIMO and i.i.d. Rayleigh slow fading channel model.	32
Figure 4.14. Outage probability of the Alamouti STBC for 8×8 and 16×16 MIMO and i.i.d. Rayleigh slow fading channel model.	32
Figure 4.15. Outage probability of the Alamouti STBC for 16×16 and 32×32 MIMO and i.i.d. Rayleigh slow fading channel model.	33

Figure 4.16. Outage probability of the Alamouti STBC for 16×16 and 64×64 MIMO and i.i.d. Rayleigh slow fading channel model.33

Figure 4.17. Capacity with outage 10% for MIMO, SIMO, MISO and SISO channels for i.i.d. Rayleigh slow fading channel model.34

Figure 4.18. Capacity with outage 10% for 8×8 MIMO and 16×16 MIMO channels for i.i.d. Rayleigh slow fading channel model.35

Figure 4.19. Capacity with outage 10% for 8×8 MIMO and 32×32 MIMO channels for i.i.d. Rayleigh slow fading channel model.35

Figure 4.20. Capacity with outage 10% for 8×8 MIMO and 64×64 MIMO channels for i.i.d. Rayleigh slow fading channel model.36



LIST OF TABLES

	Page no.
Table 3.1. Comparison of All Mobile Generations (1G-5G)	12



ABBREVIATIONS

G	: Generation
5G	: Fifth Generation
MIMO	: Multiple-Input Multiple-Output
GSM	: Global System Mobile telecommunications
UMTS	: Universal Mobile Telecommunication System
IMT-A	: International Mobile Telecommunications- Advanced
IP	: Internet Protocol
OFDM	: Orthogonal Frequency-Division Multiplexing
LTE	: Long Term Evolution (LTE)
RAT	: Radio access network
CCR	: Cloud Computing Resources
ZF	: Zero-forcing, MMSE, and MF linear precoding with SIC
MMSE	: Minimum mean square error
MF	: Matched Filter
SIC	: Successive Interference Cancellation
METIS	: Mobile and wireless communications Enablers for the Twenty- twenty Information Society
CP	: Cyclic Prefix
FBMC	: Filter Band Multi Carrier
OFDM	: Orthogonal Frequency Division Multiplexing
OFBMC	: Orthogonal Frequency Band Multi Carrier
PTT	: Push To Talk
MTS	: Mobile Telephone System
IMTS	: Improved Mobile Telephone Service
AMTS	: Advanced Mobile Telephone System
ARP	: Autoradiopuhelin
NTT	: Nippon Telephone and Telegraph
AMPS	: Advanced Mobile Phone System
NMT	: Nordic Mobile Telephones
TACS	: Total Access Communication System
FCC	: Federal Communications Commission
SIR	: Signal-to-Interference Ratio

BS	: Base Station
MS	: Mobile Station
FM	: Frequency Modulation
FDMA	: Frequency-Division Multiple Access
SMS	: Short Message Service
TDMA	: Time Division Multiple Access
CDMA	: Code Division Multiple Access
GPRS	: General Packet Radio Service
ITU	: International Telecommunication Union
MMS	: Multimedia Messaging Service
WAP	: Wireless Application Protocol
EDGE	: Enhanced Data rates for GSM Evolution
FOMA	: Freedom of Mobile Multimedia Access
Wi-Fi	: Wireless Fidelity
WLAN	: Wireless Local Area Network
HSPA	: High-Speed Packet Access
FDMA	: Frequency-Division Multiple Access
TDMA	: Time-Division Multiple Access
CDMA	: Code- Division Multiple Access
WCDMA	: Wideband-Division Multiple Access
HSPA	: High-Speed Packet Access
HSUPA	: High-Speed Uplink Packet Access
HSDPA	: High-Speed Downlink Packet Access
AMC	: Adaptive Modulation Coding
IMT-SC	: International Mobile Telecommunications-Single Carrier
IMT-MC	: International Mobile Telecommunications- multi-carrier
IMT- DS	: International Mobile Telecommunications- direct spread
IMT-TC	: International Mobile Telecommunications- time code
GPS	: Global Positioning System
LTE	: Long Term Evolution
QoS	: Quality of Service
DVB	: Digital Video Broadcasting
HDTV	: High Definition Television

Gbp	: Gigabits per second
IoT	: Internet of Things
PAN	: Personal Area Network
SDN	: Software Defined Network
WWWW	: Wireless – World Wide Wireless Web
CIR	: Channel Impulse Response
LOS	: Line Of Sight
NLOS	: Non-Line-Of Sight
CSI	: Channel State Information
LP	: Linear Precoding
ISI	: Inter Symbol Interference
dB	: decibel
SNR	: Signal to Noise Ratio
BER	: Bit Error Rate
i.i.d	: independent identical distributed
CDF	: Cumulative Density Function
M-MIMO	: Massive-Multiple-Input Multiple-Output
MISO	: Multiple-Input Single-Output
SIMO	: Single-Input Multi-Output
SISO	: Single-Input Single-Output
STBC	: Space Time Block Code

1.INTRODUCTION

In the last decades, mobile wireless systems are the most widespread communication way among people, and by this method one could communicate with machines and robots. Therefore, by population boom in planet earth, and increasing the demand on the network, it is necessary to develop new ways and techniques to improve wireless communication system. In the previous years, wireless mobile technology has achieved some significant developments that are known as wireless generations (G), beginning with the first generation (1G) in 1970. For each of these generations some sufficient technical services have been added, including frequency band and transmission technique. Now, wireless communication will be progressed toward the fifth generation (5G), whereby, there are lots of different proposed projects, which published for the next generation, and they are believe that it will accomplished at 2020 or beyond.

To increase data capacity and enhance the efficiency of the network, Multiple-Input Multiple-Output (MIMO) have been carried out as new technologies for improving the quality of channels and wireless network. This technique (MIMO) is assumed to be applied in the next generation by a considerable change in the number of antenna, which is known as massive MIMO.

Four different generations in the cellular mobile communication system has been occurred since 1980, started with analogue system (1G), which designs in the 1970s [1]. The 1G mobile telecommunication network was an analogue system that could be used for Mobile Telephony (Voice) services with speed of 2kbps. After that, 1G was progressed toward digital cellular technology (2G) system [2]. The 2G was constantly developed until it reached the Global System Mobile telecommunications (GSM) and it has been utilized for the first time in the 1990. The GSM is accommodation and the development of transfer online data through the internet assisted the advancement of a mobile network with enhance exchange data also at the finally GSM drove to the (3G) third generation technology.

The 3G centered on higher data rate, multimedia support, (UMTS) Universal Mobile Telecommunication System also is known as third generation mobile technology (3G) has been planned with higher data rate capacity and different multiple access codes.

After more progress in a mobile wireless system in the year 2009, the new generation designed that satisfy the requirements of International Mobile Telecommunications-Advanced (IMT-A) standard, that used for all services internet protocol (IP), this generation

more advancement compared to 3G, therefore, named fourth generation (4G). In 4G system more researchers attention for improvement a technique that called multiple-input multiple-output (MIMO) also used the advanced radio interface with a method of encoding digital data that known as orthogonal frequency-division multiplexing (OFDM). The 4G beginning with a standard Long Term Evolution (LTE) and then (advanced-LTE) has been designed which high data rate, the 4G system can carry out a data rate the speed 1Gbps for low mobility such as roaming and for high mobility such as mobile network reach 100 Mbps [3].

However, on this day the increasing of a subscriber of a mobile system network and internet users by smartphones and laptops also for developed all type of industrial and medical need to faster internet access, all these requirements need a new revolution in wireless communication services. Fifth generation (5G) system utilization wireless with very wide bandwidth, 5G technologies involve all kinds of advanced characteristic that make technology 5G the strongest in the near future.

2. REVIEW BASIC WIRELESS MOBILE SYSTEM

A brief history of basic progressing in mobile communication systems are given as follows.

Pankaj Sharma et al. [1] presented the history of all mobile generation, and how they developed and undergo a significant changes in the fundamental techniques. Also the advantages and disadvantages of each generation were mentioned; moreover, they illustrated the challenges of various application in all industrial fields and how 5G will increase data rate, and hence, it progress the mobile communication. On the other hand,

Reshma S. Sapakal and Sonali S. Kadam [4] presented the main development in mobile communication network from 1G to 4G. In addition, they highlighted the necessity of 5G network in the future, thus, they proposed 5G network with a new architecture that combined different independent radio access network (RAT). Also, they proposed a suitable configurable network for all mobile application and network services that called Cloud Computing Resources (CCR).

Joseph Isabona et al. [5] showed some different types of linear and non-linear precoding system for improved data rate and energy efficiency system. They made a comparison between ZF, MMSE, and MF linear precoding with SIC, ML in non-linear precoding system. Furthermore, they offered the significant gain in system performance of MIMO system by using non-linear precoding scheme, which especially could successive in the interference cancellation (SIC).

Lu, L., et al. [6] conducted a study on massive MIMO system with different aspects. They embedded a large number of antennas in the base station that could improve both energy and spectral efficiency significantly. Also, they point out some application problems of massive MIMO, especially those challenged faced on channel estimation and precoding scheme, In addition, they focus on pilot contamination while an increase in the number of antenna for adjacent cells, and the corresponding problems that could be happened for MIMO system while implementing and increasing number of antenna.

A Osseiran et al. [7] In this article are shown the scenario and concepts the EU project METIS (Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society) for a 5G system, this project believe the next generation must be a structure on the existing generation technology but need to accomplished by new radio that can be carrying and supporting very huge demand such as massive MIMO, furthermore they

aspect some scenario for 5G network mainly very low latency, long battery life and could be connected huge amount of device in small area, also METIS project proposed some network architecture for 5G like Multi-layer, Multi-node/multi-antenna and RAT network.

Arun Kumar and Manisha Gupta. [8] In this article the researchers tries to present the solve problem coverage network in the indoor area by the proposed femtocell and some other technique to improve the network in Closed area also presented the view some of organization and community toward the 5G system and solve the challenges also shown the proposed bandwidth and new spectrum for 5G, furthermore proposed the new technique that used with OFDM modulation without using CP named FMBC filter that have great effect to improve the bandwidth of 5G technology. Moreover, the researchers believe instead the OFDM proposed OFBMC technique that can more improve the bandwidth and enhancement of the system.

N Ojaroudiparchin et al. [9] presented the design for a new antenna that could suitable for mm-Wave frequency and operate at a high frequency (25-50)GHz band that proposed for 5G system, also design architecture antenna at small area dimensions about (50-100)mm at the mobile station, also design and a simulated antenna array for MIMO system that could have good performance, diversity gain, high efficiency and beam forming for small area, also need to compact la large number of antenna at small size and proposed multi-layer antenna array that accepted for MIMO system with 5G communication technology.

3.THEORY OF THE WORK

3.1.Evolution

After establishing a Wireless communication system in the last decades and become a widespread technology, a mobile system reach a significant development and great changes in coverage networking and transfer information. This development and revolution in the communication system known as mobile generations that starts of 1G up to 4G. Also, the 5G will come in the near future.

3.1.1. First Generation Technology (1G)

before the mobile cell phone was published, the radiotelephone which fixed on some vehicles known as pre-cellular phone mobile technology, some of the scientists named (zero generation) 0G, that be a basis for the first generation and modern cellular mobile technology.

In zero generation technology involved some technology to progress telephone communication system such as PTT (Push to Talk), Mobile Telephone Service (MTS) was a pre-cell radio technology which was the radiotelephone performs the land dial phone service. At the year 1964 improved the services and Improved Mobile Telephone Service (IMTS) was introduced with very limit of a number of frequency channel and subscribers used in part of North America. After some advanced and development, AMTS (Advanced Mobile Telephone System) was published as a 0G radio communication technology that can transportable telephone system [10, 11].

This generation of a mobile telephone system not published generally among people but utilized in some special fields such as commercial service and Military field also in a closed network such as a police radio and taxi transmission system, which normally fixed in the vehicle box or mounted near the driver seat. Also some time carrying in a briefcase [12].

The first models of this telephone system are:

1. At the year 1971 in Finland as a first county published a general commercial mobile radiophone known as Autoradiopuhelin (ARP) [13].
2. At the year 1972 in Germany as a second county published a commercial mobile radiotelephone known as B-Netz, B refers to the second country that utilized as a commercial mobile network [14].

In 1979, First generation mobile technology were performed and established on an analogue system which became then a fundamental for cellular structure of mobile communications system, In Japan launched the Nippon Telephone and Telegraph (NTT) the first operational automated cellular system in the world, after five years the NTT system developed and could coverage network for most people in Japan as a first public network 1G system [1]. After two years, the cellular era transferred to Europe, Also, the Advanced Mobile Phone System (AMPS) in the United States was designed at 1982. Furthermore, Nordic Mobile Telephones (NMT) and Total Access Communication System (TACS) were the two most common analogue systems [15].

AMPS technology utilized 40 MHz frequency spectrum bandwidth that specify between 800 to 900 MHz band frequencies which organized by Federal Communications Commission (FCC), the system provide the minimum reuse frequency band, also the signal-to-interference ratio (SIR) is 18 dB and the phase shift between directional antennas is 120-degree. So the frequency reuse factor for cell edge is 7 cell. At the AMPS technology for sending the signal from the base station (BS) toward mobile-station (MS), 869-894MHz channel band utilized that called forward channel. Also for a backward channel from the mobile station (MS) to a base station (BS), 824-849 MHz is applied [16, 17].

The frequency modulation (FM) technique used at the 1G system for transmitting the signals, frequency modulation most reasonable for voice transmission also for implemented voice call modulation Frequency-Division Multiple Access (FDMA) is involved [1].

3.1.2. Second Generation Technology (2G)

2G is a digital cellular system technology. It can't generally exchange information like email or online games, except a digital voice call, furthermore, some standards of 2G useful for small data transmission such as Short Message Service (SMS) [11].

In the year 1991, the digital system has been improved and advanced new technologies until the Global System for Mobile Communications (GSM) standard started in Europe, also the roaming service make the GSM be very popular that can connect between different cell phone networks, entire the world more than 2 billion subscribers over 200 countries using the GSM standard, in many places of the world people could use their telephones [11, 16].

For carrying more subscribers at the limited bandwidth 2G system developed some multiplexing techniques such as TDMA (time division multiple access) and CDMA (code division multiple access) that have more effect on spectrum efficiency, data transmission and enhance roaming service [18].

2G The 2G cellular system has some advantages over previous mobile systems that been more reliable and helpful to use. The transmission of digital signals needs less power than analogue signal so the battery life longer and less power consumption. Also, the increase the signal to noise ratio and enhance voice clarity by an implementation of a new digital coding technique. Perform the service short message one of the special features for the 2G system which operates by the digital system, furthermore the security and protection of the calls most powerful when using digital encryption coding. With most positive properties but to work cell phone at all area need powerful digital signals, in any place the coverage network not good the signals would be weak [11, 19].

After implemented the General Packet Radio Service (GPRS), 2G evolved to 2.5G. "2.5G" is the unofficial name only for a commercial title different from standard generations which are formally specified and defined by the International Telecommunication Union (ITU). With implementing the GPRS system the capacity and data rate of mobile system increased about twice times from 56 kbit/s to 114 kbit/s, also the GPRS system supported some new services like Multimedia Messaging Service (MMS) and World Wide Web (WWW) as Internet services [18].

With the development in the communication system, Enhanced Data rates for GSM Evolution (EDGE) technology for enhanced the GPRS and GSM systems operated on GSM networks. telecommunication technology can impend a big leap with EDGE system, provide a fast transmission of information and reliability, If could transport a part of information about 80KB in 4 seconds by EDGE technology in a GPRS system for the same of data needs 12 seconds this is a big difference in speed and capacity of the systems. also one of the considerable benefits of this system the subscribers of the GSM mobile system for working in the EDGE system do not need to set up any additional software program on changing the mobile equipment also not require spending any extra costs. By the implementation of the EDGE system increased utilizing the N95, N97 and blackberry mobile equipment [20]. EDGE is described as pre-third generation technology launched at the United States in 2003 by (AT&T), EDGE system can achieve triple capacity and work triple users than GSM and GPRS systems, and also for the coverage the same of subscribers, need a fewer number of radio resources [21].

