Spectrum Sharing with Overlay Constraints in Cognitive Radio Networks

Kailas[1] **, Dr.Siddarama R. Patil**[2]
[1]*Research Scholar, E&CE Department, PDACE Kalauragi-585 102*
[2]*Professor & Dean (Academic), E&CE Department, PDACE Kalauragi-585 102*

ABSTRACT - The range and spectrum allotment is a totally promising exercise to reinforce spectrum exploitation in cognitive radio networks. The licensed user provides sharing of cognitive network spectra for unlicensed users with the availability to access firm spectrum sources without annoying the overall performance of the licensed users. This simultaneous sharing of spectrum resources is restricted by licensed and unlicensed users, so that spectrum can be used more efficiently. More efficient spectrum use is the result of this synchronized sharing of narrow spectrum resources by licensed and unlicensed clients. Spectrum sharing with licensed users is accomplished by allowing unlicensed users to transmit when the licensed users' interference power constraint is satisfied. Limiting the interference power can maintain the performance of licensed users while taking into account the performance of unlicensed users sharing the available spectrum. As aresult, the interference power constraint is crucial in the spectrum sharing paradigm. This article offers strategies for spectrum access in the cognitive radio scenario.

The quality of service (QoS) performance forusers' issignificantly connected to the reliability, efficiency, and integrity of unlicensed spectrum in cognitive radio networks (CRNs).However, owing to the inherent indiscriminate feature of the dynamic spectrum for the SU's Data transmission, QoS performance for the SU's is challenging to attain in the overlay CRNs. Because the spectrum occupancy phases of the PUs are frequently modeled by Markov models, Markov-chain based analysis is routinely used to evaluate the Qos parameters of the SUs. In this research, we investigate an overlay CRN with multi-PUs, where each PU's data transmission follows the M/M/c paradigm and the SU has few channel constraints. Part of our research is focused to evaluating the influence of the interference power constraint and the effectiveness of secondary user under each constraint for overlay constraints. We begin by looking at the relevant interference power constraints. Following that, we develop a spectrum sharing system to meet a primary user's system throughput. The comparative analysis is then considered to ensure that the proposed technique is indeed feasible.

I. MOTIVATION

The core of Radio Frequency (RF) Communications is the spectrum band [4]. With ever increasing need for greater data speeds, as well as an increase in new services and users, spectral overload and traffic.

Figure 1: Illustration of spectrum congestion factors

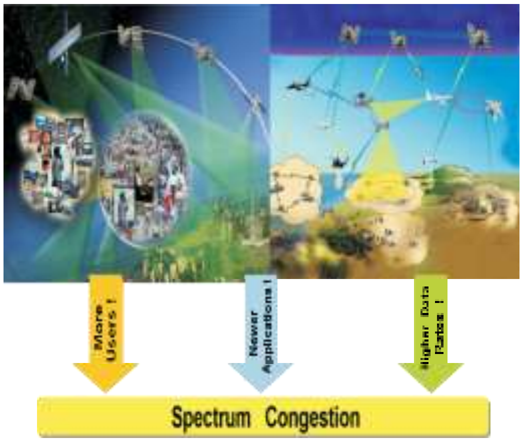

Figure1 depicts the spectrum congestion factors.Spectrum congestion is a source of concern and inconvenience for both scientific and defense users. At first inspection, as shown in Figure1, which depicts the completely allotted Federal Communication Commission's (FCC) spectrum map, it apparent that spectrum is limited [2]. According to recent findings, spectrum congestion is caused mostly by inadequate spectrum utilization instead of scarcity of spectrum [4].

II. INTRODUCTION

The term cognition is commonly used to describe the human cognitive process and reasoning ability. It is described as a mental process that uses awareness, perception,

ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

reasoning, and judgement to assess a given situation. The emergence of CR technology ushered in a new era of wireless communication. It has piqued the curiosity of researchers not only in the radio technical community but also in other areas like as networking, mathematics (game theory), economics, marketing, and business law, to mention a few. Many diverse interpretations and definitions of the term Cognitive Radio may be found in the literature due to the participation of these disparate fields.

