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LIST OF SYMBOLS.

N	Number of code length
W	Weight of the code
λ_a	Auto- correlation
λ_c	Cross- correlation
$\in$	Set membership
$\otimes$	Tensor product
$=$	Equality
$\neq$	Inequality
$\lvert C \rvert$	Number of user for OOC code.

P	Prime number (Prime code)
β	Primitive element
H	Hadamard Code
R_p	Parallel resistance
R_s	Series resistance
i_{elec}	Electronics current
TB	Absolute temperature
K_b	Boltzmann's constant
B	Electrical bandwidth
R	Receiver local resistance
D	Dispersion (ps/nm-km)
L	Attenuation (dB/km)
τ_c	Coherence time of the source
I	Average photocurrent
q	Charge of an electron, 1.602x 10^{-19} (coulombs)
I_{DC}	DC current (Amps)
Ɵ	Phase between users
$\sum$	Summation
X_i	Indicated as user X_I
Y_i	Indicated as user Y_I
T	Transpose Matrix
$\leq$	Inequality (subgroup)

LIST OF ABBREVIATIONS.

OCDMA	Optical Code Division Multiple Access
MAI	Multiple Access Interference
TDMA	Time Division Multiple Access
WDMA	Wavelength Division Multiple Access
CDMA	Code Division Multiple Access
VOD	Video on Demand
BER	Bit Error Rate
PIIN	Phase Induced Intensity Noise
OSCDMA	Optical Spectrum CDMA
IPCC	In Phase Cross Correlation
SNR	Signal to Noise Ratio
SAC	Spectral Amplitude Coding
MFH	Modified Frequency Hoping
PC	Prime Code
OOC	Optical Orthogonal Code
MZCC	Modified Zero Cross Correlation
ZCC	Zero Cross Correlation
MDW	Modified Double Weight
Optisys	Optical system
TDM	Time Division Multiplexing

FDM	Frequency Division Multiplexing
WDM	Wavelength Division Multiplexing
SCM	Sub Carrier Multiplexing
DWDM	Dense Wavelength Multiplexing
TFF	Thin-Film Filters
FBG	Fiber Bragg Gratings
FSDG	Free-Space Diffraction Gratings
PSK	Phase Shift Keying
PN	Pseudo Noise
DSSS	Direct Sequence Spread Spectrum
SAWF	Surface Acoustic Wave Filter
LED	Light Emitting Diode
GF	Galois Field
LAN	Local Area Network
RF	Radio Frequency
MUI	Multi User Interference
SS-WDM	Spectrum Slicing WDM
NRZ	Non Return Zero
FWM	Four Wave Mixing
XPM	Cross Phase Modulation
RIN	Relative Intensity Noise
SMF	Single Mode Fiber
LPF	Low Pass Filter

PEMBANGUNAN KELAS BARU KOD KORELASI SILANG SIFAR UNTUK SISTEM OPTIK CDMA.

