UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND IMPLEMENTION OF A NOVEL CODE FAMILY FOR OPTICAL CODE DIVISON MULTIPLE ACCESS SYSTEM

SYED ALWEE AL-JUNID BIN SYED JUNID.

DEVELOPMENT AND IMPLEMENTATION OF A NOVEL CODE FAMILY FOR OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEMS

By

SYED ALWEE ALJUNID BIN SYED JUNID

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of Requirements for the Degree of Doctor of Philosophy

July 2005

To My Beloved Wife and Son

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

DEVELOPMENT AND IMPLEMENTATION OF A NOVEL CODE FAMILY FOR OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEMS

By

SYED ALWEE ALJUNID BIN SYED JUNID

July 2005

Chairman: **Associate Professor Mohamad Khazani Abdullah, PhD**

Faculty: **Engineering**

Future telecommunication systems and networks are expected to provide a variety of integrated broadband services to the customers. There has been a tremendous interest in applying Code Division Multiple Access (CDMA) techniques to fiber optic communication systems. This technique is one of the multiple access schemes that is becoming popular because of the flexibility in the allocation of channels, ability to operate asynchronously, enhanced privacy and increased capacity in bursty networks.

The performance of any Optical CDMA (OCDMA) system strongly depends on the codes properties. In this study we introduce a new code for Optical CDMA namely Double Weight Code family (DW). Double Weight Code (DW) has a basic fixed weight of 2 and exists for every natural number. The DW codes possess ideal cross correlation properties, which have important characteristics in OCDMA systems since these can eliminate multiple access interference (MAI) and reduce noise. Also proposed in this

study, a Modified Double-Weight (MDW) code, which is a variation of DW code family that can have a variable weight greater than two. The MDW code possesses ideal cross-correlation properties and exists for every natural number too. It is shown through simulations, theoretical analysis and partially by the experiments that the transmission performance of DW code family is significantly better than that of existing codes such as Modified Frequency Hopping code (MFH) and Hadamard code.

The performance of DW code family, MFH and Hadamard codes were simulated using commercial simulation software, OptiSystem Version 3.0. The performance of the systems was characterized by referring to the bit error rate (BER) and the eye patterns. DW code family has shown superior performance compared to other OCDMA codes. The simulated eye pattern of one of the four MDW coded carriers running at 10Gbps over a communication-standard fiber shows a good quality transmission at the BER of 10^{-12} as opposed to only 10^{-3} and 10^{-4} for Hadamard and MFH codes.

In optical CDMA systems, the detection process affects the design of transmitters and receivers. Cross-correlation functions are generated which creates Multiple Access Interference (MAI) and this will degrade the system performance. MAI can be reduced by using subtraction techniques. The most common subtraction technique is the complementary subtraction technique and also known as balanced detection technique. In this thesis, we also introduce a new approach called AND subtraction technique. This method rejects unwanted signals that interfere with the original signals. Furthermore, the purpose of this new subtraction technique is to reduce the receiver complexity and increase system performance. It has been shown through theoretical analysis, simulation

and experimental work, the performance of the system with AND subtraction technique can be improved significantly. Based on the theoretical analysis, BER as good as 10^{-12} is achieved at the bit rate of 622 Mbps over 70 km distance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN DAN PELAKSANAAN NOVEL KOD FAMILI UNTUK SISTEM OPTIKAL CAPAIAN PELBAGAI PEMBAHAGIAN KOD

Oleh

SYED ALWEE ALJUNID BIN SYED JUNID

Julai 2005

Pengerusi: **Profesor Madya Mohamad Khazani Abdullah, PhD**

Falkulti: **Kejuruteraan**

Sistem telekomunikasi dan rangkaian masa hadapan dijangkakan dapat menyediakan pelbagai perkhidmatan jalur lebar bersepadu kepada pelanggan. Dilaporkan terdapat minat yang mendalam untuk mengaplikasikan teknik capaian pelbagai pembahagian kod (CDMA) di dalam sistem komunikasi gentian optik. Teknik ini adalah salah satu skema pemultipleksan yang popular sejak akhir-akhir ini di kalangan penyelidik oleh kerana pembahagian saluran yang anjal, berupaya berfungsi secara tak segerak, peningkatan dari segi keselamatan dan juga kapasiti dalam rangkaian yang bersifat letusan.

Prestasi sebarang sistem CDMA sangat bergantung kepada ciri-ciri kod. Dalam tesis ini telah diperkenalkan satu kod baru untuk CDMA optik yang dinamakan keluarga kod Dwi Pemberat (DW). Kod DW mempunyai pemberat asas ditetapkan kepada dua dan wujud dalam setiap nombor biasa. Kod DW ini mempunyai sifat-sifat sekatan bersilang yang unggul yang merupakan ciri yang penting dalam sistem OCDMA memandangkan ia dapat menghapuskan gangguan capaian pelbagai (MAI) dan mengurangkan hingar.

Turut dicadangkan di dalam tesis ini ialah kod Dwi Pemberat Diubahsuai (MDW), yang merupakan satu variasi yang lain dalam keluarga kod Dwi Pemberat yang mempunyai pemberat bolehubah lebih besar daripada dua. MDW juga mempunyai sifat-sifat sekatan bersilang yang unggul dan wujud dalam setiap nombor biasa. Ia akan ditunjukkan secara prinsip menggunakan simulasi secara komprehensif, analisis teori dan sebahagiannya melalui eksperimen yang menunjukkan bahawa prestasi penghantaran kod Dwi Pemberat adalah lebih baik berbanding kod yang sedia wujud seperti MFH dan Hadamard.

