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A METHOD FOR PERFORMANCE COMPARISON OF GENERATOR MATRICES IN WIRELESS COMMUNICATION

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By

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Thesis Submitted to the School of Graduate Studies,
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DEDICATION

This work is lovingly dedicated to
Our Almighty God Allah
My wife Nor Aishah Ismail
My sons Muhammad Adham Al-Faqeh
Muhammad Umar Al-Faqeh
My daughter Zahra Hanania

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

A METHOD FOR PERFORMANCE COMPARISON OF GENERATOR MATRICES IN WIRELESS COMMUNICATION

By

MOHAMAD FITERI BIN RAZALI

January 2015

Chair: Harlisya binti Harun, PhD
Faculty: Engineering

Space-Time Trellis Code (STTC) is a wireless communication system that can provide both diversity and coding gain. Since Tarokh discovered STTC in 1998, a considerable effort has been done to improve the performance of the original STTC. One way of achieving enhancement is by focusing on the generator matrix **G**. The generator matrix **G** represents the encoder structure for STTC. Having a generator matrix **G** of higher quality implies a better STTC transmission system. Until now, researchers have only concentrated on STTC of different states in analysing the performance of generator matrix **G**. No effort has been made on different generator matrices **G** of similar state. It is because no algorithm available to produce a wide variety of generator matrices **G** with diverse minimum determinants. Hence, the performance of generator matrices **G** of similar state with different minimum determinant (MD) is to be analysed. A number of generator matrices **G** with minimum determinant of four (4), eight (8) and sixteen (16) of the same state have been successfully produced.

A method was developed via coding to simulate and analyse the behaviour of different generator matrices **G** of similar state with different minimum determinant over a flat Rayleigh fading for a 4-PSK scheme in wireless communication system. The method will define the parameters and generator matrices **G** as well as establish the trellis diagram and generate the state diagram. The mapped output at the receiver will be used to evaluate the performance of generator matrices **G** in terms of Bit Error Rate (BER) output against Signal-to-Noise Ratio (SNR). This research provides an early analysis of how the generator matrices **G** of varying minimum determinant would behave

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when the signal transmission is established in a similar state of trellis. From this research, it is found that generator matrices **G** with minimum determinant of sixteen (16) has achieved a better performance relative to the generator matrices **G** with minimum determinant of eight (8). However at certain extent, increasing the minimum determinant will merely give an insignificant contribution to the improvement of the performance when only one receive antenna is used and this was shown by the performance of generator matrices **G** with minimum determinant of four (4). They achieve a better performance relative to the generator matrix **G** with minimum determinant of sixteen (16). This research can be used as a platform for future studies that employing multiple receive antennas.

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

SATU KAEDAH PERBANDINGAN PRESTASI MATRIK PENJANA DALAM KOMUNIKASI TANPA WAYAR

Oleh

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Kod Trellis Ruang-masa (KTRM) adalah satu sistem komunikasi tanpa wayar yang boleh menyediakan kepelbagaian dan meningkatkan kadar pengkodan. Sejak Tarokh memperkenalkan KTRM pada tahun 1998, satu usaha yang agak menyeluruh telah dilakukan untuk meningkatkan prestasi KTRM yang asal. Satu cara untuk mencapai penambahbaikan adalah dengan memberi fokus kepada matrik penjana **G**. Matrik penjana **G** mewakili struktur pengekod bagi KTRM. Matrik penjana **G** yang berkualiti tinggi akan menghasilkan sistem penghantaran KTRM yang lebih baik. Sehingga kini, para penyelidik hanya memfokuskan kepada KTRM dengan nod keadaan yang berbeza dalam menganalisa prestasi matrik penjana **G**. Tiada usaha dibuat untuk menganalisa matrik penjana **G** yang berbeza dengan nod keadaan yang sama. Ini disebabkan ketiadaan algorithm untuk menghasilkan kepelbagaian matrik penjana **G** yang mempunyai penentu minimum yang berlainan. Oleh sebab itu, prestasi matrik-matrik penjana **G** dengan nod keadaan yang sama tetapi penentu minimum berbeza akan dianalisa. Beberapa matrik penjana **G** dengan penentu minimum empat (4), lapan (8) dan enam belas (16) dengan nod keadaan yang sama telah berjaya dihasilkan.