3.1.3.Third Generation Technology (3G)

The main progress in the 2G system provides a clear voice communication, SMS services and involve a transfer of some information through their voice paths but the speed is slow, however 3G system technology centered on enhancing the multimedia service, improve data rate and spectral efficiency. In October 2001, the 3G system introduced as a popular commercial system through NTT Do Co Mo in Japan country. After started the 3G technology, wireless communication technology transform from the classical telephone system to a system that includes a wide data transfer, video call and broadband voice call [1, 3].

The 3G technology described through The International Telecommunication Union (ITU) that contain a set of standards supported by the International Mobile Telecommunications program IMT 2000 [16].

additionally, this generation performs a significant service for subscribers such as higher capacity by improved spectral efficiency means to increase the rate of data that transferred in a specific bandwidth in any network system, also by implementing a set of protocols for mobile system known as High Speed Packet Access (HSPA) the system capable to achieve speeds over 5.8Mbit/s for uplink and 14.4Mbit/s for downlink mobile system. Spectrum efficiency or spectral efficiency mention to the quantity of data that can be transferred over a given bandwidth in a specific digital telecommunication system [22].

The five different radio interfaces can operate on the 3G network and IMT-2000 terrestrial standard, these radios provide performance optimization in a board range environments between temporal and satellite interfaces. All five radio Interfaces technology work with FDMA, CDMA and TDMA multiplexing. IMT-FT (frequency Time) radio operate with FDMA, IMT-DS (direct spread) and IMT-MC (multi-carrier) operate under CDMA technique, TDMA estimates for IMT-TC (time code) and IMT-SC (single carrier) [23].

Generally, 3G has the following improvements on 2.5G and older systems:

- Performs better multicast services (audio and video).
- Added service GPS (global positioning system).
- Higher data speed.
- IPTV (TV through the Internet) support.
- Video-conferencing support.

For providing higher data transmission, improve quality of communication and elevated capacity, the 3G wireless/mobile system utilize High-Speed Downlink Packet Access UMTS system apply the new radio technology W-CDMA (Wideband Code Division

Multiple Access) which is downlink evolution technology uses 3G as a basic network, HSDPA with apply W-CDMA can increase data transfer reach 10 Mbit/s operating at 5 MHz bandwidth, also by using the MIMO technology data transfer approach 20 Mbit/s above 10 MHz bandwidth. Furthermore, HSDPA introduces some progress technique such as MIMO technology, Adaptive Modulation and Coding (AMC), developed design at receiver, high-speed cell search [11, 17, 20].

High-Speed Uplink Packet Access (HSUPA) is a mobile telephony protocol, also called 3.75G. HSUPA is a UMTS / WCDMA uplink evolutionary system.

With improving speed downlink data rate also increasing uplink data rate required, to meet overall progress data rate need to high uplink rate through feedback signaling, High-Speed Uplink Packet Access (HSUPA) parallel with HSUPA improved user-to-user communication such as gaming, internet email, commercial business applications. HSUPA basically increase the 3G uplink rate to 1.4Mbps and then succeeding about 6Mbps [24].

3.1.4. Fourth Generation Technology (4G)

4G compares to the 3G have the same characteristic with improvement and presented some modern technology and services such as videos chat, Multimedia Messaging Service (MMS), High-definition television (HDTV), Digital Video Broadcasting (DVB), and other entertainment like video gaming. Also with the established the Long Term Evolution (LTE) technology that recognized as a 4G system in the year 2009 could send the data very faster and watch the T.V which less noise and higher clarity than other previous mobile technologies.

The LTE technology can enhance the data rate until 1Gbps for fixed devices and users like roaming/local access, and for mobile access that has high mobility reach to 100 Mb/s, Standard 4G (or 4G LTE) technology increased download/upload speeds about four to eight times speedier than 3G,

furthermore, a new high-speed version of 4G that now available known as 4G LTE-Advanced (also recognized LTE-A, 4.5G or 4G+). That allows high speeds that reach to 1.5Gbps, but the popular product of LTE-A systems have a peak possible speed is 300Mbps in the real world [4, 12].

Also, one of the advantages of 4G over the 3G reduction the latency time that limited twice time from 120 milliseconds to 60 milliseconds, maybe the effect not appear in common application but have an important difference in automation control and online games also while running live video. LTE system developed the mobile network and channel transmission by enhanced MIMO system and increase coordination between various mobile cell site at transmitter/receiver also for reducing interference implement coordinated multipoint (CoMP) scheme [25, 26].

All existing mobile generation is classified in the Figure 3.1.

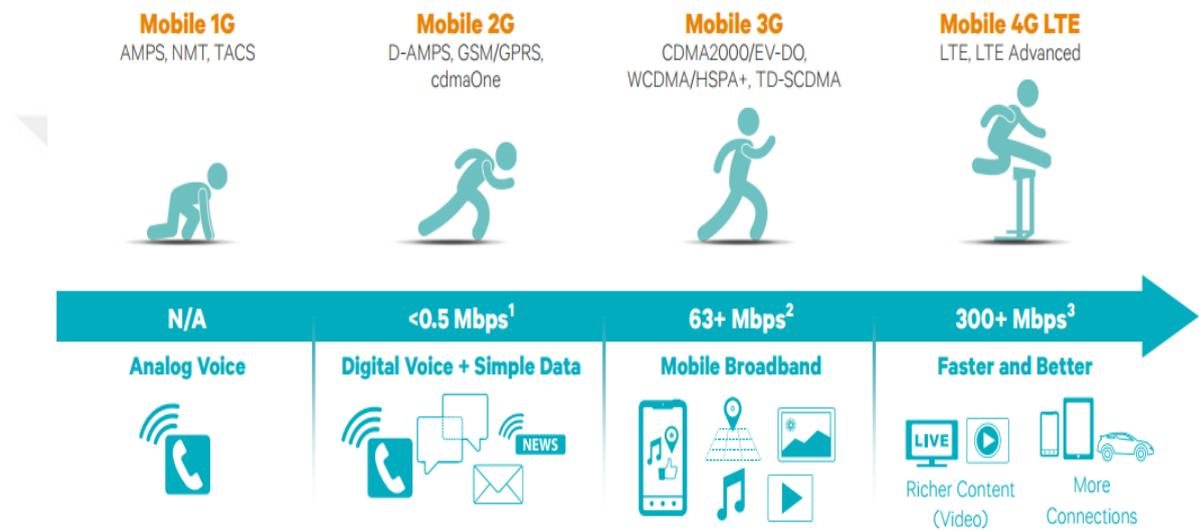


Figure 3.1. Mobile Communication: from 1G to 4G [60]

Figure 3.1 illustrates how progress and change the capacity and data transfer speed, also expand the services of communication by changing the technique of transmitting and receiving the signals and multiplexing technique etc...

3.2.Next Generation Technology (Fifth Generation (5G))

Through increasing the demand on the various communication systems and Limited capacity of existing generations, revolution the new generation and new telecommunication system Something inevitable, 5G (fifth generation) be a new generation in the telecommunication system that will be prepared in closely future 2020 or beyond according to most the organization and communication Unions, can be a perfect telecommunication system without limitation that delivers an excellent real World Wide Wireless Web (WWWW).

The 5G wireless system is designed to perform better possible services to all communication systems subscribers to provide their requirements. 5G allows huge two-directional bandwidth, at the transmitter to the receiver and in reverse direction, expected the data rate speed reach to 10 Gigabits per second. with the establish 5G technology could have a significant effect practically on whole industry fields such as IT (information technology), machines, health sciences and the self-driving car industry by providing a boost network capacity to support automotive huge data among cars and network [27]. The next generation wireless system design is an all-IP form for all communication networks, the model All-IP Network (AIPN) able to satisfy increase requirement of mobile network business, it is a general principle of all wireless radio access systems [28].

History shows the evolution of any technology and communication science or mobile system established upon several key factors, the key factor of the next-generation mobile system don't the basis on previous wireless technology but the Internet of Things (IoT) be a key factor for a 5G system, IoT defined as a Smart connectivity a massive number of machines and smart devices that constantly recognize, analytics, processing and communicate with cloud network without any human engagement. A powerful (IoT) require a strong wireless connection with minimum latency, high-speed, low power consumption, and large bandwidth [29].

The two main opinions and directions for evolution next generation are proposed, Hyper-Connected Vision and next-generation Radio Access Technology.

- ❑ In the first direction, hyper-connected vision would generate and the combination of existing and previous mobile technologies that include each SMS service and evident voice from 2G, advanced data, video and voice of 3G, massive data rate from 4G, best effort data from Wi-Fi, PAN (Personal Area Network) technology and another technologies to provide all time reliable connection, everywhere coverage, scalable service experience, zero latency and GB experience. With the main difference being a significant connection between a large number of machines for Machine-to-Machine (M2M) and the Internet of Things (IoT). Also through the new radio technology, the hyper-connected direction may provide low power consumption for next-generation wireless technology [27, 29].
- ❑ Another direction that is a more popular vision is (Next-generation radio access technology) in terms "generation-defining" vision with a special aim for huge data rates and very low latency [27, 29].

Table 3.1. Comparison of All Mobile Generations (1G-5G) [29].

Technology	1G	2G	3G	4G	5G
Publishing year	1970 – 1980	1990 - 2004	2004-2010	Now	2020 or beyond
Data rate	2kbps	64kbps	2Mbps	200Mbps to 1Gbps	more than 1Gbps
Technology	Analog Cellular Technology	Digital narrow band, Packet data	Digital broad band CDMA 2000 ,UMTS, EDGE	WiMax LTE, Wi-Fi	WWWW(coming soon)
Service	Mobile Telephony (Voice)	Digital voice, SMS, Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic Information access, Wearable devices	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing technique	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Switching system	Circuit	Circuit, Packet for core network	for air interface	All Packet	All Packet
Standards	MTS AMTS IMTS	2G: GSM 2.5: GPRS 2.75: EDGE	IMT-2000 3.5G:HSDPA 3.75G:HSUPA	Single unified standard. LTE, LTE adv. WiMAX	Single unified standard
Special Characteristic	First wireless communication	Digital version of 1G technology	Digital broadband, speed increment	Very high speed ,All IP	Complete wireless communication with almost no limitation
Country of first published	USA	Finland	Japan	South Korea	-----

For delivering a progress mobile generation each of direction hyper-connected vision and the next generation radio access technology have significant importance and may be combined together to practice as an individual set, Therefore, the possible structure of the 5G system can be designed of merging of an existing mobile generation such as 2G- 4G, PAN, Wi-Fi. And developing technology such as a software-defined network (SDN).

Each technology is complemented each other if combined and matched together. For easy understanding of all mobile generations presented a table titled comparison of whole generations (1G-5G) has been shown in Table 1.

3.2.1.Features of 5G Technologies

With the fact that the fifth generation standards techniques have not established until now, however, the researchers are expected some characteristics and proposed several specifications must be required have in the next generation, Most communication organizations define the following requirements for 5G networks:

- ❑ support a data rate 1 to 10 Gigabits per second for thousands of subscribers in the same place or office that use the 5G services, The downloading and uploading speed of 5G technology reaching the peak almost 1000x faster than 4G [29, 30].
- ❑ Latency: Smaller than 1 millisecond, will have so better than 4G.
- ❑ Expect 10 to 100 times increase number of devices and simultaneous connections compared to the current networks [7].
- ❑ The significant gain could provide for spectral efficiency compared to the current generation [31].
- ❑ 5G is designed to provide the opinion of “100% coverage” like quality and speed, will give the result of full coverage, unlimited capacity whether the subscriber is stopped or on the motility.
- ❑ Availability signal efficiency more enhanced reach 99.9%.
- ❑ 5G intend to reduce power consumption for rising Energy efficient by up to 90%.
- ❑ Remote diagnosis and remote management is the two considerable feature allowed by 5G technology [32, 33].
- ❑ Strategy avoids of error be a basis providing the high quality of 5G services.

3.2.2. 5G Technology Challenges

Though the publication of many studies, there are a few worries about the 5G technology that can define as 5G challenges. This challenges may be a factor that the 5G network does not provide all advancement and services or delay for some times. Most of the challenges are related to the economy, infrastructure and mobile standards. The fifth generation is expected to reach by the year 2020, hopefully, this technology will solve the whole challenges listed below until this time.

- ❑ Internet of Things (IoT): Providing a strong network and massive data rate to connect more than a 7 Trillion devices to be sent and received in real-time in the Internet of Things (IoT) which is managed by more than 7 billion people. There will emerge new requirement and loads on the cellular networks.
- ❑ Privacy and security: 5G guaranteed to deliver internet with very speed (lightning-fast), however, the researchers be scared to a cyber-war. A huge amount of data transfer intend to increase annoying attacks. 5G need to guarantee to protect private data, also require certainty, privacy, and cyber security.
- ❑ Power consumption: Power consumption needs to fall for rising battery life especially in mobile equipment and massive machine communication (MMC), and saving energy by 90%.
- ❑ Implementing a faster, secure, dependable and powerful network with "zero perceived" downtime or nearby to zero for services.
- ❑ Ubiquitous things communicating: This technology focuses on presenting low cost, very low energy, and handling a massive number of devices to very advanced machine (e.g., medical devices). Energy consumption, transmission power, and latency cannot be fully reached by existing cellular networks.

These challenges are summarized in Figure 3.2.

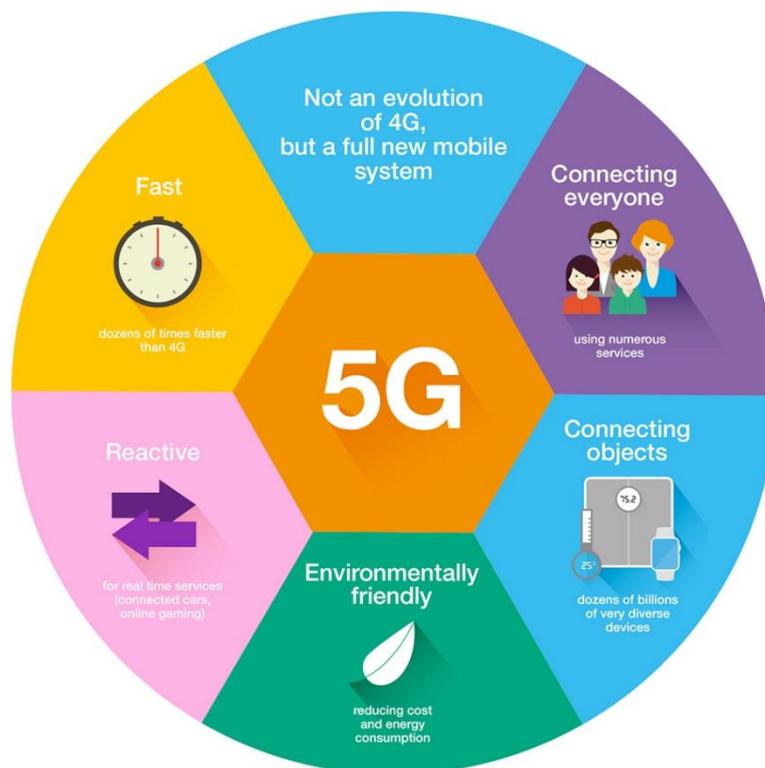


Figure 3.2. The challenges of 5G system [60].

The development and construction of the new mobile generation relate to solving the challenges are mentioned above, also standardization and infrastructure two other challenges that not referred in this figure, standardization of next-generation is a key challenge with the IMT-2020 specification. Also, another challenge is creating an infrastructure for supporting the 5G system, this includes establishing 5G NR (New Radio) and allocating the spectrum.

3.2.3.Future 5G Networks

With announcement 5G wireless in coming future, as expected the real change at quality and quantity of communication services are occurred, a country that wins 5G leadership will be a dominant player in the world. Several communication technologies access on the mobile system simultaneously also networks capable to merge different processes from various systems.

5G network is not only faster but also able to transmit big data by high speed, the frequency licensing problem and spectrum control issues will be solved by the next generation, a special software-defined radio (SDR) will be implemented with 5G communication, and also this technology will produce many numbers of non-streaming channels with different modulation schemes.

Next generation will combine all kind of excellent characteristics to perform a powerful network for various applications such as emergency response, remote surgery, driverless car, robots, smart shopping and industrial smart management [34, 35].

