BER PERFORMANCE STUDY OF PSK-BASED DIGITAL MODULATION SCHEMES IN MULTIPATH FADING ENVIRONMENT

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ABSTRACT

Digital modulation is undoubtedly significant portion in wireless communication technology. It allows the transmission of digital data via the air on high frequency carrier waves. The worst case communication channel is usually in the urban environment where there are many obstacles. Due to the obstacles and reflectors, the transmitted signal arrivals at the receiver from various directions over a multiplicity of paths. Such a phenomenon is called multipath. The project studies and identifies the PSK-based digital modulation scheme (BPSK, QPSK or GMSK) 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 simulation programs were written to simulate the channels. Each PSK-based digital modulation understudy are modeled and simulated under different channel conditions. Subsequently, a comparison study is carried out to obtain the BER performance for each PSK-based transmission scheme under 1-path and 4-path multipath fading conditions and to identify which modulation scheme gives best BER performance. The comparison study showed that BER for BPSK and QPSK are similar and they give the lowest BER under multipath fading. Nonetheless, GMSK's BER is just slightly higher than that of BPSK and QPSK. While these three modulation schemes shows high robustness under multipath fading channel, a modulation scheme that can increase transmission rate while keeping high frequency utilization efficiency should the directions of future modulation schemes. Further study on smart and adaptive modulation should also be of interest.

ABSTRAK

Tidak dinafikan bahawa teknik modulasi digital adalah amat penting di dalam teknologi komunikasi tanpa wayar. Teknik ini memungkinkan penghantaran data digital di udara pada gelombang pembawa frekuensi tinggi. Di kawasan bandar, kualiti saluran komunikasi menjadi rendah disebabkan terdapat banyak bentuk halangan. Isyarat yang sampai kepada penerima daripada berbilang sumber adalah disebabkan oleh penghalang dan pembalik. Projek ini mempelajari dan mengenalpasti skim modulasi digital berasaskan PSK (BPSK, QPSK atau GMSK) yang memberikan nilai BER yang terendah dalam persekitaran "multipath fading" menggunakan simulasi komputer. Bertitik tolak dari kes "ideal" dan "worst", model saluran komunikasi adalah dipelajari dan program ditulis untuk simulasi. Setiap modulasi digital berasaskan PSK dimodelkan dan disimulasi berdasarkan kepada saluran yang berlainan. Seterusnya satu kajian perbandingan dijalankan untuk mendapatkan tahap BER bagi setiap skim modulasi berasaskan PSK untuk keadaan saluran "Multipath Fading" untuk menentukan skim yang dapat memberikan tahap BER yang terbaik. Kajian ini menunjukkan bahawa kedua-dua BPSK dan QPSK memberikan tahap BER yang terendah. Manakala bagi GMSK, tahap BER didapati tinggi sedikit daripada BPSK and QPSK. Sementara itu ketiga-tiga teknik ini menunjukkan tahap robustness yang tinggi dalam keadaan multipath fading, teknik lain diperlukan untuk meningkatkan kadar transmissi sementara dapat mengekalkan tahap kecekapan penggunaan frekuensi tinggi. Seterusnya minat kajian lanjutan mungkin akan menjurus kepada "smart and adaptive modulation".

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CHAPTER 1

INTRODUCTION

This project studies the Bit Error Rate (BER) for several PSK based digital transmission schemes used in the mobile wireless communications.

The growing demands for voice and multimedia services on mobile wireless communications spur the advancement of the wireless communication field in the recent decade. The evolving technologies enable this to happen. One of the major underlying technologies is the digital modulation technique which allows digitized data to be carried or transmitted via the analog radio frequency (RF) channels.

Digital modulation techniques contribute to the evolution of our mobile wireless communications by increasing the capacity, speed as well as the quality of the wireless network. 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 even as I write this report. The evolution is depicted in the following figure.

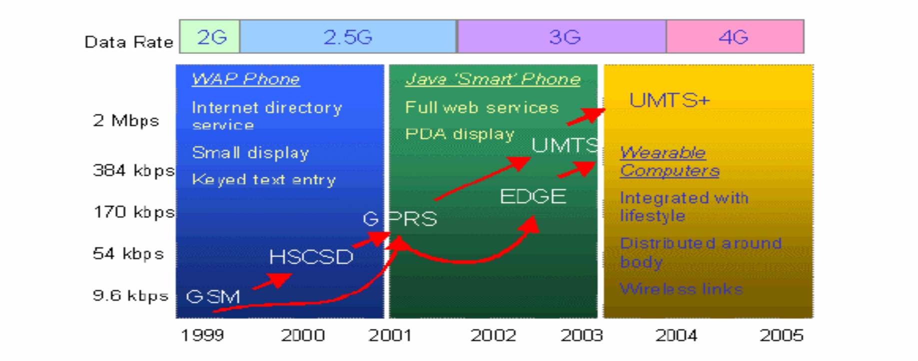

Figure 1.1 Evolution of mobile wireless communications

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 [1, 2] can be categorized into 3 periods:

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

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.

