A NEW THREE-DIMENSIONAL CODE FOR OCDMA SYSTEM

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LIST OF ABBREVIATIONS

APD	Avalanche Photo Detector
AWG	Arrayed Waveguide Grating
BER	Bit Error Rate
BS	Brillouin Scattering
CDMA	Code Division Multiple Access
CO	Central Office
DCF	Dispersion Compensating Fiber
DPD	Diluted Perfect Difference
DW	Double Weight
EDFA	Erbium Doped Fiber Amplifier
EDW	Enhanced Double Weight
EOM	Electrical to Optical Modulator
FBG	Fiber Bragg Grating
FBGr	$FBG_{receiver}$
FBGt	$FBG_{transmitter}$
FSO	Free Space Optics
FT	Fourier Transform
FTTH	Fiber To The Home
FTTx	Fiber To The x
Gbps	Gigabit per second
GF	Galois Field
IM/DD	Intensity Modulation/Direct Detection
IPCC	In Phase Cross Correlation

LAN	Local Area Network
LED	Light Emitting Diode
LPF	Low Pass Filter
MAI	Multiple Access Interference
Mbps	Mega bit per second
MD	Multi Diagonal
MDW	Modified Double Weight
MFH	Modified Frequency Hoping
MIMO	Multiple Input Multiple Output
MPP	Multi Pulse per Plane
MQC	Modified Quadratic Congruence
MW	Multi Weight
MZM	Mach-Zehnder Modulator
NDSF	Non Dispersion Shift Fiber
NRZ	Non Return to Zero
O/E	Optical/Electrical
OCDMA	Optical Code Division Multiple Access
ONU	Optical Network Unit
OOC	Optical Orthogonal Code
OOK	On-Off Keying
OOSP	Optical Orthogonal Signature Pattern
OTDL	Optical Time Delay Line
P2P	Point to Point
P2MP	Point to Multi Point
PC	Prime Code

PD	Perfect Difference
PDn	Photo Diode (0,1,2,3)
PIIN	Phase Induced Intensity Noise
PIN	Positive Intrinsic Negative
PMD	Polarization Mode Dispersion
PON	Passive Optical Networks
PRBS	Pseudo Random Binary Sequence
PSD	Power Spectral Density
Q	Quality
RD	Random Diagonal
RN	Remote Node
RS	Raman Scattering
RZ	Return to Zero
SAC	Spectral Amplitude Coding
SLD	Super Luminescent Diode
SMF	Single Mode Fiber
SNR	Signal to Noise-Ratio
SPC	Spectral Phase Coding
SPDD	Single Pulse per Plane for differential detection
SPP	Single Pulse per Plane
SPR	Single Pulse per Row
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TOFDL	Tuneable Optical Fiber Delay Line
TPC	Temporal Phase Coding

TS	Time Spreading
T/S	Time/Spatial
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WDMA	Wavelength Division Multiple Access
WHTS	Wavelength-hopping Time-spreading
ZCC	Zero Cross-correlation
1-D	One-Dimensional
2-D	Two-Dimensional
3-D	Three-Dimensional