Future of Nano-core will be excellent as it will merge with artificial intelligent (AI) also by using Artificial Intelligence will design a secure system. In addition instead of operator-centric from 3G technology or service-centric from 4G technology, the 5G network includes User-centric vision.

The 5G core will be reconfigurable multi-core technology. The core may be the integration of different advanced systems such as nanotechnology, cognitive radio and cloud computing, the 5G is based on an all-IP platform.

3.3.MIMO System

Multiple Input and Multiple Output or Massive MIMO assists in reaching the goals of next generation communication technology to perform higher data rates to more users. This is currently usable in technologies like LTE (4G) and Wi-Fi, but the number of antennas is limited.

5G networks considered depend on Massive MIMO, at the Base Station. These large-sized antenna arrays can conform flexibly to a complex environment, and by scaling up the amount of MIMO technology and applying beam forming techniques, the signal transmitted from the base station can be strongly focused into small regions of interest, towards any user, resulting in much reduced interference [36, 37].

3.3.1.Channel Model MIMO System

MIMO system allows increase capacity significantly when employing scattering environment. But in a conventional communication system can receive only one signal at the receiver, MIMO system configured of several antennas at both ends (as shown in figure 3.3). The MIMO channel path formed between of all transmit and receive antenna that considered an $n \times m$ antenna, furthermore, MIMO channel express as a linear time-variant as presented by $n \times m$ channel matrix model [38].

$$H(t,\tau) = \begin{pmatrix} h_{11}(t,\tau) & h_{11}(t,\tau) \dots & h_{1m}(t,\tau) \\ h_{21}(t,\tau) & h_{21}(t,\tau) \dots & h_{2m}(t,\tau) \\ h_{31}(t,\tau) & h_{31}(t,\tau) \dots & h_{3m}(t,\tau) \\ \vdots & \vdots & \vdots \\ h_{n1}(t,\tau) & h_{n1}(t,\tau) \dots & h_{nm}(t,\tau) \end{pmatrix} \quad (1)$$

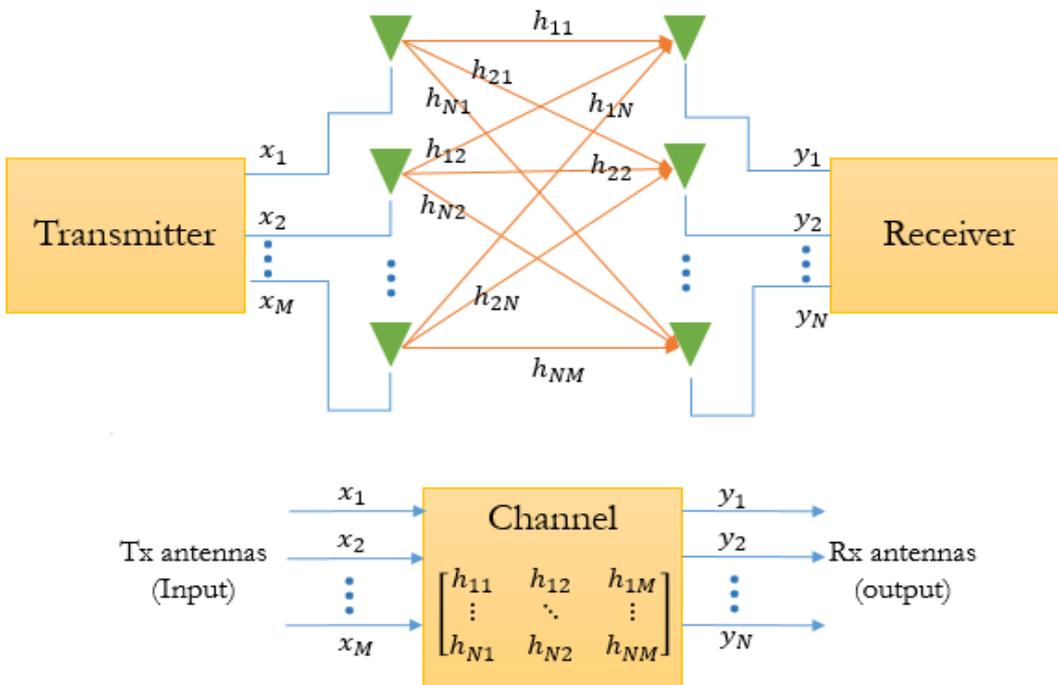


Figure 3.3. Multiple Input Multiple Output (MIMO) System [61].

In Eq. (1) $h_{nm}(t, \tau)$ represent channel impulse response between the n^{th} and m^{th} transmitter and receiver element respectively.

The received channel vector y is denoted by the channel transmission matrix H , x represents the input vector channel and n is the noise vector.

$$Y = Hx + n \quad (2)$$

3.3.2.Capacity of the MIMO channel

The MIMO channel refers to the matrix model that consists of more than one vector channel that can transmit and receive various signals at the same time and frequency band whole signals not reach to the receiver together, some signals scattered and reflected, the spatial multiplexing increase the capacity of the channel, the transmitter sends data by M transmitter and for encoding data stream uses a vector encoder, also at receiver by N number of antenna received the data, the baseband signal is the base for estimation transmitted data and each signal that transmitted M antenna need to be received by N antenna, That's it the fundamental processing of the channel MIMO system, the power of the signal, noise, and properties of the channel have a huge impact on the capacity of the channel [5, 19].

The capacity of the MIMO system for flat fading can be represented as below

$$C = \log_2 \left[\det \left(I + \frac{\rho}{M} HH^* \right) \right] \quad (3)$$

here, I is the identity matrix, ρ equals to p over σ_n^2 , p is the cumulative power, n refers noise, H is the complex channel matrix and H^* is the transpose channel matrix, also M is the transmitter antenna.

3.3.3.Advantages of MIMO system

Generally, the MIMO system has many advantages to improve wireless network signals at uplink and downlink mobile system, such as array gain, reduction the inter symbol interference, improve the reliability, enhance energy efficiency, spatial multiplexing and diversity gain, In the below illustrated the most important benefits [39, 40].

3.3.3.1.Array gain

For improving the power efficiency of the channel massive MIMO very powerful compared to conventional MIMO, until the antenna matrix array greater the size of the

antenna will be smaller and need small transmitted power, To investigate the array gain needs information about the channel (CSI) at both transmitter and receiver. Furthermore loss of channel performance more limited. Another advantage of utilizing a large array matrix could be improving the signal to noise ratio also reduced the interference, as well as the capability of limited the noise power. Also by employing the spatial dimension can separate between subscribers [39, 41].

3.3.3.2.Spatial diversity gain

Normally while the transmit signal between the transmitter and receiver, the fading of the signal occurred, one of a most effective way to mitigate fading is the spatial diversity technique that transmitted the signal by different independent faded paths, usually fading in one path is smaller than other. Also, diversity gain could be utilized in frequency, space and time, the spatial diversity more useful than frequency and time diversity because not need extra bandwidth or time. at the receiver can be integrated all arrived signal while the arranged the link MIMO channel independent paths and the transmitted signal appropriately provided [39], and the size of variability in arrived signal can be decreased Significantly more than SISO system, also, the performance of channel reliability can be increased by spatial diversity and improving the quality of transmitted signals. furthermore, the channel reliability estimated by the amount bit error rate and outage probability, by the correlation between the channel coefficient variables that produced MIMO matrix could measure the diversity gain for the channel Rayleigh fading. The expected channel reliability can be achieved by less correlation among channel coefficients and little variation in the signal happened [39, 41].

3.3.3.3.Multiplexing Gain

The demand on the wireless communication network increases dramatically daily also each subscriber need a high data rate, one of the challenges of massive MIMO improve the capacity 10 times or more [40]. by a spatial multiplexing gain the MIMO can transmit a variously independent data stream at the same bandwidth and time simultaneously, at the receiver can analyze all the data stream at the appropriate channel situation like good scattering, thus becomes the data rate improves significantly also improve the capacity of the mobile network and quality of service be a reliable. The massive MIMO system also raises the energy efficiency by directed all signals into a small area in space also by focused at small area can achieve high data rate.

Essentially. Achieving all types of gain at the same time impractical through the pilot contamination, therefore, the MIMO system needs a tradeoff between array gain and Spatial multiplexing gain also between diversity gain and multiplexing gain [40, 42].

3.4.Fading Channel Model

The mobile connection between transmitter and receiver not only line-of-sight channel but the signal also restrained by many objects, mountain, tree etc., also by strong multipath fading defiance, the reflection and diffraction that produced by any objects have a big effect on the performance of the channel [43]. The feature of the channel can be classified by many behaviors like situations of the weather, characteristic between the transceiver, the mobility case of each transmitter and receiver etc. the fast change time and Doppler shift occurred at the great mobility between the transmitter and receiver. Fading is unacceptable status happened in the wireless network when many multipath signals with different time arrive the receiver [39]. In this section presented two types of fading which they are more effective on the performance of the wireless channel communication they are Rayleigh and Rician fading channel.

3.4.1.Rayleigh Fading Channel System

In the environment, the line-of-sight (LOS) doesn't exist between the transmitter and receiver such as an urban area or mountain area the objects produced diffraction, reflection and scattering before the signal reach the receiver [44]. This separated the signal by all objects and loss line of sight between the base station and mobile users also change the phase signal called Rayleigh fading channel. The speed of moving between transmitter and receiver has an effect on the Rayleigh fading channel, while the path line of sight doesn't exist the antenna at the receiver receipt the diffracted, scattered and reflected signal, therefore the amplitude, phase and wavelength of the signal are changed, in this condition the received signal can be displayed as below.

$$s(t) = \sum_{i=1}^N a_i \cos(\omega_c t + \Phi_i) \quad (4)$$

where $s(t)$ is the received signal, ω_c represents the frequency of the signal at amplitude a_i and i^{th} number path with the phase shift ϕ_i , and N represent number of paths. Furthermore, the wireless Rayleigh fading channel can be formed by the channel impulse response (CIR) equation [45].

$$H(t)=\sum_{i=0}^{Lp-1}\eta_i\delta(t-\tau_i) \quad (5)$$

here, Lp represent the channel path number, η_i complex value and τ_i is the path delay, in the equation suppose that the channel is an independent path with average power, also by the mobility of the mobile the time is variant, however, suppose that the channel is channel impulse response.

3.4.2. Rician Fading Channel System

In the Rician channel, both direct path and indirect path are exist, usually, the main component of the channel is the direct path that denoted as a line of sight within the indirect path that produced by propagation and scattering phenomenon. the performance of the Rician channel evaluate by a factor expressed K factor or Rician factor that established as the ratio of power components of the direct and indirect path also the ratio represented linearly [43-45]. The Rician factor ratio is given by

$$K = \frac{L^2}{2\beta_r^2} \quad (6)$$

where L^2 is the LOS power and $2\beta_r^2$ is the non -LOS power.

3.5.Precoding Scheme

For transport, the data at the transmitter to the receiver the precoding scheme applied to send many data stream together as an independent and suitable weighting data stream, the precoding scheme plays a fundamental role in the perfect implementation of a massive MIMO system, also, by the detector have a significant role to reduce the impact of noise and inter-symbol interference at the receiver signal, as well as possible, eliminate a different type of unwanted signal and distortion that produced at the channel. Therefore, detection and precoding scheme is the basic mechanism to decrease the Multi-user interference at the transmitter through Modification single-stream beam forming to establish multiple streams also to recognize the information stream at the base station and mobile equipment [5, 46, 47].

In the transmitter side, the precoding system consists of the encoder and precoder scheme, encoder takes the data and makes coding symbols by combining redundancy and structured coded data. The pre-encoder handles these codes before sending for the receiver.

At the receiver side the signal that corrupted with noise decoded to retrieve the original information [48].

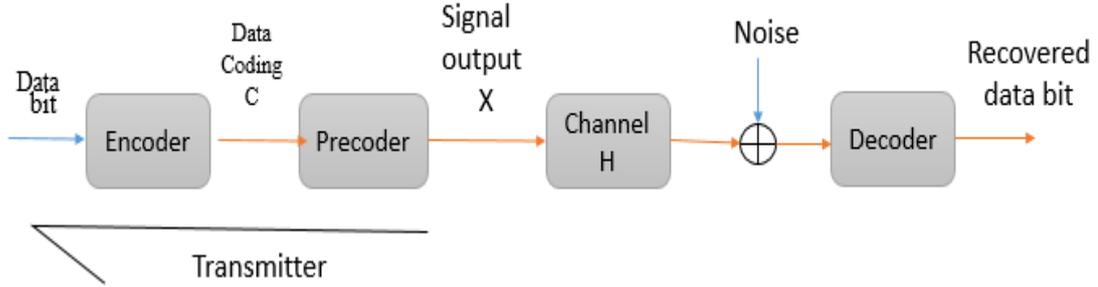


Figure 3.4. Configuration of channel precoding and transmitter information.

Generally, two basic precoding used for improving network efficiency is linear precoding and non-linear precoding as illustrated in below.

3.5.1. Zero-forcing linear precoding

Zero-forcing (ZF) precoding also known as MIMO precoding or Channel inversion precoding technique that removes all the inter-user interference at the transmitter side by directed the signals to the proposed user [49],

Also through inverting the matrix channel at the transmitter ZF precoder can completely overcome all the interference between users without having any previous information about the noise of the channel and perform the benefit simply the implementation [5, 50]. The zero forcing linear precoding (ZF-LP) system was offered for a Rayleigh channel transmission in a single cell system without considering the channel shadowing also ignored completely the mutual interference between any transmitting antennas and neglect the additive noise [51-53]. Mathematically transmitter ZF precoding channel can be expressed as:

$$W_{ZF} = (H H^H)^{-1} H^H \quad (7)$$

where H is the $K \times M$ with complex Gaussian distributed such as $h_{i,j}$ the channel between the i^{th} user and the j^{th} antenna at the BS, H^H expresses the Hermitian transpose operation.

3.5.2. MMSE linear precoding

Minimum mean square error (MMSE) precoder scheme perform to minimizes the mean square error (MSE) that is a general measurement for a quality system, MMSE-LP system does not remove completely ISI and noise distortions but reduce the error between

the transmitter and received signal, MMSE increase the detection signal-to-interference noise ratio (SINR) also can trade-off between the increase signal transmission energy and MIMO-channel interference eliminating to obtain the minimum error detection and better sum rate. the ZF precoder is not sufficient to perform the MIMO capacity when the number of the transmitter antenna and user equipment increase the loss increased to improve the channel performance the MMSE model is practiced [47, 54]. The MMSE precoding channel matrix is given by

$$W_{\text{MMSE}} = H^H (H H^H + \alpha I)^{-1} \quad (8)$$

where α is the noise of the channel and I denotes the identity matrix, H and H^H is a $K \times M$ MIMO channel matrix and transpose operations respectively.

3.5.3. SIC Non-linear Precoding

The performance of the linear precoding schemes is not perfect as required, successive interference cancellation (SIC) scheme proposed to achieve the higher performance at the receiver side, which eliminate interference to improve the data transmission at the BS, compared to ZF and MMSE linear precoding, also when applied SIC scheme a considerable performance gain can be performed in energy efficiency in a downlink massive MIMO technology [55, 56].

The SIC precoding is especially utilized to cancel interference between multiple data streams that transmitted by various antenna [57]. SIC algorithm described as a series of linear receivers that can increase the performance channel without required more complexity also for implementation not required hardware complication [53, 58, 59]. The SIC precoding received data vector is given by

$$\gamma_i = \gamma - \sum_{j=1}^{i-1} h_j s_j \quad (9)$$

where γ_i is the signal received after j^{th} stage the of interference cancellation, h_j referred to the j^{th} column vector of the channel matrix, s_j is the evaluated transmitted symbol received at the linear detector.

4. SIMULATION RESULTS AND DISCUSSION

In order to verify the theoretical analysis, which showed in the previous chapter, an implemented system simulated by applying “MATLAB 2015 a”.

In this section, the effect of increasing number of antennas in both side transmitter and receiver are displayed by using a massive number of antennas (Massive MIMO) to improve data rate capacity, enhancement probability, and minimize outage probability.

