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By

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LIST OF ABBREVIATIONS

AGC	Automatic Gain Control
ASK	Amplitude Shift Keying
BASK	Binary ASK
BER	Bit Error Rate
BFSK	Binary FSK
BPSK	Binary PSK
BS	Base Station
CDMA	Code Division Multiple Access
CT	Cordless Telephone
CT2	Cordless Telephone 2nd Generation
DECT	Digital European Cordless Communication
DQPSK	Differential QPSK
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FSK	Frequency Shift Keying
GMSK	Gaussiam Minimum Shift Keying
GSM	Global System for Mobile Communication
IF	Intermediate Frequency
ISI	Intersymbol Interference
ITU	International Telecommunication Union
LNA	Low Noise Amplifier
LO	Local Oscillator

LO2	Second Local Oscillator
LOS	Line-of-Sight
MDS	Minimum Detectable Signal
NF	Noise Figure
NRZ	Non-Return to Zero
PA	Power Amplifier
PM	Phase Modulation
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quaternary Phase Shift Keying
RF	Radio Frequency
SAW	Surface Acoustic Wave
SNR	Signal-to-Noise Ration
TDMA	Time Division Multiple Access
UHF	Ultra High Frequency
VCO	Voltage Controlled Oscillator

Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfillment of the requirements for the Degree of Master of Science.

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By

CHUAH KHAR-YEE

November 1996

Chairman : Dr. Borhanuddin Mohd. Ali

Faculty : Engineering

There are few factors that contributes to the commercial failure of the Cordless Telecommunication 2nd Generation (CT2) system. Amongst those factors are the limitations and inefficiency of the system, such as cell size, bit-error-rate, throughput and bandwidth efficiency. The aim of this study is therefore to propose a modulation technique that could potentially overcome some of the above mentioned limitations.

To model the system, a reliable data transceiver using Differential Quaternary Phase Shift Keying (DQPSK) modulation technique was designed and simulated using HP-EESof Microwave System Simulator called OmniSys. Two frequency

spectrum, namely 1-GHz and 5-GHz, which are commonly used in cellular phones and satellite communications respectively, have been selected for analysis. However, because of the higher propagation path loss for 5-GHz, only the 1-GHz system was selected for further investigation in this thesis, as a proposed frequency to improve the CT2 system.

Simulations of the DQPSK transceiver at 1-GHz have shown that bit-error-rate (BER) of 10^{-6} or better could be achieved compared to 10^{-3} in CT2. This is suitable for data transceiver with a minimum receive power (Rx_PWR) of -60dBm. The coverage also improved from 200 meters (maximum radius for CT2) to 1250 meters with acceptable transmit power (<35dBm).

The simulation also showed that the throughput (T_p) of 120 Kbit/s can be achieved compared to 72 Kbit/s for CT2 system and the bandwidth efficiency can be improved from 0.72 bit/Hz for CT2 system to 1.46 bit/Hz for the proposed system.

Thus, from these simulation results, the aim of proposing a modulation technique to improve CT2 system has been achieved. The performance of the reliable data transceiver using DQPSK modulation technique operating at 1-GHz has found to be satisfactory.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi keperluan untuk Ijazah Master Sains.

REKABENTUK DATA PEMANCAR-PENERIMA DENGAN MENGGUNAKAN TEKNIK MODULASI DIFFERENTIAL QUATERNARY PHASE SHIFT KEYING (DQPSK)

Oleh

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Terdapat beberapa faktor yang menyumbang kepada kegagalan Telekomunikasi Mudahalih Generasi Kedua (Cordless Telecommunication 2nd Generation, CT2), namun faktor-faktor utama adalah akibat had-had serta ketidakberkesanan sistem, seperti saiz sel, kadar ralat bit, "throughput" dan kekesanan lebarjalur. Tujuan kajian ini adalah untuk mencadangkan satu teknik modulasi yang berpotensi untuk mengatasi had-had seperti yang dihuraikan diatas.

Untuk memodelkan sistem tersebut, satu pemancar-penerima (transceiver) data Differential Quaternary Phase Shift Keying (DQPSK) telah direka dan

disimulasikan menggunakan Penyelaku Sistem Gelombang Mikro HP-EESof (HP-EESof Microwave System Simulator) yang dekenali sebagai OmniSys. Dalam proses rekabentuk, 2 jalur spektrum frekuensi iaitu 1-GHz dan 5-GHz yang lazim digunakan dalam telefon bimbit dan komunikasi satelit, telah dipilih untuk analisis dalam tesis ini. Tetapi, olehkerana sistem 5-GHz menghadapi kehilangan perambatan yang tinggi, maka frekuensi 1-GHz telah dipilih untuk kajian selanjutnya dalam tesis ini sebagai satu frekuensi yang sesuai untuk memajukan sistem CT2.

Hasil simulasi bagi sistem 1-GHz telah menunjukkan bahawa kadar ralat bit (BER) 10^{-6} atau lebih baik boleh diperolehi berbanding dengan 10^{-3} dalam CT2. Ini adalah sesuai untuk pemancar-penerima data dengan kuasa penerima minimum (Rx_PWR) pada -60dBm. Kawasan liputan juga dapat dipertingkatkan dari 200 meter radius maksima (untuk CT2) kepada 1250 meter dengan kuasa pemancar sederhana (<35 dBm).