ABSTRAK

Dalam tesis ini, dibentangkan sebuah kaedah untuk pembangunan kelas baru kod optik capaian pelbagai pembahagian kod (OCDMA) yang menggunakan Pengkodan Amplitud Spektrum. Kod yang dicadangkan dikenali sebagai Pengubahsuaian Kod Kolerasi Silang Sifar dan Tidak Sifar (MZCC & MNZCC). Berdasarkan teori, kaedah yang dicadangkan dalam tesis ini ialah untuk membina kod optik ini secara lebih mudah tidak rumit dan sesuai untuk seberapa jumlah pengguna, sebarang korelasi silang dan juga sebarang pemberat tertentu dan mempunyai panjang kod yang minimum. Kod MZCC ialah sebuah kod yang direka bentuk dengan kolerasi silangnya bersamaan dengan sifar. Ini adalah bertujuan untuk menghapuskan gangguan capaian pelbagai (MAI) selain untuk mengelakkan berlakunya pertindihan spektra bit diantara pengguna. Kod MZCC ini boleh dibina dengan mudah, sederhana selain ianya mempunyai prestasi hingar yang baik berbanding dengan kod optik yang sedia ada seperti kod ZCC. Manakala, Kod MNZCC yang dibentangkan dalam tesis ini mempunyai kolerasi silang yang tidak tetap dan boleh direka untuk memiliki kolerasi silang yang dikehendaki. Hal yang demikian ialah kerana kepermintaan untuk menghasilkan sesebuah kod optik dengan panjang kod yang minimum dengan pelbagai kolerasi silang untuk tujuan menghasilkan prestasi hingar yang baik (BER). Kod MNZCC ini boleh direka dengan sangat mudah dengan menggunakan teori yang dibentangkan dalam tesis ini. Kemampuan kod MNZCC lebih baik jika dibandingkan dengan kod optik yang telah sedia ada seperti kod DW. Prestasi kod yang dicadangkan disimulasikan menggunakan perisian simulasi komersil, *OptiSystem* Versi 6.0. Prestasi sistem dirujuk pada Bit Error Rate (BER). Berdasarkan simulasi, pada jarak 25 km dengan bit rate 155 Mbps kod MZCC mempunyai BER 10^{-12} berlawanan dengan BER bagi kod ZCC iaitu 10^{-5} dimana ianya bukanlah kadar piawaian kesilapan didalam sistem perhubungan.

DEVELOPMENT OF A NEW CLASS OF ZERO CROSS CORRELATION CODES FOR OPTICAL CDMA SYSTEMS.

ABSTRACT

In this thesis, presented a method for development of a new class of optical code for Optical Code Division Multiple Access (OCDMA) system using Spectral Amplitude Coding. The proposed code is called Modified Zero Cross Correlation Code (MZCC) and Modified Non Zero Cross Correlation Code (MNZCC). From theory, the proposed method is to construct optical codes with simple code construction for any number of users, any cross correlation and for a given weights having minimum length. MZCC code has been designed with cross correlation is equal to zero due to eliminating the effects of Multi Access Interference (MAI) thus to prevent from overlapping of spectra from each users. These codes is easily to construct, simple and have better noise performance compared with existing optical codes such as ZCC code. While, MNZCC code presented in this thesis is to have unfixed cross correlation and it can be designed with any desired cross correlation. MNZCC have minimum code length, easier to constructed and the ability of this code is better than existing optical codes. The requirement in OCDMA systems to have minimum code length with any desired cross correlation is the reason of these codes has been designed. The performances of proposed codes were simulated using commercial simulation software, OptiSystem Version 6.0. The performance of the systems was characterized by referring to the Bit Error Rate (BER). From the simulation results, at distance 25km with bit rate 155Mbps, MZCC code have better BER 10^{-12} as opposed to BER for ZCC code is equal to 10^{-5} which is not error rate for standard optical communication systems threshold.

CHAPTER 1

INTRODUCTION.

1.1 Overview

Telecommunication systems and networks are expected to provide a variety of integrated broadband services to the customers. To satisfy this need, these integrated networks require a substantial increase in throughput as well as range of bandwidth supported. The advanced developments in fiber optics for the past 20 years have made possible the use of optical fiber as transmission media in modern communication systems. Optical fiber offers several advantages over the existing media (e.g twisted wire pair and coaxial cable). It offers virtually unlimited bandwidth and is considered as ultimate solution to deliver broadband access to the last mile (Begovic, 2007). It also offers a much lower attenuation factor where optical signals can be transmitted over very long distances without signal regeneration or amplification. Many channels can be multiplexed to share the same fiber optic medium, thus reducing the number of links required and the cost to end users. Telecommunications networks are usually divided into four tier division local, access, metropolitan and long haul. Long haul or backbone networks span interregional/global distances 1000 km or more and provide large tributary connectivity between regional and metro domains. Backbone networks are optimized for transmission, and related costs are dominated by expensive line equipment. On the other end of the hierarchy, before the customer's local network are access networks, providing connectivity to variety of customers within close proximity. Access networks use a very broad range of technologies and protocols and represent a continual flux. A multiple access technologies are communication system where a number of users share a common transmission medium to transmit messages to a number of destinations. One of the key issues that must be resolved in moving from a single user communication system to a multi-user communication system is how to efficiently divide the available transmission medium among all users. Optical Code Division Multiple Access (OCDMA) has been recognized as one of the most important technologies for supporting many users in shared media and in some cases can increase the transmission large - capacity bandwidth of an optical fiber. OCDMA is an exciting development in short haul optical networking because it can support both wide and narrow bandwidth applications on the same network and can have large number of asynchronous users.

