International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 7, July-2014, pp: (365-376), Impact Factor: 1.252, Available online at: www.erpublications.com

A Survey of Communication Systems and Modulation Schemes for Spectrum Sensing by Cognitive Radio

Mrinal Sharma[1], Gagandeep Singh[2], Rajan Gupta[3]
[1,2]Department of Electronics & Communication, Lovely Professional University, Punjab, INDIA
[3]Department of Computer Science, Faculty of Mathematical Sciences, University of Delhi, Delhi, INDIA

Abstract: **The growth of wireless applications and spectral limitations are grave anxiety for the military service and for civilian communities. A particular spectrum task force set up by Federal Communications Commission discloses that in many bands spectrum access is a more important problem than physical scarcity of the spectrum. This is in part because present systems use a procedure draw up in the1920s where different frequency bands are allocated to users or service providers, and licenses are needed to operate with those bands. To avail unused spectrum more efficiently in dynamic environments, we desire a communication system that adapts to rapidly changing environmental conditions while ensuring that minimal or at least manageable interference is introduced to existing users. Such a technology is known as cognitive radio (CR) technology. Transform domain communication system (TDCS) and wavelet domain communication system (WDCS) have been reported to have interference avoiding capability under hostile environmental conditions. Conventionally, the Pseudo Random phase vectors in TDCS and WDCS were generated by a maximum length binary Pseudo Random sequence, which allows only a relatively small amount of users in the systems. This paper reports a method of Digital modulations schemes (FSK, PSK, CSK) and communications systems (TDCS,WDCS) for efficient utilization of the spectrum in Cognitive radio.**

Keywords: Cognitive Radio, TDCS, WDCS, Spectrum Sensing.

I. INTRODUCTION

Signal processing and efficient communication has become one of the key challenges in today's world. With so many users of digital devices, that concerns like data security [1][2][3], network security, and efficient utilization of bandwidth [4] have gone out of proportion today. Be it related to the government infrastructure [5] or the private infrastructure, these issues are prevalent in all corners of the world with India not behind. For the same reason, advanced technology like Cognitive Radio (CR) has been assessed as a strong candidate technology on utilizing spectrum efficiently in wirelessCommunication.CR is an intelligent radio which is capable of setting and configuring its own parameters including carrier frequency of transmitting and receiving and networking. Particularly, Cognitive Radio system has the capability of understanding, learning, and adapting so that it can access the spectrum more conveniently. In and TDCS (Transform-domain Communication System) was introduced as the Cognitive Radio modulation technique which uses unused spectrum and adapts to the time varying conditions of the environment. The Key idea in Transform Domain Communication System is to synthesize an adaptive waveform to avoid interference at the transmitter side, while the conventional technique tries to deal with the interference at the receiver. The Authentic communication is desirable for both military and commercial applications. The errors at receiver during communications are often due to the Radio environment interference which can be either intentional or unintentional. The intentional interference is purposely directed to the targeted communication system to disrupt the normal operation of the systems and unintentional interference is often from additive white Gaussian noise. An intentional interference can be wideband or narrow-band according to the occupation of the bandwidth. Since the narrow-band interference is more prevalent and inevitable, research efforts have been made to mitigate or avoid the effects of the narrow-band interference. In this paper, we focus on TDCS and WDCS and present a comparative analysis using simulations in MATLAB to sense the spectrum using cognitive radio.

II. SPECTRUM

The spectrum of a signal is a representation of that signal in a domain time or frequency. Spectrum is adjusted so that, for example, our radio receiver knows already which frequency bands will carry radio signals spectrum is important for various reasons, First thing is that a Spectrum is confined, Because spectrum is essentially the usable radio frequencies, it is confined by nature. we can just find the best and most suitable ways to use the spectrum because We cannot easily produce it. Second thing is that demand for wireless communication is increasing. Meaning there are many people's competing for the common and confined resource. If we drive the method in an inefficient manner we will not be able to provide the services people want and need, which could lead to importance of the spectrum.

As the world becomes speedily wireless or cordless (with wireless phones, cell phones, wireless internet, other wireless devices etc) allocation of the available spectrum to each technology becomes increasingly controversial and the radio spectrum has become a scarce commodity in many countries. Spectrum is a rare resource, each user society wants more bandwidth in order to be able to market and service more units. For any given slot of bandwidth, there is a moderate amount of data that can be shared in that bandwidth, so marketer want more bandwidth so they can handle more devices in a particular area so the scarcity of the spectrum increases. scarcity of spectrum is principally due to licensing intention that reserve frequency bands for other service providers and at fixed times or location such frequency bands are not being utilize by the primary users(PU) and access is not recognized to other users [6].

III. SPECTRUM SENSING

A. Spectrum Sensing Methods

There are several method for spectrum sensing methods[7][8]. Some of the existing methods are described as below.

1) Matched filter based sensing

It is the optimum method of detection of the primary users when we have already information about the transmitted signal. for demodulation this sensing method requires the CR unit. Disadvantage of this kind of sensing method is implementation complexity and large power consumption. It performs coherent detection method. It acquires solution (optimal) to the signal tracking but it requires prior knowledge on the received signal. Matched-filtering is known as the most suited techniques for the Primary User (PU) sensing. The principle benefit of matched filter is the very small time to gain a certain set probability of miss detection as compared to other methods. In actually, the needed number of samples can be produced as O (1/SNR) for a goal to get probability of miss detection at low Signal to Noise Ratios of filter. Here the transmitted signal is passed through the channel where the noise (AWGN) is getting presented to the signal and gives the output as a mixed signal. This mixed or noise added signal is given as a filter input. Then input of the matched filter is convoluted with the filter impulse response and the output of the matched filter is then compared with the threshold for detection of the primary user. The Matched filter needs Cognitive Radio tode-modulate the detected signals. The filter needs great information of the Primary User characteristics of signaling as operational frequency, modulation laws, and format of the frame. An execution difficulty of sensing unit is very immense. A disadvantage of this filtering is spacious power-utilization.

