UNIVERSITI PUTRA MALAYSIA

HYBRID SUBCARRIER - OPTICAL SPECTRUM CODE DIVISION MULTIPLEXING SYSTEM WITH SPECTRAL DIRECT DECODING DETECTION TECHNIQUE

RATNA KALOS ZAKIAH BT SAHBUDIN

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DOCTOR OF PHILOSOPHY

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HYBRID SUBCARRIER - OPTICAL SPECTRUM CODE DIVISION MULTIPLEXING SYSTEM WITH SPECTRAL DIRECT DECODING DETECTION TECHNIQUE

By

RATNA KALOS ZAKIAH BT SAHBUDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,

in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2010

DEDICATION

To the memory of my father Sahbudin b. Ja‟adil.

5th July 1941-13th Oct 1974

To my mother Ramlah bt. Midun, who had the arduous task of raising four children

by herself after the untimely death of my father.

To my husband Ishak b. Aris, who has supported me in all my endeavors

and all my children

Sarah Irdina, Muhammad Irfan, Muhammad Irham, Muhammad Ridwan

and Safea Irdina.

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Professor Mohamad Khazani Abdullah, PhD
Faculty: Engineering

Today‟s telecommunication systems are expected to provide a reliable, affordable, flexible, scalable services and possess substantial information carrying capacity in order to meet the increasingly high user‟s expectation. There has been tremendous interest in applying hybrid multiplexing technique to fiber optic communication systems to enhance network flexibility and scalability. Optical spectrum code division multiplexing (OSCDM) is one of the multiplexing techniques that is becoming popular because of the flexibility in the allocation of channels, ability to operate asynchronously, enhanced privacy and increased capacity in bursty nature networks. On the other hand, subcarrier multiplexing (SCM) technique is able to enhance the channel data rate of OSCDM systems. The attractive feature of the current SCM technology is cost-effective as it provides a way to take advantage of the multi-gigahertz bandwidth of the fiber optics, using well-established microwave techniques for which components are commercially available. Hence, this thesis proposes a hybrid SCM and OSCDM (SCM-OSCDM) system for the purpose of

combining the advantages of both techniques. This hybrid technique can increase the number of simultaneous users by increasing the SCM and/or the OSCDM codeword. The performance of the hybrid system strongly depends on the codes properties and the detection technique. The system utilizes a new unified code construction named Khazani-Syed (KS) code based on the Double Weight (DW) and Modified Double Weight (MDW) codes. KS code possesses an ideal in-phase cross correlation property, which led to the elimination of multiple access interference (MAI). The effect of MAI will degrade the system performance. Conventionally, MAI is reduced by using subtraction detection techniques. In this thesis, a new detection technique called Spectral Direct Decoding (SDD) is introduced. SDD technique requires less number of filters for the decoders as compared to the subtraction detection techniques and only filters out the non-overlapping spectral. Thus, eliminate the phase induced intensity noise (PIIN). The effectiveness of the new hybrid system with the proposed SDD technique has been verified and demonstrated through theoretical analysis, simulation and experimental work. The results show that the new hybrid system with the proposed SDD technique improves the performance than that using the conventional subtraction detection techniques. For example in theoretical analysis, at bit error rate (BER) of 10-9, the SDD technique provides an improvement in the total number of users over the AND subtraction by a factor of 4. The system capacity also shows an improvement of 17.734 Gbps for 20 users. Furthermore, the computer simulation results show that the transmission distance and bit rate per channel improve by 27% and 100%, respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SISTEM HIBRID SUBPEMBAWA - PEMULTIPLEKSAN PEMBAHAGIAN KOD SPEKTRUM OPTIK DENGAN TEKNIK PENGESANAN PENYAHKODAN TERUS SPEKTRUM

