UNIVERSITI PUTRA MALAYSIA

SOFTWARE-DEFINED RADIO-BASED MODULATION AND DEMODULATION SCHEME

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By

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Thesis submitted to the School of Graduate Studies, University Putra Malaysia, In Fulfilment of the Requirement for the Degree of Master of Science

April 2009

DEDICATION

This thesis is dedicated to

ALL **W**HOM **I** **L**OVE

Specially

MY BELOVED PARENTS

And

MY SISTERS

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

SOFTWARE-DEFINED RADIO-BASED MODULATION AND DEMODULATION SCHEME

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April 2009

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Software Defined Radio (SDR) has been one of the new techniques developed to change the way the traditional wireless communication systems work. Through the definition of the SDR, this thesis aims at designing a modem system which can be adapted to many modulation schemes. Designing a multi-modulation schemes system in term of hardware will cost a lot and definitely consume power and increase the interference, and for this purpose, an adaptive algorithm is designed to be capable of detecting certain modulation schemes and identifying its type, and automatically demodulating the modulated signal after the decision of the identifier has been taken using digital signal processing techniques.

Different digital modulation schemes were employed in this study for adaptation according to need. These include the Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Binary Phase Shift Keying (BPSK), and Gaussian Minimum Shift Keying (GMSK).

The adaptive system was mainly dependent on the following digital signal processing techniques: Continuous Wavelet Transform (CWT) and Fast Fourier Transform

(FFT). For this purpose, the MATLAB was used as the simulation software throughout this thesis, where the SIMULINK tool had been used for the simulation of the demodulation process.

The performance evaluation of the identification system, under each technique, had been derived in terms of signal-to-noise ratio (SNR) for the range from 4dB up to 15dB. Result's showed, the identification system was found to have a lower performance in identifying the ASK signal when using the CWT technique, particularly for low SNR value. Whereas the identification system could identify the ASK signal with the best performance using the FFT technique, even with the presence of high noise compared with other modulation schemes. Generally, most of the modulation schemes, under both techniques, have more than 90% accurate identification ability when the SNR is equal to and above 9dB. However, the identification ability of the system may vary from one modulation scheme to another, and from CWT to FFT; therefore, designing an identification system which combines both the techniques will be able to increase the ability for accurate identification.

Tesis abstrak yang dikemukakan kepada Senat Universiti Putra Malaysia dalam memenuhi keperluan ijazah Sarjana Sains

PERISIAN TERTAKRIF RADIOBERPANGKALAN MODULASI DAN PENGENYAHMODULAN SKIM

Oleh

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Perisian Tertakrif Radio (SDR) adalah satu daripada teknik-teknik terbaru untuk mengubah sistem kerja telekomunikasi tradisional tanpa wayar. Melalui definisi SDR, tesis ini bertujuan bagi mereka satu sistem modem yang boleh diadaptasi pada banyak skema modulasi. Rekaan satu multi modulasi sistem dari segi perkakasan akan menelan belanja yang banyak dan akan menggunakan kuasa serta meningkatkan gangguan, maka untuk tujuan ini, satu algoritma adaptif telah direkabentuk dan berupaya mengesan modulasi skim-skim tertentu serta mengenal pasti jenisnya, dan secara automatik demodulasi mengubah isyarat setelah keputusan pengecaman diambil menggunakan teknik-teknik pemprosesan isyarat digital.

Skim-skim modulasi digital berbeza telah digunakan dalam kajian ini untuk diadaptasi mengikut keperluan. Ini termasuklah Amplitude Shift Keying (MEMINTA), Frequency Shift Keying (FSK), Binary Phase Shift Keying (BPSK), dan Gauss Minimum Shift Keying (GMSK).

Sistem mudah suai adalah bergantung pada teknik-teknik pemprosesan isyarat digital : Gelombang Kecil Selanjar Mengubah (CWT) dan Fast Fourier Transform (FFT). Untuk tujuan ini, MATLAB telah digunakan sebagai perisian simulasi sepanjang tesis, manakala alat SIMULINK telah digunakan untuk simulasi pengenyahmodulan proses.

