CHAPTER 1
INTRODUCTION

1.1 Background

Wireless communications demand a reliable and high capacity radio spectrum. Existing scenario for frequency spectrum allocation which is provided by the government is based on fixed allocation to licensed users called Primary Users (PUs). The drawback of the existing scenario makes the available spectrum is under-utilization and causes spatial and temporal "spectral holes "[10]. Other users who do not have access rights to the spectrum called Secondary Users (SUs) cannot access the spectrum even though the PU is absent. Innovation approach Initiated by Federal Communications Commission (FCC) regarding secondary usage of spectrum to improve spectrum utilization is Cognitive Radio (CR)technology, which is an intelligent wireless communication system that is capable of realizing the conditions of the surrounding environment. One of the key challenges of CR technology is to reliably detect the presence or absence of PUs at very low signal-to-noise ratio[1].[2],[3],[10]. Spectrum sensing allows cognitive users to autonomously identify unused portions of the radio Spectrum, and thus avoid interference to primary users. Spectrum sensing for cognitive radio applications requires high sampling rate, high resolution analog to digital converters (ADCs) with large dynamic range, and high speed processing units (DSPs or FPGAs) are needed for performing computationally demanding signal processing tasks with relatively low delay[1],[2].

There have been several sensing methods which are used by researchers: a matched filter, energy detection, cyclostationary and Waveform-Based Sensing. Energy detector based approach is the most common way of spectrum sensing because of its low computational and implementation complexities. In addition, it is more generic (as compared to methods given in this section) as receivers do not need any knowledge on the primary users' signal [1]. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor. Some of the challenges with energy detector based sensing include selection of the threshold for detecting primary users, inability to differentiate interference from the noise and a poor performance under low signal-to-noise ratio (SNR).Matched-filtering is known as the optimum method for detection of primary users when the transmitted signal is known. The main advantage of matched filtering is the short time to achieve a certain probability of false alarm or probability of miss detection as compared to other methods that are discussed in this

section. However, matched-filtering requires cognitive radio to demodulate received signals. Hence, it requires perfect knowledge of the primary user's signal features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format. Moreover, since cognitive radio needs receivers for all signal types, the implementation complexity of sensing unit is impractically large. Another disadvantage of match filtering is large power consumption as various receiver algorithms need to be executed for detection[2].

Cyclostationary feature detection is a method for detecting primary user transmissions by exploiting the Cyclostationarity features. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation. Cyclic frequencies can be assumed to be known or they can be extracted and used as features for identifying transmitted signals. As the numbers of features generated in the signal increase, it will increase the detection robustness against multipath fading. However, this comes at the expense of increased complexity. In Waveform-Based Sensing, Known patterns are usually utilized in wireless systems to assist synchronization or for other purposes. Such patterns include preambles, regularly transmitted pilot patterns and spreading sequences[3].

In the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself. This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing or coherent sensing. Furthermore, it is shown that the performance of the sensing algorithm increases as the length of the known signal pattern increases. However, it is susceptible to synchronization errors. So It is necessary to establish a new method to improve detection, without prior knowledge of primary user's signal, without estimating noise power and the need for synchronization with the transmitter.

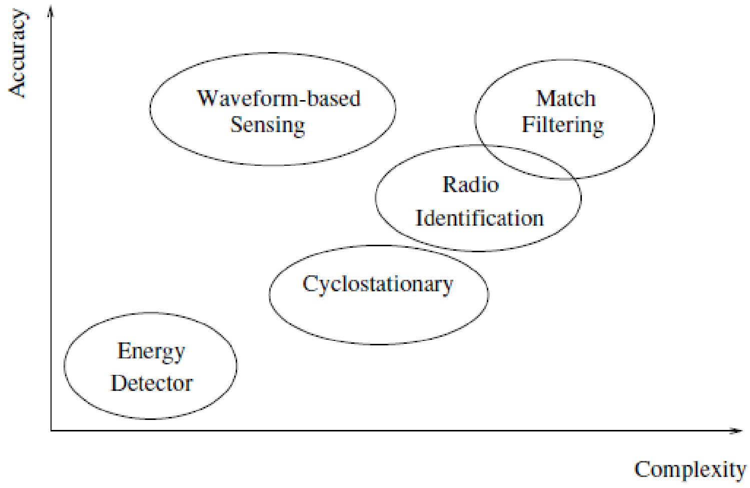

Figure 1.1 Sensing methods state of the art and their complexities [1]

Our main contribution is about the generation of test statistics based on Eigenvalues of the sample covariance or autocorrelations matrix of the received signal by applying a Fast Fourier Transform (FFT) to the sample covariance matrix. Furthermore it can be easily implemented in an FPGA with low complexity and latency to achieve fast signal detection.

1.2 Objectives

The purpose of this thesis is :

1. A prototype of an FPGA test-bed to maximize the benefits of cognitive radio technology, and to efficiently implement and Eigen value based spectrum sensing and quickly detects the presence or absence of a primary user in spectrum without estimate of noise power by sensing the DVB signal.
2. Identify parameters that may affect the detection performance of spectrum holes in wireless communication i.e. multipath fading.
3. To understand and explore different measurements tools and techniques that can improve the detection of the signal.

1.3 Problem

- The major complexity of covariance based detection comes from two parts: computation of the covariance matrix and the test statistics.

