Chapter 5
Cyclostationary Spectrum Sensing in Cognitive Radios at Low SNR Regimes

Mahsa Derakhshani
University of Toronto, Canada

Tho Le-Ngoc
McGill University, Canada

Masoumeh Nasiri-Kenari
Sharif University of Technology, Iran

ABSTRACT

Spectrum sensing is one of the key elements in the establishment of cognitive radio. One of the most effective approaches for spectrum sensing is cyclostationary feature detection. Since modulated signals can be modeled as cyclostationary random signals, this feature can be used to recognize the cyclostationary modulated signal in a background of stationary noise even at low SNR regimes. This chapter reviews non-cooperative cyclostationary sensing approaches and reports recent advances in cooperative cyclostationary sensing algorithms. New results for cooperative cyclostationary spectrum sensing are then presented, which ensure better performance as well as faster and simpler operation. In the proposed schemes, each Secondary User (SU) performs Single-Cycle (SC) cyclostationary detection for fast and simple implementation, while collaboration between SUs in final decision on the presence or absence of the PU is explored to improve its performance. Furthermore, this chapter presents another look at the performance evaluation of cyclostationary detectors in terms of deflection coefficients.

INTRODUCTION

It has been confirmed that the conventional fixed spectrum allocation strategies lead to spectrum underutilization. Despite the activity of licensed users, measurements reveal that there still exists a plenty of instantaneous spectrum availabilities in the licensed spectrum (Harrison, Mishra, & Sahai, 2010; Van de Beek, Riihija, Achtzehn, & Mahonen, 2012). This motivates the idea of opportunistic spectrum ac-

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cess (OSA) that allows SUs to utilize temporal spectrum opportunities in the licensed spectrum. Under this model, SUs need to sense the spectrum and identify spectrum holes for their transmissions, while limiting the level of interference to the licensed primary users (PUs) (Akyildiz, Lee, Vuran, & Mohanty, 2006; Goldsmith, Jafar, Maric, & Srinivasa, 2009; Haykin, 2005; Mitola, 2000; Zhao & Sadler, 2007).

Spectrum sensing, the detection of presence or absence of PUs in a specific frequency band, is one of the key elements in the establishment of cognitive radio based on OSA. This is because its accuracy, computational complexity and response time directly affect the efficiency of SU spectrum usage and the PU protection (Zhao & Sadler, 2007). The problem of spectrum sensing can be modeled as a binary hypothesis testing problem with null hypothesis that the PU is absent, and the alternative hypothesis that the PU is present (Axell, Leus, Larsson, & Poor, 2012; Yucek & Arslan, 2009).

Different approaches have been proposed for spectrum sensing in cognitive radio (Axell et al., 2012; Yucek & Arslan, 2009). Energy detection (radiometry) has been widely known for its simplicity. It measures the energy contained within the band of interest and compares it with a threshold to detect the presence of a PU signal. Though it is very well-known and uncomplicated to implement, there are several drawbacks for energy detection that might alleviate its benefits in some cases, especially at low SNR regimes. Energy detectors cannot differentiate between the energy of signal of interest and noise, thus it has a low performance at low SNR regimes. Furthermore, it is sensitive to uncertainty in noise statistics (Cabric, Mishra, & Brodersen, 2004; Digham, Alouini, & Simon, 2007; Sonnenschein & Fishman, 1992; Tandra & Sahai, 2005).

Since modulated signals exhibit cyclostationarity or spectral coherence, this feature can be used to recognize cyclostationary modulated signal in a background of stationary noise, even at low SNR regimes. Distinctive characteristics of cyclostationary signal from stationary noise make signal detection possible at low SNR regimes and in the presence of noise uncertainty, by measuring signal power at non-zero CFs (Gardner, Napolitano, & Paura, 2006; Gardner & Spooner, 1992; Gardner, 1986, 1988; Yeung & Gardner, 1996). In the cyclostationary detection, the values of either spectral correlation function or cyclic autocorrelation function at different non-zero CFs are used as test statistics for detecting signals, which improve the detection performance compared to energy detection. In the cognitive radio application, SUs are not informed of the PU signal. Thus, they cannot identify the proper CF at which signal has power. As a result, one drawback of cyclostationary non-cooperative detectors is the need for a time-consuming and computationally complex search over all possible CFs to assure presence or absence of the PU (Yeung & Gardner, 1996).

Furthermore, against severe shadowing and fading effects, excessively long detection time is required to enable reliable detection, and hence, guarantee a limited level of interference to the PUs. Cooperative sensing is proposed as a solution to enhance the detection performance without increasing the detection time. In the cooperative spectrum sensing, SUs collaborate with each other to sense the spectrum to find the spectrum holes. In other words, they share their sensing information, and then each of them decides about absence or presence of the PU in a specific bandwidth based on the shared knowledge. Since SUs sense different shadowing and fading, cooperative spectrum sensing can improve the detection performance by multi-user diversity (Akyildiz, Lo, & Balakrishnan, 2011).

Thus, in this chapter, OR (i.e., logical OR operation) and maximum-likelihood (ML) cooperative cyclostationary techniques are presented to improve the detection performance and reduce the complexity comparing with non-cooperative cyclostationary detectors. In the proposed OR and ML cooperative cyclostationary methods, each user only measures signal power at a single CF and exchanges its information with the others for further decision. The use of parallel SC detectors at different CFs by