BER PERFORMANCE STUDY OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

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ABSTRACT

A mobile radio channel is characterized by a multipath fading environment. The signal is offered to the receiver contains not only line of sight of radio wave, but also a large number of reflected radio waves that arrive at the receiver at different times. Delayed signals are a result of reflections from terrain features such as trees, hills, mountains, vehicles or building. These reflected delayed waves interfere with the direct wave and cause *intersymbol interference (ISI),* which causes significant degradation of the network performance. In order to overcome a multipath fading environment and achieve a *wireless broadband multimedia communication system (WBMCS),* it is possible to use OFDM transmission scheme. OFDM is based on parallel data transmission scheme that reduces that effects of multipath fading and renders complex equalizers unnecessary. OFDM is expected to be used in wireless LAN (WLAN) systems. In this project will study and identify the Orthogonal Frequency Division Multiplexing (OFDM) technology that gives the best BER performance in a multipath fading environment using computer simulation. Essentially, ideal and worst case communication channel models were studied and the simulation programs were written to simulate that channels. Orthogonal Frequency Division Multiplexing is modeled and simulated under different channel conditions such as AWGN and Rayleigh fading. Subsequently, a comparison study is carried out to obtain the BER performance for Orthogonal Frequency Division Multiplexing under under 1-path multipath fading conditions and to identify which channel gives the best BER performance. The comparison study showed that BER for AWGN channel gives the best BER performance compared to Rayleigh channel.

ABSTRAK

Saluran radio bergerak dikategorikan di dalam persekitaran “multipath fading”. Di bahagian penerimaan, isyarat diterima daripada pelbagai sudut dan waktu yang berbeza. Kelewatan isyarat berlaku apabila terdapatnya halangan daripada pokok, bukit, gunung, kenderaan ataupon bangunan. Hasil pembalikkan kelewatan isyarat dengan isyarat sebenar akan terhasilnya “*intersymbol interference (ISI)”*, yang akan menyebabkan pencapaian rangkaian menurun. Untuk mengatasi masalah “multipath fading” dan mencapai tahap “*wireless broadband multimedia communication system (WBMCS)”*, skim penghantaran OFDM diperkenalkan. OFDM menggunakan konsep penghantaran data digital secara selari untuk mengatasi masalah “multipath fading”. OFDM dijangka digunakan di dalam sistem komunikasi tanpa wayar rangkaian tempatatan. Di dalam projek ini akan mempelajari dan mengenalpasti teknologi “Orthogonal Frequency Division Multiplexing (OFDM)” yang akan yang memberikan nilai BER yang terbaik dalam persekitaran “multipath fading” menerusi simulasi komputer. Model saluran komunikasi yang “ideal” dan “worst” dijadikan sumber untuk dipelajari dan program ditulis untuk tujuan simulasi. Seterusnya, “Orthogonal Frequency Division Multiplexing” model direka dan disimulasi untuk setiap saluran yang berbeza seperti “AWGN” dan “Rayleigh”. Satu perbandingan kajian dilaksanakan untuk memperolehi tahap BER bagi “Orthogonal Frequency Division Multiplexing” di bawah keadaan saluran “Multipath Fading” untuk menentukan saluran yang dapat memberikan tahap BER yang terbaik. Hasil perbandingan menunjukkan BER di bawah saluran AWGN memberikan BER yang terbaik berbanding BER di bawah saluran Rayleigh.

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CHAPTER 1

INTRODUCTION

This project studies the Bit Error Rate (BER) for Orthogonal Frequency Division Multiplexing under different channels condition.

Digital multimedia applications as they are getting common lately create an ever increasing demand for broadband communications systems. Orthogonal Frequency Division Multiplexing (OFDM) has grown to be the most popular communications system in high speed communications in the last decade. In fact, it has been said by many industry leaders that OFDM technology is the future of wireless communications.

