DTV Spectrum Sensing with Pilot Tone Filtering

***Ali Eksim*[1], *Selman Kulac*[2], *and Murat H. Sazli*[3]**

[1]UEKAE, TUBITAK-BILGEM, Gebze, Kocaeli, TURKEY
alieksim@uekae.tubitak.gov.tr

[2]Turk Telekom Group R&D Directorate, METU Technopolis, Ankara, TURKEY
selman.kulac@turktelekom.com.tr

[3]Electronics Engineering Dept., Ankara University, Ankara, TURKEY
sazli@eng.ankara.edu.tr

Abstract

In cognitive radio communication technique, unlicensed users monitor the existence and availability of licensed (primary) user´s spectrum and attempt to exploit it when the primary users don't use their spectrum. In this technique, an effective spectrum sensing is very crucial for not to disturb primary user. One of the most effective spectrum sensing approaches is pilot tone detection. In many licensed digital cellular communication systems, pilot tone transmitting is preferred for its some advantages over channel estimation, synchronization, etc. In this paper, an effective pilot tone detection method is proposed. In the proposed method, Goertzel Algorithm is used in this pilot tone detection and pilot tones have been detected correctly on actual DTV signal records. Proposed method provides fast and more efficient spectrum sensing capabilities.

1. Introduction

Nowadays, wireless communication has become one of the indispensable part of human life. New communication techniques between devices and machines have been brought out as wireless communication's importance increases. These areas have been researched extensively to meet people's needs. Research efforts are focused on having devices or machines more clever and get them fulfill their functions within limited resources on their own. One of the areas of making clever devices or machines is cognitive radio area. With cognitive radio, it is intended to sense the changes in the environment and to setup communication parameters of the radio accordingly, so that users enjoy better service. In a cognitive radio system, it is essential to utilize an efficient spectrum sensing technique to sense the unused frequency bands. This spectrum sensing technique must be capable of sensing the frequency channel occupancy by the primary users before allowing the unlicensed users' transmission.

First concrete step to cognitive radio has been the permission of Federal Communications Commission (FCC), the authority of communications in USA for unlicensed usage in TV bands, not disturbing the licensed users [1]. The reason of this permission was the result of an investigation that shows that a little portion of the TV spectrum is used in rural areas. IEEE 802.22 working group has started the first cognitive radio study which is called IEEE 802.22 WRAN (Wireless Regional Area Network) for that reason.

With this IEEE 802.22 standard, supporting the data communication capability in TV bands for the rural area users is aimed. In TV bands unused channels should be used not to cause harmful interference to the existing TV receivers [2]. Thus effective real time detection of unused channels is needed. This is succeeded with effective spectrum sensing. Hence, detecting whether the TV signals including the pilot tone in used channels are present is more possible.

IEEE 802.22 WRAN architecture consists of IEEE 802.22 WRAN cells, each of which has one base station (BS) and some client stations (Customer Premise Equipment, CPE) that are out of the inclusion of the DTV. BS is transmitter, controller and decision module for spectral detection is as well [3]. The first aim of the spectrum sensing in IEEE 802.22 standard is to realize whether the TV channel is used or not. The noise at the receiver, shadow fading, Rayleigh fading, interference of the other wireless system or equipment from the DTV system or equipment, DTV signals transmitted from the adjacent channels [4] are the factors that make the realization of used / unused channels more difficult. In addition to these factors, lowering the power level (to -116 dBm) also makes the detection more difficult.

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Blind sensing and signal specific sensing are two classes of spectrum sensing techniques. Energy (or power) detection method is the most preferred method of blind sensing class. Energy detection method yields better results especially at negative SNR values which occur when there is no noise uncertainty. When there is noise uncertainty, performance of energy detection method significantly decreases. Reasons of noise uncertainty are initial error at the noise estimation, temperature dependent changes in the noise, and temperature dependent changes in amplifier gain and the errors caused by interference level changes [5]. Signal specific sensing techniques are preferred to sense the licensed users when noise uncertainty is taken into consideration. It is known that one of these techniques is pilot tone detection.

