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Volume 08, Issue 07, Pages: 74–87.

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A SURVEY ON MODULATION TECHNIQUES AND SPECTRUM SENSING IN COGNITIVE RADIO NETWORKS

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ABSTRACT
Cognitive Radio have been used to improve the wireless spectrum utilization .Due to the growing demands for the wireless medium access by different operators and service providers .The secondary users need to access the spectrum from the licensed users. The Cognitive Radio system has learning and understanding capabilities so that the stated goals may be achieved. Also, modulation and spectrum sensing plays significant role in improving the lifetime of the network. In this paper, a survey on the challenging issue in the modulation schemes and spectrum sensing in cognitive radio network.

KEYWORDS
Sensing, Detection, Eigen value, Cyclostationary.

I. INTRODUCTION

Cognitive radio techniques focus mainly on spectral congestion problem as spectrum scarcity [1] is developing in wireless technologies and services. It is more reliable and adapts transmission and reception parameters intelligently through environment sensing [2]. Cognitive radio networks improves the quality of some parameters such as modulation, routing protocols, power and others as it is a 5G technology[3], useful in bandwidth mitigation and also smart for enhancing the wireless communication through opportunistic spectrum access[4] . The regional spectrum allocation policy counteracts the free mobility of radio communication equipment. The vast majority of the accessible spectral resources have already been approved, hence there is little or no room to add any new services, unless some of the existing licenses are discontinued. Recent studies and measurements have shown that vast portions of the licensed spectra are rarely used due to the inflexible spectrum regulations. The whole idea behind CR, use is that it should prompt effective spectrum use, using intelligence and learning processes to aid the radio system to access the spectrum effectively. The scope of cognition is to reduce mutual interference between CR-based unlicensed users and licensed users, in providing coexistence between them. When licensed user's are inactive portions of the spectra can be used by the unlicensed users to transmit and receive data. Spectrum sensing plays a major role to detect the existence or non appearance of licensed user's. Various modulation strategies are employed to realize coexistence between the CR-based unlicensed system and the licensed system. This is done in this way that the unlicensed users are invisible to the LUs. The rental user accesses the unoccupied LU band in overlay fashion [5].

The Cognitive cycle consists of 4 important steps:-

Spectrum sensing :- CR should monitor the available spectrum bands, collect their data and recognize spectrum holes.

Spectrum decision:- This function relates to the selection of best spectrum bands from the detected spectrum holes according to a given criterion. The allocation of the spectrum availability to the CR users is determined based on internal policies.

Spectrum Sharing:- Several secondary users can have access to the detected spectrum holes.

However, the access of two or more secondary user to the same spectrum band results in collisions, and contention. Spectrum sharing manages the spectrum usage among multiple secondary users to minimize the harmful interference and collisions. CR network access should be coordinated to prevent multiple users colliding in overlapping portions of the spectrum.

Spectrum Mobility:- After selecting an appropriate spectrum band, the secondary user commences communication. However, due to dynamic nature of wireless environment, after a while, a primary user may start communication in the selected band. In this case, the secondary user changes its operating band to avoid interference to the primary user. This hand-off (between spectrum bands) performing functionality of CR devices is called spectrum mobility.CR users are visitors to the spectrum. If the specific portion of the spectrum is in use by a PU, the communication is continued in another vacant portion of the spectrum.

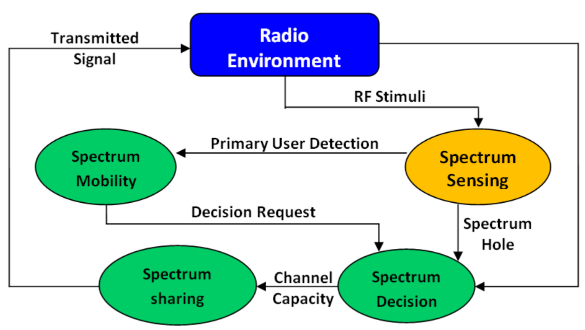

Fig.1: Cognitive cycle

The main objective of spectrum sensing survey is to make researchers aware of the recent trends in spectrum sensing and the challenges issues and future scope of the research. The paper is divided into six sections, which gives an overview of the factors like Modulation techniques, the comparison between different modulation schemes, Techniques of Spectrum sensing, challenges in Modulation and Techniques of spectrum sensing that implement sensing.