The prosperous progress of mobile communications has built the main road of the history of wireless communication. The mobile wireless communications progressed from Personal Communication Services/Network (PCS/PCN) to Global System for Mobile Radio Channel (GSM) to General Packet Radio Service (GPRS) to Enhanced Data for Global Evolution (EDGE) to Universal Mobile Telecommunication Systems (UMTS) (better known as 3G) and will continue to evolve to 4G which is under active research. The evolution is depicted in the following figure.

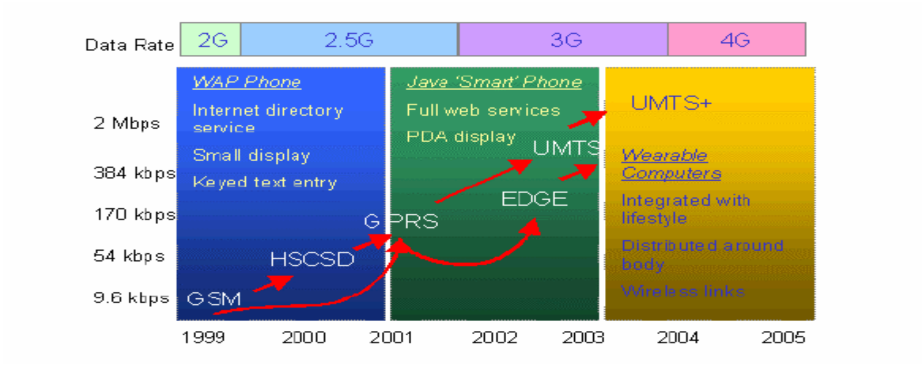

Figure 1.1: Evolution of mobile wireless communications

A step back into the history of wireless communications will reveal how this evolution was made possible.

1.1 History of Mobile Wireless Communications

The history of mobile communication can be categorized into 3 periods:

- the pioneer era
- the pre-cellular era
- the cellular era

Time	Significant
Pioneer Era	
1860s	James Clark Maxwell’s electromagnetic (EM) wave postulates
1880s	Proof of the existence of EM waves by Heinrich Rudolf Hertz
1890s	First use of wireless and forst patent of wireless communications by Gugliemo Marconi
1905	First transmission of speech and music via a wireless link by Reginald Fessenden
1912	Sinkng of the *Titanic* highlights the importance of wireless communication on the seaways; in the following years marine radio telegraphy is established
Precellular Era	
1921	Detroit Police Department conducts field test with mobile radio
1933	In the United States, four channels in the 30-40 MHz range
1938	In the United States, rules for regular services
1940	Wireless Communication is stimulated by World War II
1946	First commercial mobile telephone system operated by the Bell system and deployed in St Louis
1948	First commercial fully automatic mobile telephone system is deployed in Richmond, Virgina, in the United States
1950s	Microwave telephone and communication links are developed
1960s	Introduction of trunked radio systems with automatic channel allocation capabilities in the United States
1970	Commercial mobile telephone system operated in many countries (e.g: 100 million moving vehicles on U.S highways, “B-Netz” in West Germany)
Cellular Era	
1980s	Deployment of analog cellular systems
1990s	Digital cellular development and dual mode operation of digital systems
2000s	Future public land mobile communication systems (FPLMTSs) / International mobile telcommunications-2000 (IMT-2000) / Universal mobile telecommunication systems (UMTS) will be deployed with multimedia services
2010s	Fixed point (FP) – based wireless broadband communications and software radio will be available over the Internet
2010s	Radio over fiber (such as fiber optic microcells) will be available

Table 1.1: History of Mobile Communications

In the pioneer era, a great deal of the fundamental research and development in the field of wireless communications took place. The postulates of *electromagnetic* (EM) waves by James Clark Maxwell during the 1860s in England, the demonstration of the existence of these waves by Heinrich Rudolf Hertz in 1880s in Germany and the invention and first demonstration of wireless telegraphy by Guglielmo Marconi during the 1890s in Italy were representative examples from Europe. Moreover, in Japan, the Radio Telegraph Research Division was established as a part of the Electro technical Laboratory at the Ministry of Communications and started to research wireless telegraph in 1896.