4.1. Simulation Results for M-MIMO using (MF, MMSE, ZF and SIC pre-coding scheme

To start with, to compare the performance of massive MIMO and traditional MIMO is simulated. The comparison was carried out for achievable rate (bits/transmission) with ZF, MF, MMSE, and SIC pre-coding as a function of raising SNR for $M=8, 16, 32, 64$, respectively.

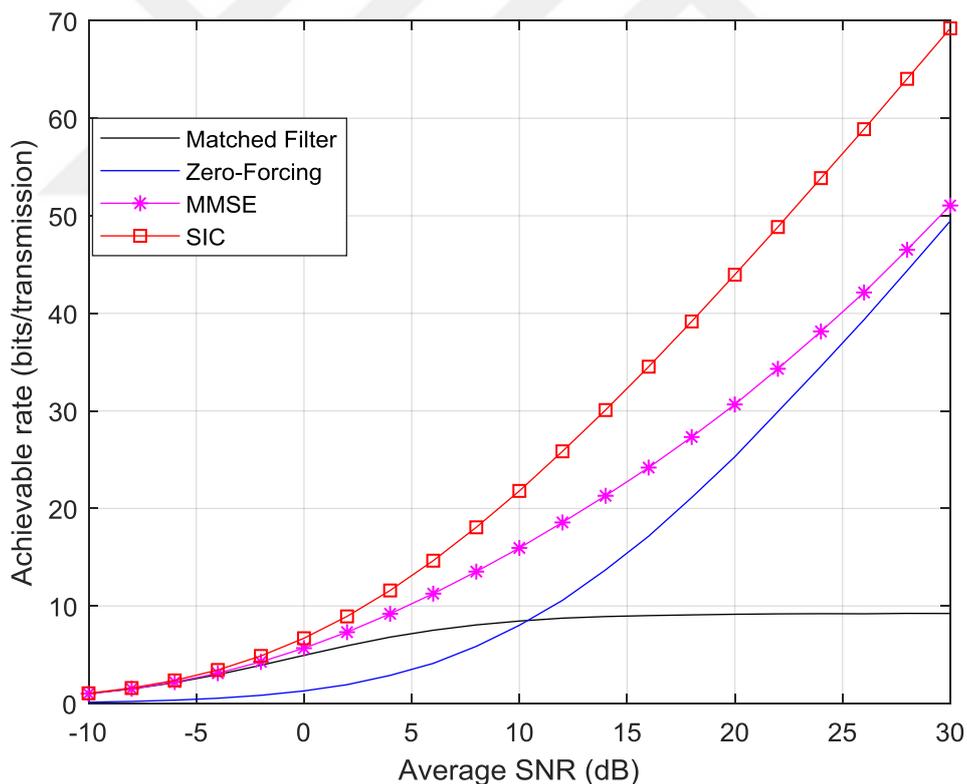


Figure 4.1. Achievable sum rate of an 8×8 MIMO for i.i.d. fast fading channel.

Figure 4.1, shows the comparison of various types pre-coding for an 8×8 MIMO. It is notice that by increasing SNR values the SIC systematically exceeds. Also, at any value of SNR, SIC was recorded bigger value with respect to ZF, MMSE and MF.

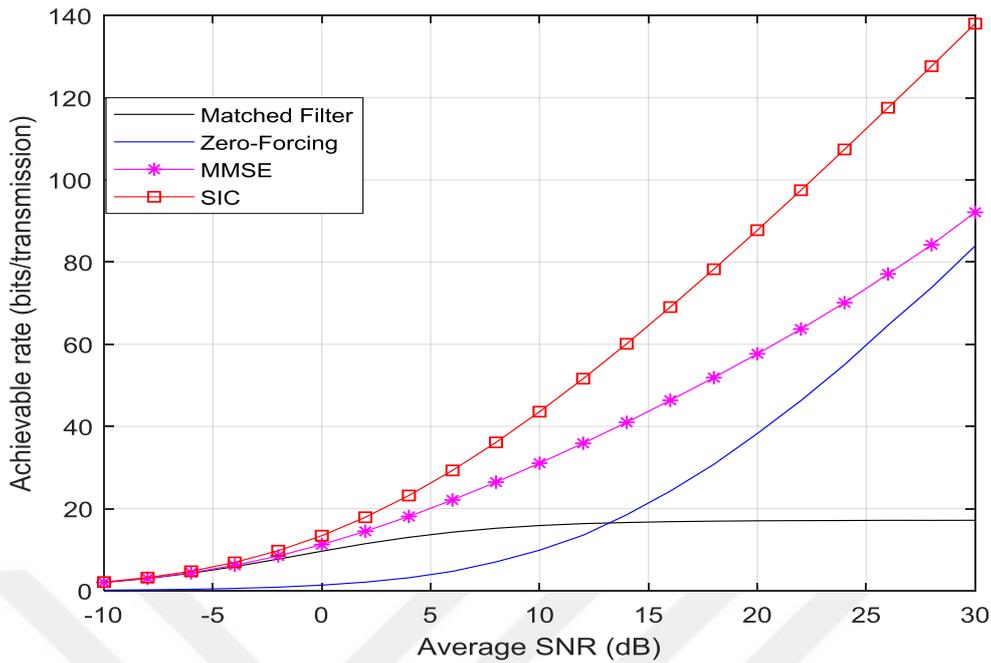


Figure 4.2. Achievable sum rate of a 16×16 MIMO for i.i.d. fast fading channel.

In Figure 4.2, the curves illustrate SIC performance gained over ZF and MMSE about 8 to 9 dB and much better than the MF, for increasing the number of the antenna. As it can be seen in Figure 4.3 and Figure 4.4 the advantages of SIC over other pre-coding schemes it is receiving 10 to 15 dB.

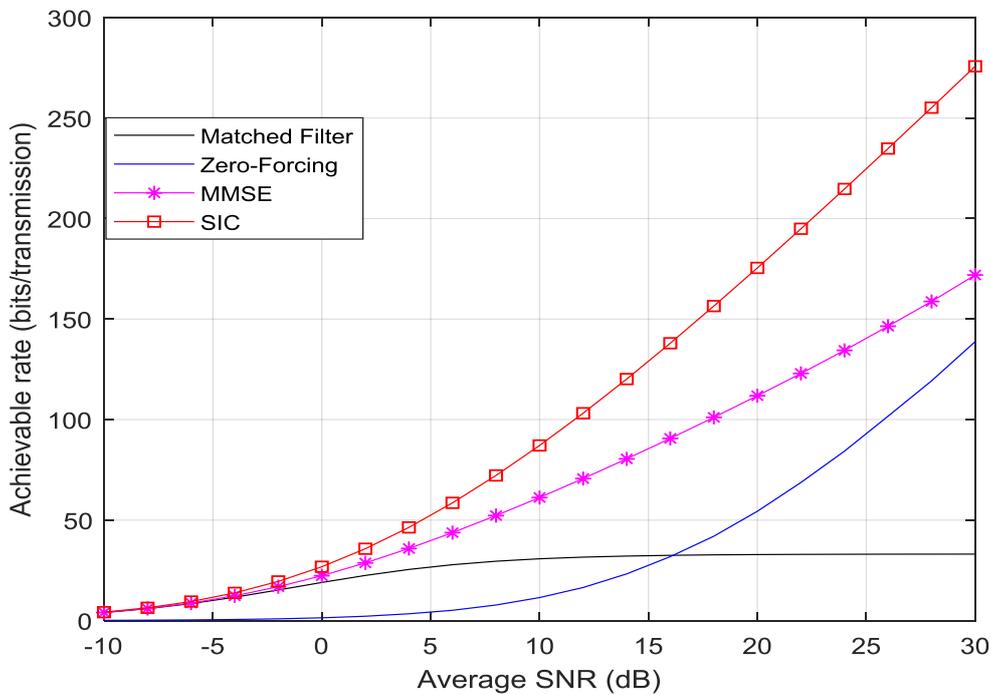


Figure 4.3. Achievable sum rate for 32×32 MIMO for i.i.d. fast fading channel.

In addition, in Figure 4.1 and Figure 4.2, each MMSE and ZF has approximately the same value at the High signal to noise ratio. However, while increases the number of antennas, the improvement of MMSE over ZF starts to increase as illustrated in Figure 4.3. The performance gain MMSE was about 6 dB over ZF at transmission sum rate of 140 (bit /transmission).

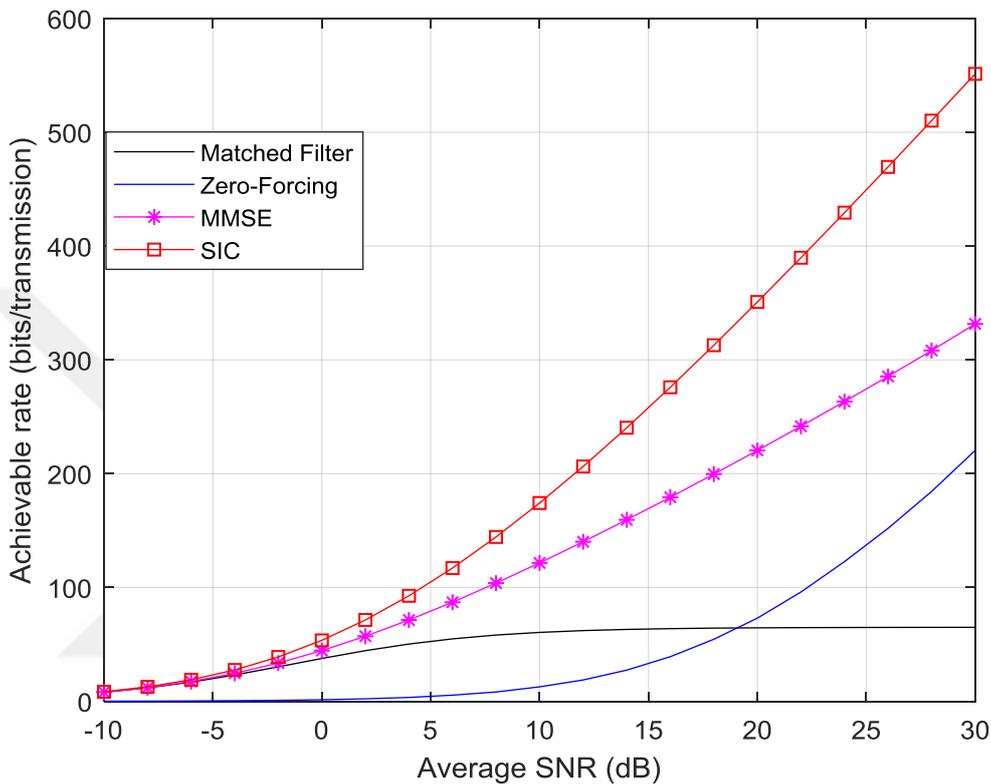


Figure 4.4. Achievable sum rate for 64×64 MIMO for i.i.d. fast fading channel.

Figure 4.4 shows that in the low average SNR values, the MF filter achieved higher sum rates than the ZF; therefore in this area, the improvement of interference is better than treated as noise. But, the MF interference elimination capability is weak. When their average achievable rate stay constant, by increasing SNR compared to MMSE, ZF and SIC, their performance were improved, Figure 4.1-Figure 4.4, also performance gain MMSE about 10 dB over ZF at transmission sum rate of 220 (bit /transmission).

Consequently, after this explanation for various types of pre-coding scheme, it is clear that SIC interference detection, cancellation, and elimination ability much more than other pre-coding schemes. Thus, the achievable rate gets more improved due to increase in the number of multiple antennas.

4.2. Simulation results for Cumulative Density Function (CDF)

In this section, the cumulative distribution function (CDF) was compared for probability of the channel as a function of selected channel rate for the different types of MIMO antenna configurations with (4×4, 8×8, 16×16, 32×32, and 64×64) antenna, where the constant value of signal to noise ratio SNR, given at 10 dB.

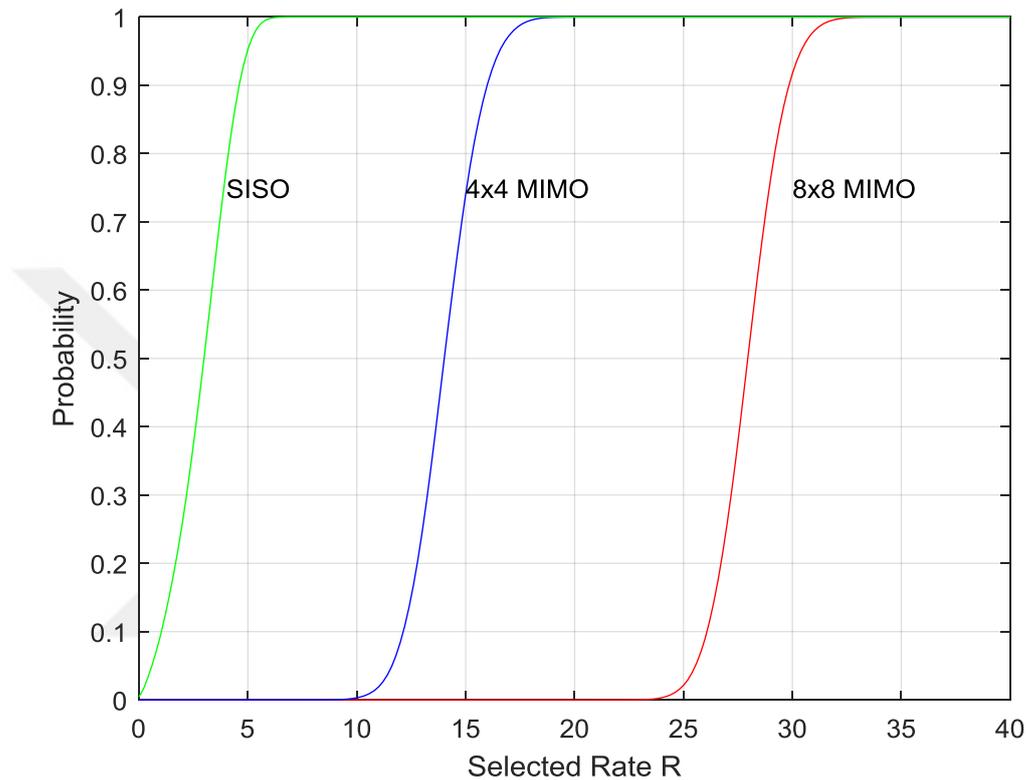


Figure 4.5. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 4×4 MIMO, and 8×8 MIMO channels.

In the Figure 4.5, the bit rate and channel capacity increased by increasing the transmitter and receiver antenna as deduced in 8×8 MIMO, 4×4 MIMO and SISO. Furthermore, achieved a gain of around 13 bps/Hz with 8×8 MIMO channel over 4×4 MIMO channel for 10dB SNR.

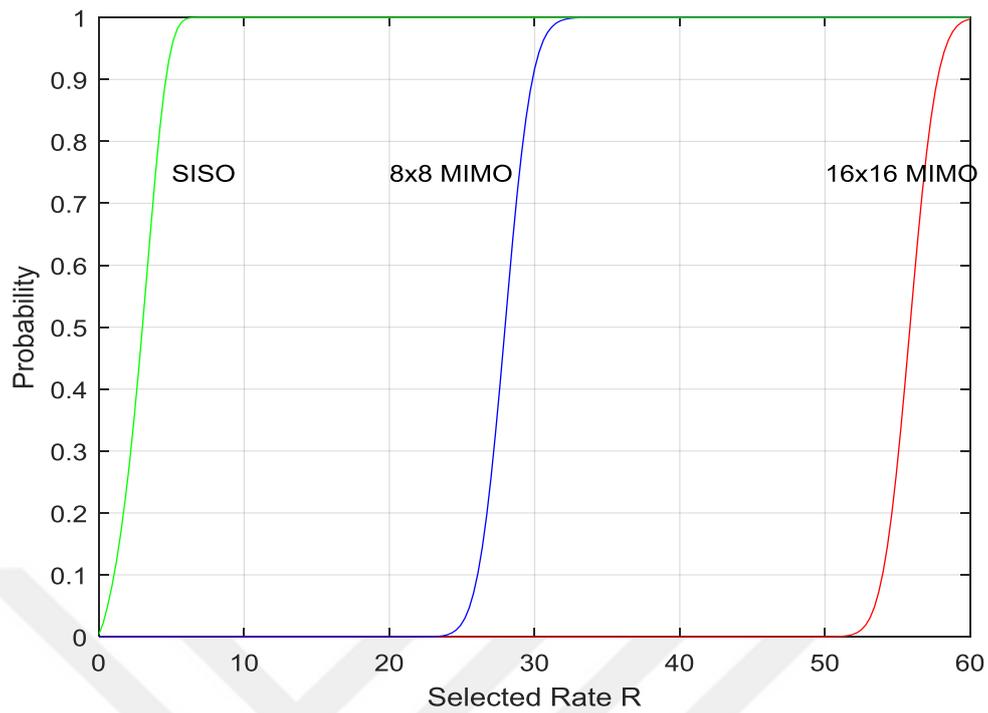


Figure 4.6. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 16×16 MIMO channels.

