A Novel 2-D Wavelength-Time Optical Code Division Multiple Access (OCDMA) Code for High-Performance System

by

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A thesis submitted
In fulfillment of the requirements for the degree of
Doctor of Philosophy

School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS

2013

GRADUATE SCHOOL
UNIVERSITY MALAYSIA PERLIS

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Acknowledgement

الحمد لله, All praises be to Allah for the opportunity to complete the thesis. First and foremost, I would like to express my sincere gratitude to my supervisor Professor Dr. Syed Alwee AlJunid Syed Junid for his continuous insight, knowledge, encouragement, guidance and motivation for the past three years. It is a privilege and a great pleasure to have him as the supervisor. My lecturers and co-supervisors, Professor Dr. R Badlishah Ahmad and Professor Dr. Farid Ghani. My friend Ir. Dr. Anuar Mat Safar and Professor Dr. Syed Idris Syed Hassan for the thought and guidance. My profound love and appreciation for my parents for their love and endless support, my wife for the perseverance and my children who make me enjoy my everyday life. I would like to thank to all the members of my research group in the UniMAP Optical Embedded Computing Cluster for the teamwork and friendship during hard times and sunny days, Junita Mohd Nordin, Rashidi Che Beson, Siti Fatimah Harun, Aishah Hussin, Zuliyana Mohammad, Nur Hidayu Ibrahim, Thanaa Hussin, Abdullah Omar Ali, Sharifah Nurhadini and UniMAP.

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LIST OF ABBREVIATIONS

ASE	-	Amplified Spontaneous Emission
APD	-	Avalanche Photodiodes
BER	-	Bit Error Rate
BLS	-	Bandwidth Optical Light Source
CDM	-	Code Division Multiplexing
CDMA	-	Code Division Multiple Access
DCF	-	Dispersion Compensated Fiber
DCS	-	Diagonal Cyclic Shift
DPDC	-	Diluted Perfect Difference Code
DS-OCDMA	-	Direct Sequence Optical Code Division Multiple Access
DW	-	Double Weight
DWDM	-	Dense Wavelength Division Multiplexing
EDFA	-	Erbium Doped Fiber Amplifier
E/O	-	Electrical-to-Optical Conversion
EOM	-	Electro-Optical Modulator
FBG	-	Fiber Bragg Grating
FEC	-	Forward Error Correction
FFH	-	Fast Frequency Hopping
FH	-	Frequency-Hopping
FTTH	-	Fiber to the Home
FWHM	-	Full Width Half Maximum
LAN	-	Local Area Network

LD	-	Laser Diode
LED	-	Light Emitting Diode
MAI	-	Multiple Access Interference
MAN	-	Metropolitan Area Network
MDW	-	Modified Double Weight
MFH	-	Modified Frequency Hopping
MMC	-	M-Matrices Code
MQC	-	Modified Quadratic Code
MZCC	-	Modified Zero Cross Correlation
NRZ	-	Non-Return to Zero
OCDMA	-	Optical Code Division Multiple Access
O/E	-	Optical-to- Electrical Conversion
OHL	-	Optical Hard-Limiter
OOK	-	On/Off Keyed
OSNR	-	Optical Signal to Noise Ratio
OTDMA	-	Optical Time Division Multiple Access
PD	-	Photo-Detector
PDC	-	Perfect Difference Code
PIN	-	Phase Induced Noise
PIIN	-	Phase Induced Intensity Noise
PMD	-	Polarization Mode Dispersion
PMMC	-	Permuted M-Matrices Code
PSK	-	Pulse Shift Keying