II. LITERATURE REVIEW

The modulation and Techniques of Spectrum sensing has been quite well studied for cognitive radio networks. Several surveys on different modulation techniques such as MB OFDM, Hierarchical modulation, automated modulation classification, Multi-Rate modulation, Adaptive modulation and coding, Stochastic modulation, Optimal modulation, Orthogonal Quadrature Amplitude Modulation, Energy efficient modulation and coding, Spatial modulation, Quadrature Spatial modulation are discussed.

Several surveys on different techniques of spectrum sensing like Energy detection, Matched filter detection, Feature detection, Waveform detection, Eigen Value Detection are discussed.

Cheng Yang et.al.,[6] proposed a UWB based cognitive radio derived from a mathematical expression of side-band interferences caused by subcarriers of multi-band MB-OFDM. Based on this, the relationship among transmitted symbols is satisfied to suppress the interferences is achieved. With this, the LDPC modulation scheme the bit rate error (BER) performance of MB-OFDM UWB based cognitive radio systems is improved and a decrease in the side-band signals is observed. With the suppression of the interferences caused by MB-OFDM UWB based cognitive radio systems the coexistence between cognitive radio system and other protected narrow band radio services can be achieved.

S. Chatterjee et.al.[7] proposed a Adaptive Modulation Schemes for OFDM-CDMA Based 4G Systems". Adaptive modulation based on multi-carrier transmission technologies for future generation 4G wireless networks where the bandwidth is a limited resource. In Rayleigh fading channels, at the receiver of adaptive modulation based coded OFDM-CDMA, for the enhancement of the systems in terms of practical implementation and data throughput capacity .The advantage of blind estimation of the channel response results in increased data throughput or spectrum efficiency.

Carlos Cordeiro et.al.[8] proved a system on an Introduction to the First Wireless Standard based on Cognitive Radios. The IEEE 802.22 Working Group WG is the first world wide air interface standard based on CR techniques. This standard includes work conducted at PHY and MAC specification, which operates in TV bands uses techniques such as spectrum management, spectrum sensing, incumbent detection and avoidance in order to achieve radio resource sharing and effective coexistence with existing licensed services.

The author proposed a system on Quantitative Comparison of Agile Modulation[9] .Non-Contiguous orthogonal frequency division multiplexing (NC-OFDM) designed to avoid interference with the transmissions of incumbent users by deactivating subcarriers within them. Also the error robustness of NC-OFDM is relatively constant regardless of deactivated subcarriers. In Multicarrier code division multiple access(MC-CDMA) ,the error performance degrades with increase in deactivated subcarriers.

Ibrahim Budiarjo et.al. [10] proposed a system on Cognitive Radio Modulation Techniques. OFDM is considered to be the efficient technique due to its spectrum access flexibility, by notching its carriers on the position of LU's band. The Drawback is that its high side lobes will interfere with the neighboring LU's band. Techniques like windowing, adjacent carriers deactivation, cancellation carriers, multiple choice sequence, and a combination of all these techniques is used to mitigate the side lobes problem.

Dengbao Du et.al. [11] showed a system for TDS-OFDM System based on the design of orthogonal sequences, which have almost perfect autocorrelation characteristics .These help in synchronization in time domain and cross correlation characteristics which can help eliminate the signal interference between different transmit antennas. In Time Domain Synchronous Orthogonal Frequency Division Multiplexing (TDS-OFDM), the characteristics of the sequences can help for synchronization and channel estimation.

The author proposed a system on Constant Envelope OFDM [12] . CE-OFDM transforms the OFDM signal to a signal designed for efficient power amplification, by phase modulation technique. The phase modulation transformation technique aims at solving the peak-to average-power ratio (PAPR) problem with OFDM. The use of cyclic prefix transmission to simplify equalization, in conjunction with the Frequency Domain Equalizer, the CE-OFDM achieves good performance in dense multipath.

Weiwen Weng et.al. [13] proved a system OFDM –MSK Scheme for MB-OFDM UWB, For multi-carrier modulation (MCM) systems, Minimum Shift Keying (MSK) has a fast roll-off –side-lobe spectrum, which is an excellent property for multi-carrier modulation (MCM) systems. This system has better out-of-band attenuation, when incumbent radio services are detected, then by turning off the sub-carriers on the corresponding interference frequency band, the interference on incumbent users will be cancelled.

