MODE DIVISION MULTIPLEXING IN RADIO-OVER-FREE-SPACE-OPTICAL SYSTEM INCORPORATING ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING AND PHOTONIC CRYSTAL FIBER EQUALIZATION

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Abstrak

Radio melalui optik ruang bebas (Ro-FSO) adalah teknologi revolusi yang digunakan untuk menyepadukan radio dan rangkaian optik tanpa menggunakan kabel gentian optik yang mahal. Teknologi Ro-FSO memainkan peranan penting dalam menyokong penyambungan jalur lebar di kawasan pedalaman dan kawasan terpencil di mana infrastruktur jalur lebar semasa tidak dapat digunakan disebabkan kesulitan geografi dan ekonomi. Walaupun kapasiti Ro-FSO boleh ditingkatkan dengan pemultipleksan pembahagi mod (MDM), jarak penghantaran dan kapasiti masih terbatas oleh kekaburan arah yang pelbagai dan kehilangan gandingan mod akibat gelora atmosfera seperti kabus ringan, kabus nipis dan kabus tebal. Tujuan utama projek ini adalah untuk mereka bentuk satu sistem pemultipleksan pembahagi mod (MDM) untuk Ro-FSO untuk komunikasi jarak jauh dan pendek. Pemultipleksan pembahagi frekuensi berortogon (OFDM) dicadangkan untuk komunikasi jarak jauh untuk mengurangkan kekaburan pelbagai arah dan gentian kristal fotonik (PCF) dicadangkan untuk komunikasi jarak dekat bagi mengurangkan kehilangan gandingan mod. Keputusan yang dilaporkan mengenai skema yang dicadangkan untuk komunikasi jarak jauh menunjukkan 47% peningkatan kuasa yang ketara akibat kekaburan yang mendalam melalui perambatan pelbagai arah dengan menggunakan OFDM dalam sistem MDM-Ro-FSO berbanding tanpa OFDM. Keputusan yang dilaporkan mengenai skema yang dicadangkan untuk komunikasi jarak dekat menunjukkan 90.6% peningkatan kuasa dalam mod dominan dengan menggunakan PCF di dalam MDM-Ro-FSO berbanding tanpa PCF. Keputusan yang dilaporkan dalam tesis ini menunjukkan peningkatan yang ketara dalam sistem Ro-FSO berbanding dengan sistem yang terdahulu dari segi kapasiti dan jarak penghantaran di bawah keadaan cuaca yang baik dan juga di bawah pelbagai peringkat kabus. Sumbangan tesis ini dijangka dapat menyediakan perkhidmatan jalur lebar yang lancar di kawasan terpencil.

Kata kunci: Komunikasi jarak dekat, Komunikasi jarak jauh, pemultipleksan pembahagi frekuensi berortogon (OFDM), gentian kristal fotonik (PCF)

Abstract

Radio over free space optics (Ro-FSO) is a revolutionary technology for seamlessly integrating radio and optical networks without expensive optical fiber cabling. Ro-FSO technology plays a crucial role in supporting broadband connectivity in rural and remote areas where current broadband infrastructure is not feasible due to geographical and economic inconvenience. Although the capacity of Ro-FSO can be increased by mode division multiplexing (MDM), the transmission distance and capacity is still limited by multipath fading and mode coupling losses due to atmospheric turbulences such as light fog, thin fog and heavy fog. The main intention of this thesis is to design MDM system for Ro-FSO for long and short haul communication. Orthogonal frequency division multiplexing (OFDM) is proposed for long haul communication to mitigate multipath fading and Photonic Crystal Fiber (PCF) is proposed for short haul communication to reduce mode coupling losses. The reported results of the proposed scheme for long haul communication show a significant 47% power improvement in deep fades from multipath propagation with the use of OFDM in MDM-Ro-FSO systems as compared to without OFDM. The results of the proposed scheme for short haul communication show 90.6% improvement in power in the dominant mode with the use of PCF in MDM-Ro-FSO as compared to without PCF. The reported results in the thesis show significant improvement in Ro-FSO systems as compared to previous systems in terms of capacity and transmission distance under clear weather conditions as well as under varying levels of fog. The contributions of this thesis are expected to provide seamless broadband services in remote areas.

Keywords: Short haul communication, Long haul communication, Orthogonal frequency division multiplexing (OFDM), Photonic crystal fiber (PCF)

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

BER	-	Bit Error Rate
CD	-	Chromatic Dispersion
DSB	-	Double Side Band
DWDM	-	Dense Wavelength Division Multiplexing
EDFA	-	Erbium Doped Fiber Amplifier
EOS	-	European Optical Society
FSO	-	Free Space Optics
IEEE	-	Institute of Electrical and Electronics Engineers
IF	-	Intermediate Frequency
ITU	-	International Telecom Union
MDM	-	Mode Division Multiplexing
OFDM	-	Orthogonal Frequency Division Multiplexing
ONU	-	Optical Node Unit
OSA	-	Optical Society of America
OTSB	-	Optical Tandem Side Band
PON	-	Passive Optical Network
QAM	-	Quadrature Amplitude Modulation
QM	-	Quadrature Modulation
QPSK	-	Quadrature Phase Shift Key
RF	-	Radio Frequency
RoF	-	Radio over Fiber
Ro-FSO	-	Radio over Free Space Optics
SNR	-	Signal to Noise Ratio
SOA	-	Semiconductor Optical Amplifier
SSB	-	Single Side Band
THz	-	Terahertz
WDM	-	Wavelength Division Multiplexing

CHAPTER ONE
INTRODUCTION

Radio over free space optics (Ro-FSO) is one of the remarkable technologies for seamless integration of wireless and optical networks without using expensive optical fibers. The future of Ro-FSO technology aims to not only build a universal platform for distributing broadband services for wireless local area networks but also address the issue of scarcity of radio frequency spectrum and channel degradation by allocating frequency spectrum in a more flexible manner. Various atmospheric turbulences, particularly fog, can affect the transmission distance, bandwidth and capacity of Ro-FSO systems. On the other hand, Mode Division Multiplexing (MDM) plays a vital role in increasing the bandwidth of optical networks. The use of MDM may also increase the aggregate bandwidth of Ro-FSO systems. The main intention of this thesis is to design MDM scheme for Ro-FSO system to make it useful for distributing broadband services.

This chapter aims to place this research thesis into context by first providing an introduction to Ro-FSO in Section 1.1 followed by the research motivation in Section 1.2. This lays the foundation for the Problem Statement in Section 1.3, followed by Research Questions in Section 1.4 and Research Objectives in Section 1.5. The scope of this research is mentioned in Section 1.6 whereas the key contribution of this thesis is presented in Section 1.7. The organization of the rest of the thesis is presented in Section 1.8.

1.1 Ro-FSO Transmission Systems

Ro-FSO technology is promising for providing a ubiquitous platform for seamless integration of radio and optical networks without expensive optical fiber cabling. The last decade has experienced enormous growth in the development of optical

The contents of the thesis is for internal user only

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