Chapter 7

Spectrum Sensing Using Principal Components for Multiple Antenna Cognitive Radios

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ABSTRACT

This chapter presents an experimental comparative analysis of the well-known Covariance-Based Detection (CBD) techniques, which include Covariance Absolute Value (CAV), Maximum-Minimum Eigenvalue (MME), Energy with Minimum Eigenvalue (EME), and Maximum Eigenvalue Detection (MED). CBD techniques overcome the noise uncertainty issue of the Energy Detector (ED) and can even outperform ED in the case of correlated signals. They can perform accurate blind detection given sufficient number of signal samples. This chapter also presents a novel CBD algorithm that is based on Principal Component (PC) analysis. A Software-Defined Radio (SDR)-based multiple antenna system is used to evaluate the detection performance of the considered algorithms. The PC algorithm significantly outperforms the MED and EME algorithms and it also outperforms MME and CAV algorithms in certain cases.

INTRODUCTION

Spectrum sensing is an enabling technology for a cognitive radio (CR) system. Extensive research has been performed in the past decade in devising accurate and robust wireless signal detection methods for CR applications. Spectrum sensing techniques can be classified into two main types. The first type relies on a priori knowledge of the channel and/or licensed user (LU) signal characteristics for signal
detection, and includes cyclostationarity-based feature detection, matched filter detection and waveform-based sensing (Yucek & Arslan, 2009). The second type of sensing techniques do not require prior knowledge of channel or PU signal characteristics, and includes energy detection, wavelet based sensing and covariance-based sensing (Yucek & Arslan, 2009). Techniques of the second type are often typically referred to as blind signal detectors. The first type of techniques generally offer a higher level of detection accuracy but their application is limited to a specific type of known wireless signal and might require the use of complex estimation techniques. On the other hand, blind signal detection techniques can be applied to most types of signals which make them a suitable choice for heterogeneous wireless environments. However, they do have some performance limitations.

Due to their flexibility and broad scope of application, blind signal detection techniques have drawn significant research interest in recent years. Energy detection (ED) is the simplest of all detection techniques, however, it requires knowledge of noise variance to correctly set the detection threshold. In practice, the noise variance is not constant and is influenced by various factors, such as temperature, humidity, device aging, radio interference etc. The performance of ED is adversely affected by even the slightest variation in the noise variance (Tandra & Sahai, 2005), which makes it undesirable for implementation in real systems. Moreover, ED is optimal for detecting independent and identically distributed (i.i.d.) Gaussian signals (Kay, 1998) but it is not optimal for detecting correlated signals, which is the case in most practical wireless systems. These limitations of ED can be overcome by covariance-based detection techniques (Zeng & Liang, 2009b; Zeng & Liang, 2009a; Zeng, Koh, & Liang, 2008; Zeng & Liang, 2007b; Zeng & Liang, 2007a; Penna, Garello, Figlioli, & Spirito, 2009; Kortun, Ratnarajah, Sellathurai, & Zhong, 2010; Zeng & Liang, 2010) that exploit the structure of the covariance matrix of the received signals and, in general, do not require knowledge of the noise variance. (An exception is the MED method that does require knowledge of the noise variance (Zeng, Koh, & Liang, 2008). CBD algorithms can accurately detect a signal at low SNR, provided a sufficient number of signal samples are used. This was the motivation for further exploring a new detection algorithm that relied on the calculation of the covariance matrix. Most of the work done on CBD methods has focused on theoretical analysis and simulations. In (Oh, et al., 2008), a hardware implementation has been performed using the CAV algorithm only; however, no comparison of results for all the CBD algorithms is presented. There are two main contributions of this chapter.

- Firstly we present a performance comparison of the existing CBD algorithms using a multi antenna SDR-based signal acquisition system. To the author’s knowledge, this is the first time that a comprehensive performance comparison of the CBD algorithms is presented while using actual wireless signals. In the previous related works, individual CBD algorithms have been reported separately in various studies but no overview is available to give a clear picture of the relative performance of different CBD algorithms in real systems. Such an overview is a major contribution of this chapter.

- The second contribution of this chapter is that, an innovative blind signal detection technique is proposed, that is based on principal component analysis (PCA). The PCA based algorithm (or PC algorithm for brevity) is very promising in comparison with the other CBD algorithms. The initial processing step required of the PC algorithm is similar to the other CBD algorithms i.e. calculation of sample covariance matrix. Due to this similarity the new technique is presented along with the CBD algorithms to give a performance comparison.