1.2 Problem Statement

The weakness of current multiple access techniques have spurred the quest for better ones. The latest technique proposed in this research is Optical CDMA. Optical CDMA was born somewhat prematurely almost two decades ago (Pingzhi Fan, 2006). The first proposal appeared almost immediately following or concurrently with those in wireless communications. The motivation was the promise to accommodate a high number of low bit rate clients to communicate simultaneously through the fiber. For the first implementations of the optical CDMA, people have tried to implement in optics, where CDMA techniques already established in wireless. They met serious difficulties in the practical implementation, and the developed techniques never displayed comparable success to that in wireless. This is mainly due to the fundamental difference between the radio frequency and optical fiber communication environments. For instance, the output characteristics of an optical source, such as phase and polarization are not controllable as of a microwave source. Also the photo detector detects incident power only, the phase and polarization cannot be easily sensed. A complex architecture is required, in order to control and detect such parameters and it is inappropriate for an access communication system. Due to these problems and difficulties, research in Optical CDMA has inceasingly developed newer encoding methods in order to achieve the CDMA objectives. Interest in optical CDMA is always high due to tremendous demand for bandwidth due to Internet services, including electronic commerce, virtual-reality, tele-networking, video on demand (VoD) etc. Customers require higher and higher bandwidth, where the traditional transmission systems are unable to fulfill. In a TDMA system, users are allocated time slots during which they can transmit their data. Since only one user can transmit at time, the total system throughput is limited by the product of the number of users and their respective transmission rate. TDMA systems also introduce significant latency penalties because of the coordination required to coordinate and grant requests for time slots from users by the central node. WDMA systems allocate the available optical bandwidth into distinct wavelength channels that are sent simultaneously by different users to permit multiple accesses. It is difficult to construct a WDMA system for a dynamic set of multiple users because of the significant amount of coordination among the nodes required for successful operation. To build a WDMA network with a dynamic user base, control channels and collision detection schemes would need to be implemented that would waste significant bandwidth. Optical CDMA communication systems require neither the time nor the frequency management systems of the previous techniques. In OCDMA the most important consideration is the code design. Improperly designed codes, the maximum number of simultaneous users and the performance of the system can be seriously degraded the systems performance due to existing of Multiple Access Interference (MAI). MAI is the interference resulting from other users transmitting at the same time, which is the main effect limiting the effective Bit Error Rate (BER) for the overall system. Many codes have been proposed for OCDMA. The popular ones are Prime Codes (Wen, 2003) and Optical Orthogonal Codes (C.S Weng, 2001). However, these codes suffer from various limitations. The codes are either too long (e.g, Optical Orthogonal Codes and Prime Codes), the constructions are complicated or the cross-correlation are not ideal (S.A.Aljunid, 2004).

1.3 Research Objective

The main goal of this research is to develop a new class of Optical CDMA codes which can be improved the performance of Optical CDMA systems. The objectives of this research included:-

a) To study various Optical CDMA codes properties such as code length, weights and desired cross correlation to improve OCDMA systems performance.
b) To develop a technique of constructing Optical CDMA codes for a given number of users, weights and desired cross correlation to have minimum code length.
c) To develop a New Class of Optical CDMA codes.

1.4 Scope of Works

In this thesis, Figure 1.1 shows a scope of works general model which is focusing on codes development for Optical CDMA systems. The proposed codes were focusing on mathematical preliminaries to design codes given any number of users and weights to have minimum code length. A new class of zero and non zero cross correlation codes was proposed in this thesis to improve significantly systems performance of OCDMA systems. Also from figures, the performance of proposed codes has been compared with existing optical codes such as slicing techniques for the broadband spectrum as a codeword. Nevertheless, as far as the scope of works is concerned, the software simulation is expected to be sufficient to prove the viability of the proposed codes and their superior performance. In development of a new class of OCDMA codes, more research and study need to be explored and understanding of derivation and calculation of the system most required.