The author proposed a system Peak-to-Average Power Ratio Reduction of OFDM Signals With Nonlinear Companding Scheme[14]. The Bit Error Rate (BER) for OFDM systems are improved with low out-of –band distortion. By properly choosing the transform parameters and compressing the large signals, also maintaining the average power constant.

Zsolt Kollar et.al. [15] proposed a system Physical Layer Considerations for Cognitive Radio Modulation Techniques. The Spectral behavior, Transmission data rate ,PAPR and CM, System complexity discussed for different modulation scheme are shown below:-

Table 1. Below illustrates the comparison between the four modulation schemes:-

Modulation scheme	Spectral behavior	Transmission data rate CP=Cyclic Prefix	PAPR and CM(cubic metric)	System complexity
OFDM	Compact	1-CP/N	High	Low
CE-OFDM	DC & Sidebands	½(1-CP/N)	Low	Medium
DFTS-OFDM	Compact	1-CP/N	Moderate	Medium
FBMC	Very Compact	1	High	High

Zhao Jianli et.al. [16] proposed a system on Identification of Cognitive Radio Modulation. For modulation recognition the neural network algorithm is combined with decision – theoretic algorithm classifier. The classifier has a good recognition performance

A. Mayers et.al. [17] proved a system on Adaptive Stochastic-Based M-ary Modulation Extension Algorithm. In this paper, the problem of spectrum scarcity due to the increasing access of the unlicensed devices to the licensed wireless spectrum is discussed .This problem is addressed by allowing unlicensed devices opportunistic access. These opportunistic devices regard licensed users as interference. The unlicensed devices sense spectrum and dynamically allocates bits to channels with good SINR. In Cognitive Radio Stochastic Modulation (CRSM) used in underlay channels with poor SINR, in additive channels both the transmitting and receiving CR sense the magnitude and variance of the interference energy in the channel. In manipulating the deviation of the signal detected at the receiver, the transmitter uses the deterministic signals as unique identifiers. At the receiver, detected change in variance is measured ,which is the indication about the presence or absence of a signal .The system is designed for use in short-range ,low power CR devices to improve BR also maintains BER.

Tao Jiang et.al. [18] proposed a system for PAPR reduction in OQAM-OFDM Systems, a multi block tone reservation (MB-TR) scheme . The OQAM-OFDM systems offer extremely low spectral side lobes, which leads to increase of the spectral efficiency. The OQAM-OFDM systems can efficiently overcome the multi-path fading channels without the help of CP, resulting in significant improvement of the data rate. The adjacent data blocks are jointly considered to obtain the clipping noise, then the peak canceling signal are achieved by the weighted least square algorithm, this fitted the waveform of the peak-canceling signal to the waveform of clipping noise.

Ahsen U.Ahmed et.al. [19] proved a system on low complexity receivers for constant envelope OFDM. The high PAPR issues in OFDM signal is reduced by using angle modulation to transform the OFDM signal to a constant envelope signal. The modulation index of CE-OFDM controls this transformation .In this system based on Taylor series expansion novel receiver for CE-OFDM is designed.

Xingzheng zhu, Bo Yang et.al. [20] proved a system on OFDMA based cognitive radio systems . The OFDMA is flexible in allocating spectrum among SU's. The CR base station adopts a full-overlay scheme to transmit both private and open information to multiple users with average delay and power constraints. For the transmission of open and private information , an online resource allocation scheme is designed based on monitoring the status of primary system as well as the channel and queue states in a CR network.

Mohammed Shaqfeh et.al. [21] proposed a system on overlay cognitive radios with channel aware adaptive link selection and buffer aided relaying. In order to enlarge the average achievable rate region, the author proposes system based on diversity of the fading channels in overlay cognitive radios. In this paper opportunistic scheduling approach is discussed ,the transmission policy selects either primary source or the secondary source to transmit in a given channel block based on channel state information. The secondary source cooperates opportunistically with the primary source by relaying its information. In terms of long-term average achievable rate region ,the use of buffers at the secondary source and primary destination enables achieving significant gains.

