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# SPECTRUM SENSING AND COOPERATIVE RELAYING IN COGNITIVE RADIO SYSTEMS: A SURVEY

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## ABSTRACT

The electromagnetic spectrum is a characteristic asset. The present spectrum authorizing plan is not able to oblige quickly growing demand in wireless communication due to the static spectrum allocation strategies. This allocation prompts increment in spectrum scarcity issue. Cognitive radio (CR) technology is a propelled remote radio design which aims to expand spectrum utilization by distinguishing unused and under-used spectrum in rapidly evolving environments. Spectrum sensing is one of the key stratergy for cognitive radio which detects the presence of primary client in authorized licensed frequency band utilizing dynamic spectrum assignment policies to utilize unused spectrum. In many areas cognitive radio frameworks coexist with other radio frameworks, utilizing the same spectrum yet without creating undue interference. The most simple and easy to implement sensing technique is energy detection. The paper focuses on common techniques on Spectrum Sensing.

**Keywords:** Channel State Information (CSI) Software Defined Radio (SDR), Signal to Noise Ratio (SNR), Orthogonal Frequency Division Multiplexing (OFDM), Bit Error Rate (BER), Spectrum Sensing.

## INTRODUCTION

The radio frequency spectrum is a limited characteristic asset that is divided into spectrum bands. In the course of the most recent century, spectrum bands have been apportioned to diverse services, for example, mobile, fixed, broadcast, fixed satellite, and mobile satellite services. As the entire spectrum bands are as of now dispensed to diverse services, most often requiring licenses for operation, a crucial issue confronting future wireless systems is to discover suitable carrier frequencies and bandwidths to take care of the anticipated demand for future services. [1] With Cognitive Radio being utilized as a part of various applications, the territory of spectrum sensing has become progressively vital. As Cognitive Radio technology is being utilized to provide a method for utilizing the spectrum all the more productively, spectrum sensing is key to this application. The ability of Cognitive Radio frameworks to get to spare sections of the radio spectrum, and to continue observing the spectrum to guarantee that the Cognitive Radio framework does not create any undue interference depends totally on the spectrum sensing components of the framework. For the overall framework to work viable and to provide the required change in spectrum efficiency, the Cognitive Radio spectrum sensing framework must have the capacity to adequately recognize some other transmissions, distinguish what they are and inform the central preparing unit inside the Cognitive Radio so that the required actions can be taken.

## RELATED WORK

In the paper **"Performance Analysis of Cognitive Radio Systems with Imperfect Channel Sensing and Estimation by Sami Akin et.al",** analysis of sensing-based spectrum access strategies, secondary users are analysed. To perform channel sensing in order to detect the activities of licensed primary users in a channel, and in realistic scenarios, channel sensing occurs with possible errors due to miss-detections and false alarms. As another challenge, time-varying fading conditions in the channel between the secondary transmitter and the secondary receiver have to be learned via channel estimation. In this paper, performance of causal channel estimation methods in correlated cognitive radio channels under imperfect channel sensing results is analyzed, and achievable rates under both channel and sensing uncertainty are investigated. Initially, cognitive radio channel model with channel sensing error and channel estimation is described. Then, using pilot symbols, minimum mean square error (MMSE) and linear-MMSE (L-MMSE) estimation methods are employed at the secondary receiver to learn the channel fading coefficients. Expressions for the channel estimates and mean-squared errors (MSE) are determined, and their dependencies on channel sensing results, and pilot symbol period and energy are investigated. Since sensing uncertainty leads to uncertainty in the variance of the additive disturbance, channel estimation strategies and performance are interestingly shown to depend on the sensing reliability. It is further shown that the L-MMSE estimation method, which is in general suboptimal, performs very close to MMSE estimation. Furthermore, assuming the channel estimation errors and the interference introduced by the primary users as zero mean and Gaussian distributed, achievable rate expressions of linear modulation schemes and Gaussian signalling are determined. Subsequently, the training period, and data and pilot symbol energy allocations are jointly optimized to maximize the achievable rates for both signalling schemes.

In the paper, **Companding techniques for Crest Factor Reduction for Cognitive Systems by Tao Jiang, Yang Yang, Yong-Hua Song**, a technique was proposed and evaluated a new nonlinear companding technique called 'exponential companding' that can adjust the amplitudes of both large and small input signals, while maintain the average power changed by properly choosing transform parameters, so as to make the output signals have a uniform distribution. Non-linear companding transform is an effective technique in reducing the PAPR of OFDM signals. In addition, the schemes based on companding technique have low implementation complexity and no constraint on modulation format and sub-carrier size. They derived a simplified maximum likelihood (ML) decoder for SLM and PTS that operates without side information. These decoders recover received COFDM in additive white Gaussian noise (AWGN), fading, and the presence of nonlinear amplifiers. They proposed SLM and PTS systems neither lose throughput due to side information nor degrade bit error rate (BER) due to errors inside information. The algorithm by decomposing a cyclic code into a direct sum of a correction sub code for encoding information bits and a scrambling sub code for encoding PAPR control bits. Consequently, can be use any of the decoding technique of cyclic codes and the modified algorithm provides error correction and PAPR control simultaneously provides error correction and PAPR control simultaneously. They presented OFDM-BPSK method can be extended to a M-QAM OFDM system by combining block coded modulation (BCM) codes with SLM method, where they use the BCM technique to construct an OFDM code with error correction capability and then use the SLM algorithm to improve the PAPR statistics.