Simulasi juga menunjukkan bahawa throughput (T_p) pada 120 kbit/s boleh dicapai berbanding dengan 72 kbit/s bagi sistem CT2 dan kekesanan lebarjalur boleh dipertingkatkan dari 0.72 bit/Hz bagi sistem CT2 kepada 1.46 bit/Hz bagi pemancar-penerima data menggunakan teknik modulasi DQPSK yang dicadangkan.

Oleh itu berdasarkan kepada analisi hasil simulasi, tujuan utama dalam mencadangkan satu teknik modulasi untuk memperbaiki sistem CT2 telah tercapai. Pencapaian bagi data pemancar-penerima yang menyakinkan dengan menggunakan teknik modulasi DQPSK yang beroperasi pada 1-GHz didapati juga adalah memuaskan.

CHAPTER I

INTRODUCTION

Communication engineers have long recognized the need to maximize the usage of expensive communication equipments and effective use of available bandwidth to minimize the blocking probabilities without sacrificing the quality and the performance of the systems (Tobagi et al., 1978; Kahn at el., 1978).

There are two main multiplexing techniques, partitioning the channel into separate non-overlapping frequency sub-bands or by scheduling each user's transmission to occur in short non-overlapping intervals in time. The first technique is called Frequency Division Multiple Access (FDMA). Each user has access to a dedicated portion of the channel at all times. In the second case, known as Time Division Multiple Access (TDMA), each user has access to the whole channel for only a fraction of the time.

To achieve effective use of available bandwidth, channel (frequency) reuse after a small distance can be achieved in FDMA system by implementing a micro cellular structure with a cell size as small as possible. This technique has been adapted in Cordless Telephone Second (CT2) generation standard (Kahn et al., 1978; Tan et al., 1993; Bersekas and Gallager, 1992). Transmissions using FDMA with Frequency Division Duplex (FDD) are widely used on first generation analogue cellular mobile radio systems. For FDMA/FDD technique, there is a group of n contiguous sub-bands occupying a bandwidth W Hz for forward or down-link radio transmissions from a Base Station (BS) to its Mobile Stations (MS), and a similar group of n sub-bands for the reverse or up-link transmissions from the MSs to their BS. For cordless telecommunication (CT), FDMA/TDD is used. In this arrangement, only one band is provided for mobile transmission, so the time frame structure is used allowing transmission to be done during one half of the frame while the other half of the frame is available to receive signal (Steele, 1995).

The efficiency of TDMA system can be improved by sending data packet by packet to improve the throughput and blocking of the system. Packet radio is a technology that extends the application of packet switching (Kahn et al., 1978; Bersekas and Gallager, 1992). Studies have shown that transmitting very long messages as units in a subnet is harmful in several ways, including delay, buffer management, error and congestion control. Thus, message represented by long string of bits can be broken into shorter bit string called packet. A packet of information includes all the addressing and controlling information based on X.25 standard from International Telecommunication Union (ITU). Comprehensive introduction to switching and packet format can be found in many textbooks including Bersekas and Gallager [1992], Cuthbert and Sapanel [1993] and Stallings [1990].

The rapid development in packet radio has been greatly stimulated by the need to provide mobile data communication equipments. Packet radio offers a highly efficient way of using a multiple access channel, particularly with a large number of mobile subscribers and users with bursty traffic. In general, packet radio network services and capabilities include transparency, area coverage and connectivity, mobility, throughput and low delay, rapid and convenient deployment, error control, routing option and addressing option (Kahn et al., 1978).

Recently, with the growth of digital communication equipments, notebook computers and the explosive increase of travel and time management have increased the need of mobile digital communications. Because frequency spectrum suitable for mobile communication is limited, therefore there is a need for communication engineers to pack as many bits as possible into the allocated frequency spectrum. To further maximize the bandwidth efficiency and improve the use of communication equipments, the combination of both FDMA and TDMA multiplex techniques have been widely used as well. The approach where TDMA/FDMA operates with FDD is employed by the Global System for Mobile Communication (GSM) and the Digital European Cordless Telecommunication (DECT) networks uses TDMA/TDD/FDMA approach (Yamauchi, 1994; Jagoda and Villepin, 1993).

Beside FDMA and TDMA, Code Division Multiple Access (CDMA) is another method that allows multiple users to access the mobile radio communication network. The system allows each user to use the bandwidth like FDMA and for the complete duration of the call like TDMA. Although CDMA has been well understood for a long time, its use in cellular radio had been avoided mainly due to the problem associated with the power control. Other problems sited were whether there are sufficient codes available for larger number of mobile users, and difficulties of synchronization. Comprehensive introduction to switching and packet format can be found in many text books including Steele [1995] and, Pahlavan and Levesque [1995].