Naveen Gupta et.al. [22] proved a system on an adaptive subcarrier sharing scheme for OFDM-based cooperative cognitive radios. OFDM with cooperative cognitive radio network facilitates subcarrier sharing to obtain spatial diversity with opportunistic spectrum access. Adaptive modulation is widely adopted in wireless communication to improve spectral efficiency. The adaptive subcarrier sharing scheme for OFDM based cooperative cognitive radio system, where the cognitive(secondary users) helps the primary system to achieve its communication in exchange with opportunistic spectrum sharing.

Fahimeh Jasbi et.al. [23] proposed a system on hybrid overlay/underlay cognitive radio network with MC-CDMA. The underutilized radio spectrum of the primary networks are utilized by the secondary users (SU's), where the cognitive radio allows the SU's. To maximize the spectral efficiency and fully utilize the primary spectrum, Overlay and underlay transmissions are employed. For Underlay, to avoid causing harmful interference to the primary user's(PU's) the SU's need to transmit at low power. Also to avoid causing harmful interference to the primary user's (PU's) ,the PU's causes high interference to the SU's. Using Multicarrier code division multiple access (MC-CDMA), a hybrid transmission system is proposed that exploits both overlay and underlay CR network because of its interference rejection and diversity exploitation capabilities. To maximize the data rate, the entire spectrum is utilized for underlay transmission to minimize the PU interference, while using the spectrum holes for overlay transmission. Two techniques operate at full load and overload scenarios.

Mahak Sardana et.al. [34] proposed a system on analysis of different Techniques of spectrum sensing. The author discussed different algorithms for spectrum sensing which includes energy based detection, matched filter based detection, cyclostationary feature detection, eigen value based detection and others. In the wireless environment, the channels suffer from fading and hidden node problem, due to this there is an exponential decay in signal strength .To overcome this problem, author proved a system on relay based cooperative spectrum sensing . In this paper , two important parameters for the channel sensing performance are probability of detection and probability of false alarm. The probability of detection increases when the number of cognitive relays increases. The Probability of sensing error decreases and gets better detection probability.

Sana Ziafat et.al. [35] proved a system on performance analysis and implementation issues for techniques of spectrum sensing.The author gives the comparison of various techniques of spectrum sensing , at high values of signal to noise ratio like 20dB and above ,all the techniques obtain 100% results but for reduced signal to noise ratio performances vary. At lower values of signal to noise ratio, matched filter and energy detector gives 30% results .Eigen value detection gives better results than all others. Also All techniques w Fatty M.Salem et.al. [36] proved a system on Matched filter Based Spectrum Sensing . The author has proposed secured authentication protocol, matched filter based spectrum sensing technique and cryptographic digital signature . The performance of Matched-filter based spectrum sensing technique in the presence of Primary User Emulation (PUE) attack is investigated, and the malicious node emulates Primary user's signals to prevent other secondary users from accessing that frequency band. The detecting and authenticating primary user's signal is proposed in this work ,where the multiple stages of 'helper nodes' ,that are initially stationary and close to primary user are responsible for this system. In the next stages the helper nodes are placed at the primary user's coverage area and nodes act as bridges for forwarding the spectrum status information, to enable secondary users to verify the cryptographic signature carried by the helper node's signal. The requirement of probability of a false alarm and the probability of missing are discussed in this work.

orks for certain SNR threshold value, fails below this threshold value.

Fareduddin Ahmed J.S et.al.[37] proposed a system on energy detection with different digital modulation techniques over rayleigh fading channels . The detection of primary user status are the major issues discussed . The author has proposed energy detection with three different digital modulation techniques like BPSK, QPSK, and 16-QAM,analyzed their performances and BER over Rayleigh fading Channel and AWGN channels.

ED works very well in sensing the signals with high SNR over Rayleigh fading channel, but performance degrades at low SNR.

The detection probability of 16-QAM is better than BPSK and QPSK.

All types of signal gives higher BER under rayleigh fading and AWGN with lower SNR, but with higher SNR BER falls in AWGN and rayleigh fading.

Deepa Bhargavi et.al. [38] proved a system on performance comparison of energy, matched – filter and cyclostationarity .The author has

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proposed two architectures that exploit cyclostationarity , spectral correlation density(SCD) detector and the magnitude squared coherence (MSC) detector. The MSC detector offered improved performance compared to other detection techniques, also cyclostationary based detectors are insensitive to uncertainty in noise variance, as the decision statistics is based on the noise rejection property of the cyclostationary spectrum. The proposed cyclostationary detectors for spectrum sensing are strong, when signal of interest has a nonzero spectral correlation at some known cyclic frequency .

