UNIVERSITI PUTRA MALAYSIA

IMPROVEMENT OF THREE-LEVEL CODE DIVISION MULTIPLEXING IN OPTICAL FIBER COMMUNICATION SYSTEMS

FARANAK KHOSRAVI

IMPROVEMENT OF THREE-LEVEL CODE DIVISION MULTIPLEXING IN OPTICAL FIBER COMMUNICATION SYSTEMS

By

FARANAK KHOSRAVI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilments of the Requirement for the Degree of Master of Science
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DEDICATION

This thesis is dedicated to

To my beloved parents

For their endless support and love.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

IMPROVEMENT OF THREE-LEVEL CODE DIVISION MULTIPLEXING IN OPTICAL FIBER COMMUNICATION SYSTEMS

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July 2013

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Three-level code division multiplexing (3LCDM) is a multiplexing technique that owes the advantages of both return to zero (RZ) and non return to zero (NRZ) techniques. The principle work of 3LCDM is based on the multiplexing of two users with each user utilizing different line coding techniques of RZ and NRZ. Both users share this communication medium to transmit the same carrier wavelength concurrently. By using 3LCDM technique over wavelength division multiplexing (WDM), the channel capacity can be doubled. However, this technique faces a major problem due to its three-level properties especially when the optical amplifier is used in long distance system. Since the noise is intensity dependent, the signals having a higher power level experience more noise as compared to the signals having lower power level. This difference causes dissimilar performance for 3LCDM users and degrades the system's performance. Dispersion is another problem that is experienced when using this technique. It broadens the width of signal pulse in the fibre due to its dependence on the fibre material's refractive index on the optical carrier wavelength. Therefore, this study aims to overcome these two problems peculiar to 3LCDM system by applying level spacing optimization and dispersion mapping.

This study was conducted using OptiSystem software interfaced with Matlab environment. In simulating the level of the spacing optimization setup, the level spacing of the upper and lower bounds of 3LCDM were controlled using two techniques, i.e., optical and electrical configurations. For dispersion mapping, periodic mapping was used for the simulation which included the effects and interactions between attenuation, dispersion, and self-phase modulation (SPM).

The performance of the system in this study was observed and evaluated. It was found that by using the level spacing optimization method for both optical and electrical configurations, 3LCDM system was improved by around 4.5 dB in OSNR and 3.5 dB enhancements in receiver sensitivity. The differences between the two techniques of optical and electrical configuration were observed by comparing chromatic dispersion tolerance. The observation showed that in electrical configuration, both users could tolerate the maximum dispersion of ± 89 ps/nm. Meanwhile, in optical configuration, dissimilar dispersion tolerances were

observed in positive and negative dispersions, where such tolerances remained between around + 88 and - 69 ps/nm respectively. Optical configuration is still more robust compared to NRZ chromatic dispersion tolerance. By applying the dispersion map, the performance has improved by 5.5 dB in OSNR, 6 dB in receiver sensitivity and 3 dB in self phase modulation (SPM) threshold. Based on these improvements, the performance of 3LCDM is comparable to the available multiplexing and modulation techniques while offering simpler transmitter and receiver architecture. When chromatic dispersion tolerance of 3LCDM system and NRZ are compared, it can be concluded that the worst channel of 3LCDM technique has a better performance of ± 42 ps/nm than that of NRZ. Hence, 3LCDM technique is suitable to be implemented in WDM transmission systems.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

Meningkatkan Prestasi Pemultipleksan Pembahagian Kod Tiga-Tahap dalam Komunikasi Gentian Optik