2) Energy detecter based sensing

In this approach the output from the detecter is compared with the threshold based on the noise floor. Some of the challenges is there while sensing with this approach they are selection of threshold,interference differnciation from the primary users.The Energy detection does not need extra information about the Primary users and therefore it is more popular**.** The Energy detection method is a non-coherent detection that uses the received signal energy to resolve the existence of a primary signals. In general CR user does not estimated to be provided with any preceding information about the primary signals that may be present with in an assured frequency band. When the secondary recipient cannot draw together any required data, then the energy detection can be used because of its capability to work regardless of the structure of the signal need to sense. Energy detector is also known as periodogram method.

Two Bases for algorithm are:

a) HO (absence of primary user)Under HO:means noise only $x(n) = w(n)$,(1)

b) HI (PU present in this operation) Under HI: noise added with signal $x(n) = h\,s(n) + w(n)$,(2)

Where n = 0, 1, 2…………………….. N- 1.Here N represents the sample index , x(n) specifies received signal , s(n) is the primary signal need to be find out and w(n) denotes the noise. Energy detection process can be completed by comparing the detected signal's energy with fixed frequency band to properly fix known decision threshold. In case of, the signal energy falls above to the threshold, and then the band is declared as in busy mode. If the signal energy lies below the band is said to be idle and could be accessed by Cognitive users.

3) Waveform based sensing

To assist synchronization known patterns are utilized in the wireless system. Pattern can be midamble, preamble or the pilot .waveform based sensing method is only applicable when the pattern is known. Advantage of this sensing is that performance of the sensing algorithm is increased as the length of the best known signal pattern is increases. Midamble pattern are those which is transmitted middle of the burst (slot)or sent the original signal where Preamble pattern is transmitted before the burst (slot)or sent exactly middle of the original signal and Pilot pattern are those which is known pattern and sensing is performed by the correlation.

4) Radio identification based sensing

In this kind of sensing several feature are extracted from the detected signal and these features helps us in the classification methods. features can be bandwidth(operational) or the center frequency of the detected signal they can be extracted using the energy detector based methods and then these features are fed to the Bayesian classifier for to determining the spectrum opportunities.

5) Cyclostationary based sensing

Cyclo-stationary based detection uses the Cyclo-stationary features for sensing algorithms are caused by the signal statics like mean and correlation.if one want to detect the signal present in the spectrum ,cyclic correlation function is used.

6) Co-operaive spectrum sensing

As the name depicts co-operative sensing in this kind of sensing method a centralized unit of the CR receives information from the CR network and it uses it to take final response.

B. Problems during spectrum sensing

Problems can occur during spectrum sensing like Hidden terminal problem, Decision making by the centralized unit in the co-operative sensing method, Hardware constraints or the sensing critical time and frequency. They are described as below.

1) Decision making by the centralized unit in co-operative sensing

The decision of the CR unit can be based on the M out of N rule, OR and the AND rule. In Co-operative sensing method it is difficult for the centralized unit to take a final decision from the several decisions of the CR units.

2) Hidden terminal problem

Hidden terminal problem means the PU is hidden due to physical hindranceor due to the multipath fading PU is hidden hence the CR while scrutinizing is not able to detect the PU properly.

3) Hardware constraints

For efficient spectrum sensing the hardware in the CR unit should be with the high accuracy and the high resolution. The A/D convertor should high resolution.

4) Critical sensing duration and frequency

While sensing a spectrum the time and frequency should be at a specified value. Sensing duration and frequency refers to time with which the spectrum is scrutinized.

C. Spectrum Hole

The overall goal of the CR is to obtain the best available spectrum through its characteristics (cognitive capability, and re-configurability).Most of the spectrum is already assigned but some of the unused spectrum is there which is referred to as white space or the spectrum holes.CR enables the usage of the temporally unused spectrum or the spectrum hole. Spectrum or radio spectrum must accommodate phone calls and data transport that is rapidly increasing at an remarkably rate. Globally, traffic on broadband systems has ascended so fastly. Spectrum management is the key thing of maintaining the use of radio frequencies to magnify efficient use of the spectrum. Spectrum management means: to debar and solve interference problem, prove and optimize the use of the Radio spectrum, management of the short and long limit frequency allotment. Cognitive radio (CR) is one such technology that could allow spectrum to be used more proficiently. It first sense and then adapts the spectrum and then utilizes it. It is the best solution for to overcome on the spectrum scarcity. Spectrum sensing means to sense, measure and pay attention to the parameters related to the characteristics of the radio channel, spectrum availability and power of transmission, noise, interference, operating environment of the radio.It is done across Time, Code, Frequency, Phase and Geographical Space.

