THE PERFORMANCE OF OFDM IN MOBILE RADIO CHANNEL

TEDDY PURNAMIRZA

A thesis submitted in fulfilment of the requirements for the award of the Degree of Master of Engineering (Electrical-Electronic & Telecommunication)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

APRIL 2005

Dedicated to my beloved Papa and Mama

ACKNOWLEGMENT

First of all, I would like to thank God “Allah SubhanaWaTaala” for his mercy and charity. In preparing this thesis, I have been helped by many people. In particular, I would like to express my deepest appreciation to my supervisor, Encik Amerrudin Baharom for his invaluable guidance in the completion of this thesis. Special thanks to Accociate Prof. Dr. Norsheila Fisal, Accociate Prof. Dr. Mazlina and Dr. Kamal for their suggestions and correction to my thesis.

My appreciation, thanks and love to Papa and Mama and all my family members who always give me support and love. To someone that always give me inspiration

Many thanks to all my course mates especially to Hafiz, Samsul, Kseven, Lester for their friendship and kindliness. You all are the best.

Last but not at least, I would like to address my thanks to my hostel mates, “Tun Safar” for his delicious mie ayam, to Aan and bang Herman for their asam padeh dagiang, to Doni for his salty sala lauak, to Mr Liem, don’t know when we will play badminton again, to Jasril and bang Nesdi who helped me when I first arrived in Johor. Also to all people that I can not mention their names one by one that have directly or indirectly help me in completing my study and thesis.

ABSTRACT

OFDM as a transmission technique has been known having a lot of strengths compared to any other transmission technique, such as its high spectral efficiency, its robustness to the channel fading, its immunity to impulse interference and its ability in handling very strong echoes.

It is mentioned in several papers and by the OFDM theory itself that because of its strength, OFDM can overcome the effect of several radio impairment factors such as the effect of AWGN, impulse noise, multipath fading, etc. In addition, several papers proposed OFDM as a transmission technique either in fixed or mobile radio channel. The efficacy of OFDM implementation in many areas such as DAB (Digital audio Broadcasting), DVB (Digital Video Broadcasting) and Wireless LAN has gained its popularity.

This project is to study and investigate the effect of some radio channel impairment factors to the performance of OFDM as well as to study and investigate the performance of OFDM in mobile radio channel including rural channel, urban channel, terrain channel and rician channel.

ABSTRAK

OFDM merupakan suatu teknik perhubungan yang terkenal mempunyai kelebihan tersendiri berbanding dengann teknik perhubungan lainnya, contohnya ia mempunyai efesiensi spekra yang tinggi, keteguhan terhadap pemudaran saluran komunikasi, kekebelannya terhadap gangguan impuls dan kemampuannya menangani echo.

Beberapa kertas penyelidikan dan teori OFDM menyatakan bahawa disebabkan oleh kelebihannya, OFDM mampu mengatasi kesan kesan yang disebabkan oleh faktor faktor penjejasan perhubungan radio, seperti AWGN, gangguan hingar impuls, kesan berbilan laluan dan lain lain. Tambahan pula, beberapa kertas penyelidikan mengusulkan OFDM sebagai teknik perhubungan sama ada untuk saluran radio tetap mahupun saluran radio bergerak. Kejayaan penerapan OFDM diberbagai aplikasi seperti DAB, DVB dan wireless LAN menyebabkan ia semakin populer.

Projek ini bertujuan untuk menyelidiki dan memahami kesan faktor faktor penjejasan terhadap prestasi OFDM dan menyelidiki prestasi OFDM didalam saluran radio bergerak, meliputi saluran kawasan terpencil, saluran kawasan bandar, saluran kawasan terbuka dan saluran rician.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

K	-	Discrete frequency (0 to N-1)
n	-	Time sample
m	-	OFDM carrier
N	-	IFFT bin size
θ_m	-	Phase modulation for OFDM carrier
cfirst	-	OFDM carrier (first)
clast	-	OFDM carrier (last)
π	-	phi (3.14 rad)

LIST OF APPENDICES

LIST OF ABBREVIATIONS

OFDM	-	Orthogonal Frequency Division Multiplexing
DVB	-	Digital Video Broadcasting
DAB	-	Digital Audio Broadcasting
LAN	-	Local Area Network
PAPR	-	Peak to Average Power Ration
BPSK	-	Binary Phase Shift Keying
QPSK	-	Quadrature Phase Shift Keying
16PSK	-	16 Phase Shift Keying
COFDM	-	Coded Orthogonal Frequency Division Multiplexing
FDMA	-	Frequency Division Multiple Access
TDMA	-	Time Division Multiple Access
ICI	-	Inter Carrier Interference
DMT	-	Discrete Multi Tone
MCM	-	Multi Carrier Modulation
DFT	-	Discrete Fourier Transform
QAM	-	Quadrature Amplitude Modulation
CNR	-	Carrier to Noise Ratio
HDSL	-	High bit rate Digital Subscribers Line
VHDSL	-	Very High speed Digital Subscriber Line
HDTV	-	High Speed Digital Television
FFT	-	Fast Fourier Transform
IFFT	-	Inverse Fast Fourier Transform
AWGN	-	Additive White Gaussian Noise
SNR	-	Signal to Noise Ratio
ISI	-	Inter Symbol Interference
BER	-	Bit Error Rate
FEC	-	Forward Error Correction
RF	-	Radio Frequency