Multi-users in a homogenous network can distribute the bandwidth using a variety of Multiple Access (MA) protocols including Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Carrier Sense Multiple Access (CSMA) [6].Till date, studies have concentrated on spectrum sharing concerns linked to legacy cellular systems, clients in the unlicensed spectrum utilising various 802.xx protocols, and more significantly, a lot of attention has been devoted to UWB communication and its capacity to coexist with other systems [9].In the case of cellular networks and unlicensed spectrum clients, spectral coexistence occurs in a limited manner through the usage of temporal and spatial diversification, as well as power management etiquettes. For narrow applications, UWB systems have proved effective[14].

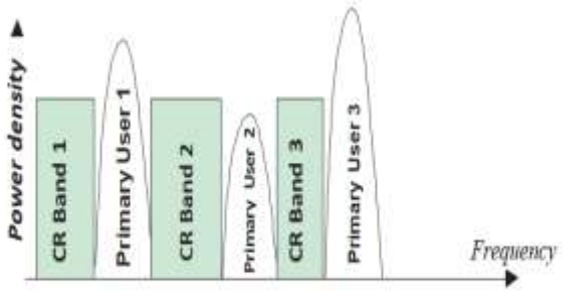

Figure 2: Details of Cognitive Radio Overlay model

III. LITERATURE REVIEW

According to [11], CR technology integrates within the hierarchical access approach. Despite the fact that the current CR definition only addresses overlay techniques, research report predicts that a hybrid methodology comprising overlay ideas may be used to enhance system performance by employing both grey and white spectral areas [13].

As a result, depending on the spectral area employed, CR can be classified as overlay-CR. Channel capacity is proportionate to bandwidth B and signal-to-noise ratio (SNR). This paper also deals the ways to increase channel capacity by exploiting both unused and underutilised parts of the spectrum. The implementation of Overlay waveforms are then offered, followed by a generic SD-SMSE architecture.

In NC-OFDM, the sub carriers which are used by the primary user will be de-activated. Therefore, there are zero-valued inputs for the IFFT of the transmitter and zero valued outputs for the FFT of the receiver. When zero-valued inputs/outputs are greater than nonzero inputs/outputs, the standard FFT/IFFT used in OFDM application in no longer efficient [1]. The authors in [5] have all proposed computationally efficient methods in implementing NC-OFDM architecture.

Multi-carrier waveforms, particularly OFDM-based waveforms, have been recognised as a good CR candidate as a result of the preceding research activities. Other physical layer factors such as power, modulation, and coding have been examined in the optimization of the CR physical layer in the following papers [7].

Dynamic spectrum access based on the CR concept will undoubtedly improve spectrum efficiency, but this will increase CR users' aerial information, limiting their effective throughput. An adaptive sub-carrier block size algorithm proportional to incumbent spectral occupancy has been proposed to reduce CR overhead [8].

To accommodate a wide range of multi-carrier signals, a general analytic framework was developed[15].

The framework can be applied to a wide range of signals known as Spectrally Modulated and Spectrally Encoded (SMSE) signals [10]. Using this SMSE framework, various multi-carrier waveforms, such as OFDM, MC-CDMA, CI/MC-CDMA, or TDCS, can be generated based on CR user needs. Because the original SMSE framework used hard decision frequency allocation, it is only applicable to overlay-CR signals. A soft decision SMSE (SD-SMSE) framework was later developed to realise overlay-CR signals in order to broaden its applicability and maximise spectrum efficiency by utilising both unused and underutilised regions[12].

ASSUMPTIONS

Throughout the manuscript, a number of assumptions have been made in order to limit the research attention and focus on physical layer waveform configuration and analysis[16]. Some of the major assumptions are as follows:

- When performing co-existence analysis, perfect synchronisation between primary and secondary users was assumed. The secondary transmitter and receiver were also assumed to be synchronised.