IV. Cognitive radio

A. Concept

Cognitive radio[8] [9] is a model or system for wireless communication. It is used as software defined radio which is a recent technology. It uses the methodology that to sense and learn from the environment and remove interferences for efficient utilization of the spectrum.CR is an example of feedback communication system.CR enhances the flexibility of personal services through a radio knowledge representation language(RKRL).RKRL represents the knowledge of radio devices, software modules, propagation, networks, user needs and application scenarios to support automated reasoning about the needs of the user.Next generation(x-g) networks also known as dynamic spectrum access network as well as cognitive radio network provides high bandwidth to the mobile users via heterogeneous architecture and dynamic spectrum access technique. The key enabling technology of the x-g network is Cognitive radio. Cognitive Radio techniques give the facility to use or share the spectrum in an opportunistic manner. Cognitive radio technology plays a vital role in sensing, sharing, management and mobility of the spectrum. It determines which portion of the spectrum is available for usage. It also detects the presence of the licensed user when a user operates in a licensed band and selects the best available channel. It also accesses the channel with other users in a coordination way and vacate the channel when license user is detected. Once the CR selects the best available channel the next responsibility is to make the network protocols.

B. Main functions

CR technology is the technology which enables the X-g network for to use a spectrum in a dynamic way. Cognitive radio is the radio which changes the transmitter unit parameters based on the interaction with the environment in which it operates. Main functions of the cognitive radios are as follows.

1) Spectrum sensing

Detecting the spectrum holes or the unused spectrum, so that it can be shared by removing the harmful interferences with other users

2) Spectrum management

To collect or capture the best available spectrum from the radio environment so that it can falls on the user communication requirements.

3) Spectrum mobility

Mobility means maintaining in the CR literature spectrum mobility refers tomaintain or balance the communication requirements during the transition to the better spectrum.

4) Spectrum sharing

Spectrum Sharing means scheduling in the CR literature. Spectrum sharing indicates to schedule the spectrum in a neat manner among coexisting user.

C. Characteristics

1) Cognitive capability

Cognitive capability means the ability to sense or capture the information or data from the radio environment.Through this capability the portion of the spectrum which is unused at a particular time and location can becomes in the front in order to avoid interference to other users after this the best available spectrum is selected and the best operating parameters are selected.

2) Reconfigurability

Cognitive re-configurability means to programme the CR dynamically according to the radio surroundings. As the hardware design of the CR unit supports CR can be programmed according to the radio environment to transmit or receive on a numbers of frequency with the use of different transmission technologies. There are some of the reconfigurable parameters that it takes into notice for the CR:

a) Operating frequency

CR is able to changing operating frequency. Based on the radio environment the operating frequency is evaluated and the communication is performed.

b) Modulation

CR identified itself that which modulation scheme is adaptive to the user needs and channel behavior at the particular time.

c) Transmission power

If high power operation is not necessary CR reduces the transmission power to lower levels for to allow more users without causing interferences.

d) Communication technology

A CR can be used as a service provider among different communication systems.

D. Components

Cognitive radio physical architecture consists of the front end unit and the baseband unit.Each part of the cognitive radio is programmed via a control bus.

1) RF/Analog Front End unit

In this unit, received signal is first amplified by a low noise amplifier or the down sampling is performed for to reduce the noise at the subsequent stages through its gain and then mixing is performed via mixer, mixer uses the received signal and the signal generated by the oscillator .the next operation is the analog to digital conversion. Channel selection filter selects a particular channel from adjacent channels. It is generally a I-F(intermediate frequency) band pass filter. Automatic Gain Controller (AGC) in the block architecture is a gain controller which adjust the gain according to the signal strength (signal is weak or strong). When the signal is stronger AGC decreases it's gain and when the signal is weaker then it increases the gain. AGC is best known as the volume adjuster or the gain controlling unit which changes the gain corresponding to the receiving signal level. Phase locked loop is used for to lock the signal on a specified frequency and it can be used for to generating precise frequencies with the fine resolution parameter.

a) Limitations while developing the cognitive radio front end

While developing the CR there were some limitations because the RF antenna receives the signal from the various transmitters operating at different power levels, bandwidths and location. And also RF front end should have the capability to search out the weak signal in large dynamic range hence this capability needs high speed (multi-GHZ) analog to digital converter with the more resolution. A multi GHz speed A/D conversion requires to reduce the dynamic range before digital conversion, it is achieved by the tunable notch filtering of the strong signals another method is to use several antennas for receiving signals and filtration, using beam forming techniques.

2) Baseband processing unit

In the baseband processing unit modulation /demodulation, encoding/decoding operations are performed. The transceiver unit is plays a very important role in the wideband sensing. Wideband sensing is totally based on the RF front end unit hardware technologies, such as wideband antenna, power amplifiers and the adaptive filters. In a large range of frequency spectrum RF front unit makes tunable the each part of it this enables to the CR to getting information from the radio environment.

E. Cognitive radioOrganization

Organization of the cognitive radio cycle consists of following.

1) Wake cycle

In this cycle the CR performs the task of channel estimation, radio scene analysis, modeling of prediction.

2) Sleep cycle

In this cycle the task of the CR is to integrate the domain knowledge.

3) Prayer cycle

In this cycle gathering of the items task is performed that can't be deal during the sleep cycle.

F. Cognitive cycle

Once the spectrum band is determined the communication is performed on it. Cognitive cycle contains these steps:

1) Spectrum sensing

In this step spectrum monitoring is performed by capturing information and then detects the unused spectrum.

2) Spectrum analysis

In this step the characteristics of the spectrum holes is estimated.

3) Spectrum decision

In this step CR unit performs the task of the determination of the data rate, bandwidth of transmission and the mode of transmission.

G. Fundamental CR tasks

1) Radio scene analysis

Radio scene analysis means estimation of the interference temperature of the radio environment and the detection of holes. This task is carried out in receiver.

2) Channel state estimation and predictive modelling

Channel state estimation refers the Estimation of the channel estate information(CSI).and predictive modeling means prediction of the channel capacity used by the transmitter. This task is carried out in receiver.