Satu kaedah telah dibangunkan menggunakan kod aturcara untuk mensimulasi dan menganalisis perilaku matrik penjana **G** yang berbeza dengan nod keadaan yang sama tetapi penentu minimum yang berbeza dalam persekitaran Rayleigh yang mempunyai kadar susut isyarat yang sekata bagi skim 4-PSK dalam sistem komunikasi tanpa wayar. Melalui kaedah tersebut, diagram trellis dan diagram nod keadaan yang mewakili matrik-matrik penjana **G** yang telah ditentukan akan dihasilkan berdasarkan parameter-

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parameter yang diberi. Output yang dipetakan pada penerima pula akan digunakan untuk menilai prestasi matrik-matrik penjana **G** dari aspek kadar kesalahan bit kepada nisbah isyarat-hingar. Kajian ini menyediakan analisis awal iaitu bagaimana matrik-matrik penjana **G** dengan penentu minimum berbeza akan berperilaku apabila penghantaran isyarat ditetapkan dalam nod keadaan trellis yang serupa. Melalui kajian ini, didapati bahawa matrik-matrik penjana **G** dengan penentu minimum enam belas (16) telah mencapai prestasi yang lebih baik berbanding dengan matrik-matrik penjana **G** dengan penentu minimum lapan (8). Walau bagaimanapun, pada tahap tertentu, apabila hanya satu antena penerima digunakan, meningkatkan penentu minimum tidak meningkatan prestasi secara ketara dan ini telah ditunjukkan oleh prestasi matrik-matrik penjana **G** dengan penentu minimum empat (4). Ia mencapai prestasi yang lebih baik berbanding matrik-matrik penjana **G** yang mempunyai penentu minimum enam belas (16). Kajian ini boleh digunakan sebagai landasan untuk kajian yang menggunakan antenna penerima yang berbilang di masa hadapan.

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I certify that a Thesis Examination Committee has met on 30 January 2015 to conduct the final examination of Mohamad Fiteri bin Razali on his thesis entitled " A Method for Performance Comparison of Generator Matrices in Wireless Communication"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 Master of Science

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This thesis was 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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LIST OF ABBREVIATIONS

KTCM	:	Kod Trellis Ruang-masa
SNR	:	Signal-to-noise-ratio
MIMO	:	Multiple-input-multiple-output
STTC	:	Space-time Trellis Code
MD	:	Minimum Determinant
4-PSK	:	4-Phase Shift Keying
BER	:	Bit Error Rate
AWGN	:	Additive White Gaussian Noise
CSI	:	Channel State Information
MSB	:	Most Significant Bit
ML	:	Maximum Likelihood
MIAT	:	Malaysian Institute of Aviation Technology
VA	:	Viterbi Algorithm
MLSE	:	Maximum Likelihood Sequence Estimator
UniKL	:	Universiti Kuala Lumpur
dB	:	Decibel
MRRC	:	Maximal-ratio-receiver Combining
MMSE	:	Minimum Mean Squared Error
FEC	:	Forward Error Correction
TSC	:	Tarokh/Seshadri/Calderbank
BBH	:	Baro/Bauch/Hansmann
PWEP	:	Pair-wise Error Probability
QPSK	:	Quadrature Phase Shift Keying
MISO	:	Multiple-input single-output

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CHAPTER 1

INTRODUCTION

1.1 Motivation of Research

There is a growth in demand for reliable high-speed wireless communication channels to support a broad range of applications. A lot of research has been carried out to improve wireless communication transmissions due to the fact that transmitted signals in wireless environments are received through multiple paths where they are attenuated by the phenomenon of fading as well as interference from other applications that share the same transmission medium. Hence, it results in performance degradations.

Diversity techniques are broadly used to increase the information capacity as well as decrease the effects of multiple path fading, thus enhancing the reliability of transmission without increasing the transmitted power or sacrificing the bandwidth [1-3]. The diversity techniques can be divided into time, frequency and space diversity. These techniques require replicas of transmitted signal which are uncorrelated or independent to each other on the receiver end.

The basis of the diversity technique is that, if two or more independent signals are received, they will fade in an uncorrelated way. For example, some signals are severely attenuated whilst the others will be less attenuated. The proper combination of the transmitted signals' replicas at the receiver will greatly reduce the fading by increasing the overall received signal-to-noise-ratio (SNR) thus improving the reliability of the transmissions [10].

In the space diversity or so-called antenna diversity technique, multiple transmit and receive antennas or multiple-input-multiple-output (MIMO) channels are employed due to its capability to increase the information capacity in wireless data transmission. The antenna arrays are arranged in space in proper distance to obtain the uncorrelated signals, which is the important feature in this diversity technique. The advantage of this technique over other aforementioned diversity techniques is that it does not induce any loss in bandwidth efficiency. The capacity of the MIMO channels can be improved by employing space-time coding technique due to the higher signal transmission quality produced [10].

