UNIVERSITI PUTRA MALAYSIA

# IMPROVEMENT OF A DYNAMIC FREQUENCY HOPPING OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEM USING POWER CONTROL METHOD

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# IMPROVEMENT OF A DYNAMIC FREQUENCY HOPPING OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEM USING POWER CONTROL METHOD

**By**

**WAMIDH J. MAZEHR ALGALBI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of Requirements for the Degree of Master of Science**

**October, 2009**

**Dedicated to**
**My dearest Family**
**For their extraordinary love and their endless care**
**Thank You**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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**October, 2009**

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In this thesis, adaptive power control method is proposed to improve the performance of dynamic frequency hopping-optical code division multiple access (DFH-OCDMA) communication system. This method is based on solving the near-far problem of power misdistribution among simultaneous users. The DFH-OCDMA has an advantage of supporting more users compared to other OCDMA techniques such as Hadamard code, modified quadratic congruence code, modified frequency hopping code, and fast frequency hopping system. Nevertheless, the bit error rate (BER) was found to deteriorate rapidly with a slight change of received power compared to the other techniques. With the change of the received power (i.e. from -10 dBm to -12 dBm), the BER could be degraded from $10^{-9}$ to $10^{-6}$. This phenomenon is strongly related to near-far problem, where users at longer path lengths will suffer higher BER compared to users at shorter path lengths. The unequal power distribution among users leads to unequal performance for them. This may cause to not all users can be supported in the

transmission system. Therefore, this study is aimed to search for a solution to increase the number of users under the DFH-OCDMA system with near-far problem.

A distributed power control algorithm was proposed to enhance the performance of the system and this was done by considering all possible noises such as the multiple access interference, phase induced intensity noise, and shot noise. The performance of the system was also observed at different issues of fibre impairments, including fibre attenuation, and optical components. The results gathered from the simulations showed that BER and signal-to-noise-ratio (SNR) for each user were significantly improved after using the power control. In specific, it is observed that the best capacity increased was 51% when the random path lengths for 110 users was between 1 to 40 km. Thus, the power control method is proven as an important enhancement to DFH-OCDMA performance. Moreover, the number of users increased in the DFH-OCDMA system with power control was 56 users while at prime code OCDMA and time hopping, only 20 users increment with power control. This result therefore shows better improvement of capacity in DFH-ODCMA compared to other Power Controlled-OCDMA.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah master Sains

**PEMBAIKAN SISTEM LOMPATAN FREKUENSI DINAMIK PENCAPAHAN KOD PELBAGAI AKSES OPTIK MENGGUNAKAN KAWALAN KUASA KAEDAH**

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Di dalam tesis ini, suatu kaedah kawalan kuasa adaptif telah diusulkan untuk memperbaiki prestasi sistem komunikasi lompatan frekuensi dinamik – multipleksi kod pelbagai akses optik (DFH-OCDMA). Kaedah ini berdasarkan penyelesaian masalah hampir-jauh bagi ketidakseimbangan kuasa di kalangan pengguna-pengguna serentak. DFH-OCDMA mempunyai kelebihan berbanding kaedah OCDMA lain seperti kod Hadamard, kod kongruens kuadratik terubahsuai, kod lompatan frekuensi terubahsuai, dan kod lompatan frekuensi cepat. Walaubagaimanapun, kadar ralat bit (BER) kod ini merosot lebih cepat dengan perubahan kuasa yang diterima berbanding kaedah-kaedah lain. Dengan mengubah kuasa penerima (iaitu daripada -10dBm kepada -12 dBm), akan mengakibatkan kemerosotan BER daripada $10^{-9}$ kepada $10^{-6}$. Fenomena ini amat berkait rapat dengan masalah hampir-jauh, di mana pengguna yang berada pada panjang laluan yang lebih jauh akan mempunyai BER yang lebih tinggi berbanding pengguna yang berada pada panjang laluan yang lebih hampir. Ketidakseimbangan kuasa di kalangan

pengguna tersebut menjurus kepada prestasi yang berbeza kepada mereka. Ini akan menyebabkan tidak semua pengguna dapat disokong dalam sesebuah sistem penghantaran. Oleh itu, kajian ini bertujuan untuk mencari penyelesaian bagi menambah bilangan pengguna di bawah sistem DFH-OCDMA yang mempunyai masalah hampir-jauh.

