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QR FACTORIZATION EQUALISATION SCHEME FOR MODE DIVISION MULTIPLEXING TRANSMISSION IN FIBRE OPTICS



MASTER OF SCIENCE IN INFORMATION TECHNOLOGY UNIVERSITI UTARA MALAYSIA 2016

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Abstrak

Sistem komunikasi optik memainkan peranan besar dalam pengendalian trafik internet di seluruh dunia. Trafik internet telah meningkat pada kadar yang dramatik dan infrastruktur rangkaian optik semasa mungkin tidak dapat menampung pertumbuhan trafik di beberapa dekad. Pemultipleks pembahagian mod diperkenalkan sebagai satu teknik baru untuk meningkatkan kapasiti rangkaian optik dengan menggunakan mod cahaya sebagai saluran individu. Salah satu isu utama dalam MDM adalah gandingan mod yang merupakan satu fenomena fizikal apabila mod cahaya bertukar tenaga antara satu sama lain semasa pembiakan melalui gentian optik menyebabkan gangguan antara simbol (ISI).

Banyak kajian berdasarkan min kuasa dua terkecil (LMS) dan kuasa dua terkecil rekursif (RLS) telah diambil bagi mengurangkan kesan mod gandingan. Walaubagaimanapun, kebanyakan pendekatan mempunyai kerumitan pengkomputan yang tinggi dan menghalang operasi sistem komunikasi berkelajuan tinggi. Pendekatan penyamaan lenyap tidak memerlukan isyarat latihan, justeru itu akan mengurangkan muatan kekal. Sebaliknya, pemfaktoran QR menunjukkan kerumitan pengkomputan yang rendah dalam penyelidikan terdahulu, dalam domain radio. Gabungan kedua-dua konsep ini menunjukkan hasil yang ketara, kerana penggunaan algoritma yang lebih ringkas mengurangkan pemprosesan yang perlu dilakukan oleh peralatan komunikasi, manakala ketiadaan latihan isyarat menjimatkan jalur lebar dan meningkatkan prestasi keseluruhan sistem. Berdasar kepada penulisan-penulisan yang ada, penyamaan lenyap berdasarkan pemfaktoran QR belum pernah digunakan dalam penyamaan MDM.

Penyelidikan ini melalui Metodologi Penyelidikan Reka Bentuk (DRM) empat-tahap untuk mencapai objektif kajian. Peringkat perlaksanaan melibatkan dua simulator yang berbeza. Simulator pertama merupakan sebuah simulator optic yang digunakan untuk mengumpul data optik awal. Kemudiannya, MATLAB digunakan untuk membangunkan skim penyamaan. Pembangunan bermula dengan penghasilan fungsi pemindahan sistem (H) untuk digunakan sebagai input kepada penyamaan yang dibangunkan. Penyamaan lenyap berdasarkan pemfaktoran QR dipilih sebagai satu cara untuk memperkenalkan penyamaan yang cekap untuk mengurangkan ISI dengan merapatkan lebar denyut. Peringkat pembangunan termasuk peringkat di mana anggaran saluran itu berlaku. Ciri-ciri statistik berdasarkan sisihan piawaian (STD) kuasa isyarat input dan output telah digunakan untuk bahagian saluran anggaran penyamaan lenyap.

Kaedah penganggaran saluran yang dicadangkan mampu membuat anggaran saluran dengan keseluruhan ralat min persegi (MSE) 0.176588301 dari isyarat awal yang dihantar. Kajian ini mendapati bahawa saluran yang paling lemah mempunyai MSE 0.771365 berbanding isyarat awal, manakala saluran terbaik mempunyai MSE 0.000185 berbanding isyarat awal. Ia telah dilakukan dengan mengelak isu-isu berkaitan pembangunan algoritma-algoritma terdahulu yang dibangunkan bagi tujuan yang sama. Algoritma dalam kajian ini terbukti mengurangkan masalah kerumitan pengkomputan, yang merupakan salah satu isu utama yang sedang dihadapi, melalui LMS dan RLS. Hasil ujian menunjukkan skema penyamaan yang dibangunkan mempunyai kerumitan 0(N) berbanding 0(N²) bagi RLS. Pada masa sama, ia adalah lebih laju dari LMS kerana masa pengiraannya adalah 0.005242 saat berbanding 0.0077814 saat bagi LMS. Keputusan ini sah bagi matrik songsang dan matrik sama.