3) Transmit power control and dynamic spectrum management

This task is carried out in the transmitter.

V. DIGITAL MODULATION SCHEMES

There a many of the digital modulation schemes FSK,PSK,CSK is basically used for modulation the cognitive radio.

A. Frequency Shift Keying

Frequency shift keying [10] is a digital modulation method in which the digital data information is transmitted through frequency(discrete) changes in the carrier. The use of frequency shift keying(FSK) is to transmit digital information, two different carrier frequencies represents zero and one.

FSK was originally used to transmit Teleprinter messages viaradios, but can be usedfor most othertypes of radio and lan dline digital telegraphy operations. More than two frequencies can be used to increase the rate of transmission .one frequency is the mark frequency and another is space frequency. In FSK “1” is called as the mark signal frequency and “0” is called as the space signal frequency. Frequency shift keying (FSK) is defined as a process of transmitting digital signals data .The two binary states logic “0(low)” and logic “1(high)” are each represented by an analog waveform. Logic zero is represented by a wave at a particular frequency, and logic one is represented by a wave at a different frequency. A modem is used to converts the binary data from a computer unit to FSK for transmission over the lines of the telephone, cables, optical fiber, or wireless media. The modem also converts incoming FSK signals to low and high digital states, which the computer can easily "understand."The general expression of FSK is

$v_{fsk}(t)=v_c \cos\{2\pi[f_c+v_m(t)\,\Delta f]t\}$(3)

Where, $v_{fsk}(t)$= binary FSK waveform, v_c= peak carrier analog amplitude, f_c=analog carrier center frequency, $v_m(t)$=binary input (modulating) signal, Δf=peak change (shift) in the analog carrier frequency.It can be seen that the peak shift in the carrier frequency (Δf) is proportional to the amplitude of the binary input signal ($\mathbf{v_m}(t)$), and the direction of the shift isdetermined by the polarity conventions. The modulating signal is a normalized binary waveform where a logic1 means + 1 V and logic 0 means -1 V.

B. Phase Shift Keying

Phase-shift keying (PSK) [10] is another type of angle-modulated, constant-amplitude digital modulation Phase shift keying, PSK, is basically used these days within a whole raft of communications systems(radio).It is particularly well suited to the growing area of data communications.PSK enables data to be carried on a radio communications signal in a more suitable manner than FSK, and some other forms of modulation. With more forms of communications transferring from analogue formats to digital, data communications is developing in importance, and along with it the various forms of modulation that can be used to ship data.PSK uses a certain number of phases, each entrusted a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each bits pattern forms the symbol that is represented by the particular phase.The detector, which is map out specifically for the symbol-set used by the modulator unit, evaluates the phase of the detected signal and maps it back to the symbol it represents, thus regain the original data. This needs the detector to be able to compare the phase of the detected signal to a reference signal such a system is termed coherent.

Bandwidth consideration for BPSK-

In, a BPSK modulator. The input carrier signal is product by the binary data. If + 1V is assigned to a logic one and -1V is assigned to a logic zero, the input carrier ($\sin \omega_c t$) is multiplied by either a plus or minus 1.The output signal is either + 1 sin $\omega_c t$ or -1 sin $\omega_c t$ the first shows a signal that is in phase with the reference oscillator, the latter a signal that is π out of phase with the reference oscillator. Each time the input logic condition changes, the output phase changes. Mathematically, the output of a Phase Shift Key modulator is proportional to Phase Shift Key output that is

$$v_{BPSK} = [\sin(2\pi f_a t)] \times [\sin(2\pi f_c t)] (4)$$

Where, f_a= maximum fundamental frequency of binary input(in hertz) and f_c= reference carrier frequency (in hertz)

C. Code Shift Keying

Ultra wideband impulse radio (UWB-IR) is a best technology that has been recently examined for data communications with high rates and ranging systems. Despite its many benefits including use of unlicensed spectrum and multipath resolving capabilities, the current implementation of Ultra Wide Band -Infra Red s exhibits some difficulties. First, the traditional UWB-IR modulation format, pulse position modulation (PPM), uses successive certain pulse transmit locations that are largely impacted by multipath-delayed pulses, which decreases the system performance. Second, increasing the rate of data in the most commonly used binary Pulse Position Modulation format is still a research difficulty . Third, periodic time-hopping codes used for MA (multiple-access) produce useless peaks for the spectrum, which may cause enhanced interference levels for the systems co-existing in the same bandwidth. M-ary CSK (MCSK), which can be combined with other UWB-IR modulations, attains data transmission by choosing one of the M orthogonal user-specific TH codes, where TH codes are used to randomize the locations of pulse transmission. While the randomized pulse transmit locations overcomes the effect of multipath-delayed pulses on the performance of the system, the selection in a random manner of TH codes increases the effective TH code period and subdue the undesired peaks in the spectrum.

VI. TRANSFORMATIONS

There are various types of transformations that are used for the signal processing and spectrum sensing. They are as follows.