In many licensed digital cellular communication system pilot tone transmitting is done for channel estimation and synchronization etc purposes. Generally, the power of the pilot tone changes between %1 and %10 of total transmitted power. Especially, pilot tone (also sinus wave transmission) is met frequently in licensed broadcast system and used receiver synchronization. In this paper, it is shown that effective pilot tone detection is done to be the guide of faster and more efficient spectrum sensing implementation. This is done with not disturbing the primary users and using original DTV broadcasting data in digital television (DTV) broadcast system which has pilot tone transmitting characteristic. The Goertzel Algorithm is used in this pilot tone detection and pilot tones have been detected errorless on studies on actual DTV signal records. In the second part of the paper, knowledge about DTV signal records and the Goertzel Algorithm are explained. In the third part of the paper, performance analysis is presented and in the last part of the paper, conclusions which paper has brought up are presented.

2. DTV Signal Records

In this study, original terrestrial DTV field measurements which Cornell University Blind Equalization Research Group (BERG), Nxt Wave Communications, Applied Signal Technology, Inc. and the Australian National University Telecommunications Engineering Group jointly took from DTV broadcastings in the city of Philedelphia in USA are used [6]. It is asserted in [7] that these measurements were taken using yagi and omni directional antennas in variety of urban, sub-urban and rural areas for 2 seconds. Furthermore, it is mentioned that these measurements were recorded as data records sampled with 50 MHz and taken to intermediate frequency.

In figure 1A, there is data record that is named with hampton328e.snp and in this data record, it is appeared that original DTV signal spectrum's middle area was notched to noise floor [8]. It is explained that this data record was formed from the measurement that was taken in Hampton Inn and Suites, room 328 at 14:20 on 24.03.2000 when the weather was clear and sunny with using yagi antenna and the transmitter frequency 545 MHz and the power 800 kW. When looked at the data record, it is understood that pilot signal seems at the lower part of the band with strength of moderate to strong.

In figure 1B, there is data record that is named with luzerne11.snp and in this data record, it is appeared that original DTV signal spectrum of this record nearly has no distortion [9]. It is explained that this data record was formed from the measurement that was taken in Corner of Luzerne and Whittacker, Philadelphia on sometime between 25.03.2000 and 31.03.2000 when the weather was windy with using yagi antenna with some antenna vibration and the transmitter frequency 545 MHz and the power 800 kW. When looked at the data record, it is understood that pilot signal seems at the lower part of the band with strength of strong.

In figure 2A, there is a data record which is named as luzerne8.snp. In this data record, it is appeared that original DTV signal spectrum's lower area was notched to noise floor [10]. It is explained that this data record was formed from the measurement that was taken in Corner of Luzerne and Whittacker, Philadelphia on sometime between 25.03.2000 and 31.03.2000 when the weather was windy with using yagi antenna with some antenna vibration and the transmitter frequency 545 MHz and the power 800 kW. Furthermore, antenna direction was contrary to the luzerne11.snp record. When looked at the data record, it is understood that pilot signal seems at the lower part of the band with strength of so weak.

In figure 2B, there is a data record which is named as mantua7.snp. In this data record, it is appeared that original DTV signal spectrum's lower area was notched to noise floor as in luserne8.snp [11]. It is explained that this data record was formed from the measurement that was taken on Mantua Street near 37th, in Philadelphia on sometime between 25.03.2000 and 31.03.2000 when the weather was sunny and windy with using yagi antenna with some antenna vibration and the transmitter's location of downtown Philadelphia. When looked at the data record, it is understood that pilot signal seems at the lower part of the band with strength of moderate.

2.1 Goertzel Algorithm

DFT is calculated with FFT algorithms. Different FFT algorithms are used for different DFT lengths (N). The mostly used case of FFT algorithm is N= 2^m (power of two FFT algorithm) case. In this case, process number is decreased to the $\log_2(N)$. It is needed less DFT frequency sample in some situations like detection of DTMF tones, FSK demodulation. In these situations, the Goertzel algorithm can be used to decrease calculation complexity two times less. The Goertzel algorithm's derivation and Z-transform structure are given in [12].

3. Performance Analysis

The Goertzel algorithm is accomplished for the signal records which knowledge given about in the second part and pilot tone output demonstrations together with signal records power spectral densities is shown in the figures below. The Goertzel algorithm is utilized only 2 msec of signal records. The net pilot tones appearances for all the original signal records are understood in all the figures. Although signals taken original records were met various distortions, it is understood from figures that pilot tones are detected clearly.

