Spectrum Sensing Technique in Cognitive Radio using WIMAX signal

Shweta Verma, Shailee Yadav

Electronics & Communication Engineering Department, ITM University, Gwalior
Email: sshweta1988@gmail.com
Email: shaily.ydv17@gmail.com

ABSTRACT
In this paper one of the most important cognitive radio task i.e. spectrum sensing is discussed. Cognitive radio is an intelligent wireless communication technology in order to increase the spectrum efficiency. Increasing efficiency of the spectrum usage is an urgent need as an intrinsic result of the increasing demand for higher data rates, better quality of services and higher capacity. Spectrum sensing and awareness are challenging requirements in cognitive radio (CR). To adequately adapt to the changing radio environment, it is necessary for the CR to detect and classify the on-the-air signals. The wireless industry has shown great interest in orthogonal frequency division multiplexing (OFDM) technology. In this paper mathematical model of the OFDM based mobile Worldwide Interoperability for Microwave Access (WiMAX) is developed and their second spectrum sensing based on cyclostationarity in cognitive radio is considered. The second-order cyclic features built-in in modulated signals is used to detect the signals order cyclostationarity is studied.

Keywords: Cognitive Radio, Cyclostationarity, OFDM, Spectrum Sensing, WiMAX

I. INTRODUCTION
Today, by unprecedented growth of wireless applications, the problem of spectrum scarce is becoming apparent. Most of the spectrum has been allocated to specific users, while other spectrum bands that haven’t been assigned are overeroded because of overuse. However, most of the allocated spectrum is idled in sometimes and locations. The Federal Communication Commission (FCC) research report [1] reveals that, seventy percent of the allocated spectrum is underutilized. So we need a technique to deal with the problem of spectrum underutilization, which makes the birth of cognitive radio. Cognitive radio [2] [3] can sense external radio environment and learn from past experiences. It can also access to unused spectrum band dynamically without affecting the licensed users, in such a way to improve the spectrum efficiency.

As orthogonal frequency division multiplexing (OFDM) has been chosen for the physical layer of many wireless standards, intensive research has been done recently on the detection, classification, and parameter estimation of the OFDM signals. Most of the classification methods are developed for generic signals and rely on cyclostationarity, with some of them employing the detection of the cyclic prefix (CP)-induced peaks in the cyclic autocorrelation function (CAF) [4]–[8]. In these methods, the CAF magnitude is either searched over a large delay range to find the peaks which introduces computational complexity, or the location of the peaks is assumed a priori known [8]. Another method is presented in [9] and [10], and uses the cyclostationarity signatures intentionally embedded in the OFDM signals. The drawback of this method is the extra overhead that results from embedding such signatures. In [11], the authors exploit the second-order cyclostationarity to classify diverse IEEE 802.11 standard signals.

The organization of this paper is as follows: The mobile OFDM signal model is outlined in section II. Simulation results are presented in section III and section IV concludes the paper.

II. MOBILE WiMAX OFDM SIGNAL MODEL
Fig.1 presents the IEEE 802.16e time-division duplex (TDD) frame structure, as per the current mobility certification profiles [12]–[14]. The standard frame duration can range from 2 ms to 20 ms; however, all
WiMAX equipments support only a 5-ms frame [15]. The frame is divided into two sub frames, one for the downlink (DL) and another one for the uplink (UL). The DL-to-UL sub frame ratio is variable, to support different traffic profiles. Transition gaps separate the adjacent DL and UL sub frames. In Fig. 1, TTG represents the DL-UL gap and is referred to as the transmit/receive transition gap, while RTG represents the UL-DL gap and is referred to as the receive/transmit transition gap. Note that the terminology used here is according to the IEEE 802.16e standard [13], [14]. The DL sub frame starts with a preamble as the first symbol, which is used for time and frequency synchronization and uniquely identifies a serving base-station. Therefore, a cognitive user within the coverage area of a base-station will periodically receive the same preamble.

![Fig.1 TDD frame structure for Mobile WiMAX](image)

The OFDM frequency-domain description is presented in Fig.2. One can note four types of subcarriers: data subcarriers to transmit information, pilot subcarriers for estimation purposes, null subcarriers for guard bands, and direct current (DC) subcarrier [14]. The first two types of subcarriers are called the used subcarriers. The pilot symbol on subcarrier is generated as $8(0.5-w_k)/3$ where $w_k$ is a value taken from a pseudorandom binary sequence that is different for each OFDM symbol [14]. The distribution of the pilot subcarriers might differ from one OFDM symbol to another in the frame, while this repeats every frame, i.e., it is the same for each $\lambda_{th}$ OFDM symbol of a frame [12]–[14]. Note that $\lambda=0$ for the preamble symbol, $1 \leq \lambda \leq N_{DL}$ for the DL OFDM symbols (excluding the preamble), and $N_{DL}+1 \leq \lambda \leq N_F-1$ for the UL OFDM symbols, with $N_{DL}$ and $N_F$ as the number of OFDM symbols in the DL (excluding the preamble) and in the frame, respectively. Note that more than one pilot distribution might be employed in the DL or UL sub frames; each pilot distribution is used in a certain set of OFDM symbols in the DL or UL sub frames [12]–[14]. The pilot symbols are usually transmitted with boosted power over the data symbols. The preamble contains only null subcarriers and subcarriers used for transmitting preamble data. According to the standard, the preamble data symbols are transmitted every third subcarrier out of the set of subcarriers, $-K_{p,d}/2$, $-K_{p,d}/2 + 1$,…….. $K_{p,d}/2$ starting from the subcarrier $-K_{p,d}/2 + S_{p,d}$ up to $-K_{p,d}/2 + S_{p,d} + 3(K_{p,d} - 1)$ where $S_{p,d} = 0, 1, 2$ and $K_{p,d}$ is the number of the preamble data symbols [12]–[14]. Fig. 3 shows the frequency domain description of the preamble when $S_{p,d}=0$. 