A. Discrete Cosine Transform

The DCT[11] of data sequence X (m),m=0,1……..M-1 is defined as:

$$G(0) = \sqrt{2}/M \sum_{m=0}^{m-1} X(m) \quad (5)$$

And,

$$G(K) = \sqrt{2}/M \sum_{m=0}^{m-1} X(m) * \cos(2m+1)K\pi/2M, (6)$$

Where, k=1,2,3,…………..M-1Here G(k) is the kth DCT coefficient.DCT coefficient is a set of basis vector that is

$$\cos(2m+1)K\pi/2M$$

The discrete coefficient is a class of discrete Chebeshev polynomials. Where Chebeshev polynomials is:

$$T(\in) = 1/\sqrt{2}$$

And ,$$Tk(\in) = \cos(k\cos^{-1}(\in)) (7)$$

It has been shown that the DCT can be used in the area of image processing for the purposes of feature selection in pattern recognition and scalar-type Wiener filtering. Inverse DCT formula is:

$$X(m) = 1/\sqrt{2}\, G(0) + \sum_{k=1}^{m-1} G(k) \cos\left(\frac{(2m+1)K\pi}{2M}\right) (8)$$

B. Fourier Transform

If one have to operate on such sequences say X(j) for i=0,1,………N-1 it is obvious to develop a theory for them .to define particular orthogonal transformation which take sequence as X(j) into another sequence A(n) of same length as

X(j) and which describes the frequency structure of X(j) also this transformation is called as Discrete Fourier Transform[12] [13] and for X(j) it is defined as:

$$A(n)= 1/N \sum_{j=0}^{N-1} \mathbf{X(j)} * \mathbf{e}^{-j2\pi nK/N} \quad (9)$$

Similarly if one have to find inverse:

$$X(j) = \sum_{n=0}^{N-1} \mathbf{A(n)} \mathbf{e}^{j2\pi nK/N} \quad (10)$$

C. Wavelet Transform

There are different types of Wavelet transforms that are commonly used [4]. They are as follows.

1) Discrete Wavelet Transform

The Wavelet Transform (WT) [4][14] [15]is a transform scheme for analyzing signals. It was developed as a substitution to the short time Fourier Transform (STFT) to conquer problems related to its frequency and time resolution characteristics. Unlike the Short Time Fourier Transform that gives uniform time resolution for all Frequencies the Discrete Wavelet Transform gives high time resolution and low frequency resolution for high frequencies only and high level frequency resolution and low time resolution for low level frequencies. In that respect it is similar to the ear of a human which reveal similar time-frequency resolution properties.The Discrete Wavelet Transform (DWT) is a unique case of the Wavelet Transform (WT) form that gives a tight characterization of a signal in frequency and time that can be evaluated efficiently. The DWT is formulated by the following equation.

$w(j,k) = \sum_j \sum_k x(k) 2^{-\frac{j}{2}} \varphi(2^{-j}(n-k))$ (11) whereφ (t) is a time function with finite energy called the mother wavelet. The DWT analysis can be presented using a algorithm to multi rate filter banks (MFB).

2) Continuous Wavelet Transform

In order to examine signals of very distinct sizes, it is necessary to use time-frequency atoms with different time pillars. The Wavelet Transform dividesignals over extended and translated functions called wavelets, which transform a continuous function(CW) into a highly unnecessary function.A wavelet is a function with zero average formulated as follows-

$$\int_{-\infty}^{\infty} \varphi(t)\, dt = 0 \quad (12)$$

Different types of wavelets have evolved with each one having different property and usage in different areas. Some examples of continuous wavelet areas follows.

D. Difference between Fourier and Wavelet Transform

Discrete Wavelet Transform is more informative and flexible than the other transforms. It is a transform that cracks the data into frequency component or sub bands. Fourier involves the decomposition of a signal into sin waves of several frequencies. The advantage of the wavelet over Fourier transform is in analyzing physical situation that the sinusoid do not have a limited duration but instead extend from minus to plus infinity. In Fourier transform domain we completely lose information about the audio signal. A wavelet expansion coefficient refers a component that is local and easier to interpret. Wavelets are adjustable and adaptable and designed for adaptive systems whereas Fourier transform is suitable if the signal consists of few stationary components.

The Fourier transform shows up in a remarkable number of areas outside of classic digital signal processing. Even taking this into account, we think that it is correct to say that the mathematics of wavelets is much larger than that of the Fourier transform. In fact, the mathematics of wavelets encompasses the Fourier transform. The size of wavelet theory is matched by the size of the application area. Initial wavelet applications involved signal processing and filtering. However, wavelets have been applied in many other areas including non-linear regression and compression. Some advantage of wavelet theory over other theories is:

(a) A wavelet transform can be used to decompose or divide a signal into small wavelets and in wavelet theory, it is possible to obtain a good estimation of the given function f by using only a few coefficients which is a great attainment as compared to Fourier transform.

(b) One of the main advantages of wavelets is that they provide a concurrent fixing or localization in domain of time and frequency. Wavelets also use fast wavelet transform, so it is very fast.

(c) Wavelet transform can frequently squeeze or de-noise a signal in absence of considerable degradation.

(d) Wavelets have the advantage of being able to divide the pure details in a signal. Smaller wavelets can be applied to dissociate the most elementary details in a signal, while very large wavelets can identify other details of coarse analysis.

(e) Wavelet theory is competent to declare aspects of data that other signal analysis method misses. The features like breakdown points and segregation in higher order derivatives are perfect example for this.

VII. TRANSFORM DOMAIN COMMUNICATION SYSTEM (TDCS)

TDCS stands for transform domain communication system. TDCS is designed to avoid the use of occupied bands by signal processing facilities at both transmitter and receiver instead of mitigating the interference only at receiver side.Thus, TDCS can be used as a cognitive radio (CR) modulation technique for overlay spectrum access systems. Transform Domain Communication System (TDCS)[16] [17] is a cognitive-radio technology that avoids frequency underutilization by doing spectrum-cleaning. Although TDCSs' is well-known when dealing with interferers, theoretical limits of TDCS in terms of spectrum efficiency remain unknown.

A. Why TDCS

The fundamental idea in TDCS is to synthesize or filter a smart adaptive waveform to avoid interference at the transmitter side instead of the more traditional mitigating of interference at the receiver end.