Abstract

Optical communication systems play a major role in handling worldwide Internet traffic. Internet traffic has been increasing at a dramatic rate and the current optical network infrastructure may not be able to support the traffic growth in a few decades. Mode division multiplexing is introduced as a new emerging technique to improve the optical network capacity by the use of the light modes as individual channels. One of the main issues in MDM is mode coupling which is a physical phenomenon when light modes exchange their energy between each other during propagation through optical fiber resulting in inter-symbol interference (ISI).

Many studies based on Least Mean Square (LMS) and Recursive Least Square (RLS) have taken place to mitigate the mode coupling effect. Still, most approaches have high computational complexity and hinders high-speed communication systems. Blind equalisation approach does not need training signals, thus, will reduce the overhead payload. On the other hand, QR factorization shows low computational complexity in the previous research in the radio domain. The combination of these two concepts shows significant results, as the use of low complexity algorithms reduces the processing needed to be done by the communication equipment, resulting in more cost effective and smaller equipment, while having no training signal saves the bandwidth and enhances the overall system performance. To the best knowledge of the researcher, blind equalisation based on QR factorization technique has been not used in MDM equalisation to date.

The research goes through the four stages of the design research methodology (DRM) to achieve the purpose of the study. The implementation stage is taken two different simulators has been used, the first one which is the optical simulator is used to collect the initial optical data then, MATLAB is used to develop the equalisation scheme. The development starts with the derivation of the system's transfer function (H) to be used as the input to the developed equalizer. Blind equalisation based on QR factorization is chosen as a way to introduce an efficient equalization to mitigate ISI by narrowing the pulse width. The development stages include a stage where the channel estimation is taken place. Statistical properties based on the standard deviation (STD) of the powers of the input and output signals has been used for the blind equalisation's channel estimation part.

The proposed channel estimation way has the ability in estimating the channel with an overall mean square error (MSE) of 0.176588301 from the initial transmitted signal. It is found that the worst channel has an MSE of 0.771365 from the transmitted signal, while the best channel has and MSE of 0.000185 from the transmitted signal. This is done by trying to avoid the issues accompanied with the development of the previous algorithms that have been utilized for the same goal. The algorithm mentioned in the study reduces the computational complexity problem which is one of the main issues that accompany currently used tap filter algorithms, such as (LMS) and (RLS). The results from this study show that the developed equalisation scheme has a complexity of O(N) compared with $O(N^2)$ for RLS and at the same time, it is faster than LMS as its calculation CPU time is equal to 0.005242 seconds compared with 0.0077814 seconds of LMS. The results are only valid for invertible and square channel matrices.

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In the name of ALLAH, Most Gracious, Most Merciful:

"Work; so Allah will see your work and (so will) His messenger and the believers;"

(The Holy Quran - AtTawbah 9:105)

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Dedication

To my eternal love and the eternal light of divine, the soul of my world, the reason I exist

To the light that lit my path.... My father

To the sun of my life, the warmth of which is overwhelming my world.... My mother

To the ones who are like the stars in my skies.... My brother and sisters

To the ones who are the breaths I take, the ones who live deep down inside my heart, my wife and children

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CHAPTER ONE: INTRODUCTION

1.1 Research Background

Currently, the volume of data traffic is growing at an estimated annual rate of more than 50%. A major portion of this traffic is linked to high-definition video streaming, multimedia file sharing, cloud computing, mobile networking, online gaming and a host of other innovative networking technologies [1]. The predicted level of global traffic over the next three years is displayed in the following Figure 1.

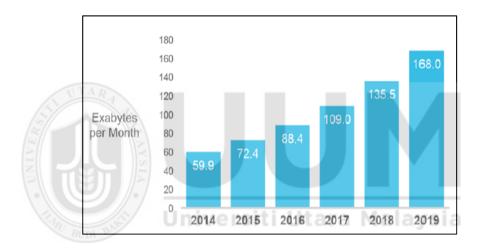


Figure 1: Annual global internet traffic growth prediction [2]

The rates of rising data and growth in the number of users have challenged service providers and prompted investigations on new technologies to cater to the overwhelming traffic in optical backbones. The void in this area has led to the development of innovative systems for capacity augmentation. This includes several multiplex techniques [3] and advanced modulation schemes [4].

As a multiplexing techniques, Mode Division Multiplexing (MDM), which has the potential for spatial multiplexing, involves the use of modes as parallel channels [5].

The contents of the thesis is for internal user only

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