- A spectrum utilizations map was assumed to be known because the spectrum sensing function requires identifying spectrum holes, primary and secondary users, and establishing an interference threshold.
- The behaviour of CR-Overlay waveforms over a frequency selective Rayleigh fading was evaluated under the assumption that the interference from the licensed users to the unlicensed users was not subject to fading effects.
- The licensed users receiver is capable of accurately estimating the channel fading coefficients demanded by the maximum diversity combiner.

IV. METHODOLOGY

The cognitive capability is typically captured in the analysis of overlay cognitive radio models with the assumptions that the unlicensed user's encoder, referred to as the cognitive encoder, knows the data sequence to be sent by the main encoder in the next transmitter block.

- For practical systems, this assumption is frequently overly idealistic.However, when the secondary and primary transmitters are close to each other, it is reasonable or after an initial failure, the primary data sequence is being transmitted to the receiver, and the secondary decoder was able to effectively decode this in the first transmission.
- This assertion also applies when the primary transmitter transmits its input data long in advance to a secondary transmitter, which may be accomplished in a different frequency spectrum.

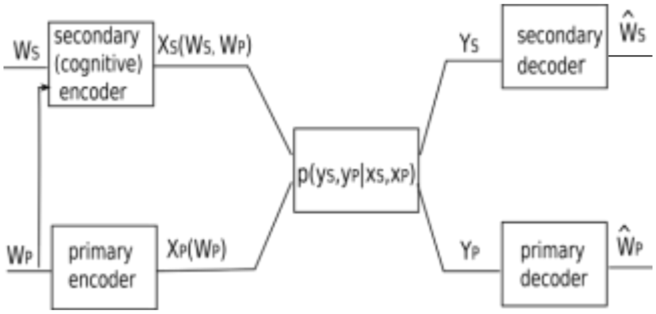

Figure 3: Overlay channel for two users

a. Cognitive Encoder for the Overlay Channel with Two Users

Figure 3 depicts the simplest overlay cognitive network, which consists of one secondary and one primary pair. The secondary user's cognitive encoder is assumed to have complete knowledge of the data sequence $W_P$conveyed by the primary encoder to the primary decoder.All users in the channel are assumed to be aware of the encoding strategies and channel gains. For this two-user channel, overlay encoding techniques have received the most attention. Figure 2 depicts without cognition, this network degrades to the two-user interference channel, with the secondary user representing User 1 and the primary user representing User 2.

Because of the common features among these two approaches, this network is known as the interference channel with one cognitive encoder in the information theory literature. The cognitive radio channel, the interference channel with asymmetric message knowledge, the interference channel with degraded message sets, and the cognitive interference channel are all names for it. When the primary user does not transmit, another special case of this channel model is to be obtained. Because the secondary transmitter, it is aware of the messages intended for both recipients, the channel confines to the broadcast network channel [16].

As a result, the two-user overlay channel combines features of both interference and broadcast channels. In certain conditions, the encoding strategies developed for these canonical channels, or their combinations, are capable of achieving capacity for the overlay channel. Following that, we review the proposed encoding strategies for the two-user overlay channel and discuss scenarios in which these schemes or their combinations achieve capacity.

Formally,theoverlay channel for two users, withonesecondaryuser(cognitive)and oneprimaryuserconsistsof

- TwooutputsymbolsY$_S$,Y$_P$
- TwoinputsymbolsX$_S$,X$_P$,and
- Aconditionalprobabilitydistribution function (CDF) $p(y_s,y_p|x_s,x_p)$.

Where,

$(xs, xp) \in Xs \times Xp$arechannelinputs.

$(ys, yp) \in Y1 \times Y2$arechanneloutputs.

Thesecondarysource$s_s$commandstotransmitamessage

$$W_s \in \mathbf{W}=\{1,\ldots\ldots,2\}$$

toitsendpoint,andtheprimary

source$s_p$commandstotransmitamessage

$$W_p \in \mathbf{W}=\{1,\ldots\ldots,2\}$$

toitsreceiving end.Information sequence$W_p$is also referred to as the secondary (cognitive) encoder.