- The performance of the covariance based detector depends on the number of samples used for computing the sample autocorrelation, Signal to Noise Ratio (SNR) and how strong autocorrelations among the samples[3].
- In practice, the statistical covariance matrix can only be calculated using a limited number of signal samples.
- The test statistics base don Eigenvalues usually done by Matlab function in a host computer[3].
- When considering the implementation of the algorithms in a hardware i.e. FPGA, How to find the effective length of auto correlation function and generate the Eigenvalues with low implementation complexity and short detection time. In order to get better detection performance in low SNR.

1.4 Scope of Work

The scope of work of this thesis is:

1. This thesis focuses solely on spectrum sensing functionality in Cognitive Radio systems and does not address other functionality such as spectrum sharing, spectrum mobility and spectrum management.
2. Evaluation of Eigenvalue based sensing for Digital Video Broadcasting (DVB),assuming one PU is using OFDM and transmit a signal on Multipath channel and the noise on the receiver side is modeled as Additive White Gaussian Noise (AWGN).
3. Evaluation of the detection algorithm is used in fixed DVB Scenario.

1.5 **Hypothesis**

The performance of the Eigenvalue based detector depends on the number of samples used for computing the sample autocorrelations, Signal to Noise Ratio (SNR) and how strong autocorrelations among the samples. However for a certain autocorrelation length the signal is no more correlated. Suppose that we found the effective length of autocorrelation function and if the number of samples is very large (asymptotic) then the Eigenvalues of the sample covariance matrix can be found easy by applying a Discrete Fourier Transform (DFT). Then two test statistics are extracted by applying a maximum minimum search algorithm based on comparators to find the maximum and minimum Eigenvalues. Finally, a decision on the presence of the signal is made by comparing the ratio of the maximum Eigenvalue to minimum Eigen value with a threshold. Detection probability and the associated threshold for the decision are found based on the statistical theory. The methods do not need any information of the signal, channel, and noise power a priori. In addition, no synchronization is needed[3].

$$\begin{pmatrix} r_{xx}[0] & r_{xx}[1]\cdots & r_{xx}[M]\cdots 0 \\ r_{xx}[1] & r_{xx}[0]\cdots & r_{xx}[M-1]\cdots 0 \\ \vdots & & \\ 0 & a_{32} & r_{xx}[0] \end{pmatrix}$$

$$\lambda = \sum_{k=-0}^{M} r_{xx}[k]\exp(-j2\pi fk) \quad (1.1)$$

1.6 **Research Method**

To test the impact of the size of the covariance matrix we will fix the Autocorrelation length of the received signal and vary the SNR. Expected results for both probability of detection (Pd) and probability of false alarm (Pfa) of the proposed test statistics slightly increase with SNR, but will reach a ceiling at some Autocorrelation length. Noting that smaller Autocorrelation length means lower complexity. In practice, we can choose a relatively small Autocorrelation length. However, it is very difficult to choose the best length. Then the generation test statistics based on Eigenvalues of the sample covariance matrix is found by applying a Discrete Fourier Transform (DFT) to the element of the sample covariance matrix .

The hardware architecture of our cognitive radio testbed consists of an Xilinx® Kintex™-7 FPGA. To make effective use of the developed hardware, a software tool chain is built around MATLAB/Simulink coupled with the Xilinx System Generator for mapping high-level block diagrams and state machine specifications to FPGA configurations. This environment supports simultaneous development of signal processing algorithms and digital design description for their hardware realization.

The Implementation process begins with the generating of PU signal then transmitted through the Multipath Channel and AWGN. Furthermore, the signals processing of the received signal for Eigenvalue based detector is carried out on an Xilinx® Kintex™-7 FPGA connected a host computer equipped with MATLAB (Simulink) enabled with Xilinx System

Generator Block set. The real-time measurement will be performed for only one receiver and transmitter (SISO) system. In comparison to the results referred from literature and formulas, Eigenvalue based detection method has better detection for following reasons; no dependence on noise power and does not need prior Knowledge of the PU's Signal.

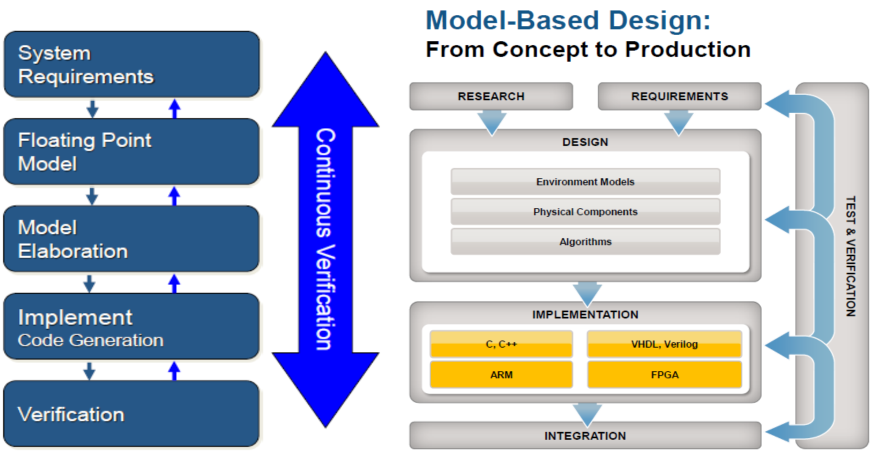

Figure 1.1 Research Methodology block diagram [13],[14]

1.7 Schedule

TABLE 1.2 : Timetable

Activity	2016					2017						
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July
Reference tracing												
Requirement identification												
Design process												
Implementation process												
Experiment design												

and plan												
Analysis/Evaluation												