Spatial modulation (SM), a wireless transmission technique which is very flexible mechanism to achieve higher spectral efficiency (SE) compared to the conventional modulation schemes .In SM ,only one transmitter is active at each time instant and the other transmitter are set to zero power. Therefore, the transmitter synchronization and inter-channel interference (ICI) are completely avoided. However, in SM each information bits carry both signal constellation and the information. The transmission of the data bit-rate of information is increased. Therefore, the best choice is Spatial Modulation technique and is proposed in future research.

III. MODULATION TECHNIQUES

Sl. No.	Modulation techniques	SNR	SER/BER	Pros	Cons	References
1.	Maximum Ratio Combining(MRC) based detection of Spatial modulation	SNR threshold above which the MRC-based SM is not practically an effective detection scheme.	SER for MRC-based detection are accurate at high SNR's	Detection Complexity of SM can be reduced	Not more efficient detection scheme should be employed in order to benefit from space domain.	[33]
2.	On the Performance of Spatial Modulation: Optimal Constellation Breakdown	The SNR of 30dB performance of 8-PSK SM is 1dB lower than QPSK SM .Reduces the number of transmit antennas by half.	SER performance worsens by increasing the transmission rate or equivalently the number of transmit antennas	Amplitude Phase Modulation (APM) size of 4 indicates smaller number of transmit antennas, provides best performance	Reducing the number of antennas results in increase in probability of error.	[32]
3.	Space modulation with CSI: Constellation Design and Performance Evaluation	Multi Antenna Space Modulation (MS Mod) provides 7-8dB performance gain at midrange SNRs.	MS Mod requires Inter Antenna Synchronization (IAS), provides more significant performance improvement compared with MSSK.	The problem of applying full or imperfect CSIT in the design of S Mod transmission schemes are considered.	Modified SSK Transmission scheme keeps the complexity same as SSK	[31]
4.	Optimal Distributed Beam forming for Cooperative Cognitive Radio Networks	With Overlay approach, The secondary network transmits its own information but keeps SINR at the primary destination above a minimum predefined		An increase in transmit power at the primary source can increase the SINR at primary receiver has negligible effect on SINR at secondary destination	Imposes a controlled interference and imposes minimum QoS to the primary network.	[30]

		threshold.				
5.	Full-Rate Cooperative Spectrum Sharing scheme for cognitive radio communications	System doubles the data rate of primary system and good QoS of secondary system even in low SNR .	Cooperative multiplexing gain is the spatial multiplexing gain it doubles the data rate even in the presence of interference	Improve the link performance, doubles the data rate.	The system achieves doubled data rate without compromising ABER performance.	[29]
6.	Deep belief network for automated modulation classifications in cognitive radio	SNR≥0dB the detection accuracy is above 90% in fading channels,above 85% in multipath fading channels.		Noise resilient spectral correlation function with low complexity, High accuracy of classification ,low computation cost	Real time detection of modulations in experimentally captured signals.	[28]
7.	Multi-Rate Modulation for Cognitive Radio over Land Mobile Satellite Channel			MRM have been worked on unknown channels either bandwidth or time. Unequal power allocation and adaptive MRM increases transmission robustness.	Error control coding techniques are costly to implement due to uncertainty of the channel parameters.	[27]
8.	Quadrature Spatial Modulation in MIMO Cognitive Radio Systems With Imperfect Channel Estimation and Limited Feedback		Tight upper bounded ABER derived using the closed –form PEP for any M-ary Modulation scheme	QSM improves secondary error performance and QSM –CR achieves a gain of 2 to 3 dBs over the SM-CR,QSM enhances the overall system performance	Presence of estimation errors.	[26]
9.	Dynamic interference-limited relay sharing in cognitive radio networks by using hierarchical modulation	~8dB(low signal-to-noise-ratio regime) and to 15dB (high SNR regime).	Average BERs for the two users.	The significant improvement of the throughput of the SU is achieved through rate adaptation, at the cost of negligible degradation in the performance of the PU.	Rate adaption increases the SU's throughput at the cost of a bit degradation in error performance.	[25]
10.	Performance Analysis of Spatial Modulation in Overlay Cognitive Radio Communications	At low SNRs, when size of both APM and Spatial domains are large, the analytical results do not match the numerical results.	Increase in primary APM size as increasing function of N_R and its SER.	Spatial modulation is low complexity, power efficient scheme, increase the data rate of a system, without increasing bandwidth requirements .Data traffic allocate more spectrum to obtain spectrum efficiency, energy efficient Ex:-mobile communication.	The primary receiver should detect both spatial and APM domains, therefore incur more errors.	[24]

