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FACULTY OF ENGINEERING

Electronics and Communications Engineering Department

Spectrum Sensing Techniques in Cognitive Radio

A Thesis

Submitted in partial fulfillment of the requirements of the degree of

Master of Science in Electrical Engineering

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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Dedication

This effort is dedicated to two men who have taught me the most important lessons in my life. To the memory of my father who gave me the thirst for new knowledge and the potential to seek it; and to the memory of Prof. Dr. Adel El-Hennawy who taught me how to be patient in the most difficult times.

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Abstract

The fast development of bandwidth requesting wireless technologies has led to the problem of spectrum shortage. However, studies present that licensed spectrum is underutilized. Cognitive radio technology pledges a solution to the problem by permitting unlicensed users, opportunistically access to the licensed bands. Spectrum sensing is a prime component of the cognitive radio technology. A large number of sensing techniques have been produced to sense the existence or not of a licensed user.

This thesis assess the performance of the energy detection based spectrum sensing technique in fading and noisy mediums. The performance of the energy detection technique was evaluated by using Receiver Operating Characteristics (ROC) curves over additive white Gaussian noise (AWGN) and fading (Rayleigh) channels.

The experiments are carried out using USRPN210 and GNU radio that help the reader to understand the concept of underutilized frequency band and its importance in Cognitive Radios.
A new threshold estimation technique for the spectrum sensing (SS) using stochastic approach for energy detection (ED) has been presented. The performance of stochastic threshold estimation approach under noise uncertainty environment has been tested. Under noise uncertainty and obeying the 802.22 standard, the stochastic threshold has achieved comparable results and even outperform the double threshold in a low signal to noise ratio (SNR).

Keywords: Cognitive radio, spectrum sensing, energy detection, GNU Radio, USRP2, Threshold, stochastic approach, noise uncertainty.

Paper Publication:

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List of Abbreviations

Abbreviation	Description
ADC	Analog to Digital Converter
AFRL	Air Force Rome Labs
AWGN	Additive white Gaussian noise
BTS	Base-station transceiver system
CA	Cyclic Autocorrelation
CDMA	Code division Multiple Access
CPU	Central Processing Unit
CR	Cognitive radio
CSD	Cyclic Spectral Density
CWT	Continuous Wavelet Transform
DAC	Digital to Analog Converter
dBm	Milliwatt-decibel
DDC	Digital down converter
DSSS	Direct Sequence Spread Spectrum
DUC	Digital up converter
DWT	Discrete Wavelet Transform
ED	Energy detection
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Array
GRC	GNU Radio Companion
GUI	Graphical user interface
IF	Intermediate frequency
IFFT	Inverse Fast Fourier Transform
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
LBT	Listen before Talk
MIMO	Multi Input Multi Output
NTRA	National Telecommunications Regulatory Authority
OFDM	Orthogonal frequency division multiplexing
OSA	Opportunistic spectrum access
PC	personal computer
PU	Primary Users
RF	Radio frequency
ROC	Receiver Operating Characteristics
SCF	Spectral Correlation Function
SDR	Software Defined Radios
SIMO	Single Input and Multiple Output
SNR	Signal to noise ratio

SS	Spectrum sensing
SU	Secondary Users
SWIG	Simplified Wrapper and Interface Grabber
UDP	User datagram protocol
UHD	Universal Hardware Devices
USRP	Universal Software Radio Peripheral
UWB	Ultra wide bandwidth
VHDL	Very high speed integrated circuits hardware description language

CHAPTER 1

Introduction

Chapter 1: Introduction

1.1 Motivation

The concerns for wireless communications and swarming of unlicensed spectrum have motivated administrative organizations and innovation designers to be perpetually forceful in giving new ways to utilize spectra. Keeping in mind the end goal to empower future wireless systems for business use or open administrations, new advancements that can give a request of size increment in system capacity are required, to either bolster more clients or higher information rates. However, it is known that frequencies that are cost-effective and can be used for wireless communication suffer from spectrum shortage.

The National Telecommunications Regulatory Authority (NTRA) radio spectrum allocation chart shown in Figure 1.1 illustrates the overlapping allotments over all the spectrum ranges, which fortifies the lack mindset. There's a need to utilize the spectrum as efficiently as possible to oblige future advancements. Keeping in mind the end goal to do that we have to investigate the spectrum precisely and conclude conclusions that will assist us make the spectrum usage operation more efficient.

The radio spectrum can treated as a natural wealth. The utilization of radio spectrum by several different transmitters and receivers is administered by the diverse regulatory authorities and organizations. CR gives an extraordinary solution to the spectrum usage problem in terms of spectrum sensing methods. Any cognitive radio includes spectrum sensing as its essential part. Spectrum sensing has a dual approach. Firstly available spectrum is detected then it is allocated to the non-serviced clients for efficient usage. The underutilized spectrum sub-bands are ordinarily known as 'spectrum holes' or 'white spaces'. The spectrum holes are considered as a frequency band not used by a licensed client at a specific time and particular geographical place. There are various dimensions of spectrum sensing involves frequency, time and geographical location. Most of the spectrum sensing approaches employs any of the aforementioned dimensions to find the spectrum gabs.

The thesis introduces the implementation of one of the spectrum sensing algorithms which is energy detection using GNU Radio and Universal Software Radio Peripheral N210 (USRPN210) through time and frequency dimensions. Besides, studying the accessible techniques of spectrum sensing helps in distinguishing the highly effective technique.

A new threshold assessment method for energy detection (ED) spectrum sensing using stochastic approach has been tested as a solution for noise uncertainty environment. This stochastic threshold has achieved comparable findings in a low SNR.