In the paper**, "Cognitive Systems with OFDM and Initial Back off'' Marc Deumal, Ali Behravan, Thomas Eriksson and Joan LluisPijoan** presented a quantitative study of both the PAPR and the performance of an OFDM system when a clip know that the larger the IBO is the lower the distortion term will be. Hence, in general, for small constellation sizes and high IBO it is more important to maintain a high power efficiency, while for large constellation sizes and low IBO PAPR-reduction is more important. This should be considered when implementing PAPR-reduction to assure that the BER performance of the system is not degraded. The paper proposed clipped signal reconstruction methods for MIMO-OFDMs based on the IAR clipping preserves the orthogonality of transmitted signals, and the clipped signals were iteratively recovered at the receiver. Finally,presented that accurate channel estimation of the clipped OFDM systems can be done with a sequence, which has constant amplitude in both frequency and time domain.They proposed a new space frequency block code (SFBC) transmitter for clipped OFDM, which has approximately half the computational complexity of conventional SFBC-OFDM and can also be applied to non-clipped OFDM.

In the paper "**Estimation Throughput Trade-Off FOR Under Relay Systems, by Ankit Kaushik et.al",** Underlay System (US) have been analyzed and explained. According to US, a power control mechanism is employed at the Secondary Transmitter (ST) to constrain the interference at the Primary Receiver (PR) below a certain threshold. However, it requires the knowledge of channel towards PR at the ST. This knowledge can be obtained by estimating the received power, assuming a beacon or a pilot channel transmission by the PR. Expressions for the channel estimates and errors determined, and their dependencies on channel sensing results, and pilot symbol period and energy are investigated. Since sensing uncertainty leads to uncertainty in the variance of the additive disturbance, channel estimation strategies and performance are interestingly shown to depend on the sensing reliability. It is further shown that the error estimation method, which is in general suboptimal, performs very close error estimation. Furthermore, assuming the channel estimation errors and the interference introduced by the primary users as zero mean and Gaussian distributed, achievable rate expressions of linear modulation schemes and Gaussian signalling are determined. Subsequently, the training period, and data and pilot symbol energy allocations are jointly optimized to maximize the achievable rates for both signalling schemes. Based on numerical analysis, it is shown that the conventional model overestimates the performance of the US

## SPECTRUM SENSING TECHNIQUES

The cognitive radio system examines all level of flexibility (time, frequency and space) to predict spectrum usage. There are a few procedures available for spectrum sensing. Spectrum sensing is a system which figures out if a given frequency band is utilized. A wide range of routines are proposed to recognize the presence of signal transmission and can be utilized to improve the detection probability.

### Energy Detection

Energy Detection is a simple detection method. The energy detection is said to be a blind signal detector in light of the fact that it overlooks the structure of the signal. Energy detection is based on the rule that, at the receiving end, the energy of the signal to be detected is computed. It estimates the presence of a signal by comparing the energy received and a known threshold $\lambda$ derived from the statistics of the noise.

### Matched Filter Detection

The best sensing technique in AWGN environment without ant prior information about the signal is ED technique. If we considered the signal structure, then we can get best performance by using matched filter method. Matched filter is a linear filter which used to maximize signal to noise ratio in presence of additive noise. It provides coherent detection. A coherent detector uses the knowledge of the phase of the carrier wave to demodulate the signal.

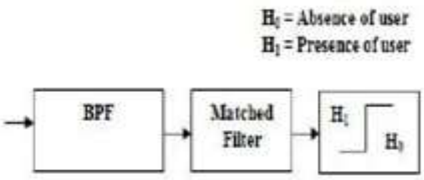


***Fig.1 Matched Filter Detection***

## Cyclostationary Feature Detection

Cyclostationary feature detection taking into account introduction of periodic redundancy into a signal by sampling and modulation. The periodicity in the received primary signal to recognize the presence of Primary Users (PU) is misused by Cyclostationary feature detector which measures property of a signal specifically Spectral Correlation Function (SCF).

SCF is mathematically defined as:

$$S_x(f)=\int Rx(\tau).\exp(-j2\pi ftd(\tau)$$

Cyclostationary feature detector can differentiate the modulated signal from the additive noise, recognize Primary User signal from noise. It is used at low SNR detection by using the data information embedded in the Primary User signal which does not exist in the noise. This method is robust to noise discrimination and it performs better than energy detector. But it has high complexity and does not perform well in case of frequency selective cases.

## Main Challenges faced in Spectrum Sensing in Cognitive Radio Systems:

1) Wireless channels change randomly over time, therefore sensing wireless channels before they change is tough.
2) Assuming that wireless channels are quasi-stationary may lead to errors i.e. degraded BER performance.
3) Due to addition of noise in the transmitted signal, detection of spectrum holes may be practically tough
4) Due to dynamic spectrum allocation, there exists a chance of 'Spectrum Overlap' causing interference between users.
5) Designing cognitive radio systems to perform error free in real time may be complex to design i.e. reduced throughput of the system. (bits/sec)

## CONCLUSION

In the present paper, we have described the basics of cognitive radio systems along with the importance of spectrum sensing. The most common techniques used for spectrum sensing have also been discussed in detail. Moreover, recent work in the field along with its salient points has also been discussed. It is expected that the paper will serve as a primer to the researchers opting for an advanced study in the field of Cognitive Radio Networks.

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