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IV. TECHNIQUES OF SPECTRUM SENSING

Spectrum Sensing:

Spectrum sensing is the process of periodically monitoring a specific frequency band to identify presence or absence of PU. It is the key to the application in cognitive radio to provide a method of using the spectrum more efficiently. For the system to operate effectively, and to provide the required improvement in spectrum efficiency, cognitive radio spectrum sensing system must be able to detect any other transmissions, identify and inform the CPU within CR so that required action be taken.

Continuous spectrum sensing:-

Monitor for alternative empty spectrum. As the Primary User returns to the spectrum, the CR (Secondary User) must have alternative spectrum available to switch on.

Monitor type of transmission. Sense the type of transmission received, so that any spurious transmissions and interference from Primary user are ignored. Two Types:

Non-Cooperative Spectrum sensing:-This occurs when CR acts on its own .It configures itself according to the signals it can detect, and the information which is pre-loaded.

Cooperative Spectrum sensing: Sensing will be undertaken by a number of different radios within a CRN. Sensing occurs when a network of CR share the sense information they gain. A Cognitive Base Station receives signals from different radios in the network and adjusts the overall CRN to adjust. Two Approaches:-

Centralized approach: In this approach, the master node within the network collects the sensing information from all the sense nodes or radios within the network. It analyses the information to determine the frequencies that can be and cannot be used. A number of different sense actions at the same time is possible. Where the central node organizes various sensor nodes to take different measurements at different times. Some nodes detects on channel signal levels. While other nodes to measure levels on adjacent channels.

Distributed approach:- No nodes takes control, communication exists between different nodes and are able to share sense information. CR devices sense and analyze the spectrum bands to detect and identify the available spectrum holes. Spectrum sensing also detects the arrival of primary user in the spectrum hole occupied by the secondary user.

Cognitive radio is a promising technology to meet the requirements. The author in the work [39],proposed that detection of primary user signals for dynamic allocation of spectrum hole to secondary users. The figure 2 presents the general model of spectrum sensing.

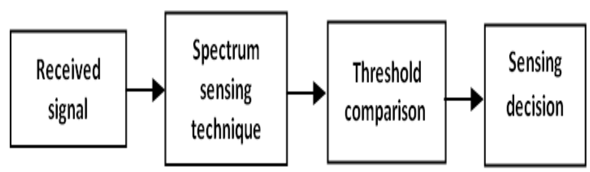

Fig.2: General model of spectrum sensing.

The spectrum sensing model can be formulated as:-

$$Y(n) = \begin{cases} x(n) & H0\text{:PU absent} \\ h * w(n) + x(n) & H1\text{: PU present} \end{cases} \quad (1)$$

where n=1….N, N is the number of samples, y(n) is the SU received signal ,w(n) is the PU signal, x(n) is the additive white Gaussian noise (AWGN) with zero mean and variance δ^2_w and h is the complex channel gain of the sensing channel.H0 and H1 denote respectively the absence the presence of the PU signal .The PU signal detection is performed using one of the techniques of spectrum sensing, to decide between the two hypothesis H0 and H1.The detector output ,also called the test statistic, is then compared to a threshold in order to make the sensing decision about the PU signal presence. The sensing decision is performed as:

$$\begin{aligned} &\text{If } T \geq \gamma, \ H1 \\ &\text{If } T < \gamma, \ H0 \end{aligned} \quad (2)$$

Where T denotes the test statistic of the detector and γ denotes the sensing threshold. If PU signal is absent, SU can access to the PU channel.

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Otherwise it cannot access to that channel at that time[40].