Kod Tiga Dimensi Baru bagi Sistem OCDMA

ABSTRAK

Banyak kod disediakan bagi OCDMA tidak koheren berdasarkan satu dimensi (1-D), dua dimensi (2-D), dan tiga dimensi (3-D) dengan mengeksplotasi satu atau lebih sumber secara spontan. Kod 3-D PD (3-D Perfect Difference) dicadangkan bagi masa spektrum / sistem OCDMA ruang dalam usaha untuk meningkatkan bilangan pengguna dengan menggunakan panjang kod yang lebih pendek. Sebaliknya, kekompleksan sistem terutamanya penyahkod atau dekoder didapati semakin meningkat. Dalam penyelidikan ini, kod 3-D baru, yang dikenali juga sebagai kod 3-DDPD/MD (Three-Dimensional Diluted Perfect Difference/ Multi Diagonal) dicadangkan bagi sistem OCDMA tidak koheren, untuk membatalkan MAI (Multi Access Interference), mitigasi PIIN (Phase Induced Intensity Noise), bagi membolehkan penempatan pengguna spontan yang ramai dan mengurangkan kekompleksan dekoder sistem 3-D. Kod 3-D DPD/MD dibangun berdasarkan kod DPD dan MD. Kajian daripada kod yang dicadangkan, termasuk terbitan matematik bagi persamaan prestasi SNR (Signal to Noise Ratio (SNR) dan BER (Bit Error Rate) di bawah kesan penerima hinggar, dan kesahihan dengan menggunakan perisian simulasi optik. Prestasi sistem dikaji di bawah kesan kadar data, jarak, kuasa diterima, dan jenis pengesan foto. Keputusan teori menunjukkan bahawa kod 3-D DPD/MD menunjukkan prestasi yang lebih baik daripada kod 3-D PD, 2-D DPD, dan 2-D PD, berdasarkan jumlah pengguna yang sama, yang dapat menempatkan lebih ramai pengguna spontan dengan kadar data dan kuasa diterima yang sama. Pada BER 10^{-9}, ia dapat menampung 1020 pengguna spontan pada 0.622 Gbps dan -7 dBm, jika dibandingkan dengan 660, 570 dan 490 pengguna bagi kod 3-D PD, 2-D DPD dan 2-D PD, masing-masing, dengan faktor penambahbaikan adalah 54%, 78% dan 108%. Di samping itu, kod yang dicadangkan juga mampu menyediakan prestasi yang lebih baik daripada kod yang lain pada 1.25 Gbps. Tambahan pula, kod 3-D DPD/MD mampu menyediakan 600 pengguna aktif pada kuasa diterima yang rendah -15 dBm dengan kadar data 0.622 Gbps. Justeru, kecekapan spektrum berdasarkan kod 3-D DPD/MD dapat ditingkatkan lebih daripada 27%. Sebagai tambahan, penggunaan kod 3-D DPD/MD mampu mengurangkan kekompleksan dekoder lebih daripada 50%, jika dibandingkan dengan kod 3-D PD. Dengan kata lain, keputusan simulasi mengesahkan kod yang dicadang untuk menyokong kebezaan perkhidmatan dalam rangkaian optik melalui pemodelan simulasi. Sebagai kesimpulan, kecekapan spektrum yang tinggi, kekompleksan sistem yang rendah, dan jumlah pengguna spontan yang lebih ramai boleh ditempatkan melalui penggunaan kod yang dicadang dalam rangkaian OCDMA.

A New Three-Dimensional Code for OCDMA System

ABSTRACT

Many codes have been proposed for incoherent OCDMA based on one-dimensional (1-D), two-dimensional (2-D), and three-dimensional (3-D) by exploiting one or more resources simultaneously. The 3-D Perfect Difference (3-D PD) code has been proposed for spectral/time/spatial OCDMA system in order to increase the number of users by using shorter code lengths. But, the complexity of the system, especially the decoder, is increased. In this research, a new 3-D code namely, Three-Dimensional Diluted Perfect Difference/ Multi Diagonal (3-D DPD/MD) code is proposed for the incoherent OCDMA system, to completely cancel the Multi Access Interference (MAI), mitigate the Phase Induced Intensity Noise (PIIN), accommodate a large number of simultaneous users and reduce the complexity of the 3-D system decoder. The 3-D DPD/MD code has been developed based on the DPD and MD codes. The study of the proposed code, included the mathematical derivation of the performance equations in terms of Signal to Noise Ratio (SNR) and Bit Error Rate (BER) under the effect of receiver noises, and the validation by using optical simulation software. The system performance was investigated under the effect of data rate, distance, received power, and the photo-detector type. Theoretical results showed that the 3-D DPD/MD code system achieved better performance than the 3-D PD, 2-D DPD, and 2-D PD codes of similar total users where a larger number of simultaneous users can be accommodated using the same data rate and received power. At BER of 10^{-9}, it could support 1020 simultaneous users at 0.622 Gbps and -7 dBm compared with 660, 570 and 490 users of 3-D PD, 2-D DPD and 2-D PD codes, respectively, where the improvement factors were 54%, 78% and 108%. Also, the proposed code provided better performance than the others at 1.25 Gbps. Moreover, the 3-D DPD/MD code provided 600 active users at lower received power of -15 dBm with data rate of 0.622 Gbps. Consequently, the spectral efficiency based on the 3-D DPD/MD code was enhanced by more than 27%. In addition to that, the using of the 3-D DPD/MD code reduced the decoder complexity by more than 50% when compared with the 3-D PD code. On the other hand, the simulation results validated the proposed code to support the service differentiation in optical networks via simulation modeling. As a result, a high spectral efficiency, low system complexity, and a large number of simultaneous users can be accommodated by adopting the proposed code in the OCDMA networks.