FM	-	Frequency Modulation
UHF	-	Ultra High Frequency
CDMA	-	Code Division Multiple Access
DBPSK	-	Differential Binary Phase Shift Keying
DQPSK	-	Differential Quadrature Phase Shift Keying
D16PSK	-	Differential 16 Phase Shift Keying

CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, the mobile telecommunications industry faces the problem of providing the technology that be able to support a wide variety of services ranging from voice communication with a bit rate of a few kbps to wireless multimedia in which bit rate up to 2 Mbps. In order to support that kind of technology, third generation (3^{rd}) for mobile communication is now being developed, and still not be mature yet.

Several systems have been proposed as candidate for the 3^{rd} generation mobile telecommunication system, OFDM is one of proposed system that have a lot of attentions for some reasons.

The first reason is that the successful implementation of OFDM in several applications. OFDM has successfully been implemented in the wireless broadcasting applications such as DVB (Digital Video Broadcasting) and DAB (Digital Audio Broadcasting). Recently, OFDM has been successfully used in wireless LAN application. Standard such as IEEE 802.11a and HIPERLAN/2 are the results of the growing interest in OFDM. [1]

The second reason is that OFDM has a lot of advantages compared to the conventional systems. OFDM uses spectrum efficiently by spacing its carriers as close as possible, this is enabled by making the carriers orthogonal to each other.

Since OFDM can overcome the effect of multipath fading by using a guard period, OFDM need only a simple equalization method in combating selective fading channels [2]. The weakness of an OFDM system is its sensitivity to frequency offset and its high Peak to Average signal Power Ratio (PAPR) [1].

Since OFDM has a lot of advantages compared to conventional systems and the successfulness of its implementation, therefore it is interesting and challenging to investigate the cha racteristic and performance of this systems in mobile radio channel.

1.2 Objective

The main objective of this project is to study and investigate the effect of several radio channel impairment factors to the performance of OFDM system as well as to study and investigate the performance of OFDM in mobile radio channel.

1.3 Scope of Project

The scope of this project is limited to OFDM system with IFFT size 512 and number of carrier 200. The guard period type used is a cyclic extension of symbol where has the length of 20 percents of length of symbol. The useful part of OFDM symbol is 40 *us* and the length of guard period is 8 *us*. The carrier spacing is 1/40 *us* = 25 KHz so that the 5 MHz bandwidth is occupied with 200 carrier. The total symbol rate of this system is 40/48x 5 MHz = 4.166 Msps.

In this project, The OFDM transceiver used three modulation techniques those are BPSK, QPSK and 16 PSK to show the trade off between system capacity and system robustness. The mobile radio channel is modeled based on model that explained in subchapter 3.3 and its delay profile parameter is taken from reference 28.

The OFDM system is simulated using Matlab 6.5 and all the simulation results are represented in term of Bit Error Rate (BER) in 2-D graph.

1.4 Organization of Thesis

The first chapter briefly introduces this project by explaining the project background, objectives and scope of project.

Second chapter were written based on study literature reading, covering the explanation of basic theory of OFDM transceiver and radio mobile channel.

Third chapter explains about the model of OFDM system including OFDM transmitter, OFDM receiver, and mobile radio channel. The simulation parameters that were used in this simulation and the OFDM model program flowcharts are also explained

The simulation results and its analysis are presented in chapter four along with its conclusions.

Chapter 5 concludes the analysis results and propose some future works that can be done in order to dig this project deeper and wider.

CHAPTER 5

CONCLUSION AND FUTURE WORK

As the conclusion, the objectives of this project have been achieve. The study and investigation on the performance of OFDM signal in mobile radio channel including rural channel, urban channel, terrain obstructed channel and rician channel have been done as well as the study and investigation several effect of radio channel impairment factors such as AWGN, impulse noise, delay spread.

Below are the conclusion of about the study results:

- Since OFDM is not intended to combat the noise effect, it is observed and concluded that the performance of OFDM is similar to a standard single carrier digital transmission

- OFDM signal is resistant enough to clipping distortion caused by nonlinearity in power amplifier

- The effect of multipath can be eliminated by using guard period, as long as guard period is longer than delay spread.

- OFDM signal can tolerate impulse noise

- OFDM for this particular simulation shows good enough performance in rural, urban and rician channel

- For this particular simulation, OFDM signal can not be used in rural channel. To make it acceptable in rural channel, it is needed to add guard period time longer than delay spread (16 *us*)

- Mobile velocity does not effect significantly to the performance of OFDM.

Although the objective of this project has been achieved successfully, it is still need further study in order to dig this project deeper and wider. Several suggested future works that can be done are listed below

- In this project, several factors including the effect of AWGN, clipping, delay spread and impulse noise have been simulated, more work can be done on investigating the effect of frequency stability error, the effect of phase offset and the effect of phase noise

- In this project, OFDM was simulated in its basic system without applying any error correction method, equalization and interleaving. Future work can be done on investigating the effect of these factors in order to increase the performance of OFDM.