An(R_s,R_p,n)code is comprised of two data sequence pairs. $\mathbf{W}_s,\mathbf{W}_p$,are functions for encoding

$$X^n=f_s(W_s,W_p) \tag{1}$$

$$X^n=f_p(W_p) \tag{2}$$

and two decrypting functions

$$\hat{W}s=g_s(Y^n)\text{……….. (3)}$$

$$\hat{W}p=g_p(Y^n)\quad\text{…………………(4)}$$

A rate set **(Rs, Rp)** is feasible if, for possible s > 0, a **(Rs, Rp, n)** code occurs for sufficiently large n such that the error probability of the code is $P_e \leq s$. Thetwo-user overlay channel capacity region is the closure of the set of all feasible rate sets(R_s, R_p).

The only difference between this description and the corresponding descriptions for the interference channel is in the secondary cognitive encoder's encoding function (2). Unlike in the interference channel, the encoder in this case knows both data sequences **Ws** and **Wp** and therefore can form encoded sequences that rely on both. We'll also look at the AWGN interference channel provided by (4), integrated with cognitive encryption process by the unlicensed users.

The supplementary information will assist the cognitive encoder to use collaborative efforts to boost the primary pair's rate and pre-coding against interference to strengthen on its rate. Before clarifying the cognitive encoder's encoding practices, we provide a brief description of the Gelfand-Pinsker encoding scheme. This strategy, also known as binning, can be used for interference channel estimation.

V. Analysis of Overlay-CR Simulation

Only the unused spectrum is allocated for secondary users in current Cognitive radio methods. Figure4 depicts the overlay spectrum sharing scenario. Secondary user bands are identified by spectral bins with a value of one, while primary user bands are identified by bins with a value of zero.

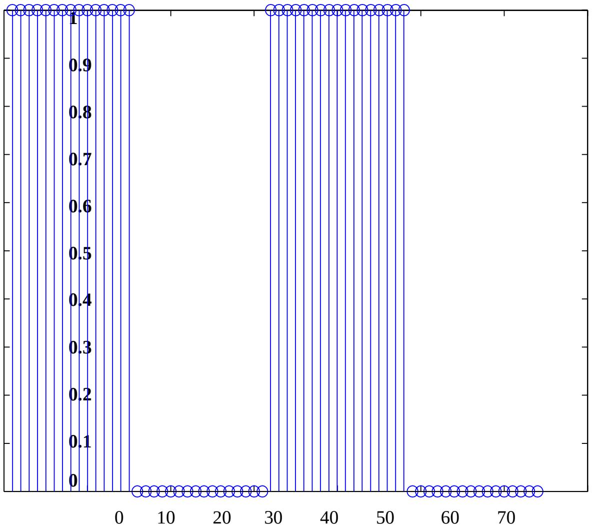

Figure4:Spectrum response for CR users in a scenario with non-contiguous spectrum

