UNIVERSITI PUTRA MALAYSIA

DYNAMIC TRANSMIT ANTENNA SHUFFLING SCHEME FOR HYBRID MULTIPLE-INPUT MULTIPLE-OUTPUT SYSTEMS IN LAYERED ARCHITECTURE

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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 my family members especially my beloved parent
for their endurance support and love"

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

DYNAMIC TRANSMIT ANTENNA SHUFFLING SCHEME FOR HYBRID MULTIPLE-INPUT MULTIPLE-OUTPUT IN LAYERED ARCHITECTURE

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Chairman: Sabira Khatun, PhD

Faculty: Engineering

The wireless evolution has been stimulated by an explosive growing demand for a wide variety of high quality of services in voice, video, and data. This rigorous demand has made an impact on current and future wireless applications, such as digital audio broadcasting and video streaming. In particular, one of the main challenges in the single-input single-output (SISO) wireless communication is a wireless channel that suffers from numerous physical impairments due to multipath propagation. Besides, the constraints posed by limited power, capacity and scarce spectrum make the design of SISO reliability challenging. The idea of multiple antennas at the transmitter and receiver has introduced multiple-input multiple-output (MIMO) system, which increases robustness to the effect of multi-path fading provides higher data rates without consuming extra bandwidth and power.

In this thesis, three major advances on multiple-input multiple-output (MIMO) systems are presented. First, V-BLAST/STBC transceiver scheme, which incorporates the vertical Bell-labs layered space-time (V-BLAST) and Alamouti's

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space-time block codes (STBC) is considered. This transceiver scheme is able to enhance the MIMO wireless communication system performance in terms of bit error rate (BER) by achieving spatial diversity and multiplexing gain simultaneously. A new detection algorithm based on QR decomposition, denoted as LC-QR, is proposed. The QR decomposition is a common signal processing technique for MIMO detection. The computational complexity (total number of arithmetic operations) of proposed LC-QR algorithm is significantly lower than the conventional QR decomposition, zero-forcing (ZF) and minimum mean square error (MMSE) detection algorithm. Finally, the performance of V-BLAST/STBC transceiver scheme with proposed LC-QR algorithm is compared with other MIMO systems, such as V-BLAST and orthogonal space-time block codes. The BER performance of V-BLAST/STBC scheme is better than V-BLAST scheme while the system capacity of V-BLAST/STBC scheme is higher than orthogonal space time block codes.

The second part contributes to the field of dynamic transmit antenna shuffling scheme for MIMO system to maximize the system capacity and reducing BER. Channel state information (CSI) is assumed to be known by the transmitter via a dedicated feedback channel. Dynamic transmit antenna shuffling scheme improves the performance of MIMO by selecting the appropriate pairs of antennas at transmitter based on the CSI from receiver. Two dynamic transmit antenna shuffling schemes, namely ‘Optimal’ and ‘Max STBC’, are proposed to enhance the V-BLAST/STBC transceiver scheme with LC-QR proposed in the first part. The ‘Optimal’ dynamic transmit antenna shuffling scheme with low complexity feedback requirements improves the BER performance significantly with a gain of 2 dB at

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BER of 10^{-3} compared to the V-BLAST/STBC transceiver scheme without transmit antenna shuffling capability. Besides, the 'Max STBC' dynamic transmit antenna shuffling scheme increases the system capacity of V-BLAST/STBC transceiver scheme for 4 %.

In the third part, an implementation of a multi-layered space-frequency orthogonal frequency division multiplexing transceiver scheme (MLSF-OFDM) that integrates SF-OFDM with V-BLAST OFDM in a layered architecture has been considered. The MLSF-OFDM system is modeled over Monte-Carlo time-variant channel model with different maximum Doppler frequency. Special training sequences are used in the least square (LS) channel estimation method to obtain a desirable crest-factor, which is defined as the ratio of peak amplitude of waveform to the root mean square (RMS) value of the waveform, of the transmitted training signal and eliminate the influence of inter-symbol interference (ISI) on the channel estimation performance. A fast QR decomposition detection algorithm, denoted as FAST-QR, is proposed for MLSF-OFDM. It is shown that the computational complexity of proposed FAST-QR detection algorithm is approximately 48 % lower than the conventional QR decomposition detection algorithm. Besides, the result shows that the BER performance of proposed FAST-QR detection algorithm degrades marginally compared to ZF with successive interference cancellation (SIC-ZF) detection algorithm.