![Fig.2 OFDM frequency description](image)
According to the above description, we express the discrete time mobile WiMAX OFDM signal affected by noise as

\[ r(n) = r_P(n) + r_{DL}(n) + r_{UL}(n) + w(n) \]  

(1)

where \( r_P(n) \), \( r_{DL}(n) \), and \( r_{UL}(n) \) are the signal components corresponding to the preamble, and the DL (excluding the preamble) and UL sub frames, respectively, and \( w(n) \) is the additive zero-mean Gaussian noise. Furthermore, \( r_P(n) \), \( r_{DL}(n) \), and \( r_{UL}(n) \) are given respectively as

\[ r_P(n) = a_P \sum_{k=0}^{K_P-1} b_k g(n - lD - lN_F^{-1}D_G) \]

(2)

\[ r_{UL}(n) = a_{UL} \sum_{k=-K_{UL}/2}^{K_{UL}/2-1} d_{k,f} g(n - lD - lN_F^{-1}D_G) \]

(3)

\[ r_{DL}(n) = a_{DL} \sum_{k=-K_{DL}/2}^{K_{DL}/2-1} c_{k,l} g(n - lD - lN_F^{-1}D_G) \]

(4)

Where \( K_P \), \( K_{DL} \), and \( K_{UL} \) are the number of used subcarriers in the preamble, DL, and UL symbols, respectively, \( a_P, a_{DL} \), and \( a_{UL} \) are the amplitude factor, \( D \) is the OFDM symbol period equal to the useful OFDM symbol duration, \( D_u \) plus the CP duration, \( D_{cp} \), \( b_k \) is the preamble data symbol transmitted in the \( 3k-K_P/2+S_{p,d} \)th subcarrier of the preamble, with \( -K_P/2+S_{p,d} \) as the position of the first subcarrier used to transmit preamble data and \( S_{p,d} \) \( \epsilon \{0,1,2\} \), \( c_{k,l} \), and \( d_{k,l} \) are the symbols (data and pilot) transmitted on the \( k \)th subcarrier and within the \( l \)th OFDM symbol which belongs to the DL and UL sub frames, respectively (note that the distribution of pilot subcarriers could be different for different groups of OFDM symbols) \( N_{UL} \), is the number of OFDM symbols in the UL sub frame, \( g(n) \) is the impulse response of the transmit and the receive filters in cascade, and \( D_G = D_{TG} + D_{RG} \) is the total duration of the transition gaps within each frame, with \( D_{TG} \) as the TTG and RTG transition gaps, respectively. The data symbols are taken either from a quadrature amplitude modulation (QAM) or phase shift keying (PSK) signal constellation, and are assumed to be zero-mean independent and identically distributed (i.i.d.) random variables. The fast Fourier transform (FFT) size for generating OFDM symbols is equal to the total number of subcarriers (used and guard band subcarriers), and equals \( D_u \).
The OFDM parameters for mobile WiMAX signals are presented in Table I. As one can notice, the FFT size is scalable with the bandwidth: when the available bandwidth increases, the FFT size also increases, such that the useful symbol duration (equal to the reciprocal of the subcarrier frequency spacing, $\Delta f$) is fixed. This in turn leads to a constant useful OFDM symbol duration.

Using the signal model in (2)–(4), one can express the autocorrelation function of $r(n), R(n, \tau)$ as the sum of autocorrelation functions corresponding to the signal components, signal and noise, and only noise. We expect that non-zero significant values of $R(n, \tau)$ are attained at certain delays, for which we subsequently study $R(n, \tau)$ and its representation as a Fourier series, and further determine the expressions for the CAF at CF $\alpha$ and these delays, $R(\alpha, \tau)$ and set of CFs, $\{\alpha\}$.

### III. SIMULATION RESULTS

The signals are simulated with 5 MHz double sided bandwidth. For WiMAX, the number of subcarriers is 256, for the mobile WiMAX signal $T_{CP}/T_U$ equals 1/4. Here we use 256 FFT with 1/4 CP, QAM with 16 points and unit variance of the signal constellation is used to modulate the data subcarriers. The pilot subcarriers in mobile WiMAX are modulated according to the IEEE 802.16e standard [21].
IV. CONCLUSION
Radio frequency spectrum is a very valuable resource in wireless communication systems and it has been a major research topic from last several decades. Cognitive radio is a promising solution which enables spectrum sensing for opportunistic spectrum usage by providing a means for the use of spectrum holes. In this paper, spectrum sensing Using WiMAX is described in detail with mathematical calculations. In this paper, spectrum sensing based on cyclostationarity in cognitive radio is considered. The second-order cyclic features built-in in modulated signals is used to detect the signals. Due to high complexity of cyclostationary feature detection, we choose to detect specific frequencies and cyclic frequencies based on the signal’s feature to degrade complexity greatly.

REFERENCES