B. TDCS modulation

Functional TDCS implementation includes environmental sampling, spectral estimation, thresholding, notching, phase generation, phase mapping, and inverse transformation to obtain the time-domain FMW(fundamental modulated waveform).TDCS modulator consist of some of the stages as:-

1) Spectrum identification (ID)

Spectrum identification step is used for to find the interference free spectral region. Periodogram, autoregressive (AR), and wavelet-based techniques are some of the spectral estimation techniques.

2) Spectrum magnitude

After the spectrum identification the next step is to calculate the spectrum magnitude. For to calculating the magnitude of the spectrum we apply a threshold to the estimated spectrum it generates a "clean" or interference-free spectrum A(w). Amplitudes of interfering frequency components exceeding the threshold are set to zero, and the remaining spectral.

3) Random phase

In this block a complex valued phase vector is generated for element by element multiplication. The use of PR coding in DS-CDMA is to spread the spectrum, whereas TDCS uses the PR code to randomize the phase of the spectral components.

4) Magnitude scaling

Magnitude scaling is means to scale the magnitude of the transmitted symbols to provide desired energy in the signal spectrum B(w). Magnitude scaling effectively permits all communication symbols to be transmitted with equal energy (i.e. for spectrum notching due to interference, the desired energy is distributed equally among all remaining components).

5) Inverse transform and buffer

Inverse transform and buffer block generates the time-domain FMW b(t)(fundamental modulated waveform) by taking the suitable inverse transform of spectrally coded frequency components. The FMW b(t) is stored in buffer register and used by the modulator for subsequent stages.

C. Modulation

TDCS uses basically two binary modulations: antipodal signaling and a form of orthogonal modulation called cyclic shift keying (CSK).

D. Antipodal modulation

Antipodal modulation is a form of signaling where binary signals are the negative of each other.

E. CSK modulation

CSK means cyclic code shift keying, The CSK modulation technique takes advantage of noise-like FMW properties (i.e., correlation of time-shifted versions of the FMW with itself approaches to zero).

F. Matlab Simulations for TDCS

TDCS can be implemented on the MATLAB, for TDCS implementation on Matlab. We have to estimate a spectrum and then we have to notch the spectrum. When the spectrum is estimated then it is notched. We can see the Matlab plots for the power spectral density of the spectrum in Fig. 1 and the power spectral density of the spectrum after notching process in Fig. 2.