Prestasi keluarga kod Dwi Pemberat, MFH dan Hadamard disimulasikan dengan menggunakan perisian simulasi komersil, OptiSystem versi 3.0. Prestasi sistem diterjemahkan dengan merujuk kepada kadar ralat bit, (BER) dan corak mata. Kod keluarga Dwi pemberat telah berjaya menunjukkan prestasi yang lebih baik berbanding dengan kod OCDMA yang lain. Berdasarkan simulasi, corak mata salah satu daripada empat penghantar isyarat pada kadar 10 Gbps dalam gentian berpiawaian komunikasi menunjukkan kualiti penghantaran yang baik dengan BER pada 10^{-12} berbanding dengan hanya 10^{-3} dan 10^{-4} bagi kod Hadamard dan MFH.

Dalam sistem OCDMA, proses pengesanan memberi kesan terhadap rekabentuk penghantar dan penerima. Fungsi sekatan bersilang akan terjana dan hal ini menyebabkan terjadinya gangguan capaian pelbagai (MAI) dan boleh menyebabkan prestasi sistem itu merosot. MAI boleh dikurangkan dengan menggunakan teknik penolakan. Teknik penolakan yang sering digunakan ialah teknik penolakan pelengkap dan teknik ini juga dikenali sebagai teknik pengesanan terimbang. Di dalam tesis ini,

juga akan diperkenalkan satu pendekatan baru yang dinamakan teknik penolakan AND. Penggunaan kaedah ini bertujuan untuk membuang isyarat yang tidak diingini daripada mengganggu isyarat asal. Selain itu, teknik ini juga bertujuan untuk mengurangkan pembinaan rekabentuk penerima yang kompleks dan seterusnya meningkatkan prestasi sistem. Dengan menggunakan teknik penolakan AND ini, prestasi sistem dapat ditingkatkan dengan mendadak dan hal ini telah dibuktikan melalui analisis teori, simulasi dan secara eksperimen. Secara teori, kualiti penghantaran yang baik dengan BER pada 10^{-12} di catatkan pada jarak 70 km pada kelajuan data 622 Mbps.

ACKNOWLEDGEMENTS

First of all, I would like to express my greatest gratitude to ALLAH Almighty, for His help and support during the course of life and the moment of truth. Alhamdulillah.

I would like to express my appreciation and sincere gratitude to my supervisor, Associate Professor Dr Mohamad Khazani Abdullah for his continuous support, encouragement and endless patience towards completing the research. These special thanks also dedicated to my supervisory committee member; Professor Dr Borhanuddin Mohd Ali, Associate Professor Dr Abdul Rahman Ramli and Associate Professor Dr. Mahamod Ismail for their invaluable guidance and constructive criticisms throughout the success of this project.

My special thanks to Mr. Dhazhiril Abdul Samad for his help and discussions and solving of problems in this project. I would also like to thank to all my colleagues from, Photonics Lab for their support and encouragement. Working with all of you is a good experience that could never be forgotten.

A huge appreciation to my beloved wife, Sharifah Noor Hamidah and to my son, Syed Mohammad Ammar; your continual support and patience made me strong in completing the thesis.

Last but not least, I would like to thank my father-in-law, mother-in-law, and the rest of my family who keep encouraging and supporting me in whatever I do. Thank you very much.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BER	-	Bit Error Rate
CD	-	Chromatic Dispersion
CDM	-	Code Division Multiplexing
CDMA	-	Code Division Multiple Access
CIDF	-	Component Iteration Data Flow
CO	-	Central Office
CW	-	Continuous Wave
DFB	-	Distributed Feed Back
DW	-	Double Weight
DWDM	-	Dense Wavelength Division Multiplexing
EDFA	-	Erbium-Doped Fiber Amplifier
ESCON	-	Enterprise Systems Connections
FDDI	-	Fiber Distributed Data Interface
FDMA	-	Frequency Division Multiple Access
FH	-	Frequency-Hopping
FP	-	Fabrey Perrot
FSAN	-	Full Service Access Network
FTTH	-	Fiber to the Home
FWM	-	Four Wave Mixing
GF	-	Galois Field
IP	-	Internet Protocol
ISI	-	Inter Symbol Interference

LAN	-	Local Area Network
LCM	-	Liquid Crystal Modulator
LD	-	Laser Diode
LED	-	Light Emitting Diode
LMDS	-	Local Multipoint Distribution Service
MAI	-	Multiple Access Interference
MAN	-	Metropolitan Area Network
MDW	-	Modified Double Weight
MFH	-	Modified Frequency Hopping
NDSF	-	Non-Dispersion Shifted Fiber
NRZ	-	Non-Return to Zero
OCDM	-	Optical Code Division Multiplexing
OCDMA	-	Optical Code Division Multiple Access
OOC	-	Optical Orthogonal Codes
OOK	-	On/Off Keyed
OSCDMA	-	Optical Spectrum Code Division Multiple Access
OSNR	-	Optical Signal to Noise Ratio
PIIN	-	Phase Induced Intensity Noise
PMD	-	Polarization Mode Dispersion
POP	-	Point of Presence
PRBS	-	Pseudo Random Binary Sequence
PSD	-	Power Spectral Density
QoS	-	Quality of Service
QPSK	-	Quadrature Phase Shift Keying