PERFORMANCE IMPROVEMENT IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED OPTICAL COMMUNICATION SYSTEMS

A THESIS

submitted by

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ॐ सरस्वती मया दृष्ट्वा, वीणा पुस्तक धारणीम् ।
हंस वाहिनी समायुक्ता मां विद्या दान करोतु में ॐ ।।

Dedicated to

My Parents, Brother

Who taught me the value of study and perseverance ethic and have given me endless support

My Wife and Daughter

Who encouraged me in the odds during Ph.D work

Declaration

I hereby declare that the entire work embodied in this thesis is the result of investigations carried out by me in the **School of Computing and Electrical Engineering,** Indian Institute of Technology Mandi, under the supervision of **Dr. Satyajit Thakor,** and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice,due acknowledgments have been made wherever the work described is based on finding of other investigators.

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Date:

THESIS CERTIFICATE

This is to certify that the thesis titled **PERFORMANCE IMPROVEMENT IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED OPTICAL COMMUNICATION SYSTEMS**, submitted by **Pravindra Kumar**, to the Indian Institute of Technology Mandi for the award of the degree of **DOCTOR OF PHILOSOPHY** is a bonafide record of the research work done by him under my supervision. The content of this thesis, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

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Date:

Dr. Satyajit Thakor

(Supervisor)

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ABSTRACT

Keywords: *Passive optical network (PON), free space optical (FSO) link, OFDM, CDM-OFDM, square root module (SRM) device, three time slotted analog network coding (3T-ANC), transmit frequency diversity, receive space diversity, minimum Euclidean distance (MED), MeijerG-function.*

Orthogonal frequency division multiplexing (OFDM) technique gives improved performance in passive optical network (PON) system and free space optical (FSO) communication link due to its dispersion compensation capability, high bandwidth efficiency, flexibility on both multiple services and dynamic bandwidth allocation (DBA), narrow-band interference, and increased tolerance capacity against fading. The increasing demand for high bandwidth or more capacity and world wide connectivity for data and other multimedia rich application from private and business users, can be fulfilled by OFDM based PON/FSO (OFDM-PON/FSO) system at every scale, from core to metro, access networks and in-building or in-house networks. The light wave system, with prodigious bandwidth of several hundred terahertz (THz) in the infrared light wave region, can provide a staggering capacity of 100 Tb/s and beyond. Thus, the optical communication systems have become indispensable as the backbone of the modern-day information infrastructure. The PON features a point-to-multipoint (P2MP) architecture to provide broadband access that becomes the most popular solution for fiber-to-the-home (FTTH) deployment among operators. PON-based FTTH has been widely deployed ever since 2004 and is defined in ITU-T G.984 series. FSO communication link with its high data rate, capacity same as of optical fiber and secure communication over an unlicensed spectrum have become a promising technique where the installation of optical fiber is not possible. This thesis focuses on the performance improvement in terms of bit-error-rate (BER), receiver sensitivity, link length, spectral efficiency, transmission capacity or maximum achievable rate. In particular, our focus is to obtain lower complexity optical OFDM architecture in PON and FSO transmission system.

To increase the number of customers or access distance in PON/FSO link and to reduce the number central offices (COs) in any PON system, high optical power budget is required. To improve the optical power budget, we propose to use three dimensional OFDM (3-D OFDM) technique that increase minimum Euclidean distance (MED) and performance improvement as a result. In 3-D OFDM technique, 3-D signal mapper and 2-D IFFT is used. The performance can further be improved using forward error correction (FEC) codes.

To provide the security on physical layer in OFDM-PON and OFDM-FSO link, reduced optical beating interference (OBI) among different optical network units (ONUs) in upstream direction in PON system, performance improvement in presence of multi-user interference (MUI), reduced required electrical bandwidth, and reduced inter-carrier interference (ICI), we propose to use PON and FSO architecture based on combination of OFDM and CDMA known as CDM-OFDM that gives enhanced optical power budget and reduced OBI among different ONUs because of high cross-correlation among different spreading codes. This architecture provides security on physical layer due to individual user defined spreading codes. In spite of using CDM, there is a significant saving in bandwidth thereby decreasing computational complexity in digital signal processing.

To compensate the problem for non-linear behaviour of chromatic dispersion in PON system, non-linear behaviour of temporal dispersion in FSO link, due to square-law characteristic of photo-detector (PD), we propose to use square root module (SRM) device, placed after PD, in the receiver architecture. The SRM device does the inverse function of the square-law characteristic performed at the PD diode and helps to improve the performance in terms of chromatic dispersion tolerance in PON system, termpoal dispersion in FSO link.

Finally, we address the non-line-of-sight (NLoS) situation of FSO link in which communication breakdown between two users. To make possible the information exchange, a relay can be used but at the cost of less achievable rate or throughput and increased electrical power. In this work, we propose to use three time slotted analog network coding (3T-ANC) scheme that gives improved error performance and increased throughput. The 3T-ANC scheme has no optical-to-electrical and electrical-to-optical conversion interface at the relay resulting into reduced cost, complexity, and less required electrical power.

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