Sebuah algoritma kawalan kuasa berselerak telah dicadangkan untuk memperbaiki prestasi sistem ini dengan mengambil kira semua punca hingar seperti interferens akses pelbagai, hingar intensiti berpunca fasa, dan hingar tertembak. Prestasi sistem dipantau dari segi isu-isu kecacatan gentian yang berbeza termasuk pengecilan dalam gentian, dan komponen optikal. Hasil simulasi telah menunjukkan bahawa BER dan nisbah-isyarat-kepada-hingar (SNR) bagi setiap pengguna telah diperelokkan secara signifikan setelah menggunakan kawalan kuasa. Secara terperinci, didapati bahawa penambahan kapasiti terbaik adalah sebayak 51%, apabila panjang laluan rawak bagi 110 pengguna serentak berukuran antara 1 hingga 40 km. Oleh itu terbukti bahawa kawalan kuasa adalah penting bagi penambahan prestasi DFH-OCDMA. Malahan, bilangan pengguna yang bertambah dalam DFH-OCDMA dengan kawalan kuasa adalah sebanyak 56 manakala bagi kod prima OCDMA dan lompatan masa, hanya 20 pertambahan pengguna dengan kawalan kuasa. Keputusan ini seterusnya menunjukkan penambahbaikan kapasiti yang lebih tinggi dalam DFH-OCDMA berbanding kawalan kuasa OCDMA yang lain.

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I certify that a Thesis Examination Committee has met on **23-10-2009** to conduct the final examination of **WAMIDH J. MAZEHR ALGALBI** on his thesis entitled "**IMPROVEMENT OF A DYNAMIC FREQUENCY HOPPING OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEM USING POWER CONTROL METHOD** "in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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## DECLARATION

I declare that the thesis is my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

**WAMIDH J. MAZEHR ALGALBI**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ASE | Amplified Spontaneous Emission |
| BER | Bit Error Rate |
| BS | Base Station |
| CDMA | Code Division Multiple access |
| CPC | Centralized Power Control |
| DCF | Dispersion Compensating Fiber |
| DFH | Dynamic Frequency Hoping |
| DPC | Distributed Power Control |
| DS | Direct Sequence |
| FFH | Fast Frequency Hoping |
| Gbps | Giga bit per second |
| GF | Galois Field |
| IM/DD | Intensity Modulation/Direct Detection |
| LAN | Local Area Network |
| MAI | Multiple Access Interference |
| Mbps | Mega bit per second |
| MFH | Modified Frequency Hoping |
| MQC | Modified Quadratic Congruence |
| MS | Mobile station |
| OCDMA | Optical Code Division Multiple access |
| OOC | Optical Orthogonal Code |
| OOK | On-Off Keying |

| | |
|---|---|
| PC | Prime Code |
| PIIN | Phase Induced Intensity Noise |
| SIR | Signal to Interference Ratio |
| SAC | Spectral Amplitude Coding |
| SMF | Single Mode Fiber |
| SNR | Signal to Noise Ratio |
| TDM | Time Division Multiplexing |
| TDMA | Time division Multiple Access |
| TLS | Tunable Laser Source |
| TOF | Tunable Optical Filter |
| WDMA | Wavelength Division Multiple access |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Optical fibre is a medium in which communication signals are transmitted from one location to another, in the form of light guided through thin fibres of glass or plastic. These signals are digital pulses or continuously modulated analogue streams of light, representing information which can be regarded in the form of voice information, data information, computer information, video information, or any other types of information [1]-[2].

Optical fibres communication system is a promising candidate in providing the solution for tremendous growth of transmitted capacity demands in telecommunication and data communication services. It has been developed rapidly in the last two decades to meet the increasing demand in transmission capacity of the internet and multimedia applications. The main development has been done in the optical devices and technologies, while the systems still involve the use of simple modulation, detection, and multiplexing techniques. A few advanced optical communication techniques have also been proposed in the last decade to improve the performance of the system [2]-[4].

Optical fiber is generally chosen for systems which require higher bandwidth or span longer distances than electrical cabling can accommodate. The main benefits of fibre are due to the fact that it has exceptionally low loss, it allows long distances between

amplifiers or repeaters; and its inherently high data-carrying capacity, and as such, it requires thousands of electrical links to replace a single high bandwidth fibre cable.

### 1.2 Multiple Access Technique with Power Control Rule

In communication environment, a multiple access communication system is one of communication techniques. A multiple access is required for combining and separating traffics on a shared physical medium in case users are not at the same place, which is often well-known

There are three major types of multiple access, namely time division multiple access (TDMA), wavelength division multiple access (WDMA) [5] and optical code division multiple access (OCDMA).

