



**Sudan University of Science and Technology  
College of Graduate Studies**

**Performance, Evaluation and Enhancement of Some  
Orthogonal Frequency Division Multiplexing Techniques**

**تقويم أداء بعض تقنيات نظام مزج تقسيم التردد المتعامد**

**A thesis is submitted for the fulfillment of the requirements for the degree of  
Doctor of Philosophy in Communications Engineering,  
Department of Electronic Engineering**

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**August 2009**

# **DEDICATION**

**To my family**

**To my Wife**

**To my lovely child's Braa, Riyadh, Maheir and  
Shrouge.....**

**To the soul of my mother**

**My Dedication.....**

# ACKNOWLEDGEMENT

I would like to thank my supervisors Professor Izzeldin Mohamed Osman from Sudan University Of science and Technology and Dr. Iman Abuel Maaly A/Rahman from Khartoum University for their supervision, advice and great support.

## ABSTRACT

This research investigates the evaluation of Coded Frequency Division Multiplexing (COFDM) and Dual OFDM performance under wireless transmission system drawbacks. COFDM and DOFDM simulation model have been designed using Matlab & Simulink.

Different modulation schemes such as BPSK, QPSK, DQPSK, 8PSK and 16PSK were executed using the model. The model was enhanced with different channel estimation techniques such as Combi-type pilot channel estimation techniques with singular value decomposition (SVD) and applying a raised cosine filters in the simulation model.

Different types of channel estimation strategies have been studied such as Comb-type pilot channel estimation and Block-Type Pilot Channel Estimation. The model system has been enhanced by applying Convolution Encoder and Viterbi Decoder in the system where a good receiving spectrum power was achieved as illustrated in the power spectrum graphs. The evaluation of performance measurements have been considered by comparing their performance effect under different types of modulation schemes. To be able to compare the different modulation schemes there was a need for a simulator that was realistic enough to provide reliable results. Therefore the coded and Dual OFDM simulator were modeled. The signal was subjected to wireless transmission system drawbacks, such as Multiple Path Rayleigh Fading and Additive White Gaussian Noise (AWGN). Different types of performance measurements have been considered such as  $BER$ ,  $SER$ ,  $E_b/N_o$ ,  $E_s/N_o$  &  $S/N$ . These performance measurements have been evaluated and compared with different modulation schemes with and without filtering as illustrated in the graphs. Reed Solomon (RS) Encoder and Decoder were installed in the system. The coding blocks were set with the desirable values of parameters. To fulfill a high signal quality the sample time was set to be  $8e-5$

seconds. The dual model (Double error correction, forwarded and afterward) achieved a better received signal quality when compared with other ones.

When applying the capacity rate equations in different modulation schemes with different numbers of channel bits, different channel capacities were achieved. When using BPSK & QPSK we get Mbps of 8.467, energy to noise ratio of 9dB, Bit Error Rate (BER) of  $1e-6.5$  and Symbol Error Rate (SER) of 0.499%, 0.751% respectively. When using DBPSK & DQPSK, we get Mbps of 16.934. And we get BER of  $1e-3.6$ ,  $1e-3$  respectively. And we get energy to noise ratios of 9 dB, 14dB respectively. Also we get SER of 0.508%, 0.994% respectively. When using 8PSK & 16PSK we get Mbps of 33.868. And BER of  $1e-7.25$ ,  $1e-5.5$  respectively and we get energy to noise ratios of 15dB, 18 dB respectively. And we get SER of 0.998% for both of them. Therefore and with reference to the results obtained from calculations and graphs, 8 PSK and 16 PSK achieved a high data rate in high signal to noise ratio but with high bit error rate (BER) and high symbol error rate (SER). BPSK and QPSK achieved a lower data rate in low signal to noise ratio and with low bit error rate and low symbol error rate. DBPSK and DQPSK achieved a higher data rate with high signal to noise ratio, but in low bit error rate and acceptable SER.

The simulation indicated that DQPSK yields the best performance therefore we introduced it as the most capable modulation scheme for enhancing OFDM.

# مستخلص

ان هذا البحث حقق وقيم الأداء لنظام مقسم التردد المتعامد و المتعدد الارسال المشفر (COFDM) و الثنائى (DOFDM). تم تصميم نموذج نظام (COFDM) و الثنائى (DOFDM) بواسطة برنامج Matlab & Simulink. وقد تم التحقيق فى قابلية النظام كمخطط تعديل مثالى (Modulation Scheme). وقد تم انجاز ذلك بتطبيق مخططات تعديل مختلفة مثل 16PSK, 8PSK, DQPSK, DBPSK, QPSK, BPSK فى الجسم.