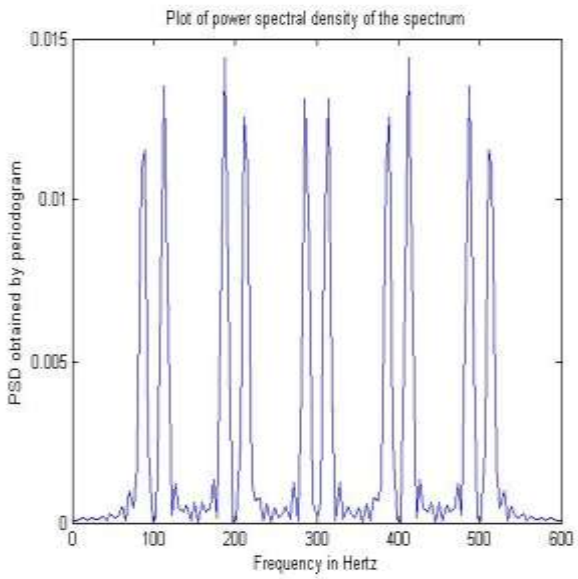

Fig. 1 Power Spectral Density of the spectrum

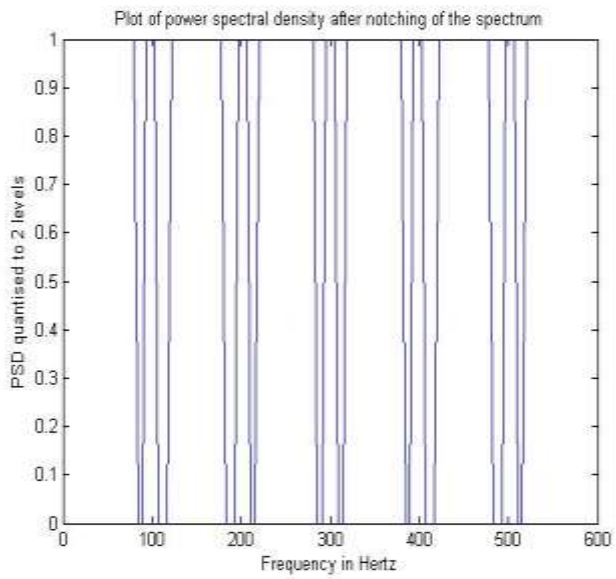

Fig. 2 Power Spectral Density of the spectrum After spectrum notching

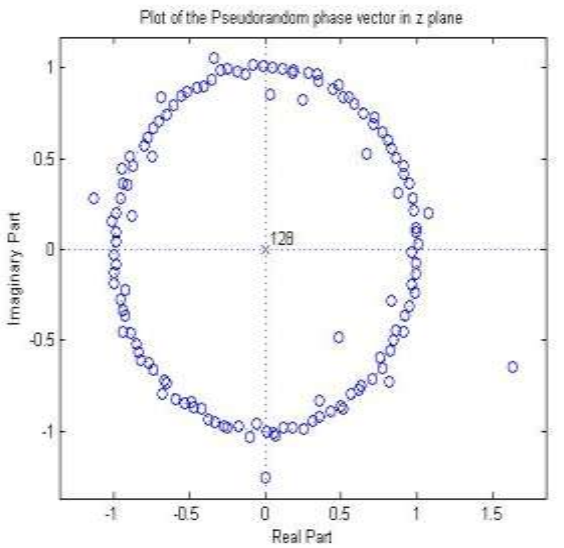

Fig. 3 Pseudorandom phase vector in Z- plane

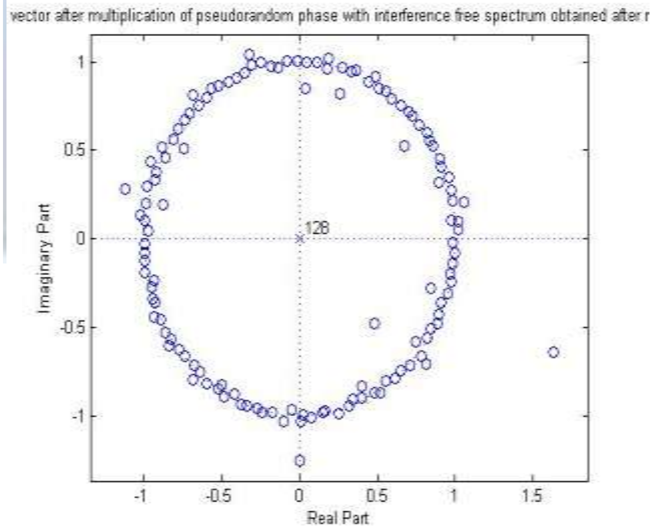

Fig. 4 Vector plot after multiplication of PR phase with interference free spectrum

After spectrum notching process we have a spectrum, now the next step is to generate a pseudorandom phase (MATLAB plot Fig. 3) and then we can perform the mapping with phase. Than we multiple the pseudorandom phase with the interference free or notched spectrum (MATLAB plot Fig. 4). Now the output is scaled and we perform an IFFT on it and store it on the buffer.Now, the data is ready to be transmitted we use CSK modulation for the transmission and we can see the data at the receiving point. We can implement a receiving unit in MATLB to check the receiving data for the errors in the transmitted word data .we perform MATLB programming for to know the errors in the 1000 transmitted words we can see the plots and take observations for errors.

In 1978, the first step was implemented on transform-domain signal processing when Milstein present a Surface Acoustic Wave (SAW) device, it was shown also that ideal filtering subliminal with time-domain processing, could be developed in the frequency domain, a processing known as Transform Domain (TD)processing. After this presentation, bandpass and notch Transform Domain filters were framed and they are capable to remove interference. In 1991,the Andren/Harris corporation patented a Low Probability of Intercept(LPI) communication system because its techniques was similar to those Introduce by German in 1989,in which German analyzed a spread spectrum system based on transform domain processing at both the transmitter and receiver location. Andren-Harris and German both systems use TD processing to perfectly defer spectral areas those have interference. In 1996, Radcliffe generated a model in software – MATLAB to simulate and characterize performance of the TDCS defined by the Andren/Harris Corporation and German model. Radcliffe's work shows the level of correction receivable with a transform domain communication system related to a traditional Direct Sequence Spread Spectrum (DSSS) system for the interference underplot. Ahead advancement in TDCS development was made in 2001 when Klein improved Radcliffe's work by changing the Fourier-based spectral estimation function with a Wavelet-based system, grant born to the Wavelet Domain Communication System (WDCS).

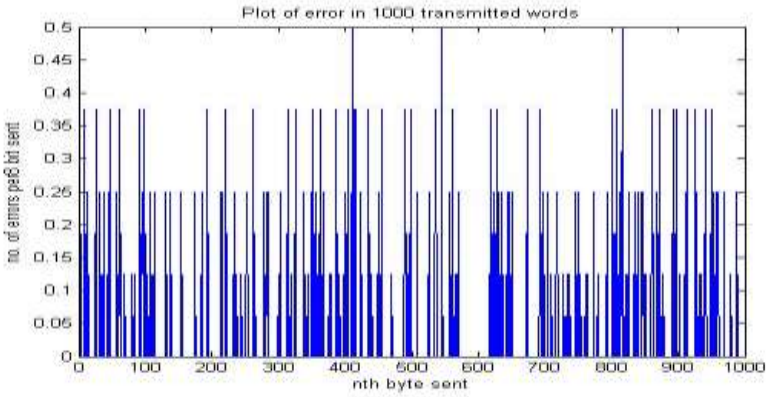

Fig. 5 Plot of Error in 1000 transmitted words

Several modulation techniques have been disseminated to reduce interference effects. Two developmental communication systems pointing interference avoidance capabilities are Transform Domain Communication System (TDCS) and the Wavelet Domain Communication System (WDCS). The TDCS and WDCS are particularly designed to operate successfully in an environment consisting hostile, unintentional interference. Unintentional interference indicates low-level interference with the most opening source being Additive White Gaussian Noise (AWGN), such that , noise keeps a power spectral density (PSD) with constant value over each frequencies parameter , source of unintentional interference may be television and radio stations, cellular telephones, and radar Intentional interference is differ from the unintentional interference because it extensively defined as a radiation source which keeps enough energy that is designedly achieved at a communications system with the exclusive function of outrage system operation. It is classified as narrowband or wideband.

VIII. WAVEFORM DOMAIN COMMUNICATION SYSTEM(WDCS)

Klein adduce that WDCS spectral estimation could be further elevated by substituting the original Wavelet processing method with a Wavelet packeted composition, pointing potential for more actual electromagnetic spectral estimates. A advocacy was also made that WDCS investigation be expanded at hwart binary modulation to assume M-ary modulation for increased flow of capacity.