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Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untul ijazah Doktor Falsafah

SKIM PENYUSUNAN ANTENA PEMANCAR DINAMIK UNTUK HIBRID BERBILANG-MASUKAN BERBILANG-KELUARAN DALAM REKA BENTUK LAPISAN

Oleh

CHONG JIN HUI

Januari 2010

Pengerusi: Sabira Khatun, PhD

Fakulti: Kejuruteraan

Evolusi wayarles telah dirangsangkan oleh permintaan yang semakin besar dalam kualiti servis suara, video dan data yang tinggi. Permintaan ini telah membawa kesan kepada aplikasi wayarles semasa dan masa depan, seperti penyiaran audio berdigit dan aliran video. Salah satu cabaran dalam satu-masukan satu-keluaran (SISO) komunikasi wayarles ialah saluran wayarless mengalami keadaan kelemahan fizikal yang disebabkan oleh lintasan perambatan berbilang. Selain itu, kerumitan seperti kuasa terbatas, muatan dan spektrum yang tidak mencukupi telah memberi cabaran kepada reka bentuk reliabiliti SISO. Idea antena berbilang di pemancar dan penerima telah memperkenalkan sistem berbilang-masukan berbilang-keluaran (MIMO) yang meningkatkan ketegapan isyarat kepada kesan lintasan perambatan berbilang dan ini telah membekalkan kadar data yang lebih tinggi dengan tidak menggunakan lebar jalur dan kuasa yang ekstra.

Dalam tesis ini, tiga kemajuan yang utama dalam sistem MIMO telah dipersembahkan. Pertama, skim penghantar-terima V-BLAST/STBC yang

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menggabungkan lapisan tegak ruang-masa makmal-Bell (V-BLAST) dan pengekod blok ruang-masa Alamouti (STBC) telah diperkenalkan. Skim penghantar-terima ini dapat meningkatkan sistem komunikasi wayarles MIMO dari segi kadar ralat bit (BER) dengan memperoleh perbezaan ruang dan pertambahan multipleks serentak. Satu pengesanan algoritma baru (LC-QR) yang berdasarkan penguraian QR telah dicadangkan. Penguraian QR ialah satu teknik proses isyarat MIMO yang umum. Kekompleksan pengkomputeran (jumlah nombor operasi aritmetik) LC-QR algoritma yang dicadangkan adalah lebih rendah daripada penguraian QR konvensional, pemaksaan-sifar (ZF) dan ralat-minimum-min-kuasa-dua (MMSE) pengesanan algoritma. Akhirnya, prestasi skim penghantar-terima V-BLAST/STBC dengan algoritma LC-QR yang dicadangkan telah dibandingkan dengan sistem MIMO yang lain, seperti V-BLAST dan STBC orthogonal. Prestasi BER skim penghantar-terima V-BLAST/STBC adalah lebih baik daripada skim V-BLAST manakala muatan skim penghantar-terima V-BLAST/STBC adalah tinggi daripada skim STBC orthogonal.

Bahagian kedua menyumbang kepada medan skim penyusunan antena pemancar dinamik untuk memaksimumkan muatan sistem dan mengurangkan BER dalam sistem MIMO. Informasi keadaan saluran (CSI) adalah diketahui oleh pemancar melalui saluran maklum-balas. Skim penyusunan antena pemancar dinamik dapat meningkatkan prestasi MIMO dengan memilih pasangan antena yang sesuai di pemancar berdasarkan CSI dari penerima. Dua skim penyusunan antena pemancar dinamik dikenali sebagai ‘Optimal’ dan ‘Max STBC’ telah dicadangkan untuk meningkatkan prestasi skim penghantar-terima V-BLAST/STBC dengan algoritma LC-QR di bahagian pertama. Skim penyusunan antena pemancar dinamik ‘Optimal’

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dengan kekompleksan maklum-balas yang rendah dapat meningkatkan prestasi BER skim penghantar-terima V-BLAST/STBC dengan pertambahan sebanyak 2 dB dalam BER (10^{-3}). Selain itu, skim penyusunan antena pemancar dinamik 'Max STBC' dapat meningkatkan muatan skim penghantar-terima V-BLAST/STBC sebanyak for 4 %.

Dalam bahagian ketiga, satu skim penghantar-terima lapisan berbilang ruang-frekuensi multipleks pembahagian frekuensi orthogonal (MLSF-OFDM) yang mengabungkan SF-OFDM dengan V-BLAST OFDM dalam lapisan struktur telah diperkenalkan. Sistem MLSF-OFDM telah dijalankan dalam model saluran masa-varian Monte-Carlo dengan frekuensi Doppler maksimum yang berlainan. Jujukan latihan khas (TS) telah digunakan dalam anggaran saluran Least-Square (LS) untuk memperoleh factor creast isyarat latihan yang dipancarkan dan merendahkan kesan gangguan antara simbol. Satu algoritma penguraian QR yang pantas yang dikenali sebagai FAST-QR telah dicadangkan untuk skim MLSF-OFDM. Kekompleksan pengkomputeran algoritma FAST-QR adalah 48 % lebih rendah daripada penguraian QR konvensional. Di samping itu, hasil graf menunjukkan bahawa prestasi BER algoritma FAST-QR diturunkan sedikit berbanding dengan algoritma pemaksaan-sifar dengan pemotongan gangguan berturut-turut (SIC ZF).

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I certify that an Examination Committee has met on 30 April 2009 to conduct the final examination of Chong Jin Hui on his Doctor of Philosophy thesis entitled "Dynamic Transmit Antenna Shuffling Scheme for Hybrid Multiple-Input Multiple-Output in Layered Architecture" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee are as follows:

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DECLARATION

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

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(CHONG JIN HUI)

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