PON	-	Passive Optical Networks
PSD	-	Power Spectral Density
QoS	-	Quality of Service
RF	-	Radio Frequency
SAC	-	Spectrum-Amplitude Coding
SDH	-	Synchronous Digital Hierarchy
SMF	-	Single Mode Fiber
SNR	-	Signal-to-Noise Ratio
SOA	-	Semiconductor Optical Amplifier
SONET	-	Synchronous Optical Network
SPE	-	Spectral-Phase Encoding
SPM	-	Self-Phase Modulation
TBG	-	Tunable Bragg Grating
TDMA	-	Time Division Multiple Access
TOFDLs	-	Tunable Optical Fiber Delay Lines
TPE	-	Temporal-Phase Encoding
WAN	-	Wide Area Network
WDM	-	Wavelength Division Multiplexing
WDMA	-	Wavelength Division Multiple Access
WHTS	-	Wavelength-Hopping/Time-Spreading
ZCC	-	Zero Cross Correlation
DFSA	-	Depth First Search Algorithm
1-D	-	One-Dimensional
2-D	-	Two-Dimensional

LIST OF SYMBOLS

Time interval	N_T
Weight	w/W
Pulse power profile	$p(t)$
Light carrier frequency	ω
Phase noise	$\phi(.)$
Chip pulse power profile	$b(t)$
Stationary complex Gaussian random process	$u(t)\ \omega$
Power spectral density of the pulse	$S(f)$
Effective ionization ratio of the APDs	K_e
Responsivity	$\Re$
Excess noise factor of APD	F_e
Optimum APD gain	G_{opt}
Mean gain	G_{bar}
Ionization coefficient ratio	k
Number of users	K
Code length	N
Basic code's column size	N_B
Basic codes row size	K_B
Length	l
Spectral width	Δv
Chip width	ΔF

Cross-correlation	λ_c
Auto cross-correlation	λ_a
Number of wavelength	M
Spectral encoding	X_g
Spatial encoding	Y_k
Average photocurrents	I
Noise equivalent electrical bandwidth of the receiver	B
Coherent time of light incident to the photodiode	τ_c
Electron's charge	e
Boltzmann's constant	K_b
Absolute receiver noise temperature	T_n
Receiver load resistor	R_L
Central frequency	f_0
Bandwidth of the source	Δf
Effective power of a broadband source at the receiver	P_{sr}
Unit step function	$u(f)$
Noise equivalent electrical bandwidth of the receiver	B_r
Coherent time of optical signal received	τ_r
Photocurrent output from receiver	I_r
Shot noise	N_{sh}
Responsivity of the photo receiver	qR
Optical received power	P_r
Absolute temperature	T
Electrical bandwidth	B_e

Receiver resistance	R
Response time of photo-detector	T_r
Data transmission rate	R_b
Receiver noise temperature	T_n
Data bit of each users	$d(w)$
Maximum number of spreading sequences	Φ_{max}
Spreading sequence	S_k

Novel 2-D Panjang Gelombang-Masa Teknik Berbilang Capaian Pembahagian Kod Optik (OCDMA) Untuk Sistem Prestasi-Tinggi