From the fundamental research and the resultant developments in wireless telegraphy, the application of wireless telegraphy to mobile communication systems started from the 1920s. This period, which is called the pre-cellular era, began with the first land-based mobile wireless telephone system installed in 1921 by the Detroit Police Department to dispatch patrol cars, followed in 1932 by the New York City Police Department. These systems were operated in the 2MHz frequency band. Unfortunately, during World War II, the progress of radio communication technologies was drastically stimulated.

In 1946, the first commercial mobile telephone system, operated in the 150MHz frequency band, was set up by Bell Telephone Laboratories in St. Louis. The demonstration system was a simple analog communication system with a manually operated telephone exchange.

Subsequently, in 1969, a mobile duplex communication system was realized in the 450MHz frequency band. The telephone exchange of this modified system was operated automatically. The new system, called the Improved Mobile Telephone System (IMTS), was widely installed in the United States. However, because of its large coverage area, the system could not manage a large number of users or allocate the available frequency bands efficiently.

The cellular zone was concept was developed to overcome this problem by using the propagation characteristics of radio waves. The cellular zone concept divided a large coverage area into many smaller zones. A frequency channel in one cellular zone is used in another cellular zone. However, the distance between the cellular zones that use the same frequency channels is sufficiently long to ensure that the probability of interference is quite low. The use of the new cellular zone concept launched the third era, known as the cellular era.

The first generation of cellular mobile communication was developed from 1980 to 1990. In this period, research and development (R&D) centered on analog cellular communication systems.

In the United States, an analog cellular mobile communication service called A*dvanced Mobile Phone Service* (AMPS) was started in October 1983 in Chicago.

In Europe, several cellular mobile communication services were started. In Norway, *Nordic Mobile Telephone* (NMT) succeeded in the development of an analog cellular mobile communication system.

In the United Kingdom, Motorola developed an analog cellular mobile communication system called the *total access communication system* (TACS) based on AMPS in the 1984-1985 periods. In 1983, NMT started a modified NMT-450 called NMT-900. Moreover, C-450, RTMS and Radiocom-2000 were, respectively, introduced in Germany, Italy and France.

Meanwhile, in Japan, *Nippon Telephone and Telegraph* (NTT) developed a cellular mobile communication system in the 800 MHz frequency band and started service in Tokyo in December 1979. Furthermore, a modified TACS that changed the frequency band to adjust for Japanese frequency planning and was called JTACS was also introduced in July 1989. Subsequently, *narrowbakd TACS* (NTACS), which introduced the required frequency band in half, started service in October 1991.

So far, the evolution of the analog cellular mobile communication system is described. There were many problems and issues, for example, the incompatibility of the various systems in each country or region, which precluded roaming. In addition, analog cellular mobile communication systems were unable to ensure sufficient capacity for the increasing number of users, and the speech quality was not good.

To solve these problems, the R&D of cellular mobile communication systems based on digital radio transmission schemes was initiated. These new mobile communication systems became known as the second generation (2G) of mobile communication systems, and the analog cellular era is regarded as the first generation (1G) of mobile communication systems.

In Europe, the global system for mobile communication (GSM), a new digital communication system that allowed international roaming and using 900 MHz frequency band had been introduced in 1992.

First Generation (1G) is described as the early analogue cellular phone technologies. Actually, 1G is a hybrid of analog voice channels and digital control channels. The analog voice channels typically used Frequency Modulation (FM) and the digital control channels used simple Frequency Shift keying (FSK) modulation. NMT and AMPS cellular technologies fall under this categories.

Second Generation (2G) described as the generation first digital fidely used cellular phones systems. 2G digital systems use digital radio channels for both voice (digital voice) and digital control channels. GSM technology is the most widely used 2G technologies. This gives digital speech and some limited data capabilities (circuit switched 9.6kbits/s). Other 2G technologies are IS-95 CDMA, IS-136 TDMA and PDC.

Two and Half Generation (2.5G) is an enhanced version of 2G technology. 2.5G gives higher data rate and packet data services. GSM systems enhancements like GPRS and EDGE are considered to be in 2.5G technology. The so-called 2.5G technology represent an intermediate upgrade in data rates available to mobile users.