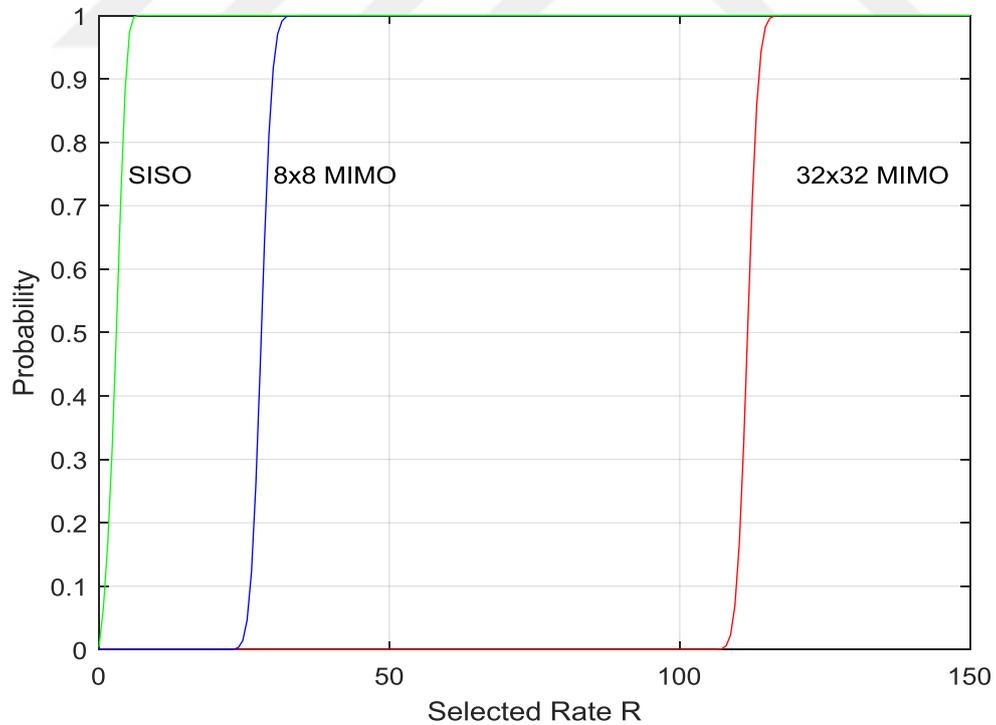


Figure 4.7. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 32×32 MIMO channels.

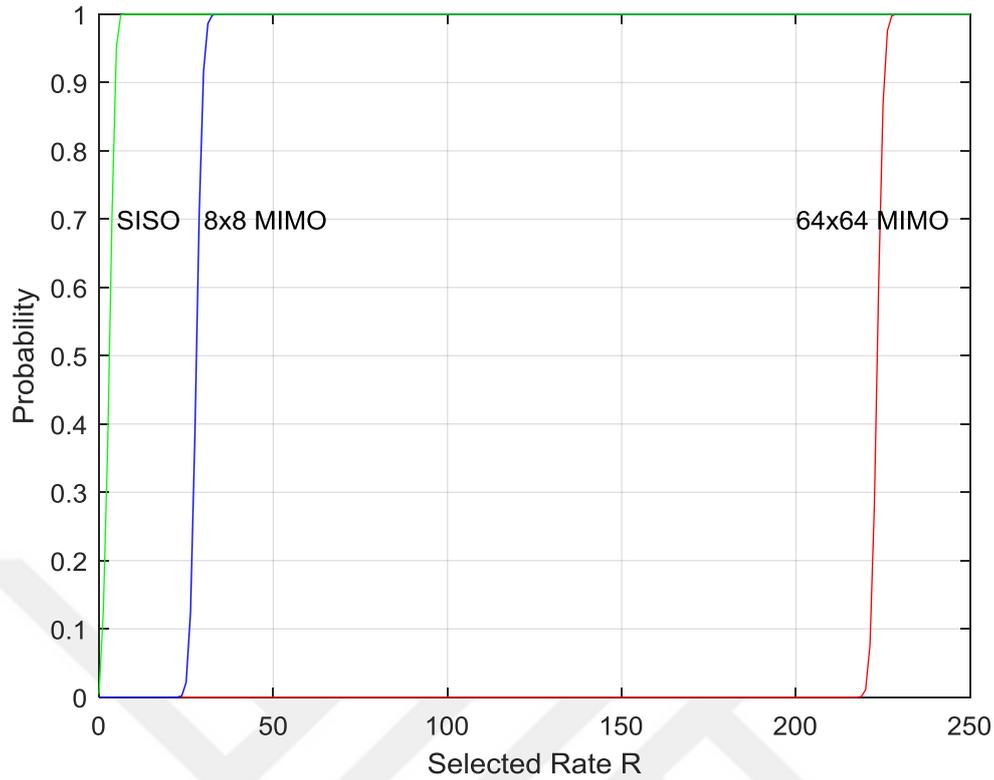


Figure 4.8. Cumulative distribution functions of the maximal achievable rate at SNR=10dB for a SISO, 8×8 MIMO, and 64×64 MIMO channels.

Increasing the number of antennas more had a significant influence on the channel capacity rate as seen in the Figure 4.6-Figure 4.8, respectively, for the channel capacities with maximum of 64×64 antennas and minimum for SISO antenna system. After explaining the mentioned plots it can be seen that for a small number of antennas such as single, 4 and 8, there are not a sufficient difference between the channel capacities of different MIMO channel. Whoever, for a numerous number of antennas, the improvement in channel capacity performance plainly appeared, In Figure 4.8, the achieved gain around 200 bps/Hz with 64×64 MIMO channel over 8×8 MIMO channel at SNR is equal to 10dB.

4.3. Simulation Results for Ergodic Capacity

In this section, the different number of the antenna (M-MIMO) system were compared with different of type antenna configurations such as SIMO, MISO, SISO system, by a comparison between ergodic capacity versus number of the antenna for the value of SNR assumed to be constant at 0 dB. There are four different statuses which are shown in Figure 4.9.

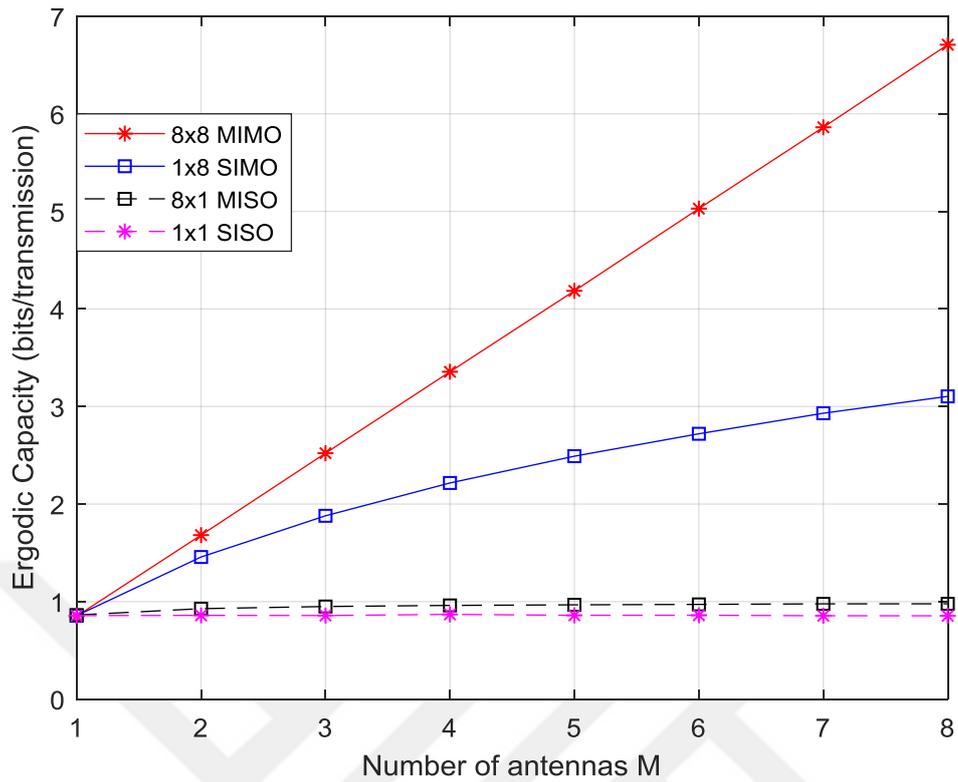


Figure 4.9. Capacity vs. number of antennas for 8×8 MIMO, 1×8 SIMO, 8×1 MISO and SISO.

Figure 4.9 displayed the capacity of MISO and SISO system, which are close to each other. Also it is found that the increase in number of transmitter without increasing the number of receivers could not influence the capacity, but with increased number of receiver antennas or in both transmitter and receiver a significant effect on improvement capacity was found.

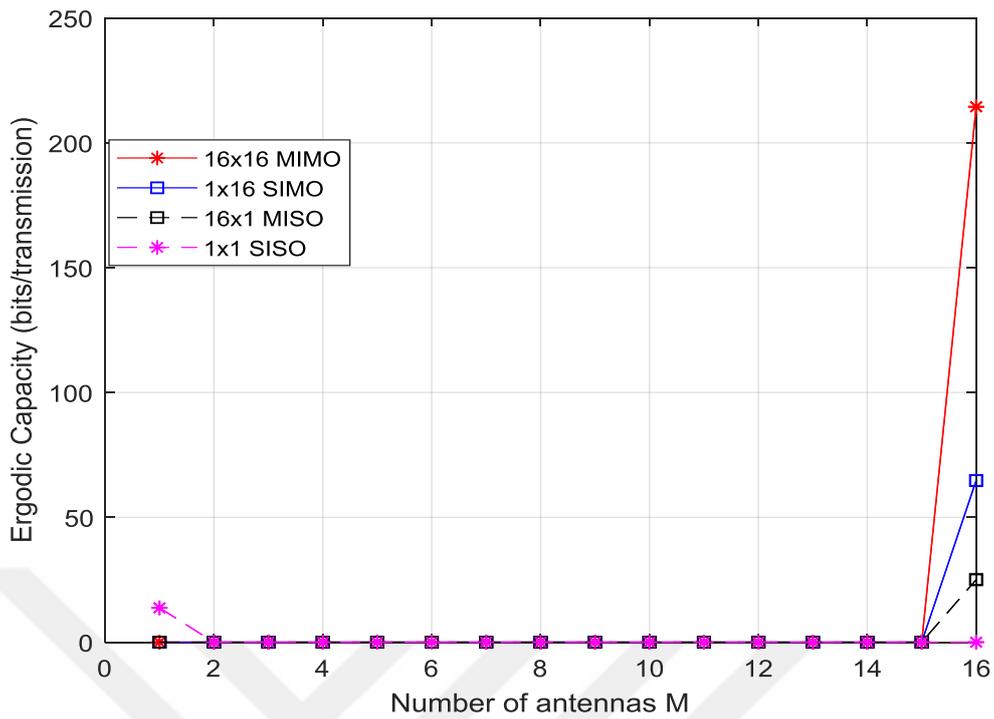


Figure 4.10. Capacity vs. number of antennas for 16×16 MIMO, 1×16 SIMO, 16×1 MISO and SISO system.

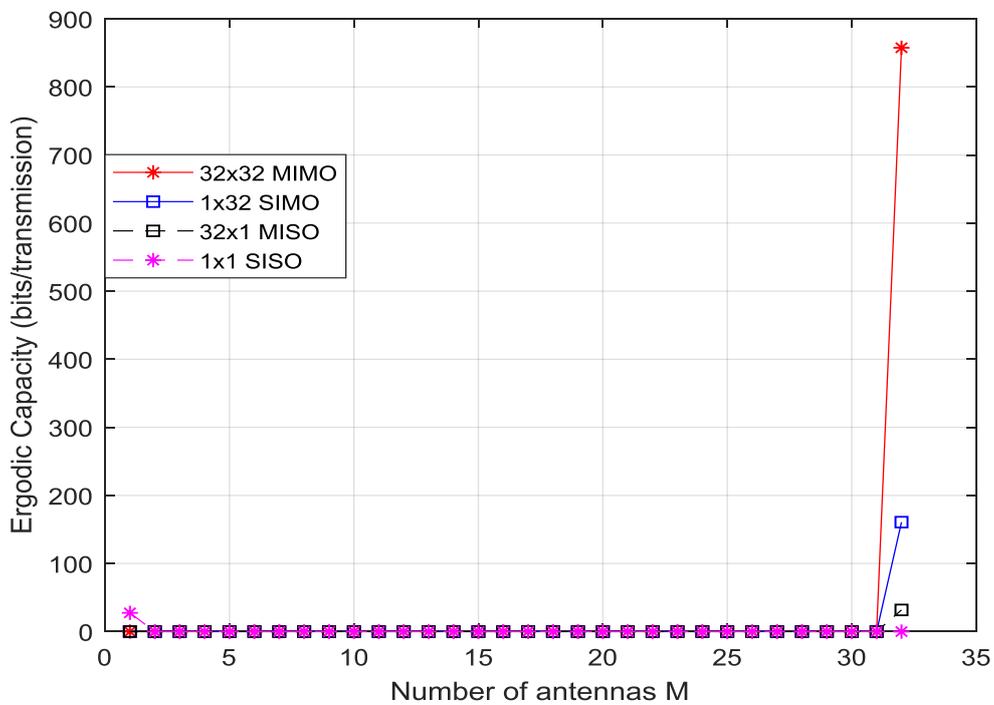


Figure 4.11. Capacity vs. number of antennas for 32×32 MIMO, 1×32 SIMO, 32×1 MISO and SISO system.

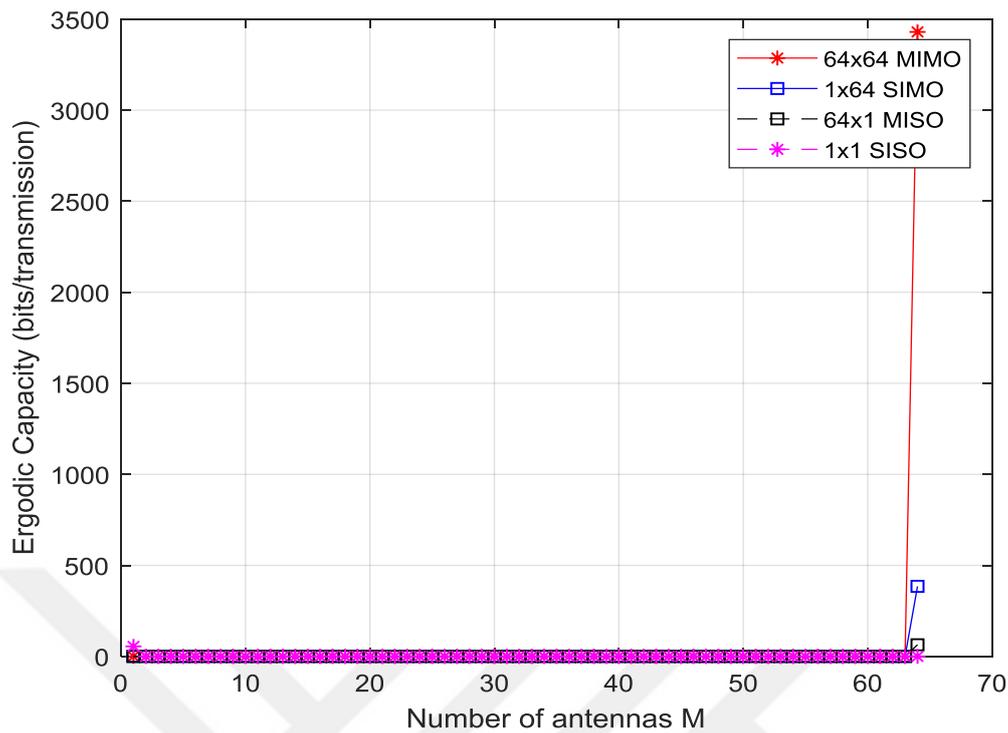


Figure 4.12. Capacity vs. number of antennas for 64×64 MIMO, 1×64 SIMO, 64×1 MISO and SISO system.