A. WDCS IMPORTANCE

The TDCS performance was severely deficient when associated with swept-tone interference which is a kind of non-stationary interference. Klein's original WDCS[18]overcame this deficiency and successfully conducted in the existence of non-stationary interference with narrowly decreased communication execution. As a further improvement, this finding considers a wavelet packet decomposition technique to provide more corrected spectral estimation, effectively taxes to non-stationary interference sources, and distant past results from binary modulation to comprise M-ary modulation.

The original WDCS implementation used a lineal wavelet-based transform to perform spectral estimation and was evolved to overcome two main TDCS shortcomings:

1) The Fourier-based estimator instinctively dilates interference energy into proximate spectral domains not containing interference energy, an inefficiency probably resulting in less performance.

2) The TDCS is unable to impactly estimate the spectral type of non-stationary interferences.

CONCLUSION

In this paper we discussed the cognitive radio as a potential solution to address the spectral problem. An adaptive waveform processing technique called Transform Domain Communication System is introduced as a candidate for achieving cognitive radio aims. Many simulation scenarios are considered to demonstrate the spectral coexistence concept. The proposed wavelet packet based WDCS provides acceptable M-Ary, orthogonal cyclic shift keyed (CSK), communication performance while provides significant interference avoidance capability. The WDCS is highly capable of estimating a spectrum, searching unused spectrum and mitigating interference impacts. This denotes that it is a strong candidate for reliable communication systems or for cognitive radio technology (CR-technology).

REFERENCES

[1]. Gupta, Rajan, AnkurAggarwal, and Saibal K. Pal. "Design and Analysis of New Shuffle Encryption Schemes for Multimedia." Defence Science Journal 62, no. 3 (2012): 159-166.

[2]. Gupta, Rajan, NeeharikaChaudhary, AnikaGarg, and Saibal K. Pal. "Efficient and Secured Video Encryption Scheme for Lightweight Devices." INROADS-An International Journal of Jaipur National University 3, no. 1s2 (2014): 346-351.

[3]. Gupta, Rajan, Saibal K. Pal, and NeeharikaChaudhary. "A Novel Lightweight Encryption Scheme for Multimedia Data."International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463, Vol. 3 Issue 1, January-2014, pp: (91-96).

[4]. Sharma, Mrinal, Gagangdeep Singh, and Rajan Gupta. “Application of Wavelet – An advanced approach of transformation”.Advanced Research in Electrical & Electronic Engineering (ISSN: 2349-5804), Volume 1, Issue 1, pp. 28-34.

[5]. Gupta, Rajan, S.K.Muttoo, and Saibal K. Pal. “Analysis of Information Systems Security for e-Governance in India”. Proceedings of National Workshop on Cryptology-2013, TS II, pp. 17-25.

[6]. Levin, Harvey J. The invisible resource: use and regulation of the radio spectrum. Routledge, 2013.

[7]. Yucek,Tevfik, and Hüsey in Arslan. "A survey of spectrum sensing algorithms for cognitive radio applications." Communications Surveys & Tutorials, IEEE 11, no. 1 (2009): 116-130.

[8]. Akyildiz, Ian F., Won-Yeol Lee, Mehmet C. Vuran, and ShantidevMohanty. "NeXt generation/dynamic spectrum access/cognitive radio wireless networks: a survey." Computer Networks 50, no. 13 (2006): 2127-2159.

[9]. Goldsmith, Andrea J., and Larry J. Greenstein. Principles of Cognitive Radio. Cambridge University Press, 2012.

[10]. Fitton, Mike. "Principlesof digital modulation." Toshiba Research Europe Limited (2002).

[11]. Chitprasert, B., and K. R. Rao. "Discrete cosinetransform filtering." Signal processing 19, no. 3 (1990): 233-245.

[12]. Cooley, J., P. Lewis, and P. Welch. "The finite Fourier transform." IEEE Transactions on audio and electroacoustics 17, no. 2 (1969): 77-85.

[13]. Heckbert, Paul. "Fourier Transforms and the Fast Fourier Transform (FFT) Algorithm." Computer Graphics 2 (1995): 15-463.

[14]. Chun-Lin, Liu. "A tutorial of the wavelet transform." ed: NTUEE, Taiwan (2010).

[15]. Polikar, Robi. "The wavelet tutorial." (1996).

[16]. Zhou, Ruolin, Qian Han, Reginald Cooper, VasuChakravarthy, and Zhiqiang Wu. "A software defined radio based adaptive interference avoidance TDCS cognitive radio." In Communications (ICC), 2010 IEEE International Conference on, pp. 1-5. IEEE, 2010.

[17]. Hu, Su, Guoan Bi, Y. Guan, and Shaoqian Li. "TDCS-Based Cognitive Radio Networks with Multiuser Interference Avoidance." (2013): 1-8.

[18]. Klein, Randall W., Michael A. Temple, R. L. Claypoole, Richard A. Raines, and James P. Stephens. "Wavelet domain communication system (WDCS) interference avoidance capability: Analytic, modeling and simulation results." InMilitary Communications Conference,2001. MILCOM 2001. Communications for Network-Centric Operations: Creating the Information Force. IEEE, vol. 2, pp. 1034-1038. IEEE, 2001.

[19]. Lee, Marion J., Michael A. Temple, Roger L. Claypoole, and Richard A. Raines. "Transform domain communications and interference avoidance using wavelet packet decomposition." In Wireless Communications and Networking Conference, 2002. WCNC2002. 2002 IEEE, vol. 1, pp. 255-259. IEEE, 2002.