UNIVERSITI PUTRA MALAYSIA

# *PEAK TO AVERAGE POWER RATIO REDUCTION BASED ON OPTIMUM PHASE SEQUENCE IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEMS*

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# PEAK TO AVERAGE POWER RATIO REDUCTION BASED ON OPTIMUM PHASE SEQUENCE IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEMS

By
SOMAYEH MOHAMMADY



Thesis Submitted to the Graduate Studies, Universiti Putra Malaysia, in fulfillment of the requirement for the Degree of Doctor of Philosophy

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**DEDICATION**

This thesis is dedicated to my husband Pooria and his helps are deeply appreciated. This thesis is also dedicated to my dear father and mother for all the encoragements and supports.

Abstract of 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: Assoc. Prof. Roslina binti Mohd. Sidek, PhD**

**Faculty: Engineering**

Orthogonal Frequency Division Multiplexing (OFDM) is a form of a Frequency Division Multiplexing (FDM) scheme that is used in recent broadband wireless communication systems. The main advantage of OFDM systems is immunity against the fading phenomena caused by natural multipath environment. However, there is a major drawback of high Peak-to-Average Power Ratio (PAPR). Signal with high PAPR forces the Power Amplifier (PA) to work in its nonlinear region, which generates distortions. The PA has to be operated with back-off to avoid high PAPR, which decreases the power efficiency. To overcome the PAPR problem in OFDM systems, several techniques are introduced such as Conventional Selected Mapping (C-SLM) and Dummy Sequence Insertion (DSI). In C-SLM method, by increasing the number of Inverse Fast Fourier Transform (IFFT) blocks, the PAPR performance is enhanced at the expense of complexity and side information, which results in high cost and spectrum efficiency degradation. In DSI method, inserting the dummy signals degrades the spectrum efficiency and also exhibits data rate loss.

In this thesis, two schemes have been proposed in order to reduce PAPR. The first proposed scheme is called DSI-SLM, which combines the modified dummy sequence of the DSI with the phase sequence of the SLM. As a result of applying this scheme, the PAPR performance is enhanced and the complexity is reduced compared to C-SLM. The second proposed method is named Optimum Phase Sequence with Dummy Sequence Insertion (OPS-DSI) that is designed to improve the DSI-SLM method in terms of complexity and side information. In OPS-DSI method, the optimum phase sequence is applied while only one IFFT is performed and the side information can be placed within the dummy signals.

In order to demonstrate the feasibility of these methods in actual systems, the prototype of DSI-SLM and OPS-DSI methods are carried out in Field Programmable Gate Array (FPGA). The implementation results are comparable with simulation results. However, there is less than 0.1dB difference which is due to the constraints of the FPGA input and output bit resolutions. Finally, these methods are integrated with Digital Predistortion (DPD) and actual PA to represent an OFDM transmitter system. This results in Power Added Efficiency (PAE) enhancement by an average of 17%, which leads to less power consumption and prolonged battery life. This system is simulated based on IEEE 802.16e standard and the results are numerically analyzed and compared with various numbers of dummy signals and candidate signals. The DSI-SLM method reduces PAPR by 3.6dB. Almost 76% reduction in total complexity is also achieved compared to C-SLM, meanwhile OPS-DSI method enhances PAPR performance by 4.2dB and total complexity reduction by 95%. Hence, OPS-DSI outperforms DSI-SLM in terms of PAPR and complexity. Their Bit Error Rates (BERs) are in acceptable range of $10^{-4}$ at $S_b/N_b$=14 dB.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk ijazah Doctor Falsafah

**PENGURANGAN NISBAH KUASA PUNCAK KEPADA PURATA BERDASARKAN JUJUKAN FASA OPTIMUM DALAM SISTEM-SISTEM PEMULTIPLEKSAN PEMBAHAGIAN FREKUENSI ORTOGON**