Figure 4.9 was plotted for an 8×8 MIMO system that analyzed with three types of antenna system. It is notice that the capacity of MIMO system is much better than other systems, also Figure 4.10 -Figure 4.12 show the results achieved for impact of increasing the number of antenna raised the ergodic capacity significantly. Moreover, plainly showed that channel capacity increases rapidly.

In contrast, in MISO, SIMO and SISO technologies, by increasing the number of antennas the ergodic capacity was slowly improved.

The simulation results showed that using the massive MIMO can be achieved a great performance gain in the ergodic capacity as compared to the other MIMO antenna configuration.

4.4.Simulation results for outage probability

This section presents and investigation results of various antenna configuration types at slow fading channel, by uses Alamouti STBC codes. At the same transmission rate of 4 bits per transmission ($R=4$), the effect of increasing number of multiple antennas on the outage probability has been studied.

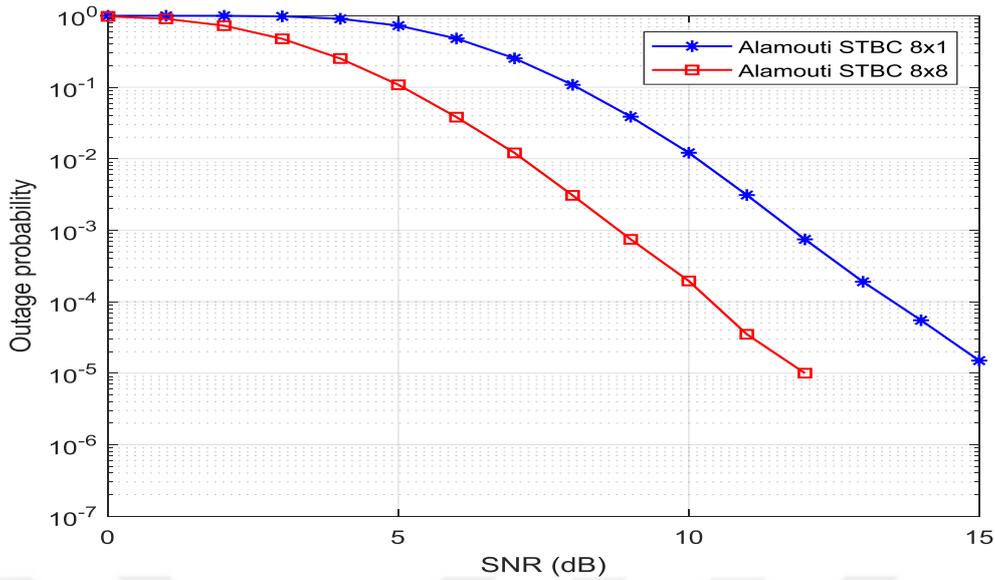


Figure 4.13. Outage probability of the Alamouti STBC for 8×1 and 8×8 MIMO and i.i.d. Rayleigh slow fading channel model.

Figure 4.13 compares the 8×1 MISO with 8×8 MIMO techniques, where the outage probability minimized when using Alamouti STBC for 8×8 antennas. Also there is a diversity gain of the Alamouti STBC for 8×8 MIMO system about 3dB when the outage probability equal to 10^{-5} compared with Alamouti STBC for 8×1 MISO, in another word, utilizing MIMO system gives as lower outage probability as other technique, including MISO, and SIMO systems.

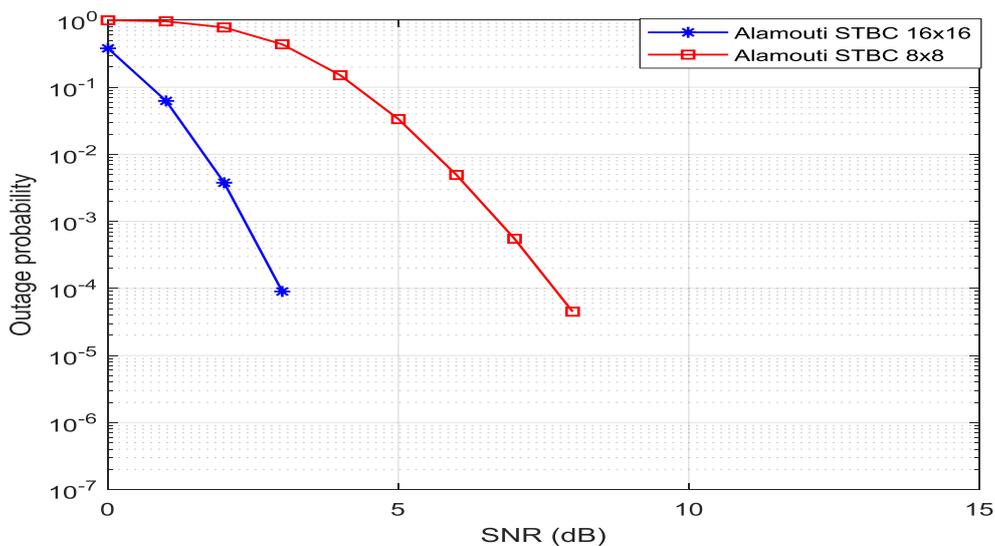


Figure 4.14. Outage probability of the Alamouti STBC for 8×8 and 16×16 MIMO and i.i.d. Rayleigh slow fading channel model.

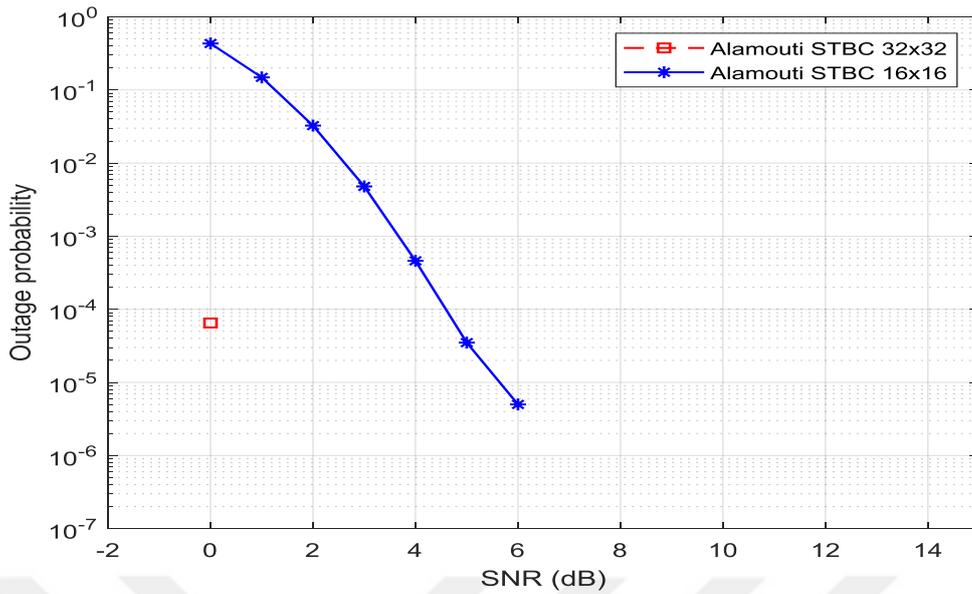


Figure 4.15. Outage probability of the Alamouti STBC for 16×16 and 32×32 MIMO and i.i.d. Rayleigh slow fading channel model.

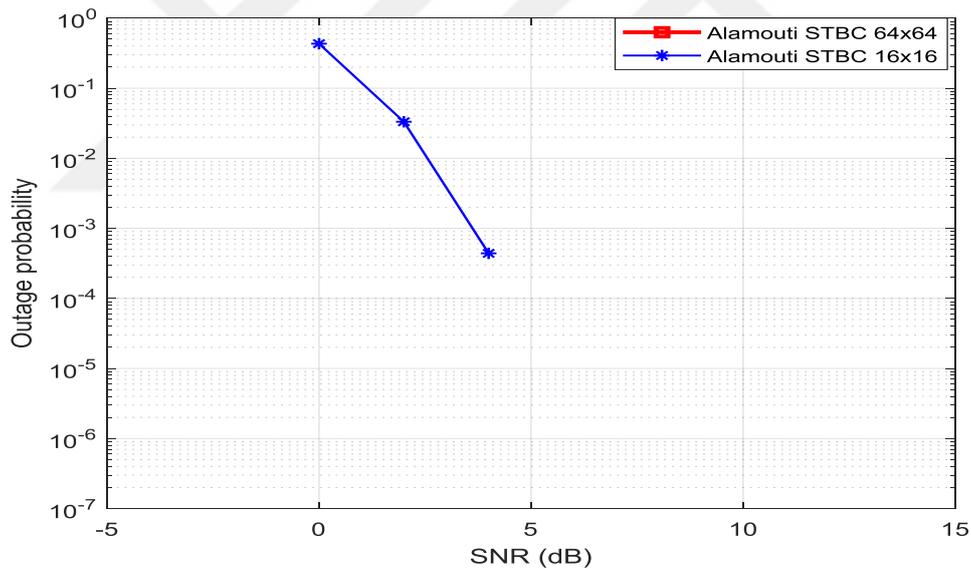


Figure 4.16. Outage probability of the Alamouti STBC for 16×16 and 64×64 MIMO and i.i.d. Rayleigh slow fading channel model.

In the Figure 4.14-4.16 massive MIMO has been handled and compare with conventional MIMO. By increasing the number of the antenna in both transmitter and receiver, with fixed transmission rate at 4 bits per transmission, the diversity gain enhanced and the performance of outage probability improved. Especially in Figure 4.15 and Figure 4.16, it is obvious when massive MIMO (32×32 and 64×64) antennas utilized, the outage probability approached to zero.

4.5. Simulation results for capacity with outage probability

This section deals with how to improve the capacity of outage and achieving the largest outage capacity for a specific rate of outage probability (10 %). To show that, by varying the number of antenna in transmitter and receiver, the effect of using various types of antenna configuration on the capacity with outage of the massive MIMO system has been studied when the transmission rate equal to 10bits/s and get a great capacity in minimum signal to noise ratio (SNR) as possible.

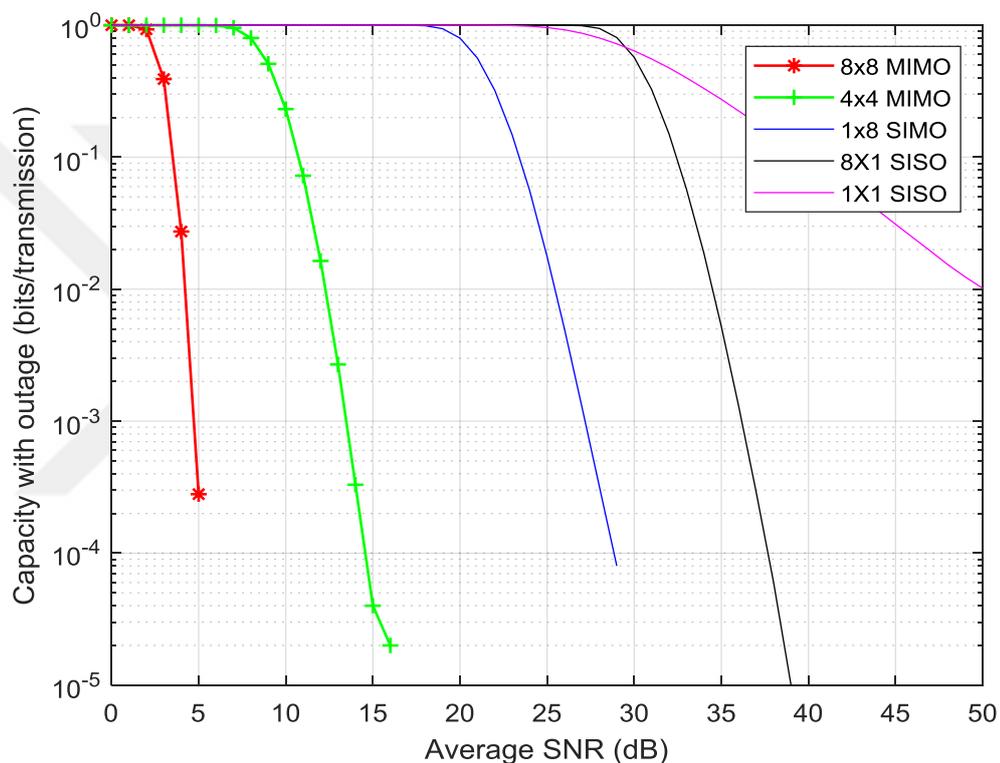


Figure 4.17. Capacity with outage 10% for MIMO, SIMO, MISO and SISO channels for i.i.d. Rayleigh slow fading channel model.

Figure 4.17 shows five types of the antenna system, which compared to show how to achieve a high capacity with outage. MIMO system could achieve better capacity in low SNR, where the capacity of 4×4 MIMO gives 0.1 values at 11dB, while, 1×8 SIMO system at 23dB achieved the same value. This reveals that the MIMO system gives 13dB gain over SIMO, also when compare 8×8 MIMO with 4×4 MIMO at capacity of 0.1, the gain is about 6dB. Besides, if MIMO system compared with the other antenna configuration, such as MISO and SISO, it appears much better than them.

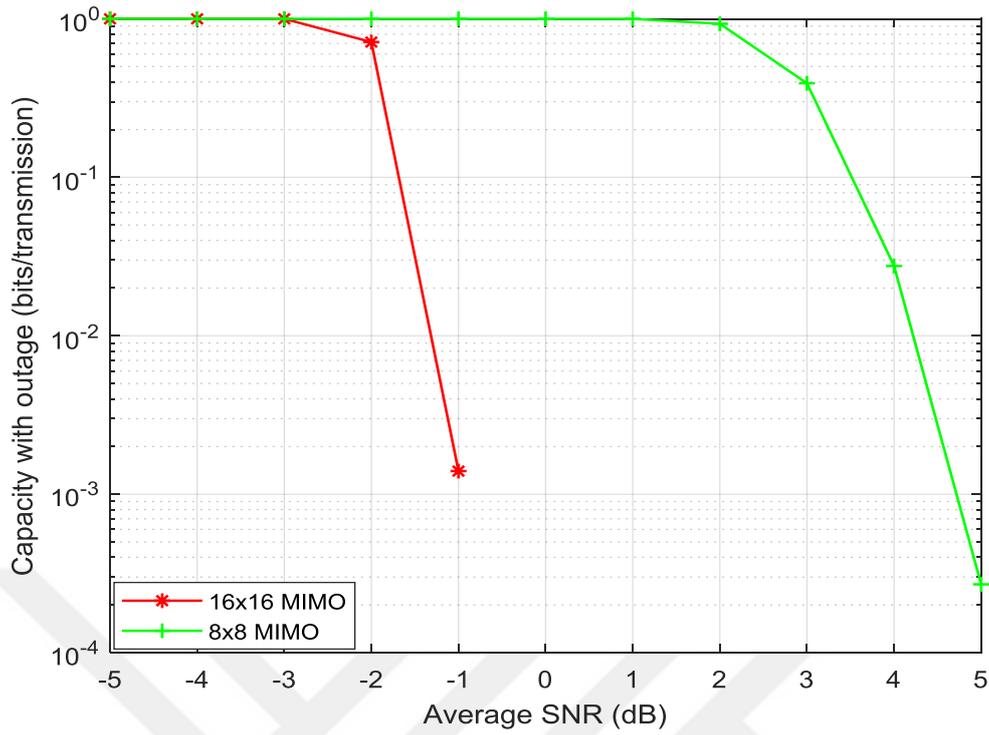


Figure 4.18. Capacity with outage 10% for 8×8 MIMO and 16×16 MIMO channels for i.i.d. Rayleigh slow fading channel model.