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1.2 Development of Space-Time Trellis Code

In wireless communications, radio spectrum availability is quite restricted. Hence, a new wireless communication system is acquired in order to significantly increase the communication spectral efficiency which will increase the communication capacity. Multiple antenna transmission systems, together with advance coding techniques such as Space-Times Trellis Codes (STTC), will vastly increase the communication capacity since the signals are transmitted redundantly from multiple antennas which could combat the fading effect during transmission without increasing the transmitted power. STTC was introduced in 1998 by Tarokh et al. [1, 2, 28] for wireless communication as a high-data rate, bandwidth, and power-efficient method over the Rayleigh and Rician fading channel. The STTC technique is one of the coding structures in the space-time coding technique. This technique is based on the trellis structure which can be decoded using soft-decoding techniques such as the Viterbi decoder. Improvement in code design criteria for the STTC coding technique based on generator matrices **G** has evolved gradually since its introduction. A lot of research is being carried out in this coding technique in order to achieve better and higher signal transmission quality. In the early introduction of STTC in 1998 by Tarokh et al. [1, 2, 28] until recent development of the coding technique, the newly developed STTC generator matrices **G** [4-9] have successfully improved the distance of codeword symbol (minimum determinant) compare to the previous generator matrices **G**.

In this thesis, an encoder and Viterbi decoder are used to simulate the performance of the STTC generator matrices **G** with a minimum determinant (MD) of four (4), eight (8) and sixteen (16) of similar state 4- Phase Shift Keying (4-PSK) in a flat Raleigh fading environment. The Bit Error Rate (BER) for a range of SNR is analysed to evaluate the performance of respective STTC generator matrices **G**.

1.3 Problem Statement

In the conventional wireless communication system, a single antenna is used at both the transmitter and the receiver. The multipath effect is one of the major concerns in this system since the signals take many paths to reach the receiver which causes problems such as fading, cut-off, and intermittent reception of the signal. In digital wireless communication, this will cause the reduction in data speed and increase the number of errors. The multiple antenna transmission system is designed to increase the channel capacity and improve the data transmission reliability. STTC is a coding technique designed for a multiple antenna transmission system. This coding technique employs generator matrices in order to encode the input data and map it to the transmitted symbols. The performance of generator matrices **G** of different states for 4-PSK scheme with 2 transmit antennas and 1 receive antenna over a

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flat Rayleigh fading have been studied and analysed [11, 40]. By designing the encoder structure with more states, the coding advantage of the codes can be improved [1]. Nevertheless, the behaviour of the generator matrices **G** of similar states but varying minimum determinants also need to be studied in order to improve the performance of STTC in communication systems. No effort has been made before because no algorithm available to produce a wide variety of generator matrices **G** with diverse minimum determinants until recent development of an algorithm by [4]. The performance of generator matrices **G** of 4-PSK scheme for minimum determinants of four (4), eight (8) and sixteen (16) in 4-state trellis structure to be analysed because they are currently widely produced in STTC communication. A method via coding is developed which will define the parameters and generator matrices **G** as well as establish the trellis diagram and generate the state diagram. The mapped output at the receiver will be used to evaluate the performance of generator matrices **G**. This research provides an early analysis of how the generator matrices **G** of varying minimum determinant would behave when the transmission is established in a similar state of trellis.

1.4 Objectives

In this thesis, the following objectives are needed to ensure the success of the research.

a) To simulate the generator matrices **G** with different minimum determinants over a flat Rayleigh fading for a 4-PSK scheme.

b) To analyse the performance of each generator matrix **G**, based on the SNR and BER simulated output.

1.5 Scope of Research

The performance of the generator matrices **G** over communication channels has become one of the most popular areas of research in improving the performance of STTC in communication systems. One way of achieving enhancement is by focusing on the generator matrix **G** which represents the encoder structure for STTC. Until now, researchers have only concentrated on STTC of different states in analysing the performance of generator matrix **G** and no effort has been made on different generator matrices **G** of similar state due to the difficulties to produce a wide variety of generator matrices **G** with diverse minimum determinants The behaviour of the generator matrix **G** is crucial in determining its effects on the transmitted signal. Hence, the performance of generator matrices **G** of similar state with different minimum determinant (MD) to be analysed.

1.6 Organization of Thesis

The organization of this thesis is as follows:

Chapter One provides an introduction, problem statement, objectives and scope of the thesis.

Chapter Two consists of literature review of the space-time trellis code and design criteria for STTC over Rayleigh fading. This chapter will review all the work done as well as the code construction and performance.

Chapter Three states the methodology used in achieving the objectives, which explains the method of carrying out the simulation generator matrices **G** of similar state but varying minimum determinants.

Chapter Four presents the simulation results to show which minimum determinant of generator matrices **G** that have better signal to noise ratio for the same data rates transmission.

Chapter Five concludes the finding and explain the future development and recommendation for this research.

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