Oleh
RATNA KALOS ZAKIAH BT SAHBUDIN
Januari 2010

Pengerusi: Profesor Mohamad Khazani Abdullah, PhD

Fakulti: Kejuruteraan

Sistem telekomunikasi pada masa kini dijangka dapat memberi perkhidmatan yang boleh dipercayai, mampu dimiliki, fleksibel, dapat berkembang dan memiliki keupayaan untuk membawa maklumat dengan kapasiti yang besar bagi memenuhi keperluan pelanggan yang semakin meningkat. Penggunaan teknik pemultipleksan hibrid untuk sistem komunikasi gentian optik telah mendapat perhatian untuk menambah fleksibiliti dan keupayaan rangkaian untuk berkembang. Salah satu daripada teknik pemultipleksan yang semakin popular adalah pemultipleksan pembahagian kod spektrum optik (OSCDM) kerana kesesuaian dalam pembahagian saluran, keupayaan untuk beroperasi secara tak segerak, peningkatan dari segi keselamatan dan juga kapasiti dalam rangkaian yang bersifat merebak. Bagi teknik pemultipleksan subpembawa (SCM), ia berupaya untuk menambah kadar data saluran untuk sistem OSCDM. Antara ciri-ciri yang menarik bagi teknologi SCM pada masa kini ialah penggunaan teknik gelombang mikro yang terbukti baik serta komponen-komponen yang terdapat di pasaran dengan harga yang berpatutan. Ia

juga memberi jalan untuk menggunakan kelebihan lebar jalur gentian optik yang berbilang-gigahertz. Oleh itu, tesis ini mencadangkan satu sistem hibrid pemultipleksan subpembawa dan pemultipleksan pembahagian kod spektrum optik (SCM-OSCDM) dengan tujuan menggabungkan kelebihan kedua-dua teknik tersebut. Teknik hibrid ini dapat menambahkan lagi bilangan pengguna serentak dengan cara menambahkan SCM dan/atau kata kod OSCDM.

Prestasi sistem hibrid bergantung kuat kepada ciri-ciri kod dan teknik pengesanan. Sistem ini menggunakan pembinaan kod penggabungan baru yang diberi nama kod Khazani-Syed (KS) berasaskan kepada kod-kod Dwi Pemberat (DW) dan Dwi Pemberat Terubahsuai (MDW). Kod KS mempunyai ciri-ciri sekaitan silang yang unggul, yang dapat menghapuskan gangguan akses pelbagai (MAI). Gangguan ini akan menyebabkan prestasi sistem tersebut menurun. Pada kebiasaannya MAI dapat dikurangkan dengan menggunakan teknik pengesanan penolakan. Di dalam tesis ini, satu pendekatan baru yang diberi nama teknik pengesanan penyahkodan terus spektrum (SDD) diperkenalkan. Teknik SDD memerlukan jumlah penapis untuk penyahkodan yang kurang berbanding dengan jumlah penapis yang diperlukan oleh teknik pengesanan penolakan dan hanya menapis spektrum yang tidak bertindih. Oleh itu, hingar keamatan teraruh fasa (PIIN) dapat dihapuskan. Keberkesanan sistem hibrid dengan menggunakan teknik pengesanan SDD ini telah diuji dan dibuktikan dengan menggunakan analisa teori, simulasi dan eksperimen. Hasil keputusan menunjukkan prestasi sistem hibrid dengan menggunakan teknik pengesanan SDD lebih baik berbanding dengan menggunakan teknik pengesanan penolakan. Sebagai contoh, pada kadar ralat bit (BER) 10-9, teknik SDD dapat memperbaiki jumlah bilangan pengguna sebanyak 4 kali ganda berbanding teknik penolakan AND. Kapasiti sistem juga menunjukkan peningkatan sebanyak 17.734 Gbps untuk 20 pengguna. Tambahan pula, keputusan simulasi komputer menunjukkan jarak penghantaran dan kadar bit setiap saluran meningkat sebanyak 27% dan 100%, masing-masing.

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I certify that a Thesis Examination Committee has met on 26 January 2010 toconduct the final examination of Ratna Kalos Zakiah bt Sahbudin on her thesis entitled "Hybrid Subcarrier-Optical Spectrum Code Division Multiplexing System with Spectral Direct Decoding Detection Technique" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy. Members of the Thesis Examination Committee were as follows:

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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 Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 13 May 2010

DECLARATION

I declare that the thesis is my original work except for the 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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RATNA KALOS ZAKIAH BT SAHBUDIN

Date: 1 May 2010

TABLE OF CONTENTS