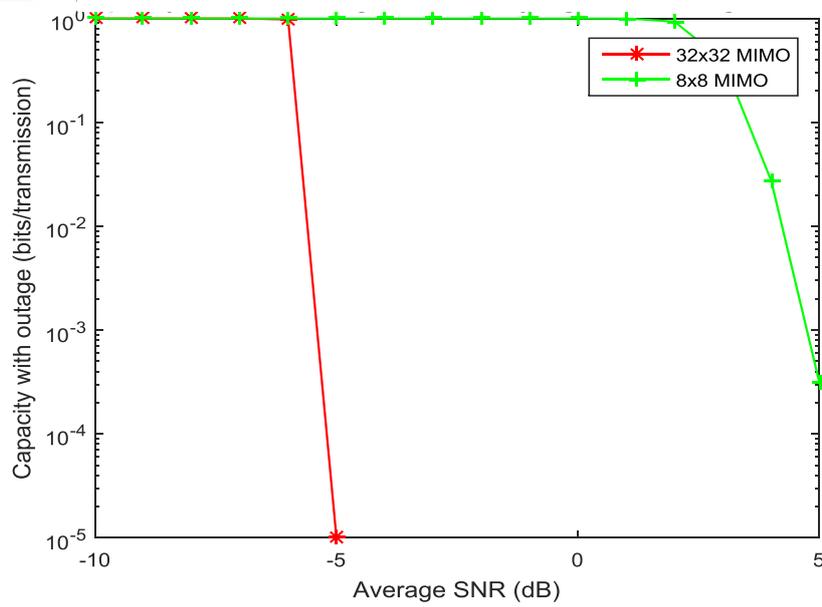


Figure 4.19. Capacity with outage 10% for 8×8 MIMO and 32×32 MIMO channels for i.i.d. Rayleigh slow fading channel model.

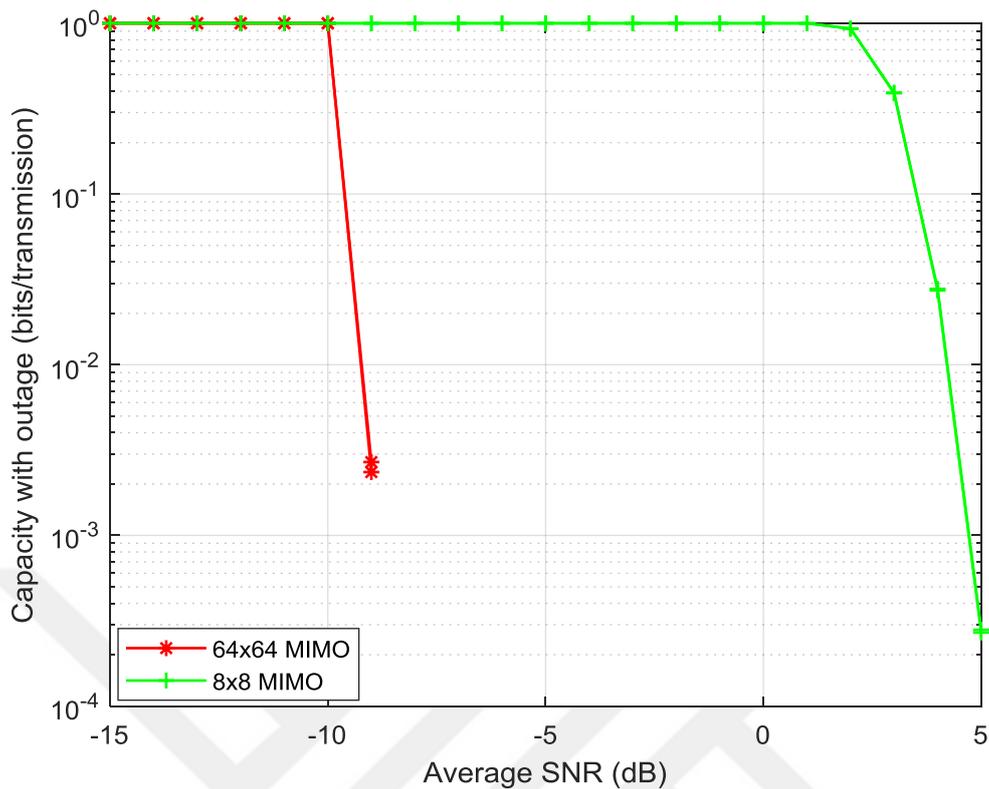


Figure 4.20. Capacity with outage 10% for 8×8 MIMO and 64×64 MIMO channels for i.i.d. Rayleigh slow fading channel model.

The effect of the antenna system on the outage capacity performance of the massive MIMO system presented in Figure 4.18-4.20. By increasing the number of antenna especially in massive MIMO like 16×16, 32×32 and 64×64 antenna configuration, a better capacity could be achieved with a constant rate of outage. The gain of 64×64 MIMO system is 10dB and 6dB over 16×16 and 32×32 MIMO system respectively. These results show that the same capacity of outage in lower SNR can be achieved by increasing the number of antennas.

5.CONCLUSION

In this study, mobile generations are introduced also presented next-generation mobile technology expectation, challenges and effects on technology progress, In chapter three MIMO channel model studied, capacity, advantages and a balance between the various of gain illustrated, the advantages of massive MIMO over conventional MIMO for increase data rate and getting reliable channel are discussed.

Massive-MIMO technique is analyzed for the fifth generation mobile wireless system by using MATLAB simulations to prove, explain and present a practical application. Simulation results show that massive MIMO can provide transport high data rate without the need to increase the transmit power and increase of bandwidth.

In the simulation results for the different type of precoding scheme while increasing the number of antennas achievable data rate has been increased to a good agreeable amount as proved by the results from the simulation, especially for SIC pre-coding system. Fig. 4.1-4.4 shows that the theoretical result of the different precoding scheme with massive MIMO is nearly equal to the simulated result.

From the second simulation cumulative distribution function (CDF) which shown in fig 4.5-4.8 the channel probability more improved with the massive MIMO system compared to a conventional MIMO system.

In the third and fourth simulation results, outage probability and Capacity with outage respectively are simulated, in both case clearly displayed even increase the MIMO system antenna the capacity of the channel increased and outage of the signal between transmitter and receiver limited. In fig 4.17 illustrated increase number of the antenna at the receiver side have more effect on the improving capacity of channel compare to increase antenna at the transmitter side.

From all the results of the massive MIMO, as invented that the channel performance of the 64x64 system is much better than other MIMO systems that simulated at this thesis. Therefore it implies while the number of antennas increased can get a strong connection between transmitter and receiver.

REFERENCES

- [1] **Sharma, P.**, 2013. Evolution of mobile wireless communication networks-1G to 5G as well as future prospective of next generation communication network, *International Journal of Computer Science and Mobile Computing*, **2**(8), 47-53.
- [2] **Ameen, J.J.H.**, 2017. 5G Next Generation Mobile Wireless Technology with Massive MIMO Continue 4G Revolution, Key Technologies and Challenges, *Eurasian Journal of Science and Engineering*, **2**(2), 40-47.
- [3] **Wang, C.-X., Haider, F., Gao, X., You, X.-H., Yang, Y., Yuan, D., Aggoune, H., Haas, H., Fletcher, S., and Hepsaydir, E.**, 2014. Cellular architecture and key technologies for 5G wireless communication networks, *IEEE Communications Magazine*, **52**(2), 122-130.
- [4] **Sapakal, M.R.S. and Kadam, M.S.S.**, 2013. 5G mobile technology, *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, **2**(2), pp: 568-571.
- [5] **Isabona, J. and Srivastava, V.M.**, 2017. Downlink massive MIMO systems: Achievable sum rates and energy efficiency perspective for future 5G systems, *Wireless Personal Communications*, **96**(2), 2779-2796.
- [6] **Lu, L., Li, G.Y., Swindlehurst, A.L., Ashikhmin, A., and Zhang, R.**, 2014. An overview of massive MIMO: Benefits and challenges, *IEEE journal of selected topics in signal processing*, **8**(5), 742-758.
- [7] **Osseiran, A., Boccardi, F., Braun, V., Kusume, K., Marsch, P., Maternia, M., Queseth, O., Schellmann, M., Schotten, H., and Taoka, H.**, 2014. Scenarios for 5G mobile and wireless communications: the vision of the METIS project, *IEEE Communications Magazine*, **52**(5), 26-35.
- [8] **Kumar, A. and Gupta, M.**, 2018. A review on activities of fifth generation mobile communication system, *Alexandria Engineering Journal*, **57**(2), 1125-1135.
- [9] **Ojaroudiparchin, N., Shen, M., and Fr, G.**, 2015. *Multi-layer 5G mobile phone antenna for multi-user MIMO communications*. in *Telecommunications Forum Telfor (TELFOR)*, 23rd. 2015. IEEE.
- [10] **Singh, S. and Singh, P.**, 2012. Key concepts and network architecture for 5G mobile technology, *International Journal of Scientific Research Engineering & Technology (IJSRET)*, **1**(5), 165-170.
- [11] **Bhalla, M.R. and Bhalla, A.V.**, 2010. Generations of mobile wireless technology: A survey, *International Journal of Computer Applications*, **5**(4), 26-32.
- [12] **Mehta, H., Patel, D., Joshi, B., and Modi, H.**, 2014. 0G to 5G mobile technology: a survey, *J. of Basic and Applied Engineering Research*, **1**(6), 56-60.
- [13] **Reed, J.H., Bernhard, J.T., and Park, J.-M.**, 2012. Spectrum access technologies: The past, the present, and the future, *Proceedings of the IEEE*, **100**(Special Centennial Issue), 1676-1684.
- [14] **Osman, A.S.**, 2006. BER Performance Study of Orthogonal Frequency Division Multiplexing (OFDM), Universiti Teknologi Malaysia.
- [15] **Pandya, R.**, 1995. Emerging mobile and personal communication systems, *IEEE Communications Magazine*, **33**(6), 44-52.
- [16] **Gupta, P.**, 2013. Evolvement of mobile generations: 1G to 5G, *International Journal for Technological Research in Engineering*, **1**, 152-157.
- [17] **Pereira, V. and Sousa, T.**, 2004. Evolution of Mobile Communications: from 1G to 4G, *Department of Informatics Engineering of the University of Coimbra, Portugal*.
- [18] **Mishra, A.R.**, 2004. Fundamentals of cellular network planning and optimisation: 2G/2.5 G/3G... evolution to 4G, John Wiley & Sons.

- [19] **Almers, P., Bonek, E., Burr, A., Czink, N., Debbah, M., Degli-Esposti, V., Hofstetter, H., Kyösti, P., Laurenson, D., and Matz, G.,** 2007. Survey of channel and radio propagation models for wireless MIMO systems, *EURASIP Journal on Wireless Communications and Networking*, **2007**(1), 019070.
- [20] **Chuang, J., Cimini, L.J., Li, G.Y., McNair, B., Sollenberger, N., Zhao, H., Lin, L., and Suzuki, M.,** 1999. High speed wireless data access based on combining EDGE with wideband OFDM, *IEEE Communications magazine*, **37**(11), 92-98.
- [21] **Furuskar, A., Mazur, S., Muller, F., and Olofsson, H.,** 1999. EDGE: Enhanced data rates for GSM and TDMA/136 evolution, *IEEE personal communications*, **6**(3), 56-66.
- [22] **Johansson, K., Bergman, J.,** 2009. Gerstenberger, D., Blomgren, M., and Wallén, A. *Multi-carrier HSPA evolution*. in *VTC Spring 2009-IEEE 69th Vehicular Technology Conference*. IEEE.
- [23] **Weigel, R., Maurer, L., Pimingsdorfer, D., and Springer, A.,** 2001. *RF transceiver architectures for W-CDMA systems like UMTS: State of the art and future trends*. in *Proc. of the Intern. Symp. on Acoustic Wave Devices for Future Mobile Communications Systems*.
- [24] **Bergman, J., Ericson, M., Gerstenberger, D., Göransson, B., Peisa, J., and Wager, S.,** 2008. HSPA Evolution—Boosting the performance of mobile broadband access, *Ericsson Review*, **85**(1), 32-37.
- [25] **Štencel, V., Müller, A., and Frank, P.** 2010. *LTE advanced—A further evolutionary step for next generation mobile networks*. in *20th International Conference Radioelektronika 2010*. IEEE.
- [26] **Tran, T.-T., Shin, Y., and Shin, O.-S.,** 2012. Overview of enabling technologies for 3GPP LTE-advanced, *EURASIP Journal on Wireless Communications and Networking*, **2012**(1), 54.
- [27] **Yadav, R.** 2017. *Challenges and evolution of next generations wireless communication*. in *Proceedings of the International MultiConference of Engineers and Computer Scientists*.
- [28] **Mitra, R.N. and Agrawal, D.P.,** 2015. 5G mobile technology: A survey, *ICT Express*, **1**(3), 132-137.
- [29] **Karki, R. and Garia, V.,** 2016. Next Generations of Mobile Networks, *International Journal of Computer Applications*, **975**, 8887.
- [30] **Gohil, A., Modi, H., and Patel, S.K.,** 2013. *5G technology of mobile communication: A survey*. in *Intelligent Systems and Signal Processing (ISSP), 2013 International Conference on*. IEEE.
- [31] **Jungnickel, V., Manolakis, K., Zirwas, W., Panzner, B., Braun, V., Lossow, M., Sternad, M., Apelfrojd, R., and Svensson, T.,** 2014. The role of small cells, coordinated multipoint, and massive MIMO in 5G, *IEEE Communications Magazine*, **52**(5), 44-51.
- [32] **Nichita, M.V., Ciofîrnae, P., Luca, R.L., and Petrescu, V.N.** *5G propagation: Current solutions and future proposals*. in *2016 12th IEEE International Symposium on Electronics and Telecommunications (ISETC)*. 2016. IEEE.
- [33] **Sheetal, J.** *Architecture of 5g technology in mobile communication*. in *Proceedings of 18th IRF International Conference, 11th January*. 2015.
- [34] **Sharma, P., Verma, M., Sundriyal, N., and Chauhan, J.,** 2014. 5G Mobile Wireless Technology, *International Journal of Research*, **1**(9).
- [35] **Vora, L.J.,** 2015. Evolution of mobile generation technology: 1G to 5G and review of upcoming wireless technology 5G, *International Journal of Modern Trend sin Engineering and Research*.