Penilaian prestasi sistem pengenalpastian, dibawah setiap teknik, telah diterbitkan dalam nisbah isyarat kepada gangguan (SNR) untuk julat daripada 4dB sehingga 15dB. Keputusan menunjukkan, sistem pengenalpastian telah didapati untuk mempunyai satu prestasi yang lebih rendah dalam mengenal pasti isyarat ASK bila menggunakan teknik CWT, terutama untuk nilai SNR yang rendah. Manakala sistem pengenalpastian boleh mengenalpasti isyarat ASK dengan persembahan terbaik menggunakan teknik FFT, meskipun dengan kehadiran gangguan bunyi berbanding dengan skim modulasi lain.

Umumnya, kebanyakan skim-skim modulasi, dibawah kedua-dua teknik, mempunyai lebih daripada 90% keupayaan pengenalpastian yang tepat apabila SNR sama dengan 9dB dan lebih. Bagaimanapun, keupayaan pengenalpastian sistem ini boleh berubah daripada satu skim modulasi kepada modulasi yang lain, dan daripada CWT kepada FFT; oleh itu, mereka satu sistem pengenalpastian yang menggabungkan kedua-dua teknik ini akan dapat mempertingkatkan keupayaan untuk pengenalpastian yang lebih tepat.

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APPROVAL

I certify that a Thesis Examination Committee has met on 27 April 2009 to conduct the final examination of Ahmed Mohamed Salih Bakhraiba on his thesis entitled "Software Defined Radio Based Modulation and Demodulation Scheme" in accordance with 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 candidate be awarded the Master of Science degree. Members of the Examination 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 UPM or other institutions.

AHMED M.S. BAKHRAIBA

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LIST OF ABBREVIATIONS/ SYMBOLS

4^{th} G	Fourth Generation
ADC	Analog to Digital converter
AM	Amplitude Modulation
AMC	Automatic Modulation Classification
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BT	Bandwidth multiplied by Time
CC	Cyclic Cumulants
CDPD	Cellular Digital Packet Data
CPBFSK	Direct Sequence Spread Spectrum
CNR	Carrier to Noise Ratio
CPM	Continues Pulse Modulation
CWT	Continues Wavelet Transform
DAC	Digital to Analog Converter
DDC	Digital Down Converter

DECT	Digital European Cordless Telephone
DFT	Discrete Fourier Transform
DSP	Digital Signal Processing
DUC	Digital Up Converter
FFT	Fast Fourier Transform
FM	Frequency Modulation
FPGA	Field Programmable Gate Array
FSK	Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GPS	Global Position System
GSM	Global System for Mobile communication
HDR	Hardware Defined Radio
HWT	Haar Wavelet Transform
IF	Intermediate Frequency
LNA	Low Noise Amplifier
MSK	Minimum Shift Keying
OOK	On-Off Keying
PA	Power Amplifier
PC	Personal Computer
PSK	Phase Shift Keying

QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SDR	Software Defined Radio
SNR	Signal to Noise Ratio
STFT	Short Time Fourier Transform
VCO	Voltage Control Oscillator

LIST OF SYMBOLS

w_c	Carrier frequency
θ_c	Carrier phase
A	Signal Amplitude
$m(t)$	constant has value 0 in case of sent binary 0, value 1 in case of sent binary 1
S	Signal power
$S(t)$	Modulated Signal (Transmitted Signal)
$X(t)$	Modulated Signal (Received Signal)
N	Number of observed symbols
T	Symbol duration and bit duration
u_t	Standard unit pulse of duration T
φ_i	$\varphi_i \in \left\{ \frac{2\Pi}{M}(m \approx 1), m = 1,2,\ldots, M \right\}$
ω_i	$\omega_i \in \{\omega_1, \omega_2, \ldots, \omega_m\}, \theta_i \in (0.2\pi)$
α	The scale of the coefficient
b and τ	Translation (time)
$*$	Complex conjugates
$\psi(t)$	Mother wavelet
Ψ_a	Baby wavelet

σ^2	Statistical variance
I	In Phase Carrier
Q	Quadrature Carrier
B_b	Signal Bandwidth
BT	Factor of Bandwidth multiply by symbol time equal 0.3
j	Level of decomposition
$y_s(i)$	The smoothed value for the ith data point
N	Number of neighboring data points on either side of $y_s(i)$