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Radiation Sensing For Cognitive Radio

A thesis
Submitted in partial for the requirements of the degree of M.Sc in the Electrical Engineering

Submitted By

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Summary

This thesis discusses one of the modern digital communication systems in the field of wireless communications which is a cognitive radio system. The main objective of this work is analyzing the ability of a cognitive radio system to sense a wide bandwidth spectrum, detect the available empty spectrum bands and use these empty slots for establishing wireless communications networks in order to utilize the spectrum in a better way and increase the spectrum efficiency. There are many studies done to scan the spectrum and estimate the spectrum utilization in the sensed bands. These studies all have similar characteristics: they are all wideband, conducted for short periods of time, and require expensive equipment. The sites where these studies were conducted include Chicago, Illinois, Singapore, USA, Los Angeles, CA, USA, Paris, France and many other countries. The conclusions of these studies are also similar. These all studies showed that the spectrum utilization is very low at their respective locations.

In order to scan the spectrum and measure the spectrum utilization in the sensed bands, a proposed wideband RF front end spectrum sensor for cognitive radio applications in the upper UHF frequencies has been conducted. The proposed RF front end sensor is a part of cognitive radio receiver block diagram which consist of four main units, which are RF front end, wideband Analog to Digital Converter (ADC), software reconfigurable digital baseband radio and a cognitive engine. As a result of the difficulty and cost of implementing the cognitive radio receiver as a whole, we designed and implemented the antenna and the RF front end part. The proposed sensor consists of an antenna, an RF front end and a spectrum analyzer. The proposed antenna is designed to operate in the intended frequency range from 1.7 to 2.7 GHz. The proposed wideband antenna designed from a microstrip rectangular patch with a partial ground plane. The bandwidth of the proposed patch was enhanced by using partial ground technique. The proposed antenna was designed using a ready-made software package (CST microwave studio and measurement). Then the designed antenna has been fabricated by using thin film and photolithography technique and has been measured by using the vector network analyzer. Performance evaluation has been conducted for the simulated and measured results which determined that the designed antenna achieved the required goals which are the return loss is less than -10 dB at the required bandwidth from (1.7 to 2.7) GHz, the voltage standing wave ratio is less than 2 over the planned bandwidth and the designed antenna radiation pattern is an omnidirectional pattern. The total area of the fabricated proposed antenna is (60mm*58mm). The other RF front end components are built from of the shelf commercial parts. Then we used a commercial spectrum analyzer for frequency analysis of the detected signals and to measure the spectrum utilization in the higher UHF frequencies. It is planned to build our own spectrum analyzer based on virtual national instrument. So, this is the RF part of the sensor which proves to have sensitivity comparable to the spectrum analyzer.

We introduced in details our wideband spectrum sensor design, implementation and carried out many spectrum detections measurements with different sensing times to estimate the spectrum utilization in the upper part of the Ultra-High Frequencies (UHF). The spectrum data the proposed sensor collected is the power present at a given frequency. Two major spectrum sensing results were conducted.

Firstly, The proposed spectrum sensor was applied to measure the spectrum utilization in the frequency band from 1.7 to 2.7 GHz and the results showed that the spectrum utilization is estimated to be from 0.4 percent to 2 percent with average spectrum utilization equal to 1.175% and the detected RF signals are originated from the mobile communication systems, specifically, the uplink band (1710-1785) MHz, and Downlink band (1805-1880) MHz in addition to fewer signals from the surveillance radar band (2686-2900) MHz and very fewer signals from the Bluetooth band from (2400-2485) MHz.

Secondly, the proposed sensor was applied to measure the spectrum utilization in the frequency bands from 1700 to 1950 MHz and from 1837 to 2087 MHz also the results showed that the spectrum utilization is estimated to be from 5.5 percent to 22.7 percent with average spectrum utilization equal to 12.35% and the detected RF signals are originated from the GSM band uplink (1710-1785) MHZ, and Downlink (1805-1880) MHz. The higher the estimated utilization of the second bands results is due to higher ability to detect smaller signals as the noise floor of the spectrum analyzer is made lower.

Finally, our implemented sensor advantages are its wide bandwidth from 1.7 to 2.7 GHz, low cost, simple implementation, very small size, and relatively high sensitivity to detect weak signals.

Keywords: Cognitive radio, RF front end, Spectrum Hole, Spectrum Sensing, Wideband Spectrum Sensor.

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List of Abbreviations

ACMSA	Aperature Coupled Microstrip Antenna
ADC	Analog-to-Digital Converter
A/D	Analog-to-Digital
AIC	Analog Information Converter
ANT	Antenna
ASICs	Application Specific Integrated Circuits
AWGN	Additive White Gaussian Noise
BW	Bandwidth
BPF	Band Pass Filter
CDMA	Code Division Multiple Access
CE	Cognitive Engine
COMSEC	Communications Security
CPC	Cognitive Pilot Channel
CR	Cognitive Radio
CRNs	Cognitive Radio Networks
CRS	Cognitive Radio System
CST	Computer Simulation Technology
CSMA	Carrier Sense Multiple Accessing
DAC	Digital-to-Analog Converter
DC	Direct Current
DoS	Digital Of Service

DSA	Dynamic Spectrum Access
DSP	Digital Signal Processing
DSSS	Direct Sequence Spread Spectrum
DTV	Digital Television
ECMA	European Computer Manufacturers Association
EDGE	Enhanced Data Rates for GSM Evolution
ETSI	European Telecommunications Standards Institute
FBW	Fractional Bandwidth
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FHSS	Frequency Hopping Spread Spectrum
FPGA	Field-Programmable Gate Array
FR	Flame Retardant
GND	Ground
GPIB	General Purpose Interface Bus
GPP	General Purpose Processors
GPS	Global Positioning System
GSM	Global System for Mobile
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
ISM	Industrial, Scientific and Medical
ITU	International Telecommunication Union