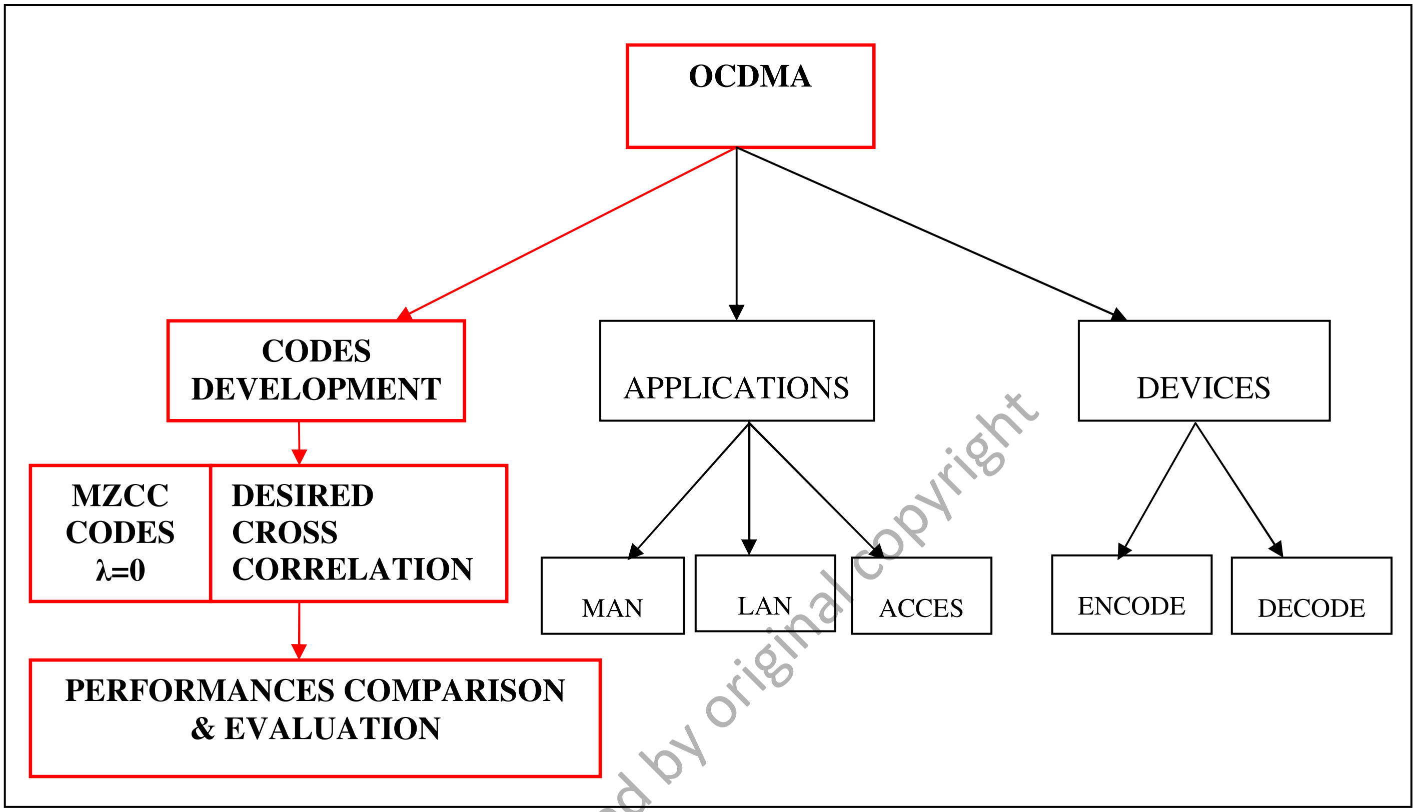

Figure 1.1 A General Model Scope of Works.