5.1 Classification of techniques of spectrum sensing:

They are broadly classified into three main types as transmitter detection or non-cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection technique is further classified into energy detection, matched filter detection, cyclostationary feature detection, waveform detection, eigen value detection [39, 41]. Figure-3 shows the detailed classification of spectrum sensing technique.

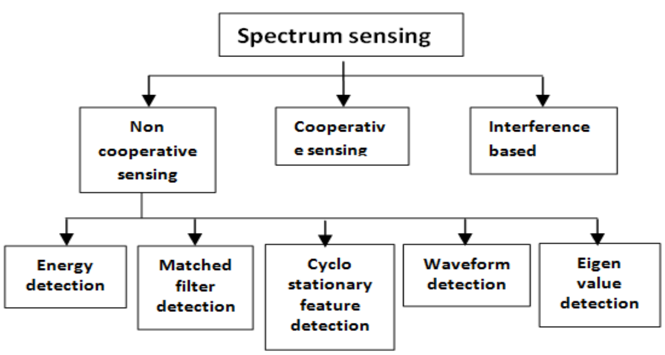

Fig.3 : Classification of techniques of spectrum sensing

5.2 Energy detection:

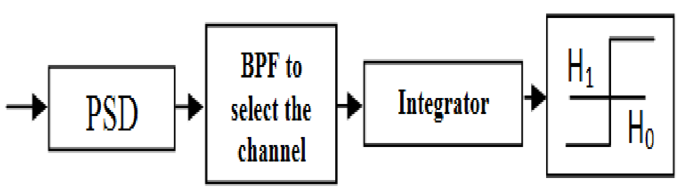

Fig.4: Block diagram of Energy detector [38].

Where, H_0=Absence of user, H_1=Presence of user
The block diagram of Energy detector is shown in figure 4. In this method, the signal is passed through band pass filter of bandwidth W and is then passed through integrator, where the signal is integrated over time interval. This signal is then compared to a predefined threshold, to discover the existence or the absence of the primary user. The threshold value can be set to be fixed or variable based on channel conditions. The decision based energy detection can be expressed as:-

If $T_{ED} \geq \lambda$, PU signal present

If $T_{ED} < \lambda$, PU signal absent ——— (3)

Where λ denotes sensing threshold, T_{ED} denotes the energy of the SU received signal [40]. Based on the sensed energy, this non coherent detection method detects the primary signal. There is no requirement on a priori knowledge of primary user signal. In cooperative sensing, energy detection is the most popular sensing technique. It performs better at high SNR's it has low computation and implementation complexity and Sensing time is less than in feature detection [39].

5.3 Matched filter detection:

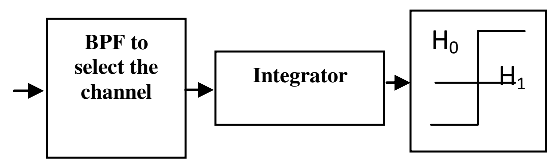

Fig.5:- Block diagram of Matched filter detection

Where H_0=Absence of user, H_1=Presence of user
Matched filter is a coherent detection technique and is a linear filter designed to maximize output signal-to-noise ratio for a given input signal [41].It employs a correlator matched to the signal of interest [36]. Matched filter technique is applied, when secondary user has a priori knowledge of primary user. The operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal The operation of matched filter detection is expressed as:-

$$Y(n) = \sum_{k=-\infty}^{\infty} \mathbf{h}[\mathbf{n}-\mathbf{k}]\, \mathbf{x}[\mathbf{k}] \quad \text{———} \quad \mathbf{(4)}$$

Where x is the unknown signal and is convolved with the h, the impulse response of matched filter that is matched to the reference signal for maximizing the SNR. Best performance at all range of SNRs (if the receiver has enough knowledge of Transmitter)requires near perfect transmitter information at receiver .Transmission characteristics can be chosen to improve accuracy. Least sensing time required [39].

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5.3 Cyclostationary Feature detection:

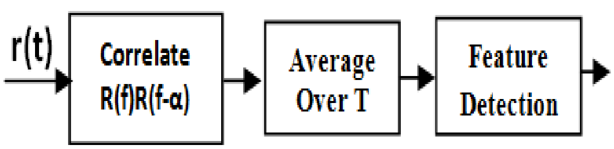

Fig. 6:-Block diagram of Cyclostationary Feature detection

Cyclostationary are the processes having periodicity in statistical properties like mean, autocorrelation of primary user waveform. Using this CR can detect random signal with specific modulation technique in presence of random stochastic noise. he features are extracted using Spectral Correlation Function(SCF), which has two dimensional function having cyclic frequency α. SCF having $\alpha = 0$ define power spectral density [35]. This technique takes large time in computation and is complex, but provides better performance than energy detection .Performs well at all range of SNR's [39].