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.

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 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.

1G analog cellular systems were actually 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**.

The first commercial analog cellular systems include Nippon Telephone and Telegraph (NTT) Cellular – Japan, Advanced Mobile Phone Service (AMPS) – US, Australia, China, Southeast Asia, Total Access Communications system (TACS) - UK, and Nordic Mobile Telephone (NMT) – Norway, Europe.

2G digital systems use digital radio channels for both voice (digital voice) and digital control channels. 2G digital systems typically use **more efficient modulation technologies**, including Global System for Mobile communications (GSM), which uses a standard 2-level Gaussian Minimum Shift Keying (GMSK).

Digital radio channels offer a universal data transmission system, which can be divided into many logical channels that can perform different services. 2G also uses multiple access (or multiplexing) technologies to allow more customers to share individual radio channels or use narrow channels to allow more radio channels into a limited amount of radio spectrum band. The 2 basic types of access technologies used in 2G are: frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA). The technologies either reduce the RF channel bandwidth (FDMA), share a radio channel by assigning users to brief timeslot (TDMA), or divide a wide RF channel into many different coded channels (CDMA).

Improvements in modulation techniques and multiple access technologies amongst other technologies inadvertently led to 2.5G and 3G. For example, EDGE can achieve max 474 kbps by using 8-PSK with the existing GMSK. This is 3x more data transfer than GPRS.

1.2 Application of digital modulation techniques

The following table nicely summarizes the various digital modulation techniques used in wireless communications.

Modulation format	Application
MSK, GMSK	GSM, CDPD
BPSK	Deep space telemetry, cable modems
QPSK, $\pi/4$ DQPSK	Satellite, CDMA, NADC, TETRA, PHS, PDC, LMDS, DVB-S, cable (return path), cable modems, TFTS
OQPSK	CDMA, satellite
FSK, GFSK	DECT, paging, RAM mobile data, AMPS, CT2, ERMES, land mobile, public safety
8, 16 VSB	North American digital TV (ATV), broadcast, cable
8PSK	Satellite, aircraft, telemetry pilots for monitoring broadband video systems
16 QAM	Microwave digital radio, modems, DVB-C, DVB-T
32 QAM	Terrestrial microwave, DVB-T
64 QAM	DVB-C, modems, broadband set top boxes, MMDS
256 QAM	Modems, DVB-C (Europe), Digital Video (US)

Table 1.1 Applications for different modulation format

The table also includes video applications that use digital modulation techniques. The numerous modulation formats shown above can be broadly classified into 3 categories:

- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)

- Phase Shift Keying (PSK)

This project concentrates on PSK modulation techniques in which a finite number of phases are used to represent digital data. These will be explained in length in the following chapter.

1.3 Objectives of the project

- To study and compare PSK-based digital transmission schemes used in GSM, GPRS, and 3G
- To design and evaluate PSK based communications systems in a Multipath Fading Channel using computer simulation (MATLAB)
- To obtain and compare the Bit Error Rate (BER) Performance for a few variations of PSK based digital transmission schemes

1.4 Scope of the project

Due to the time constraint of Project 1 and 2, three variations of PSK-based digital transmission schemes used in the current mobile wireless communication are the focus of this project:

- BPSK
- QPSK
- GMSK

1.5 Motivations

The three PSK schemes above are chosen as subject study since they are the basis of all modulation schemes used in the current & upcoming wireless technologies.

By learning to design and evaluate the 3 PSK based communications 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.

This project uses 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 PSK based communications 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
- model and simulate of the transmission system for:
  - BPSK Modulation
  - QPSK Modulation
  - GMSK Modulation
- compute and compare the BER.

1.6 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.

Multipath is a phenomenon that occurs as a transmitted signal is reflected by objects in the environment between the base station and a user. These objects can be buildings, trees, hills, or even trucks, cars and lampposts. 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 PSK scheme (BPSK, QPSK or GMSK) that gives the best BER performance in a multipath fading environment. This project also tries to identify the level (i.e. the number of path in the Multipath Fading Channel) where the PSK modulation schemes are no longer affected by the Signal Energy per bit over noise power density ratio (Eb/No).