The optical CDMA has several advantages over TDMA and WDMA; these include a complete utilization of the entire time frequency domain by each subscriber, the flexibility in network design and the security against interception, in addition to the lower multi-access interference (*MAI*).

There are several challenging points in researches and these can still be explored for a practical realization and development of the OCDMA. These include the multiple access interference (*MAI*) which is naturally present in almost all forms of the OCDMA, increasing the network capacity in terms of the number of concurrent users, as well as the codes which can support various traffic demands in small bandwidth and good bit error rate (BER) performance.

Based on the above discussion, the main source of noise for each user is the interference signals from other users. This interference limits the capacity in the fibre optic network. A number of methods have been proposed to reduce this interference such as using low cross-correlation codes [6], and applying power control method into the system [7].

Generally, power control methods adjusts the power level so that the signal-to-noise ratio is equal for all users, in spite of the different lengths between B.S and M.S, which will result in the determination of one B.S from many (usually the nearest B.S) that will supply the service to M.S [8],[9].

In the optical networks, the power control is used to adjust the carrier to the interference ratio (CIR), as a related with the fibre path loss [10]. The power control is used to support some of all simultaneous users when the quality of service (QoS) becomes lower than the boundary condition. The power control adjusts and optimizes the required power to achieve the target of QoS by controlling the transmitted power as a relationship with data rate and the number of users [11]. The QoS is determined by service utilization which is dependent on the bit rate (data stream).

### 1.3 The Quality of Service Parameters

In the field of computer networking and other packet-switched telecommunication networks, the QoS term refers to the resource reservation control mechanisms which are in addition to achieve the quality of service. The quality of service is the ability to provide different priorities to different applications [12], users, or data flows, or to

guarantee a certain level of performance to a data flow. For example, a required bit rate, delay, jitter, packet dropping probability and/or bit error rate which may be guaranteed. The QoS guarantees are important if the network capacity is insufficient (especially for real-time streaming multimedia applications such as voice over IP, online games and IP-TV, since these often require fixed bit rate and delay sensitive) and in networks where the capacity is a limited resource.

In the field of telephony, quality of service is defined in the ITU standard X.902 as "A set of quality requirements on the collective behaviour of one or more objects." The quality of service comprises requirements on all the aspects of a connection, such as the service response time, loss, signal-to-noise ratio, cross-talk, echo, interruptions, frequency response, loudness levels, and so on. A subset of telephony QoS is the grade of service (GoS) requirements, which comprises aspects of a connection related to the capacity and coverage of a network such as the guaranteed maximum blocking probability and outage probability. The QoS world network performance also includes the following concepts [13]:

- Dependability,
- Transmitted performance, and
- Charging correctness.

From the previous discussion, it is clear that the QoS indicator, by one or many parameters like the number of simultaneous users and data flows, is to guarantee a certain level of performance to a data flow. In this thesis, the *SNR* and *BER* were taken as the QoS to guarantee a certain level of performance to a data flow.

## 1.4 Problem Statement and Motivation

Dynamic Frequency Hoping-optical CDMA (DFH-OCDMA) system is one of the OCDMA techniques. As indicated in the earlier section, this technique has an advantage of having the highest number of simultaneous users among all OCDMA techniques. The highest number of simultaneous users is achieved and assumed as receiving fixed power which satisfies an adequate value of SNR [14]. Similarly in the DFH-OCDMA, the SNR and BER are respectively and seriously degraded with a minor change in the value of the received power. For example, a fix received power of Pr = -10 dBm is required to achieve the BER= $10^{-9}$, a number of simultaneous users (K=110). With minor changes made to the received power value (-10 to -12) dBm indicated above, the BER is degraded from accepting the value above BER= $10^{-7}$. Meanwhile, other techniques will have the approximately similar BER value [15]. Therefore, a rule to solve this high sensitivity in changing of the received power is therefore needed. This high sensitivity clearly appears or is derived with the near-far problem when some users received it from short-path lengths and from other long path lengths. This will result in a low SNR for the some users (i.e. usually the far users) [16]. Therefore, the use of power controlling method is proposed to solve the near-far problem in DFH-OCDMA. In other words, the power control is a key for many technologies which are used to adjust the received power with the target SNR as an optimum received power (not too high and too low values).

Many power control techniques have been proposed in the optical network, i.e. for both the transmitter ($T_x$) and receiver ($R_x$), so as to optimize the optical transmitted power. The optical power control for the OCDMA networks was discussed in [16] -