Abstract

Pertumbuhan mendadak permintaan jalur lebar, seiring dengan kemajuan dalam perkhidmatan komunikasi terkini dan juga kemunculan aplikasi baru telah memberi banyak inspirasi tentang pentingnya aplikasi teknik akses pelbagai pembahagian kod (CDMA) dalam rangkaian optik. Faktor gangguan utama dalam CDMA optik (OCDMA) adalah untuk mengatasi hingar gangguan akses berganda (MAI) yang mendorong berlakunya kadar ralat bit. Ciri kod ideal dengan sekaitan-silang minimum akan mengurangkan MAI, mengurangkan intensiti hingar fasa teraruh (PIIN) dan meningkatkan kod berskala. Sebahagian kerja yang di jalankan akan menganalisis bagaimana OCDMA boleh disesuaikan ke dalam rangkaian optik untuk generasi masa depan. Dalam tesis ini, dua-dimensi (2-D) baru tidak jelas berat kembar diubahsuai (MDW) OCDMA gelombang masa dicadangkan dan ditunjukkan. Tesis ini bermula dengan pembinaan system 2-D MDW OCDMA yang tidak jelas dengan peruntukan gelombang dan sumber dimensi masa kepada matlamat untuk mencapai matlamat prestasi dan rekabentuk parameter. Pembaharuan 2-D MDW OCDMA menggunakan teknik pengesanan imbangan untuk mengurangkan MAI. Kod secara teori dianalisis dan di simulasi untuk mencapai prestasi yang bagus. Ciri-ciri yang bagus tentang sekaitan-silang penahanan akan menghasilkan perbandingan PIIN yang optimum kepada 2-D PDC dan 2-D MQC. Perkara ini dapat dilihat melalui nilai SNR yang tinggi atau BER yang rendah selari dengan penambahan pengguna. Hasil perbandingan diantara kod 2-D MDW dengan 2-D PDC, 2-D MQC dan 1-D MDW, menunjukkan prestasi yang baik dari segi pengguna, BER, kadar bit dan jarak. Kod ini juga menunjukkan pencapaian yang baik apabila ralat BER hanyalah 10^{-9}, dan kod pengguna juga mencecah 189 orang pengguna iaitu dua kali ganda daripada prestasi 2-D PDC. Kuasa efektif terendah (P_{sr}) yang digunakan untuk penghantaran optikal digunakan untuk meminimumkan keperluan kuasa kepada pengguna dicapai pada -22.5 dBm. Gabungan gelombang dan serpih-masa boleh mempertingkatkan prestasi keseluruhan system. Kod yang dicadangkan berjaya mengurangkan MAI dengan teknik pengesanan seimbang. Simulasi model 2-D MDW OCDMA dicipta untuk mengesahkan kod ini boleh digunakan sebagai kadar ralat bit (BER), kadar bit dan prestasi jarak jauh. Kesimpulannya, kod 2-D MDW OCDMA berjaya mengurangkan MAI dan PIIN selain turut menghasilkan pengguna yang tinggi, mengurangkan P_{sr}, meningkatkan kadar bit dan menambah jarak penghantaran bit.

A Novel 2-D Wavelength-Time Optical Code Division Multiple Access (OCDMA) Code for High-Performance System

Abstract

The explosive growth of bandwidth demand, together with advance in latest communication services and emerging applications has inspired huge interest in application of code division multiple access (CDMA) technique in optical network. The major interference factor in optical CDMA (OCDMA) is to overcome the multiple access interference (MAI) noise which induces the occurrence of bit error rate. Ideal code property with minimum cross-correlation will mitigate MAI, reduce phase induced intensity noise (PIIN) and expand code scalability. Part of the work devotes to analyzing how OCDMA can suit into the future generation of optical network. In this thesis the new incoherent two-dimensional (2-D) modified double weight (MDW) OCDMA wavelength-time is proposed and demonstrated. The thesis begins with an explicit construction of incoherent 2-D MDW OCDMA system with allocation of wavelength and time dimensions resources to aspire performance goals and designed parameters. A novel 2-D MDW OCDMA uses balance detection for mitigating MAI. The code is theoretically analyzed and simulated for the performance. The good property of cross-correlation results in optimum PIIN suppression in comparison to the other codes such as 2-D PDC and 2-D MQC. This is reflected through high SNR value or low bit error rate (BER) as the cardinality increases. The comparison outcome of the proposed 2-D MDW code with 2-D PDC, 2-D MQC and 1-D MDW code indicates substantial performance improvements in cardinality, BER, bit rate and distance. The proposed code achieves high scalability; below 10^{-9} BER error floor the code cardinality reaches 189 simultaneous numbers of users which is double the 2-D PDC performance. The lowest effective transmitted power (P_{sr}) for minimum optical transmission requirement for smallest number of users is achieved at -22.5 dBm. The combination of wavelength and time-chip can be further enhanced the overall system performance. The proposed code has successfully mitigating MAI by the balance detection technique. The 2-D MDW OCDMA simulation model is developed to validate the realization of the code for BER, bit rate and distance performance. In short the 2-D MDW OCDMA code successfully suppresses PIIN and mitigating MAI which result in high cardinality, reduce P_{sr}, high bit rate and distance.