1.7 Methodology and Report Structure

This is a simulation project which studied the BER performance for BPSK, QPSK and GMSK transmission schemes. This study involves five main procedures to achieve its objectives. They are the modeling and simulation of the communication channels, BPSK transmission system, QPSK transmission system and GMSK transmission system and lastly calculation and comparison of BER. The following flowchart summarizes the procedures:

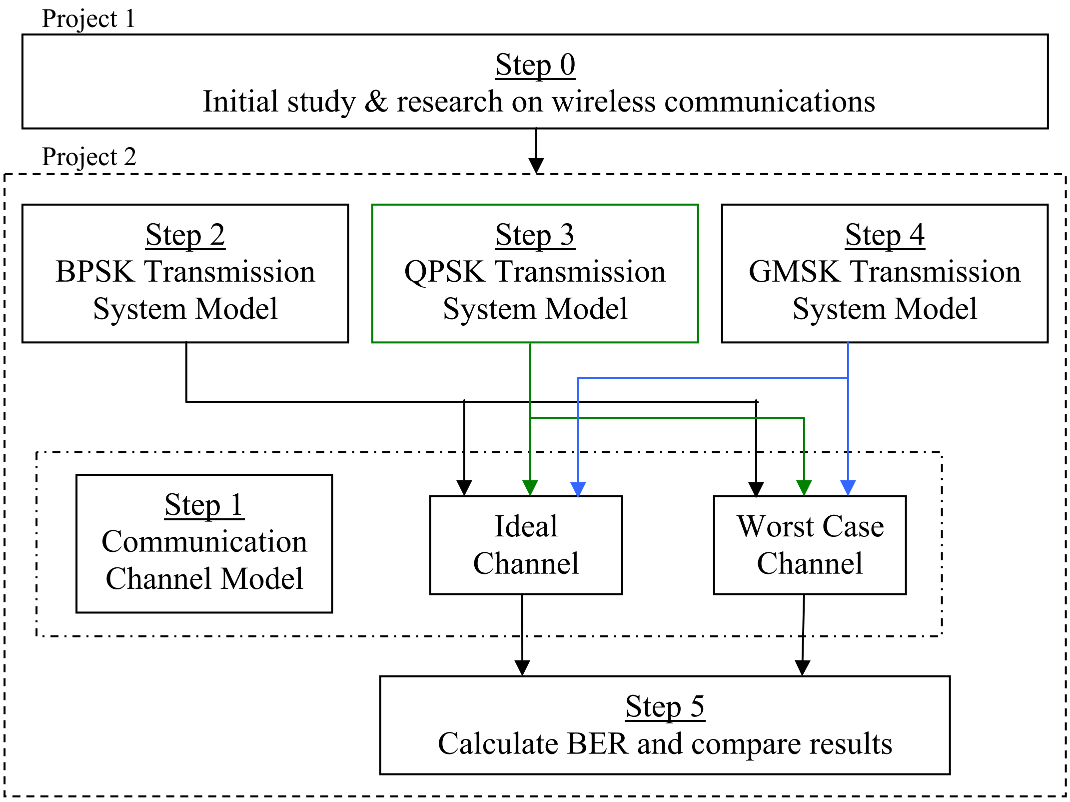

Figure 1.2 Flowchart for multipath fading implementation

Prior to the actual modeling and simulation of the PSK based transmission systems, objectives, scope, motivations and problem statements are identified. This is documented in Chapter 1 together with the overview of the project. The timelines for Project 1 and Project 2 are attached in Appendix A and B.

The second chapter delves deeper into the subject matter which is digital modulation scheme and mobile propagation channel. Extensive research is carried out on the existing wireless communications system and its underlying modulation schemes The PSK-based digital modulation scheme and communication channel under focus are explained in length.

The third 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

Subsequently, the next chapter, Chapter 4, writes about the modeling and simulation of digital transmission systems for BPSK, QPSK and GMSK. This chapter illustrates the mathematical models used to in writing the MATLAB codes. The resulting computer simulation programs were simulated and instances of the signals were taken to verify the programs.

The fifth chapter puts together all the simulation programs written in the previous two chapters to obtain the BER performance for each PSK-based digital transmission system. The two types of communication channels (AWGN and Multipath Channel) are initialized. The PSK-based transmission systems are simulated under the same conditions to obtain the BER performance.

The final section of this report gives all the results obtained throughout the project. Discussions and analysis on the results are included in this section.

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