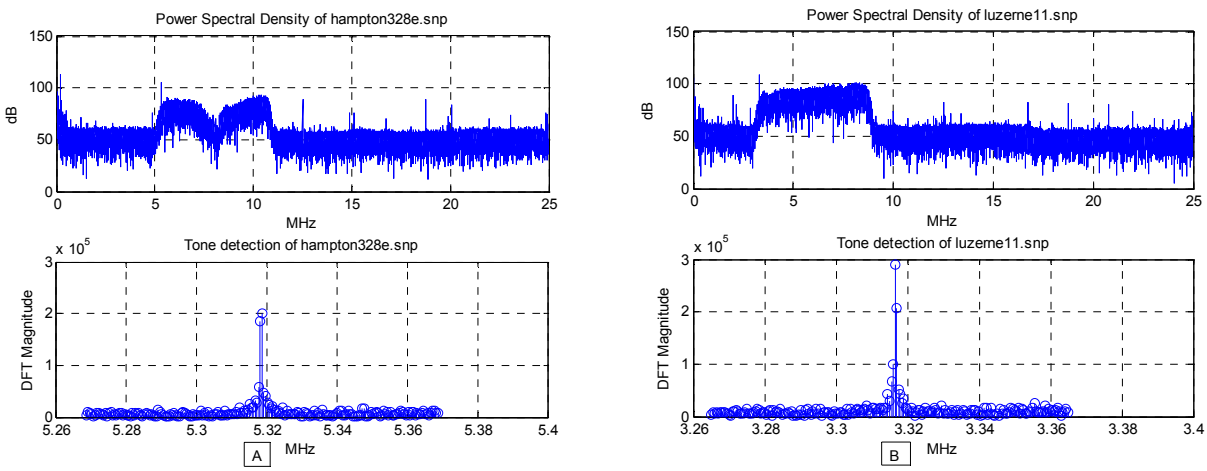

Figure 1: A) hampton328.snp DTV data record's power spectral density and tone sensing with the Goertzel Algorithm
B) luzerne11.snp DTV data record's power spectral density and tone sensing with the Goertzel Algorithm

4. Conclusion

In cognitive radio technique, an effective spectrum sensing is required because of the not disturbing the primary users. One of the effective spectrum sensing methods is pilot tone detection method. In many licensed digital cellular communication system pilot tone transmitting is done because of channel estimation, synchronization etc. In this paper, it is shown that effective pilot tone detection is done to be the guide of faster and more efficient spectrum sensing implementation. This is done with not disturbing the primary users and using original DTV broadcasting data in digital television (DTV) broadcast system which has pilot tone transmitting characteristic. The Goertzel Algorithm is used in this pilot tone detection and pilot tones have been detected errorless on studies on actual DTV signal records.

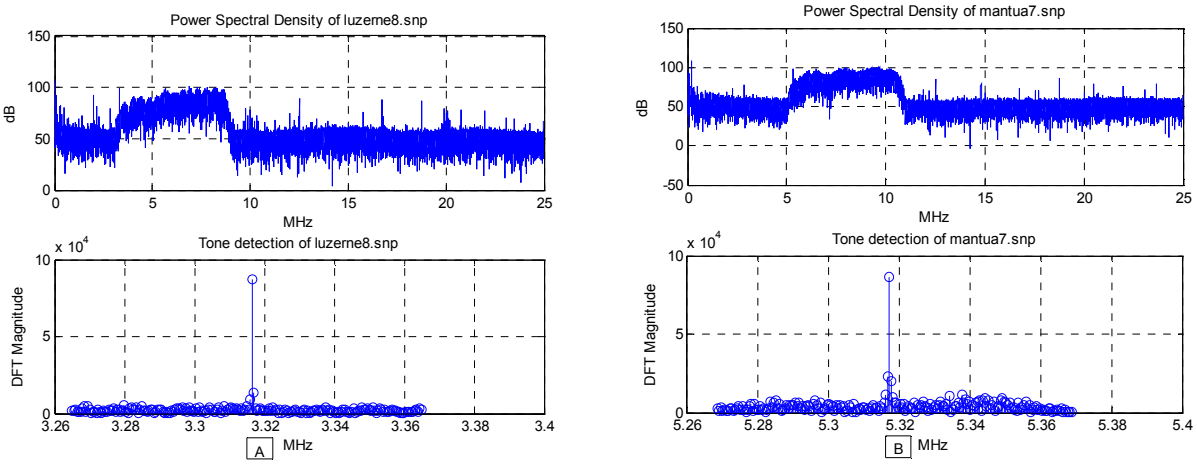

Figure 2: A) luzerne8.snp DTV data record's power spectral density and tone sensing with the Goertzel Algorithm
B) mantua7.snp DTV data record's power spectral density and tone sensing with the Goertzel Algorithm

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