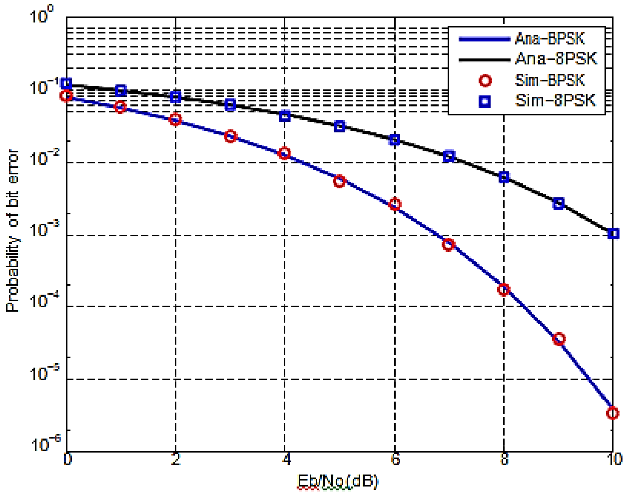

Figure 5: Overlay NC-OFDM waveform performance in an AWGN channel

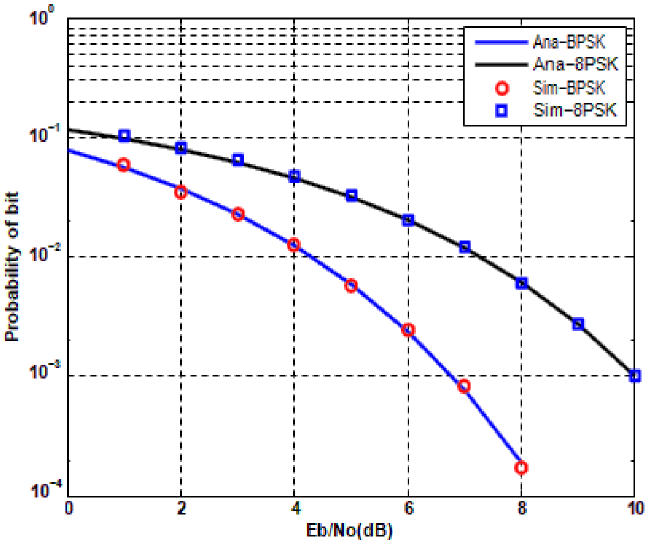

Figure 6: Overlay NC-MC-OFDM waveform performance in an AWGN channel

ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

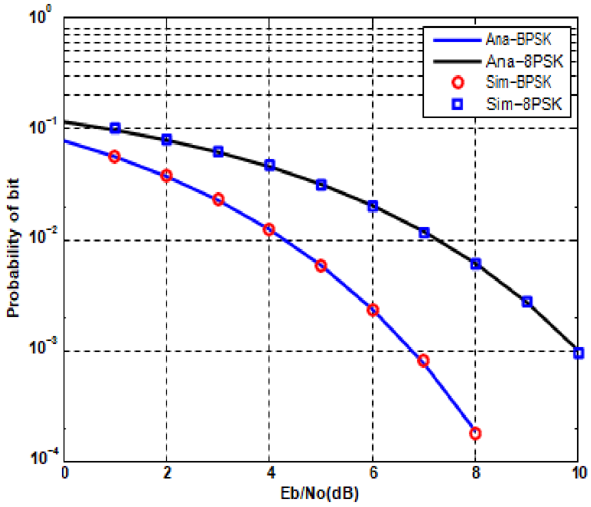

Figure 7: Performance of overlay NC-CI/MC-CDMA waveform in AWGN channel

It is assumed that 32 non-contiguous sub-carriers will be available for secondary CR users at any given time. Figures 5 through 7 shows the performance of four non-contiguous overlay waveforms. The analysis shows that with flawless synchronization between primary and secondary users, non-contiguous waveforms like NC-MCCDMA, NC-OFDM, NC-CI/MC-CDMA, and TDCS using 8PSK and BPSK modulation match the theoretical expressions of 8PSK and BPSK modulation under AWGN network conditions.

VI. Multi-path Fading Simulation Analysis of Overlay Waveform

This section shows overlay-CR waveforms in a frequency selective fading channel. NC-OFDM, NC-MC-CDMA, CI/MC-CDMA, and TDCS are all multi-carrier waveforms that have been implemented.

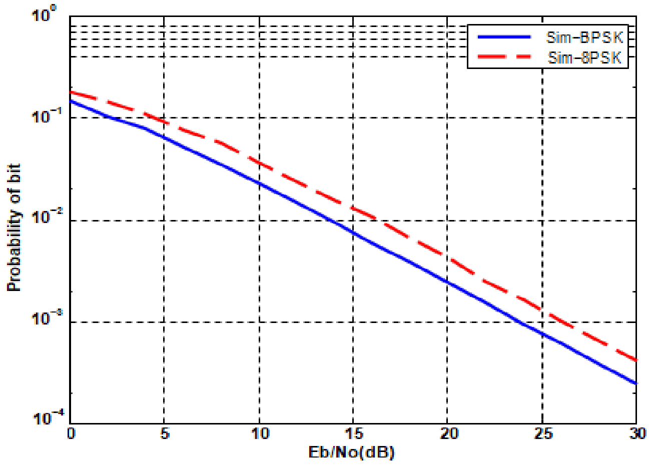

Figure 8: Overlay NC-OFDM waveform performance in a Frequency Selective Fading channel

