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Walid Jamal Hassan Hassasneh

M.Sc. Thesis

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Jerusalem-Palestine
2007

Dedication:

This work is dedicated to most precious one my mother's spirit, Khadijeeh, who loved and gave me all hopefulness in life.

Declaration:

I certify that this thesis submitted for the degree of Master is the results of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has been submitted for a higher degree to any other university or institution.

Signed:……………………..

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Date: 25/05/2007

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Abstract

Code Division Multiple Access is a common wideband communication system, due to its high data rates, bandwidth efficiency, multiple user services and securities. However, this scheme doesn't treat channel problems perfectly. Hence, the Multi-Carrier (MC-CDMA) of combining Orthogonal Frequency Division Multiplexing (OFDM) with CDMA is found, using the advantages of both schemes. Further advantages can be achieved by combination of MC transmissions with Direct Sequence (DS) CDMA, known as MC-DS-CDMA, which is considered as one important technique for beyond third generation mobile wireless systems. Actually, this technique has been adopted for CDMA2000 third generation cellular standard.

The MC-DS-CDMA better compensates multipath fading problems of non-ideal channels by using adaptive channel estimator filters. Furthermore, this scheme can suppress the Multiple Access Interference (MAI) problem due to cross-correlation properties of its spreading codes, by using adaptive receivers. Indeed, this performance is obtained under certain conditions.

Channel status information are assumed to be perfectly known when considering a receiver structure of a decorrelator along each carrier for suppressing MAI, followed by a Maximum Ratio Combiner (MRC). Unfortunately, the channel coefficients are unknown and must be estimated to compact these fading effects. In reality, the Kalman filter based channel estimator works well in time varying fading channels. However, this requires the *a priori* estimation of the autoregressive (AR) parameters. Based on the well-known Jakes model, AR parameters can be obtained by first fitting AR process autocorrelation function to the Jakes one and then solving the resulting Yule-Walker equations (YWE). But we have to pay attention to the condition number of the autocorrelation matrix of this YWE, which determines the accuracy of the solution.

Due to the band-limited nature of the Jakes Doppler spectrum, severe ill-conditioning problems in solving YWE are unavoidable for all but very small AR model orders. For this reason and for the sake of simplicity, we find previous studies focus only on first and second order AR models. To avoid the ill-conditioning problem, a very small positive bias is added to the main diagonal of the autocorrelation matrix in the YWE. Indeed, this can remove band-limitation of the original spectrum.

As the ill-conditioning can be solved investigating the relevance of high order AR models can be done, hence, better approximations to the Rayleigh fading channel could be achieved. However, the higher AR model orders the higher computational costs. Thus, a compromise between the model accuracy and the computational cost has to be found.

In this work we investigate high AR model orders using Kalman filtering based channel estimator for a synchronous MC-DS-CDMA scheme in time varying fading channels.

Simulation results of BER performance for different channel estimators under realistic Jakes fading channel is presented, which investigates the relevance of high AR model

orders for retrieving transmitted data sequences using the Kalman filtering based channel estimator.

Furthermore, we consider the high order AR models with known Doppler rates, or equivalently, mobile speed, with different fading rate scenarios.

For the purpose of comparative study, we also carry out channel estimation by Least Mean Square (LMS) and Recursive Least Square (RLS) channel estimators, followed by MRC. Simulation results show that the Kalman filter based channel estimator provides better results than those based on LMS or RLS, especially in high Doppler rate environments. In addition, increasing the AR model order yields better modeling approximation to the fading channel and provides lower BER. Furthermore, a fifth order AR model can provide a trade-off between the accuracy of the model and the computational cost.

الملخص

يستخدم نظام MC-DS-CDMA في الجيل الثالث من ألاتصالات, وذلك بسبب سعة عرض النطاق الترددي, ودعمه لعدد كبير من المستخدمين, بالإضافة للخدمات التي تحتاجها الانظمة الحديثة للإتصالات اللاسلكية. بالحقيقة هذا النوع من الانظمة أعتمد للأجهزة الخلوية التي تستخدم ب 3G CDMA 2000.

بإستخدام المرشحات الحديثة لهذا النوع من الأنظمة يمكن حل مشاكل تعدد المسارات للموجات الكهرومغناطيسية والذي ينتج عنه ما يعرف بمشكلة التضاؤلات Multipath Fading , كما ويقاوم هذا النظام مشاكل تداخل المستخدمين MAI بكفاءة عند إستخدام مرشحات متطورة مثل ما يسمى مستقبل الديكورريلاتور Decorrelator Receivers.

إن مرشح الكلمان Kalman Filter ذو كفاءة عالية مقارنة مع الانواع الاخرى مثل LMS و RLS. ولتطبيق هذا المرشح نحتاج الى ما يعرف بنموذج الترداد التلقائي Autoregressive Model. والذي يحتاج بدورة برمترات AR parameters التي قد نجدها من حل معادلة ما يعرف ب يل ولكر Yule-Walker Equation.