Limitation in Communication

Since the frequency spectrum suitable for mobile communication is so limited, a lot of studies have also been carried out in the area of data compression techniques to reduce the number of bits required to send a given message, better modulation techniques to improve bit rate per unit bandwidth hence to maximize the use of frequency spectrum.

The goals (Sklar, 1988) of the communication designer to use the frequency spectrum (bandwidth) effectively are clear, and they are;

- to maximize transmission bit rate, B_R
- to minimize probability of bit error, P_B
- to minimize required system bandwidth, BW
- to minimize required power, or equivalently to minimize required bit energy to noise power spectrum density E_b/N_o
- to maximize system utilization, or equivalently to provide reliable service for a maximize number of users, N_u

However there are several constraints and theoretical limitations such as;

Table 1 Key Parameters for Cordless Telecommunication 2nd Generation

Parameters	
Frequency band	800 - 1000 MHz
Multiple Access	FDMA
Duplex	TDD
Carrier Spacing	100 kHz
Modulation	GMSK
Bit Rate	72 kbit/s
Maximum Coverage	200 meters
Bit Error Rate (BER) @ -94dBm	10^{-3}
Hand-off	No

There are few factors that contributed to the failure of CT2 system; technical issue, marketing and commercial errors. Technical issue was attributable to the delay of formulating the specification. Amendments to the 1989 standard were not published until the next year, thereby delaying product development and marketing (Jagoda and Villepin, 1993). However, the failure of CT2 system were mainly due to the following factors (Pahlavan, and Levesque, 1995);

- with a channel spacing of 100 kHz, the bandwidth efficiency of CT2 is only 0.72 bit/sec/Hz, which is very inefficient.

- the system was designed mainly for voice (BER of 10^{-3}). With the growth of notebook computer, transceiver with minimum BER of $<10^{-6}$ is required to send data.

- the system allows to initiate but not receive calls and the system cannot provide call handoff to another base station.

- the coverage is too small, therefore call must be made next to base station. Due to small coverage, users need to find where Telepoints are before making call.

Objective of the Study

The main purpose of this thesis is to design a Reliable Data Transceiver Using Differential Quaternary Phase Shift Keying (DQPSK) Modulation Technique that could potentially solve the frequency bandwidth limitation in digital portable communication. Based on Shannon's theorem (Chapter 2), 16-QAM (16-Quadrature Amplitude Modulation) can provide higher bit rate per bandwidth than DQPSK, however, the additional complexity of 16-QAM may cancel the benefits associated with this observation. Due to its advantages, DQPSK still find wide application in high speed carrier modulation data transmission systems.

In this investigation, the modulation technique, throughput, coverage and error performance (Bit Error Rate, BER) of a hand held transceiver have been studied using an available microwave simulation software. To investigate the system, a few parameters (Table 2) are set for the project.

Table 2 Design Specification for Reliable Data Transceiver

		Targeted
1.	Modulation Technique	DQPSK
2.	Carrier Frequency, F_c	1000 MHz
3.	Throughput, T_p	$\geq$ 100 KBit / sec
4.	Coverage, Radius	$\geq$ 1000 meters
5.	Receive Sensitivity	$\leq$ -60 dBm
6.	Error Performance, P_e	$\leq 10^{-6}$ @ $E_b/N_o \leq 20$ dB

For a fair comparison, the carrier frequency for the proposed reliable data transceiver was set at 1000 MHz. To ensure the system has higher throughput compared to CT2 (72 Kbit/s), the minimum throughput for the system was predetermined at 100 Kbit/s. For coverage, 1000 meters (radius) was selected since this is the normal cell size for high frequency cellular. To design a reliable data transceiver, $\leq$ -60 dBm and $\leq 10^{-6}$ were predetermined for receive sensitivity and error performance (P_e) respectively.

The Goal of Study and Organization of Dissertation

The overall goal of the study is to propose a system that could potentially overcome the limitations of the CT2 system. Several simulation studies using HP-EESof Microwave System Simulator called OmniSys were conducted to validate the proposed system.

In this report, first a brief literature review and background theory are presented in Chapter 2. Overall transceiver designs using OmniSys are given in Chapter 3, while Chapter 4 discusses how the system test bench is assembled to analyze the performance of the transceiver. The simulation results and discussion is presented in Chapter 5, and summary and conclusion of this thesis in this area of study will be given in Chapter 6.

CHAPTER II

LITERATURE REVIEW

Noise in Communication Systems

Noise, in the broadest sense, can be defined as any unwanted disturbance that obscures or interferes with a desired signal, and make it more difficult to extract the information (Motchenbacher, and Connelly, 1993). In general noise is a totally random signal and it consists of all frequency components that are random in both amplitude and phase therefore it cannot be predicted exactly, nor can it be totally eliminated, but it can be manipulated and its effects minimized. If the instantaneous amplitude of noise can be predicted, noise would not be a problem in electrical system anymore. Although noise cannot be predicted, but much noise has a Gaussian or normal distribution of instantaneous amplitude with time.

Noise is the major factor that limits the performance of communication systems (Freeman, 1991). In communication systems, noise can be grouped into 4 categories; thermal noise, inter-modulation noise, crosstalk and impulse noise.