Third Generation (3G) mobile communication systems often called with names 3G, UMTS and WCDMA promise to boost the mobile communications to the new speed limits. The promises of third generation mobile phones are fast Internet surfing, advanced value-added services and video telephony. Third-generation wireless systems will handle services up to 384 kbps in wide area applications and up to 2 Mbps for indoor applications.

Fourth Generation (4G) is intended to provide high speed, high capacity, low cost per bit, IP based services. The goal is to have data rates up to 20 Mbps. Most propable the 4G network would be a network which is a combination of different technologies, for example, current celluart networks, 3G celluar network and wireless LAN, working together using suitable interoperability protocols.

1.2 Objectives of the project

- To study a concept of Orthogonal Frequecy Division Multiplexing (OFDM) Tranmission Technology in WLAN enviroment
- To design and evaluate Orthogonal Frequency Division Multiplexing (OFDM) in a Multipath Fading Channel using computer simulation (MATLAB)
- To obtain and compare between the theoretical and simulation result for Orthogonal Division Multiplexing (OFDM) under different communication channel
- To obtain and compare the Bit Error Rate (BER) Performance for different communication channel

1.3 Scope of the project

In this project, I focused on designing the matlab code for two different channel conditions that affects the BER performance for Orthogonal Frequency Divison Multiplexing (OFDM) in WLAN environment. Both channels are:

- AWGN Channel
- Rayleigh Channel

Digital modulation that has been used in this project is QPSK modulation.

1.4 Motivations

OFDM is expected to be used in future broadcasting and wireless LAN (WLAN) systems. IEEE802.11a is the technology that used OFDM concept. Since wireless technologies become a very high demand nowadays, OFDM is chosen to be a subject study.

By learning to design and evaluate the Orthogonal Frequecny Division Multiplexing (OFDM) system using computer simulation, I will be able to establish my position in the research and development of wireless communications and further design and simulate more complex systems.

In this project, I'm using the MATLAB computer-simulation software, which is produced by MathWork Inc. MATLAB, a sophisticated language for matrix calculation, and stands for MATrix LABoratory. MATLAB is chosen as the computer language to design the Orhtogonal Frequency Division Multiplexing (OFDM) systems because it is one of the most popular computer simulation languages in the world. MATLAB is used throughout this project to:

- model and simulate the communication channel (AWGN and Rayleigh)
- model and simulate of the transmission system for OFDM using QPSK modulation

- compute and compare the BER.

1.5 Problem statement

Mobile wireless systems operate under harsh and challenging channel conditions. The wireless channel is distinct and much more unpredictable than the wireline channel because of factors such as multipath and shadow fading, Doppler spread, and delay spread or time dispersion. These factors are all related to variability that is introduced by the mobility of the user and the wide range of environments that may be encountered as a result.

In wireless communications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of mutipath include atmospheric, ducting, ionospheric reflection and refraction and reflection from terrestrial objects such as mountains and buildings. The reflected signals arrive at the receiver with random phase offsets, because each reflection generally follows a different path to reach the user's receiver. The result is random signal fades as the reflections destructively (and constructively) superimpose on one another, which effectively cancels part of the energy signal for brief periods of time. The degree of cancellation or fading will depend on the delay spread of the reflected signals, as embodied by their relative phases and their relative power.

The project studies and identifies the Orthogonal Frequency Divison Multiplexing (OFDM) that gives the best BER performance in a multipath fading environment using QPSK modulation system. This project will identify the best BER performance between different types of communication channel. The outcome from the BER vs Signal Energy per bit over noise power density ratio (Eb/No) will be shown in the graph format.