للمقارنة بين مخططات التعديل المختلفة كانت هناك الحاجة لتصميم نظام محاكاة (Simulator) بحيث يستطيع ان يزودنا بنتائج موثوق بها. لذا تم تصميم نموذج مقسم التردد المتعامد و المتعدد الارسال المشفر (COFDM) و الثنائى (DOFDM) بواسطة برنامج Matlab & Simulink. ولتحسين كفاءة النظام فقد تم اخضاعه الى مسارات تقييم مختلفة. لقد اخضعت الاشارة لمساوى التوصيل اللاسلكى كما هو الحال فى ظاهرة (ريلى) فى اضمحلال الاشارة ذات المسار المتعدد وظاهرة ضوضاء (جوسيان) البيضاء المضافة. اذن فان قياسات الاداء مثل معدل الخطاء فى وحدة معدل قياس خطأ البيانات اللاسلكى و المعروف ب (BER) ومعدل الخطاء الرمزى و المعروف ب (SER) ومعدل الاشارة بالنسبة للضوضاء و المعروف ب (S/N) ومعدل الطاقة بالنسبة للضوضاء و المعروف ب (E/N) وقوة الارسال والاستقبال. كل هذه تتأثر مجملا بالمعوقات أفة الذكر. ولرفع كفاءة النظام فقد تم وضع جهاز ترشيح ذو قيم مناسبة علاوة على ذلك تم وضع جهاز (ريد سولومون) للتشفير وفك التشفير داخل النظام. كما تم ايضا وضع مخططات التشفير بمواصفات ذات قيم محددة. لقد تم فحص نماذج تعديل مختلفة بمرشح ومن غيره. بالاضافة الى ذلك فقد تم وضع كل مواصفات النموذج بحيث يحقق أداء اشارة ارسال جيدة. و لتحقيق اشارة ذات نوعية ممتازة فقد ضبط زمن النموذج ليكون (5-8e) ثانية.

ان النموذج المزوج (تصحيح الخطاء قبل وبعد الارسال) يحقق نوعية اشارة مستلمة ذات نوعية جيدة مقارنة بالآخرى. وقد تم التحقيق من ذلك عند اخضاع النظام الى حاسب الأخطاء ومن ثم اخضعت الاشارة الى عوائق نظام الارسال اللاسلكى ونظام تعدد المسارات. لمعالجة هذه العوائق تم تصميم مرشح حبيب التمام.

بالاشارة للمعادلات المستنبطة والتي تم تطبيقها فى مخططات التعديل المختلفة, عليه تم الحصول على معدل بيانات مختلفة. تم الحصول على سعه 8.467 Mbps عند معدل خطأ رمزى 0.499%, 0.751% فى حالة BPSK & QPSK على التوالى وتم الحصول على 16.943Mbps عند معدل خطأ رمزى 0.994%, 0.508% فى حالة استخدام DBPSK & QPSK على التوالى. وقد تم الحصول على معدل بيانات 33.868Mbps عند معدل خطأ رمزى 0.998%, عند استخدام 16PSK & 8PSK.

وبنا عليه وعند الرجوع للإشكال الناتجة من مخطط المحاكاة و المعادلات أعلاه, وجد أن نظام BPSK & QPSK يحقق معدل سعة بيانات منخفضة و معدل خطأ بيانات منخفضة و لذلك فانه غير مناسب لسعة البيانات العريضة.

ووجد أن نظام 8PSK & 16PSK يحقق سعة بيانات عالية مع معدل خطأ بيانات عالي. ووجد أيضا أن نظام DQPSK يحقق معدل سعة بيانات عالية مع معدل خطأ بيانات منخفض.

اشار نموذج المحاكاة الى ان هذا المخطط التعديلى انتج افضل أداء لذا قدم كمخطط تعديل مثالى لتحسين النظام. انجز هذا بتطبيق المتغيرات فى بعض المعادلات المستنبطة و ايضا من مجسم المحاكاة الذى مكنا من الحصول على اشارة جيدة الأداء و النوعية.

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## List of Acronyms

AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
DBPSK	Differential Phase Shift Keying
DQPSK	Differential Quadrature Phase Shift Keying
CIR	Channel Impulse Response
DAB	Digital Audio Broadcasting
DFE	Decision Feedback Equalizer
FFT	Fast Fourier Transform
ICI	Inter-carrier Interference
IDFT	Inverse Discrete Fourier Transform
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
ISI	Inter-symbol Interference
LAN	Local Area Network
MMSE	Minimum Mean-square Error
OFDM	Orthogonal Frequency Division Multiplexing
PAPR	Peak-to-average Power Ratio
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
SNR	Signal-to-noise Ratio
TDMA	Time Division Multiple Access
WLAN	Wireless Local Area Network