على اي حال, حل هذه المعادلة بسبب ضماد الطبيعة للوسط ذو الطيف المحدود يعاني مما يعرف بمشكلةالعصابة Ill-conditioning لجميع الدرجات ما عدا القليل منها.ولهذا نجد السابقيين في الموضوع درسوا لدرجات منخفضة أقصاها الدرجة الثانية. وللتعامل مع هذا النوع من المشاكل "لحل يل ولكر" نحيز مصفوفة الترابط التلقائي Autocorrelation matrix بإضافة رقم موجب صغير على قطرها. مما يزيل العصابة في الطيف الأصلي.

هنا بهذا البحث نقدم مرشح كلمان لتقدير الوسط – ظاهرة التضاؤلات- على درجات الترداد التلقائي دون حد أقصى. مع إستخدام الديكوروليتر لحل مشكلة تداخل المستخدمين. توضح نتائج البحث أن الدرجة الخامسة مقبولة للدقة وتعقيد الحسابات.

TABLE OF CONTENETS

List of Figures

List of Tables

List of Acronyms and Abbreviations

1G	**First Generation**
2.5G	**Two and Half Generation**
2G	**Second Generation**
3G	**Third Generation**
3GPP	**Third Generation Partnership Project**
4G	**Forth Generation**
ACF	**Autocorrelation Function**
AMPS	**Advanced Mobile Phone Service**
APA	**Affine Projection Algorithms**
AR	**AutoRegressive**
ATM	**Asynchronous Transfer Mode**
AWGN	**Additive White Gaussian Noise**
B3G	**Beyond Third Generation**
BER	**Bit Error Rate**
B-ISDN	**Broadband Integrated Services Digital Network**
BRLS	**Block Recursive Least Mean Square**
BS	**Base Station**
CCL	**Cross-correlation**
CDMA	**Code Division Multiple Access**
CEPT	**Conférence Européenne des Postes et Télécommunication**
CT2	**British cordless telephone system**
DA	**Data Aided**
DAMPS	**Digital-AMPS**
dB	**Decibel**
DD	**Decision Directed**
DECT	**Digital Enhanced Cordless Telecommunication**
DFE	**Decision Feedback Equalizer**
DNR	**Preliminary Draft of New Recommendation**
DS-CDMA	**Direct Sequence -CDMA**
EDGE	**Enhanced Data Rates for GSM Evolution**
EM	**Expectation Maximization**
F	**Frequency**
FDMA	**Frequency Division Multiple Access**
FFH	**Fast Frequency Hopping**
FH-CDMA	**Frequency Hopping CDMA**
FM	**Frequency Modulation**
GPRS	**General Packet Radio Service**
GSM	**Global System for Mobile Telecommunication**
HDTV	**High Definition Television**

iid	**Independent and Identical Distributed**
IMT-2000	**International Mobile Telecommunications 2000**
IS	**Interim Standard**
IS-54	**The Pan-American DAMPS TDMA Mobile**
IS-95	**The Pan-American CDMA Mobile Radio**
ISDN	**Integrated Services Digital Network**
ISI	**Intersymbol Interference**
ITU	**International Telecommunication Union**
KF	**Kalman Filter**
LAN	**Local Area Network**
LMS	**Least Mean Square**
LOS	**Line-of-sight**
MA	**Multiple Access**
MAI	**Multi-access Interference**
MC-DS-CDMA	**Multi-Carrier Direct Sequence CDMA**
MC-CDMA	**Multi-Carrier CDMA**
MF	**Matched Filter**
MMSE	**Minimum Mean Square Error**
MRC	**Maximum Ratio Combiner**
MS	**Mobile Station**
MSE	**Mean Square Error**
MT-CDMA	**Multi-Tone CDMA**
NAMPS	**Narrowband AMPS**
NDA	**Non Data Aided (Blind technique)**
NLMS	**Normalized Least Mean Square**
NMT	**Nordic Mobile Telephone**
NMTS	**Nordic Mobile Telephone System**
NTT	**Nippon Telegraph and Telephone Company**
OFDM	**Orthogonal Frequency Division Multiplexing**
PDC	**Personal Digital Cellular**
Pdf	**Probability Density Function**
PHP	**Personal Handy Phone**
PLMR	**Public Land Mobile Radio**
PN	**Pseudo Noise**
PSD	**Power Spectral Density**
QoS	**Quality of Service**
RLS	**Recursive Least Square**
SC-DS-CDMA	**Single-Carrier DS-CDMA**
SFH	**Slow Frequency Hopping**
SIR	**Signal to Interference Ratio**
SNR	**Signal to Noise Ratio**