CHAPTER 1

INTRODUCTION

1.1 Overview

The optical communication system can accommodate the bandwidth growth requirements by transmitting at high data bit rates over long distances. The wide bandwidth, low loss, small size and weight, electrical isolation, and signal security of optical fiber make it the best candidate to deliver broadband access to the last mile (Keiser, 2003).

Optical fiber communication system is a recent type of communication systems, where the information is transported using optical signal carrier and fiber optics as a transmission channel (Yin & Richardson, 2009). Consequently, the most important design issue of a very high speed optical communication system is the efficient exploitation of the available bandwidth. Since the optical bandwidth of many terahertz greatly exceeds electronic devices speeds. The simplest method to increase the transmission capacity of the optical fiber beyond the electronic components limits is to combine multiple light sources from different transmitters into the same optical fiber. At the receivers, selective devices are used to separate the received optical signal again for individual Photo-detection. Multiple access is necessary in optical communication systems to provide different applications over similar optical networks, where it can provide a total traffic of Terabits per second per fiber. The multiplexing technique is the process of combining multiple optical signals prior to being launched into fiber optic

(Ghafouri-Shiraz & Karbassian, 2012). The main types of multiplexing are briefly discussed in the next section.

1.2 Multiple Access Techniques

Recent years have witnessed a huge revolution in information technology, where the use of computers and Internet are pervasive to our daily lives. All of these require high-speed data transfer. Optical fiber can cater to this, making it the best candidate for use in modern communication systems, however, the presence of multiple subscribers in a network require that there be a way of combining data prior to sending via a common transmission channel. Various schemes have been introduced to improve the transmission capacity of optical fiber communication systems via the combination of multiple data streams of low bit rates into an optical fiber.

The optical access networks completely depend on multiple access techniques for better exploitation of a fiber optic bandwidth and permitting multiple optical channels to transmit simultaneously over the fiber optic. There are three main types of multiple access techniques being used in optical communication systems (Ghafouri-Shiraz & Karbassian, 2012):

1- Time Division Multiple Access (TDMA),
2- Wavelength Division Multiple Access (WDMA)
3- Optical Code Division Multiple Access (OCDMA).

These systems are often considered capable of making the system resources available to each user. Various multiple access schemes will be discussed in detail in the next sub-sections.

1.2.1 Time Division Multiple Access

Time Division Multiple Access (TDMA) system allocates a pre-assigned time slot for each subscriber in the network, where it has the right to send or receive data, which interleaves with the time slots of other subscribers. Each subscriber has to queue to transmit or receive data. Therefore, the system latency will increase with increasing number of users, due to the increased number of time slots in the system (Hall, 1999). TDMA systems can provide a large number of subscribers; however, the time-serial nature of this technique degrades the system performance, especially the data rate. TDMA is a synchronous system that requires a strong centralized control to synchronize the transmitters and the receivers to allocate a correct time slot for each user (Yin & Richardson, 2009). Figure 1.1 illustrates the TDMA block diagram. The main unit in this diagram is the selector switches in the transmitters and receivers sides, where the queue times are regulated. The synchronization between these selector switches is crucial towards TDMA operations.