- Future work can be also done on comparing the performance of OFDM using different modulation techniques

REFERENCES

1. Martoyo, H.Shober, F. Jondral, CDMA versus OFDM, A performance comparison in selective fading channels. IEEE 7th Int. Symposium on spread spectrum tech & appl, Prague, Czech Republic page 139. Sept 2002

2. Louis Litwin, An introduction to multicarrier modulation, IEEE Potential vol 19, no 20 April-May 2000

3. L. Thibault, G.Soulodre, and T.Grusec, "EIA/NRSC DAR System Subjective Test Part II: Transmission Impairments," IEEE Trans Broadcasting Vol 43, No 4, December 1997, pp 353-369.

4. R.W. Chang, "Synthesis of band-limited orthogonal signals for multichannel data transmission system, " Bell sys, tech. J., Vol.45, pp.1775-1796, Dec. 1996

5. B.R. Saltzberg, " Performance of an efficient parallel data transmission system," IEEE Trans Com Technol, vol COM-15, Dec 1967

6. R.R. Mosier and R.G. Clabaugh, " Kineplex, a bandwidth efficient binary transmission system, " AIEE Trans, vol 76, pp 723-728, Jan 1958

7. M. S. Zimmerman and A.L. Kirsch, “ The AN/GSC-10 (KATHRYN) variable rate data modemfor HF radio, “ IEEE Trans Commum Technol, vol.COM-15, pp 197-205, Apr 1967

8. P.A Bello, “Selective fading limitation of the Kathryn modem and some system design consideration, “ IEEE Trans Commun Technol, vol COM-13, pp320-333, September 1965

9. G.C. Porter, Error distribution and diversity performance of a frequency differential PSK HF modem, “ IEEE Trans Commun Technol, vol COM-16, pp567-575, Aug 1968.

10. Weinstein, S.B and Ebert. P. M, “Data transmission by frequency division multiplexing using the discrete Four ier transform”, IEEE Trans Comm Technology, vol COM-19, No 15, Oct 1971.

11. Hirosaki B, “An orthogonally multiplexed QAM system using the discrete Fourier transform,”IEEE Trans Commun, vol COM-29 pp 982-989, July 1981

12. S. Hirosaki, S. B Hasegawa and A Sabato, “ Advanced groupband data modem using orthogonally multiplexed QAM technique, “ IEEE Trans Commun, vol COM-34, pp-34, pp 587-592, June 1986

13. W.E Keasler and D.L. Bitzer, " High speed modem suitable for operating with a switched network," US patent No 4,206,320, June 1980

14. Telebit Corporation, " Comparative performance results for asymmetrical duplex, V.32 (extended), and multicarrier modems," CCITT SG XVII, Contribution D56, Sept 1989.

15. E. Feig and F. Mintzer, " Sequence transmission: Coding in frequency domain, " IBM Res Rep RC 13701, IBM T. J. Watson Res. Cen, Mar 1998.

16. R.V Paiement, "Evaluation of single carrier and multi carrier modulation techniques for digital ATV terrestrial broadcasting

17. Nogueroles, R. Bossert, M, Donder, A and Zyablov, V. "Improved performance of a random OFDMA mobile communication system", IEEE conference proceeding VTC, 1998

18. E.F. Casas and C.Leung, " OFDM for data communication over mobile radio FM channels-part 1: analysis and experimental results" IEEE Trans Commun vol COM 39 No 5 May 1991

19. P.S Chow, J.C. Tu and J.M. Cioffi, " Performance evaluation of a multi channel transceiver system for ADSL and VHDSL services, " IEEE J. Selected area commun, Vol SAC-9 No 6 pp 909-919

20. William Y Zou and Yiyan Wu, " COFDM: An Overview" IEEE Transaction on Broadcasting", Vol 41 no 1, March 1995

21. Erich Cosby, OFDM Simulation (matlab), 2001 Virginia Tech. Northern Virginia Center

22. J. H. Stott, The how and why of COFDM, 1998

23. Who Is Fourier?, The Transnational College of Lex, Language Research Foundation (available at amazon.com), 1995

24. Eric Lawrey, Thesis, The suitability of OFDM as a modulation technique for wireless telecommunications, with a CDMA comparison, 1997

25. M. Beach, "Propagation and System Aspects", University of Bristol, Future Communication System course, April 1994

26. T.S Rappaport, "Wireless Communication Principles & Practice", IEEE Press, New York, Prentice Hall, pp 169-177, 1996

27. T. N. Zogakis, P. S. Chow, J. T. Aslanis, J. M. Cioffi,"Impulse Noise Mitigation Strategies" Communications, 1993. ICC 93. Geneva. Technical Program,

Conference Record, IEEE International Conference on , Volume: 2 , Pages:784 - 788 vol.2, 23-26 May 1993

28. L. Thibault, G.Soulodre, and T.Grusec, “EIA/NRSC DAR System Subjective Test Part II: Transmission Impairments,” IEEE Trans Broadcasting Vol 43, No 4, December 1997, pp 353-369.