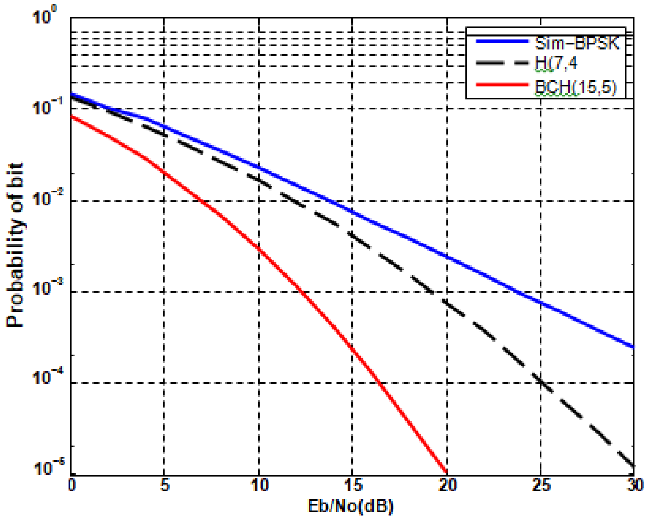

Figure 9: Overlay NC-OFDM waveform performance with channel coding in a Frequency Selective Fading channel

Figure 8 depicts the efficiency of NC-OFDM with both 8PSK and BPSK frequency modulation. Because NC-OFDM conveys a distinct symbol on each subcarrier and each subcarrier experiences flat fading, the diversity gain due to frequency selective combining is increased.

Figure 9 depicts an OFDM waveform that makes use of channel coding to take advantage of channel diversity.

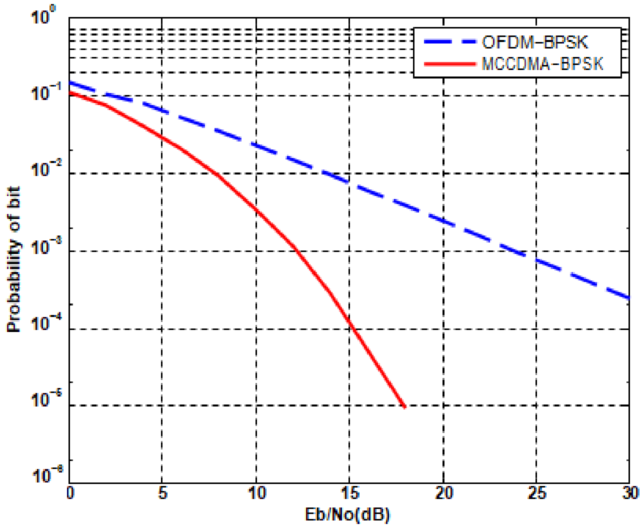

Figure 10: Performance of NC-OFDM and NC-MCCDMA waveform in Frequency Selective Fading channel.

The performance of NC-OFDM-BPSK and NC-MC-CDMA BPSK modulations is shown in Figure 10. The high performance owing to the eight - fold spectral selectivity gains achieved by using the MRC diversity approach is shown.

Waveform of SD-SMSE Overlay

Overlay waveforms exploit unused spectral bands which are currently used in Cognitive Radio technics. Current CR transmission is clearly a subset of soft decision CR when no underutilised frequency components are used. If the underutilised variable b is forced to be zero and the frequency assignment variable a is forced to be binary in the SMSE framework:

$$\mathbf{b}=[0,0,\mathit{0}.....,0]$$

$$\mathbf{a}=[a_0,,...,a_N-1],a_m\in\{0,1\} \quad (3.15)$$

VII. CONCLUSION AND FUTURE WORK

More than just preventing customer complaints should be the goal of quality control personnel. Daily routines for all potential application have yet to be developed. To maximise channel capacity and improve spectrum efficiency, both unused and underutilised spectral regions must be used. An emerging SMSE framework based on hard decision spectrum utilization has been extended to a soft decision SMSE structure for core network waveforms suitable for CR-based application fields. The Cognitive Radio based SDR is capable of dynamically generating overlay, underlay, and hybrid overlay/underlay waveforms user's needs, given an established set of SD-SMSE design variables. Each of these three waveforms is assessed in a CR context using the SD-SMSE framework under Additive white Gaussian noise and frequency dependent Rayleigh fading constraints.