Oleh

**SOMAYEH MOHAMMADY**

**Januari 2012**

**Pengerusi: Assoc. Prof. Roslina binti Mohd. Sidek, PhD**

**Fakulti: Kejuruteraan**

Pemultipleksan Pembahagian Frekuensi Ortogon (OFDM) ialah satu bentuk Pemultipleksan Pembahagian Frekuensi (FDM) yang digunakan dalam sistem jalur lebar komunikasi tanpa wayar terkini. Kelebihan utama sistem-sistem OFDM ialah ketahanan terhadap fenomena pemudaran disebabkan oleh persekitaran berbilang lorong semula jadi. Bagaimanapun terdapat satu kelemahan utama, iaitu Nisbah Kuasa Puncak Kepada Purata (PAPR) yang tinggi. Isyarat PAPR yang tinggi memaksa Penguat Kuasa (PA) bekerja dalam kawasan tak linear yang akan menghasilkan pemesongan. PA perlu dikendalikan secara undur balik yang akan mengurangkan kecekapan kuasanya. Untuk mengatasi masalah PAPR dalam sistem OFDM, beberapa teknik telah diperkenalkan seperti Pemetaan Terpilih Konvensional (C-SLM) dan Sisipan Jujukan Tiruan (DSI). Dalam kaedah C-SLM, dengan penambahan jumlah blok Jelmaan Fourier Pantas Songsang (IFFT), prestasi PAPR bertambah baik tetapi akan menjadi lebih rumit dan memerlukan lebih maklumat sisi yang menyebabkan peningkatan kos dan penurunan spektrum. Dalam kaedah DSI, memasukkan isyarat tiruan akan menurunkan kecekapan spektrum dan menyebabkan kehilangan kadar data.

Dalam tesis ini, dua kaedah telah dicadangkan untuk mengurangkan PAPR. Kaedah pertama yang dicadangkan dipanggil DSI-SLM yang menggabungkan jujukan tiruan terubahsuai DSI dengan jujukan fasa SLM. Penggunaan kaedah ini meningkatkan prestasi PAPR dan mengurangkan kerumitan berbanding dengan C-SLM. Kaedah yang kedua dinamakan OPS-DSI yang direka untuk memperbaiki kaedah DSI-SLM dari segi kerumitan dan maklumat sisi. Dalam kaedah OPS-DSI, jujukan fasa optimum digunapakai manakala hanya satu IFFT digunakan dan maklumat sisi boleh ditempatkan dalam isyarat tiruan.

Untuk menunjukkan kaedah ini boleh dilaksanakan dalam sistem sebenar, skema DSI-SLM dan OPS DSI dilaksanakan pada Tatasusunan Get Boleh Aturcara Medan (FPGA). Keputusan pelaksanaan setanding dengan keputusan simulasi. Bagaimanapun, terdapat perbezaan kurang daripada 0.1dB yang disebabkan oleh resolusi bit masukan dan keluaran FPGA. Akhirnya kaedah-kaedah ini digabungkan dengan model Praherotan Digit (DPD) dan PA untuk mewakili sistem pemancar OFDM. Ia menghasilkan peningkatan Kecekapapan Tembahan Kuasa (PAE) sebanyak 17% yang mana akan mengurangkan penggunaan kuasa dan memanjangkan hayat bateri. Sistem ini disimulasi berdasarkan piawai IEEE 802.16e dan keputusan berangka dianalisis dan dibandingkan dengan pelbagai bilangan isyarat tiruan dan isyarat calon. Kaedah DSI-SLM dapat mengurangkan PAPR sebanyak 3.6dB. Hampir 76% pengurangan jumlah kerumitan dicapai berbanding C-SLM, sementara skim OPS-DSI prestasi PAPR sebanyak 4.2dB dan mengurangkan kerumitan sebanyak 95%. Maka, OPS-DSI mengatasi DSI-SLM dari segi prestasi PAPR dan kerumitan. Kadar Ralat Bit (BER) kedua-duanya berada didalam julat yang boleh diterima iaitu $10^{-4}$ pada $S_b/N_b$=14dB.

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Somayeh Mohammady

Date: February 2012

I certify that an Examination Committee has met on to conduct the final examination of Somayeh Mohammady on her doctor of philosophy thesis entitled "Peak To Average Power Ratio Reduction Based On Optimum Phase Sequence In Orthogonal Frequency Division Multiplexing Systems" 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 was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. 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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**SOMAYEH MOHAMMADY**

Date: 11 January 2012

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