1.5 Research Methodology.

Since, optical codes can be represented as vectors; linear algebra has been used for the design of these codes. The codes are treated as rows of a matrix of finite dimension; the methods of design and analysis of matrix algebra are best suited in these cases. For the codes to be unique the code matrix is required to have a finite value of its rank for a given set of users. The in phase auto correlation functions and the cross correlation functions of the codes can easily be defined in term of the dot and cross product of the rows of the matrix. Similarly, the weight of the codes is given by the inner (dot) product of the vector representing the codes.

The length of the codes can also be controlled by controlling the number of columns of the code matrix. In summary, all the parameters of the codes can be defined in term of the parameters of the matrix representing the codes set. The simulation software (*Optisys 6.0*) has been used to simulate the design of these codes to see the performance comparison in term of noise performance with the existing optical codes. The performance of these codes and existing optical codes are simulated and calculated such as BER and Q-Factor using numerical analysis.

A software simulation is important since it normally considers all practical factors (although numerically) which will be considered in the theoretical development. For instance, the effect of material dispersion and non-linearity are not considered in the theoretical development. The simulation was carried out for various systems under study based on the general model scope of works in Figure 1.1. Using *Optisys 6.0* software, each of the systems was tested by varying sets of design parameters.

1.6 Thesis Outline

Pursuing the introductory, the rest of the thesis comprises of six chapters and the overviews of all the chapters are as follows:

Chapter 2: Chapter 2 presents the literature reviews on Multiple Access Technique overviews and the existing optical codes such as Zero Cross Correlation (ZCC), Optical Orthogonal Code (OOC), Prime Code (PC), and Modified Frequency Hoping Code (MFH).

Chapter 3: Chapter 3 describes the parameters to be analyzed for the proposed codes.

Chapter 4: Chapter 4 describes on the proposed code construction, evaluation and comparison performance with the existing optical codes such as ZCC code.

Chapter 5: Chapter 5 describes on the codes with any desired cross correlation code construction to have minimum length.

Chapter 6: Chapter 6 discusses all the result and analysis obtained based from code mathematical preliminaries and simulation using optical software *Optisys 6.0*

Chapter 7: Finally, conclusion of the overall research and suggestion for the future work is presented in the last chapter.

CHAPTER 2

LITERATURE REVIEW.

2.1 Introduction.

This chapter provides details about the Multiple Access Technologies. It starts with a discussion on existing Multiple Access Techniques, advantages of OCDMA, various Optical CDMA codes and their properties.

2.2 Multiple Access Techniques.

Multiple access techniques represent one of the essential functions of access networks. The three basic multiple access are Wavelength Division Multiple Access (WDMA) also known as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) (Hikmet Sari, 2000). In these three schemes, receivers discriminate among various signals by the frequency channels, time slots and use of different codes respectively. Multiplexing is the combination of multiple signals into a single signal transmission. Multiplexing is used because it greatly increases transmission capacity and reducing system costs. There are three main types of the multiplexing techniques in communication systems; there are Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM) and Wavelength Division Multiplexing (WDM) (Xinchen Liu, 2001). Multiplexing is also the process of merging several streams of lower-speed data into a single high-rate stream for transmission (Abdullah, M.K, 2008). A variety of fiber optic multiplexing technologies have been invented to help address some of the bottle necks that exist in today's networks, and to make better use of the enormous bandwidth available in the fiber optic transmission medium. These methods vary in their ability to meet the particular needs of the service provider and in the complexity of equipment required to add and drop particular channels. Due to the differences between multiple accesses and multiplexing, multiplexing is more suitable for long distance networks, while access is more suitable for shorter distance access networks.

FDMA is the most classic multiple access technique, widely used today in satellite, cable, and radio networks to multiplex analog or digital signals. It consists of assigning a separate carrier frequency to each other. In FDMA, each transmitter is assigned a distinct frequency channel so that receivers can discriminate among them by tuning to the desired channel.

TDMA is a technology for shared medium usually radio networks. It allows several users to share the same frequency by dividing it into different time slots. The users transmit in rapid succession, one after the other, each using their own timeslot. This allows multiple users to share the same transmission medium radio frequency whilst using only the part of its bandwidth they require.