REFERENCES

[1]. Q. Zhao and B. M. Sadler, “A survey of dynamic spectrum access,” *IEEE Signal Processing Magazine*, vol. 24, pp. 79–89, May2007.

[2]. J.Mitola,“CognitiveRadio-AnIntegratedAgentArchitectureforSoftwareDefined Radio,Ph.D.Dissertation,”*Teleinformatics,RoyalInstituteofTechnology-Sweden*, 2000.

[3]. A. M. Wyglinski, “Effects of bit allocation on non-contiguous multicarrier-based cognitive radio transceivers,” *Proceedings of the 64th IEEE Vehicular Technology Conference*, September2006.

[4]. L. Hanzo, M. Munster, B. Choi, and T. Keller, *OFDM and MC-CDMA for Broad-band Multi-User Communications*. Wiley,2003.

[5]. V. Chakravarthy, A. Shaw, M. Temple, and A. Nunez, “Tdcs, ofdm and mc-cdma : Abrieftutorial,”*IEEECommunicationsMagazine*,vol.43, p.S11=S16,September 2005.

[6]. V. Chakravarthy, Z. Wu, A. Shaw, M. Temple, R. Kannan, and F. Garber, “A generaloverlay/underlayanalyticexpressionrepresentingcognitiveradiowaveform,”*in IEEE Int'l Conf. on Waveform Diversity and Design*, June2007.

[7]. T. Rappaport, *Wireless Communications - Principles and Practice*. Prentice Hall Communications Engineering and Emerging Technology Series, 2nd ed.,2002.

[8]. M. Roberts, “A General Framework For Analyzing, Characterizing andImplementingSpectrallyModulated,SpectrallyEncodedSignals,Ph. D.Dissertation,”*Electri- cal and Computer Engineering, Air Force Institute of Technology*, September2006.

[9]. E. Like, V. Chakravarthy, and Z. Wu, “Reliable modulation classification at low snr using spectral correlation,” *IEEE Consumer communications and Networking Conference*, January2007.

[10]. E. Like, V. Chakravarthy, and Z. Wu, “Modulation recognition in multipath fading channels using cyclic spectral analysis,” *accepted for publication in IEEE GLOBE- COM*,2008.

[11]. T. Clancy, “Dynamic Spectrum Access in Cognitive Radio Networks, Ph.D.Disser- tation,” *Computer Science, University of Maryland*, April2006.

[12]. T. Clancy and W.Arbaugh, “Measuring interference temperature,” *Virginia Tech Wireless Personal Communication Symposium*, June2006.

[13]. J. Neel, “Analysis and Design of Cognitive Radio Network and Distributed RadioResourceManagementAlgorithms,Ph.D.Dissertation,”*ElectricalEngineering, Virginia Polytechnic Institute and State University*, September2006.

[14]. W.A.Gardner,“Measurementofspectralcorrelation,”*IEEETransactionsonAcous- tics, Speech and Signal Processing*, vol. 34, October1986.

[15]. A. Fehske, J. Gaeddert, and J. H. Reed, “A new approach to signal classification using spectral correlation and neural networks,” *1st IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks*,2005.

[16]. R. S. Roberts, W. A. Brown, and H. H. Loomis, “Computationally efficient algorithmsforcyclicspectralanalysis,”*IEEESignalProcessing Magazine*,April1991.

[17]. B. Krenik, “Clearing interference for cognitive radio,” *EE Times.*, August2004.

ISSN (Print): 2204-0595
ISSN (Online): 2203-1731