- [36] **El Misilmani, H. and El-Hajj, A.** *Massive MIMO Design for 5G Networks: An Overview on Alternative Antenna Configurations and Channel Model Challenges.* in *High Performance Computing & Simulation (HPCS), 2017 International Conference on.* 2017. IEEE.
- [37] **Boccardi, F., Heath Jr, R.W., Lozano, A., Marzetta, T.L., and Popovski, P.,** 2013. Five disruptive technology directions for 5G, *arXiv preprint arXiv:1312.0229*.
- [38] **Kaur, N. and Kansal, L.,** 2013. Performance comparison of MIMO systems over AWGN and Rician channels with zero forcing receivers, *International Journal of Wireless & Mobile Networks*, **5**(1), 73.
- [39] **Jabbar, S. and Li, Y.,** 2016. Analysis and evaluation of performance gains and tradeoffs for massive MIMO systems, *Applied Sciences*, **6**(10), 268.
- [40] **Larsson, E.G., Edfors, O., Tufvesson, F., and Marzetta, T.L.,** 2013. Massive MIMO for next generation wireless systems, *arXiv preprint arXiv:1304.6690*.
- [41] **Ngo, H.Q., Larsson, E.G., and Marzetta, T.L.** *Massive MU-MIMO downlink TDD systems with linear precoding and downlink pilots.* in *2013 51st Annual Allerton conference on communication, control, and computing (Allerton).* 2013. IEEE.
- [42] **Papadopoulos, H., Wang, C., Bursalioglu, O., Hou, X., and Kishiyama, Y.,** 2016. Massive MIMO technologies and challenges towards 5G, *IEICE Transactions on Communications*, **99**(3), 602-621.
- [43] **Kumar, S., Gupta, P., Singh, G., and Chauhan, D.,** 2013. Performance analysis of Rayleigh and Rician fading channel models using Matlab simulation, *International Journal of Intelligent Systems and Applications*, **5**(9), 94.
- [44] **Xiao, C., Zheng, Y.R., and Beaulieu, N.C.,** 2006. Novel sum-of-sinusoids simulation models for Rayleigh and Rician fading channels, *IEEE Transactions on Wireless Communications*, **5**(12).
- [45] **Varade, S. and Kulat, K.,** 2012. BER comparison of Rayleigh fading, Rician fading and AWGN channel using chaotic communication based MIMO-OFDM system, *International Journal of Soft Computing and Engineering*, **1**(6).
- [46] **Farhang, A., Marchetti, N., Figueiredo, F., and Miranda, J.P.** *Massive MIMO and waveform design for 5th generation wireless communication systems.* in *1st international conference on 5G for ubiquitous connectivity.* 2014. IEEE.
- [47] **Gao, X., Edfors, O., Rusek, F., and Tufvesson, F.** *Linear Pre-Coding Performance in Measured Very-Large MIMO Channels.* in *VTC Fall.* 2011.
- [48] **Vu, M. and Paulraj, A.,** 2007. MIMO wireless linear precoding, *IEEE Signal Processing Magazine*, **24**(5), 86-105.
- [49] **Ramanath, S., Debbah, M., Altman, E., and Kumar, V.** *Asymptotic analysis of precoded small cell networks.* in *INFOCOM, 2010 Proceedings IEEE.* 2010. IEEE.
- [50] **Shao, X., Yuan, J., and Shao, Y.,** 2007. Error performance analysis of linear zero forcing and MMSE precoders for MIMO broadcast channels, *IET communications*, **1**(5), 1067-1074.
- [51] **Cheikh, D.B., Kelif, J.-M., Coupechoux, M., and Godlewski, P.** *Multicellular zero forcing precoding performance in Rayleigh and shadow fading.* in *Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd.* 2011. IEEE.
- [52] **Cho, Y.S., Kim, J., Yang, W.Y., and Kang, C.G.,** 2010. MIMO-OFDM wireless communications with MATLAB, John Wiley & Sons.
- [53] **Battikh, D.B.C.,** 2012. Outage probability formulas for cellular networks: contributions for MIMO, CoMP and time reversal features, Télécom ParisTech.
- [54] **Achra, N., Mathur, G., and Yadav, R.,** 2013. Performance analysis of MIMO OFDM system for different modulation schemes under various fading channels,

- International Journal of Advanced Research in Computer and Communication Engineering*, 2(5), 2098-2103.
- [55] **Zanella, A., Chiani, M., and Win, M.Z.**, 2005. MMSE reception and successive interference cancellation for MIMO systems with high spectral efficiency, *IEEE Transactions on Wireless Communications*, 4(3), 1244-1253.
- [56] **Kobayashi, R.T., Ciriaco, F., and Abrão, T.** 2014. *Performance and complexity analysis of sub-optimum MIMO detectors under correlated channel.* in *Telecommunications Symposium (ITS), 2014 International*. 2014. IEEE.
- [57] **Mandloi, M., Hussain, M.A., and Bhatia, V.** 2016. *An improved multiple feedback successive interference cancellation algorithm for MIMO detection.* in *Communication Systems and Networks (COMSNETS), 8th International Conference on*. 2016. IEEE.
- [58] **Lee, K., Chun, J., and Hanzo, L.**, 2007. Optimal lattice-reduction aided successive interference cancellation for MIMO systems, *IEEE Transactions on Wireless Communications*, 6(7).
- [59] **Arévalo, L., de Lamare, R.C., Haardt, M., and Sampaio-Neto, R.**, 2017. Decoupled signal detection for the uplink of massive MIMO in 5G heterogeneous networks, *EURASIP Journal on Wireless Communications and Networking*, 2017(1), 131.
- [60] <https://www.electronicshub.org/5g-technology/>
- [61] <https://www.gaussianwaves.com/2014/08/introduction-to-multiple-antenna-systems/>

CURRICULUM VITAE

Abubakr Wsu Muhammed

General Information:

<i>Data of birth</i>	01/01/1985
<i>Mobile Phone</i>	+964 -750 - 113 - 2122
<i>E-Mail</i>	abobakrwm@gmail.com
<i>Gender</i>	Male
<i>Marital Status:</i>	Married
<i>Nationality</i>	Iraq
<i>Address</i>	Rania/ Sulaymaneyah/ Iraq

Work Experience:

Type	Place	Year
<i>Electrical and Communication Engineer</i>	Korek Telecom /Radio Network department-Erbil	2009-2011
<i>Electrical Engineer</i>	Shahan Company for Building Construction	2011-2012
<i>Electrical Engineer</i>	Akar Company for Electrical Construction	2012-2014
<i>Electrical Engineer</i>	Raparin University / Directorate of Engineering and Projects	2013- Present

Education:

<i>Graduate</i>	college of Engineering / Electrical engineering department	Salahaddin University	2008-2009
-----------------	---	------------------------------	------------------

APPENDIX

MATLAB CODE

% Achievable rate of MIMO 8*8 receivers for a fast fading channel. Figures (4.1-4.4)

```
clear all
% number of channel realization
It = 10000;

% Number of transmit and receive antennas
M=8;
% SNR range in dB
% SNR = ratio between total transmit power and noise variance

SNRdBvalues = [-10:2:30];
% initialize variables: maximal achievable rate for one SNR value and one channel
realization
Cmf = zeros(1,It);
Czf = zeros(1,It);
Cmmse = zeros(1,It);
Csic = zeros(1,It);

SNRidx=0;
for SNRdB=SNRdBvalues
    SNRdB
    SNRidx = SNRidx + 1;
    SNR=10^(SNRdB/10);
    % compute maximal achievable rate
    for kk=1:It
        % generate channel realization
        H = (randn(M)+j*randn(M))/sqrt(2);
        % Matched filter
        for ii=1:M
            % output SNR for each stream

            hi = H(:,ii);
            Hib = H; Hib(:,ii)=zeros(M,1);
            SNRi(ii) = real( ( abs(hi'*hi)^2) / (hi'*Hib*Hib'*hi + hi'*hi/SNR*M) );
        end
        Cmf(kk) = sum ( log2( 1 + SNRi) );
        % maximal achievable rate
        %zero forcing
        Dzf = inv(H'*H)/SNR*M;
        SNRzf = real( diag(1./diag(Dzf)) );
        % output SNR (diagonal matrix)
        Czf(kk) = log2( det(eye(M) + SNRzf) ); % maximal achievable rate
        %MMSE
        Dmmse = inv(H'*H + eye(M)/SNR*M);
```



```

Hmimo4x4 = ( randn(4) + j*randn(4) )/sqrt(2);
Cmimo4x4(kk) = log2(real(det( eye(4) + SNR/2*Hmimo4x4*Hmimo4x4' ))));
Hsiso = ( randn + j*randn )/sqrt(2);
Csiso(kk) = log2(real(det( 1 + SNR*Hsiso*Hsiso' ))));
end
% CDF estimates
xi = linspace(0,40,201);
CDFmimo8x8 = ksdensity(Cmimo8x8,xi,'function','cdf');
CDFmimo4x4 = ksdensity(Cmimo4x4,xi,'function','cdf');
CDFsiso = ksdensity(Csiso,xi,'function','cdf');
%plot
figure(1)
plot(xi,CDFmimo8x8,'r');
hold on
plot(xi,CDFmimo4x4,'b');
grid
plot(xi,CDFsiso,'g');
xlabel('Selected Rate R')
ylabel('Probability')
title('Cumulative Density Function at 10dB')
text(30,.75,'8x8 MIMO')
text(15,.75,'4x4 MIMO')
text(4,.75,'SISO')
hold off
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Capacity vs number of antennas for a 8x8 MIMO system, a 1x8 SIMO system, a 8x1
MISO system and a SISO system.
Figures (4.9-4.12)

```

```

clear all
% Maximum number of transmit and receive antennas
Mmax = 8;

```

```

% number of channel realization
It = 8000;

```

```

Cmimo = zeros(1, Mmax);
Csimo = zeros(1, Mmax);
Cmiso = zeros(1, Mmax);
Csiso = zeros(1, Mmax);

```

```

SNRdB = 0; % in dB
SNR = 10.^(SNRdB./10); % linear scale
for kk=1:It

```

```

    for M = 1:Mmax

```

```

        % MIMO

```

```

Hmimo = ( randn(M) + j*randn(M) )/sqrt(2);
Cmimo(M) = Cmimo(M) + log2(real(det( eye(M) + SNR/M*Hmimo*Hmimo' ))));
%% SIMO
hsimo = ( randn(M,1) + j*randn(M,1) )/sqrt(2);
Csimo(M) = Csimo(M) + log2( 1 + SNR*norm(hsimo)^2);

%% MISO
hmiso = ( randn(M,1) + j*randn(M,1) )/sqrt(2);
Cmiso(M) = Cmiso(M) + log2( 1 + SNR/M*norm(hmiso)^2);

%% SISO
hsiso = ( randn + j*randn )/sqrt(2);
Csiso(M) = Csiso(M) + log2( 1 + SNR*abs(hsiso)^2);
end
end

Csiso = Csiso/It
Csimo = Csimo/It
Cmiso = Cmiso/It
Cmimo = Cmimo/It

figure(1)
plot(1:Mmax, Cmimo,'r-*)
hold on
plot(1:Mmax, Csimo,'b-s')
plot(1:Mmax, Cmiso,'k--s')
plot(1:Mmax, Csiso,'m--*')
xlabel('Number of antennas M')
ylabel('Ergodic Capacity (bits/transmission)')
title('Ergodic Capacity for i.i.d. Rayleigh fast fading channel - SNR=0dB')
legend('8x8 MIMO', '1x8 SIMO', '8x1 MISO', '1x1 SISO')
grid
hold off
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Outage probability of the Alamouti STBC for a 8x1 MISO and
% 8x8 MIMO system and an i.i.d. Rayleigh slow fading channel model. Figures (4.13-
4.16)

clear all

% number of channel realizations. This number needs to be increased when
% estimating a small probability
It = 200000;

% SNR range in dB
SNRdBvalues = [0:1:15];

% transmission rate: 4 bits per transmission
R=4;

```

```

SNRidx = 0;
for SNRdB=SNRdBvalues
    SNRdB
    SNRidx = SNRidx + 1;
    SNR=10^(SNRdB/10);

    % initialize variables: number of channel realizations where R exceeds
    % the maximal achievable rate for Alamouti 1x8 and 8x8
    N1=0;
    N2=0;

    for kk=1:It

        % generate channel realization
        H1 = (randn(1,8) + j*randn(1,8))/sqrt(2); % 8 tx and 1 rx antennas
        H2 = (randn(8) + j*randn(8))/sqrt(2); % 8 tx and 8 rx antennas

        % Alamouti 1x8
        SNR1 = norm(H1)^2*SNR/2; % SNR
        C1 = (log2(1 + SNR1)); % Max achievable rate
        N1 = N1 + .5*(1-sign(C1-R)); % number of channel realizations where R exceeds
C1

        % Alamouti 8x8
        SNR2 = ( norm(H2(8,:))^2 + norm(H2(8,:))^2 )*SNR/2; % SNR of Alamouti 8x8
        C2 = (log2(1 + SNR2)); % Max achievable rate
        N2 = N2 + .5*(1-sign(C2-R)); % number of channel realizations where R exceeds
C2

    end

    % Outage probabilities
    P1(SNRidx) = N1/It; % Alamouti 8x1
    P2(SNRidx) = N2/It; % Alamouti 8x8

end

figure(1)
semilogy(SNRdBvalues, P1,'b-','linewidth',1)
hold on
semilogy(SNRdBvalues, P2,'r-s','linewidth',1)
grid
title('Alamouti STBC - Outage probability for 8x1 MISO and 8x8 MIMO')
xlabel('SNR (dB)')
ylabel('Outage probability')
legend('Alamouti STBC 8x1','Alamouti STBC 8x8')
axis([0 15 10e-8 1])
grid on
hold off

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Capacity with outage 10% for MIMO, SIMO, MISO and SISO channels. Figures (4.17-
4.20)

```

```
clear all
```

```
% number of channel realization. This number needs to be increased when
% estimating a small outage probability
```

```
It = 100000;
```

```
fprintf('Total number of channel realizations: %d\n', It);
```

```
% SNR range in dB
```

```
SNRdBvalues = 0:50;
```

```
% Selected transmission rate: 10bits/s
```

```
R=10;
```

```
% initialize variables = number of channel realizations for which the
% selected rate exceeds the maximal achievable rate
```

```
N_mimo8x8 = zeros(1,length(SNRdBvalues));
```

```
N_mimo4x4 = zeros(1,length(SNRdBvalues));
```

```
N_simo1x8 = zeros(1,length(SNRdBvalues));
```

```
N_miso8x1 = zeros(1,length(SNRdBvalues));
```

```
N_siso1x1 = zeros(1,length(SNRdBvalues));
```

```
for kk=1:It
```

```
    if mod(kk,10000) == 0
```

```
        fprintf('Number of channel realizations: %d\n', kk);
```

```
    end
```

```
        % generate channel realization
```

```
        Hmimo8x8 = ( randn(8) + j*randn(8) )/sqrt(2);
```

```
        Hmimo4x4 = ( randn(4) + j*randn(4) )/sqrt(2);
```

```
        Hsimo1x8 = ( randn(8,1) + j*randn(8,1) )/sqrt(2);
```

```
        Hmiso8x1 = ( randn(1,8) + j*randn(1,8) )/sqrt(2);
```

```
        Hsiso1x1 = ( randn + j*randn )/sqrt(2);
```

```
        SNRidx = 0;
```

```
        for SNRdB = SNRdBvalues
```

```
            SNR = 10.^(SNRdB./10); % linear scale
```

```
            SNRidx = SNRidx + 1;
```

```
            % number of channel realizations for which the selected rate exceeds the maximal
achievable rate
```

```
            % MIMO 8x8
```

```
            Cmimo8x8 = log2(real(det( eye(8) + SNR/8*Hmimo8x8*Hmimo8x8' )));
```

```
            N_mimo8x8(SNRidx) = N_mimo8x8(SNRidx) + (1-sign(Cmimo8x8 - R))/2;
```

```

% MIMO 4x4
Cmimo4x4 = log2(real(det( eye(4) + SNR/4*Hmimo4x4*Hmimo4x4' )));
N_mimo4x4(SNRidx) = N_mimo4x4(SNRidx) + (1-sign(Cmimo4x4 - R))/2;

% SIMO 1x8
Csimo1x8 = log2(real(det( 1 + SNR*norm(Hsimo1x8)^2 )));
N_simo1x8(SNRidx) = N_simo1x8(SNRidx) + (1-sign(Csimo1x8 - R))/2;

% MISO 8x1
Cmiso8x1 = log2(real(det( 1 + SNR/8*norm(Hmiso8x1)^2 )));
N_miso8x1(SNRidx) = N_miso8x1(SNRidx) + (1-sign(Cmiso8x1 - R))/2;

% SISO
Csiso1x1 = log2(real(det( 1 + SNR*norm(Hsiso1x1)^2 )));
N_siso1x1(SNRidx) = N_siso1x1(SNRidx) + (1-sign(Csiso1x1 - R))/2;

end

end

Pout_mimo8x8 = N_mimo8x8/It
Pout_mimo4x4 = N_mimo4x4/It
Pout_simo1x8 = N_simo1x8/It
Pout_miso8x1 = N_miso8x1/It
Pout_siso1x1 = N_siso1x1/It

%plot
figure(1)
semilogy(SNRdBvalues,Pout_mimo8x8,'g-+');
hold on
semilogy(SNRdBvalues,Pout_mimo4x4,'r-*');
grid
semilogy(SNRdBvalues,Pout_simo1x8,'b');
semilogy(SNRdBvalues,Pout_miso8x1,'k');
semilogy(SNRdBvalues,Pout_siso1x1,'m');
xlabel('Average SNR \rho (dB)')
ylabel('Capacity with outage (bits/transmission)')
title('Capacity with 10% outage for i.i.d. Rayleigh slow fading channel')
legend('8x8 MIMO','4x4 MIMO','1x8 SIMO','8x1 MISO','1x1 SISO')
grid on
hold off

```