5.4 Waveform detection

Waveform based sensing, also called edge detection, is based on the continuous wavelet transform and allows finding the signal decomposed coefficients. The wavelet transform allows mapping from one dimensional signal x(t) ,to two dimension coefficients f(s, u). The Frequency-time analysis can be performed at the frequency corresponds to parameter s, at time constant corresponding the parameter u. The wavelet based sensing is operated, by computing the continuous wavelet transform of the signal to perform the power spectral density. The local maximum of the power spectral density corresponds to the edge, which is compared to a threshold to decide on the spectrum occupancy [40].

The sensing decision is :-

$$\left.\begin{array}{l}\text{If } \; e \geq \lambda \text{ , PU signal absent} \\ \text{If } \; e < \lambda \text{ , PU signal present}\end{array}\right\} \text{———— } \mathbf{(5)}$$

Where e is wavelet edge and λ denotes sensing threshold. Performs well at each value of SNR's, Medium complexity, Requires transmitter signal to contain a known pattern, less sensing time[39].

5.5 Eigen Value Detection:

Eigen value detection is based on random matrix theory. Primary user waveform information is not required. It is not complex [35].The Block diagram of Eigen value detection is shown in figure 7.

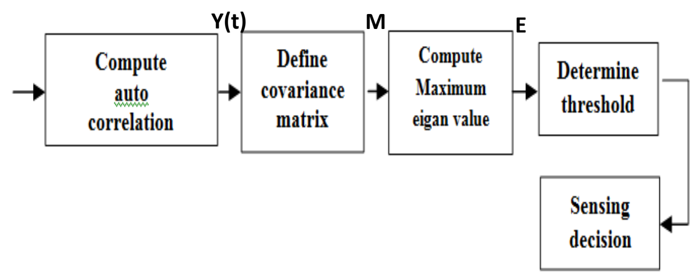

Fig.7:-Block diagram of Eigen Value detection

Performs well at all SNR's ranges ,high computation complexity ,low implementation complexity, Does not need prior knowledge of the signal power or noise power but are based purely on the sensed signal, maximum and minimum eigen values can be chosen to improve accuracy, less sensing time [39]. Narrowband sensing techniques exploit the spectral opportunities over narrow frequency range .In literature many narrowband sensing algorithms were proposed. Energy detection, feature detection are most popular algorithms and eigen value based detection are the most advanced.

VI. CONCLUSIONS

Cognitive Radio technology as discussed has proved to be a great boon for efficient modulation and spectrum utilization to fulfill the spectrum demand of growing wireless technologies. This paper gives an overview of different modulation techniques and their comparison. The system models that implement spectrum sensing algorithms, classification of techniques of spectrum sensing and their comparison. It also provides a summary of research challenges associated with modulation techniques resulting in high data rates services, mobility in wireless networks, reduced BER, increased data throughput, augmented coverage and network capacity, reduce sidelobe power level with 0dB

PAPR, frequency domain shaping in reducing energy in signal tail. Research challenges with spectrum sensing in different network approaches. The main focus of this paper, is the study of advanced modulation techniques suitable for 5G - 6G communications, also the study includes techniques of spectrum sensing like energy detection, matched filter detection, feature detection .

Multi-Rate modulation the dy-homogeneous signal properties to transmit over multiple band frequencies and time scales to achieve robustness, unequal power allocation over the symbols of MRM according to data sensitivity. Spatial modulation in Overlay CRN, is a MIMO systems, it aims to increase the data rate of the system without increasing the bandwidth requirement and negligible degradation in performance of the PU. Quadrature Spatial modulation enhances the overall system performance in the presence of estimation errors. Narrowband Spectrum sensing plays a important role in wideband sensing applications. Researchers can find more effective solutions to deal with research challenges of both modulation techniques and spectrum sensing. To improve various detection parameters, Dual stage sensing has a great scope of research in future that can combine different spectrum sensing.

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