Oleh

FARANAK KHOSRAVI

Julia 2013

Pengerusi: Makhfudzah Mokhtar, PhD

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Pemultipleksan pembahagian kod tiga-tahap (3LCDM) merupakan teknik pemultipleksan yang mengambil kedua-dua kelebihan teknik kembali-ke-sifar (RZ) dan tidak kembali-ke-sifar (NRZ). Prinsip 3LCDM adalah berdasarkan pemultipleksan dua pengguna di mana setiap pengguna menggunakan teknik pengekodan baris yang berbeza, iaitu NRZ dan RZ. Kedua-dua pengguna berkongsi media komunikasi untuk memancar melalui jalur gelombang pembawa dan tempoh masa yang sama. Dengan menggunakan teknik 3LCDM, kapasiti saluran bertambah dua kali ganda berbanding dengan WDM. Walau bagaimanapun, teknik ini menghadapi masalah yang ketara disebabkan oleh ciri-ciri tiga tahapnya terutamanya apabila penguat optik digunakan dalam sistem jarak jauh. Oleh kerana hingar bergantung kepada keamatan, isyarat yang mempunyai tahap kuasa yang lebih tinggi akan mengalami hingar yang lebih berbanding kepada isyarat yang mempunyai tahap kuasa yang lebih rendah. Perbezaan ini menyebabkan prestasi operasi yang berbeza-beza antara pengguna-pengguna 3LCDM dan menurunkan prestasi sistem keseluruhannya. Serakan adalah satu lagi masalah yang dialami apabila menggunakan teknik ini. Ia menyebabkan perlebaran isyarat denyut dalam gentian optik disebabkan pergantungannya pada indeks biasan gentian optik. Oleh itu, kajian ini bertujuan untuk mengatasi kedua-dua masalah yang khusus kepada sistem 3LCDM dengan menggunakan pengoptimuman jarak tahap dan pemetaan penyerakan.

Kajian ini telah dilaksanakan menggunakan perisian Optisystem yang berantara muka dengan persekitaran Matlab. Dalam set simulasi pengoptimuman penjarangan tahap, jarak tahap atas dan bawah 3LCDM dikawal menggunakan dua pendekatan iaitu, konfigurasi optik dan elektrik. Sementara itu, simulasi untuk pemetaan penyerakkan mengambil kira kesan dan interaksi antara parlaifan, penyerakkan, dan modulasi fasa sendiri (SPM). Pemetaan berkala digunakan sebagai peta penyerakkan dalam simulasi ini.

Dalam kajian ini, prestasi sistem yang dicadangkan telah diperhatikan dan dinilai. Dengan menggunakan kaedah pengoptimuman penjarangan tahap untuk kedua-dua konfigurasi optik dan elektrik, prestasi sistem 3LCDM bertambah baik iaitu peningkatan sebanyak 4.5 dB untuk OSNR dan 3.5 dB untuk sensitiviti penerima. Perbezaan antara kedua-dua teknik ini boleh diperhatikan dalam perbandingan toleransi penyebaran kromatik. Pemerhatian ini

menunjukkan bahawa, dalam konfigurasi elektrik, kedua-dua pengguna boleh bertahan dengan penyerakkan maksimum ± 89 ps / nm. Manakala dalam konfigurasi optik, toleransi penyebaran yang berbeza diperhatikan dalam penyerakkan positif dan negative di mana toleransi itu kekal sekitar masing-masing 88 dan -69 ps / nm. Ia masih lebih mantap berbanding toleransi penyerakkan kromatik NRZ. Dengan menggunakan teknik pemetaan penyebaran, prestasi telah meningkat sebanyak 5.5 dB dalam OSNR, 9 dB dalam sensitiviti penerima dan 3 dB di ambang SPM. Berdasarkan penambahbaikan ini, prestasi 3LCDM adalah setanding dengan teknik-teknik pemultipleksan dan modulasi yang tersedia ada manakala memudahkan pemancaran dan rekabentuk penerima. Tambahan pula, toleransi penyerakan kromatik 3LCDM dan NRZ dibandingkan. Dari perbandingan ini, boleh disimpulkan bahawa saluran yang terburuk menggunakan teknik 3LCDM mempunyai prestasi ± 42 ps / nm lebih baik daripada NRZ. Oleh itu, ini menjadikan teknik 3LCDM sangat berguna untuk melaksanakan sistem penghantaran WDM.

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I certify that an Examination Committee has met to conduct the final examination of Faranak Khosravi on her Master of Science thesis "Improvement of Three-Level Code Division Multiplexing in Optical Fiber Communication Systems" on 30th December 2013 in accordance with Universiti Putra Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree.

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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Date: 30 December 2013

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