1.6 Methodology and Report Structure

This is a simulation project which studied the BER performance for Orthogonal Frequency Division Multiplexing (OFDM) under different communication channels. This study involves four main procedures to achieve its objectives. The procedures involved modeling and simulations of the communication channel between ideal and worst case, OFDM transmission system, QPSK transmission system and calculation and comparison of BER. The following flowchart summarizes the procedures:

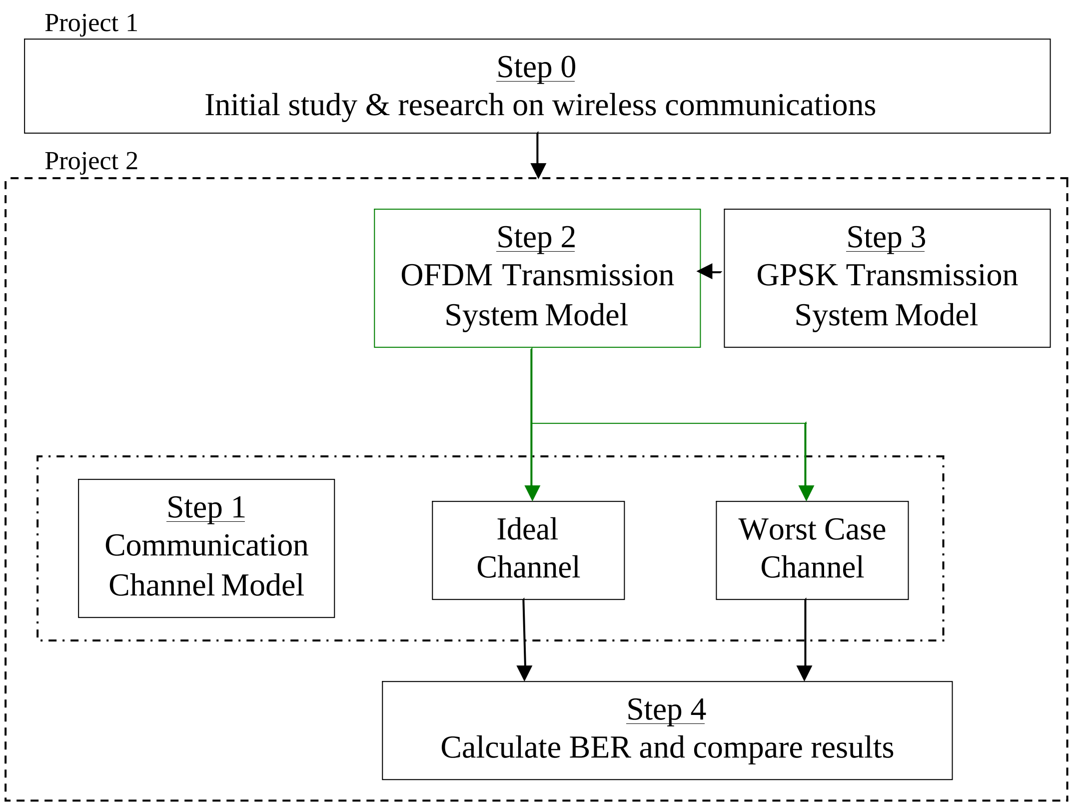

Figure 1.2 Flowchart to calculate BER performance

In Chapter 1, there is an introduction of this project, where it contained history of mobile communication, objectives, scope, motivations and problem statements.

The second chapter, more concentrate on the subject matter which is Orthogonal Frequency Division Multiplexing (OFDM). Extensive research is carried out on the existing wireless communications system and its underlying modulation schemes.

In Chapter 3, concept of the digital modulation scheme is discussed. In this chapter, concentrate more on quadrature PSK since this modulation has been chosen as a digital modulation in OFDM.

Subsequently, the next chapter, Chapter 4, we will focus on communication channel that exists in wireless communication, how the communication channels contribute in the BER performance of OFDM.

The fifth chapter outlines the modeling and simulation of communication channel using MATLAB. Two channels are modeled; they are the ideal communication channel and the worst case communication channel.

In chapter 6, outlines the modeling and simulation of quadrature PSK (QPSK).

While in chapter 7, outline the modeling and simulation of the Orthogonal Frequency Division Multiplexing (OFDM) under different communications channels.

The second last and last chapter will conclude on the results from all the simulations. Discussions and analysis on the results are included in this section.

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