Energy Detection using Analog to Information Converter Block in Cognitive Radio

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Abstract:- *The fast development of wireless applications and services has resulted in a large demand for spectrum resources. The cognitive radio is a novel notion that can be applied to a variety of situations. wireless spectrum resources in a cost-effective and sufficient manner. The Spectrum sensing is a cognitive radio function. This is a paper about develops a wavelet packet-based energy detecting technique For spectrum sensing, use a transform. The team's performance The proposed technique is tested with different Signal to Noise ratios. Ratios for various sample sizes, as well as the likelihood of a false alarm Segmentation level and wavelet function used in wavelet analysis Convert a packet. Simulations yield the best feasible parameter setting, resulting in the most accurate detection of the primary signal. Simulations produce the best possible parameter configuration, resulting in the most successful primary signal detection. Simulations yield the best feasible parameter setting, resulting in the most efficient identification of the primary user signal.*

Keywords: ***Cognitive Radio; Energy Detection; Spectrum Sensing; Wavelet Packet Transform***

I. Introduction

The radio frequency spectrum has a finite amount of capacity. With advancements in technology, more amounts of data must be conveyed. The bandwidth requirement for this is growing at an exponential rate. Due to user demand and geographic constraints, a considerable part of licenced bandwidth is currently unused the majority of the time. The cognitive radio is capable of meeting the bandwidth need. The main premise of cognitive radio is to determine whether or not the principal (authorized) user is using the bandwidth allotted to them. Cognitive radio allows the secondary user to use the primary user's spectrum when the prime user is not utilising it.

The cognitive radio must change the secondary user to a different bandwidth if the primary user wants to use his allocated bandwidth, [2]. This process must be carried out in such a way that no interaction between the Primary User (PU) and the Secondary User (SU) occurs (SU).

Spectrum sensing, spectrum analysis, and spectrum judgement are the three functions of the cognitive radio. Several strategies for detecting the principal user have been proposed by researchers.

matched filtering detection (MFD), radio identification based (RID) Energy detection (ED), waveform detection (WD), and cyclo-stationary feature detection (CFD) are just a few of the ways [4].

Because the energy detection technique is the simplest, requires the least amount of calculation, and is simple to implement, it is widely used for spectrum sensing. The main issue with energy detection (ED) is that detection achievement degrades in the presence of varying unknown noise power. The knowledge of the primary user's signal is not necessary at the receiver for identification in this manner. The signal is evaluated by comparing the output of the energy detector to a noise-dependent threshold. The setting of a threshold for main signal detection is a significant difficulty. The probability of detection (PD) changes as different factors are changed.

Energy detection is the simplest method for bandwidth sensing because it reduces the probability of computation and is simple to implement. The main issue with energy detection (ED) is that its performance degrades when the noise power fluctuates. For identification in this technique, the receiver does not need to know the primary user's signal. By comparing the outcomes of the energy detector with a noise-dependent threshold, the signal is recorded. The choice of a threshold for primary signal detection poses a significant challenge. With changes in various parameters, the probability of detection (PD) changes.

Cognitive radio is a concept that will change the world in the future. This technology has had a major impact on all organizations that transport data, including all communication-related companies, the military, and the medical field, among others. For the majority of users, cognitive radio can offer high-bitrate information transmission without interruption [5] [6].

A crucial feature of cognitive radio is bandwidth sensing (CR). The goal of cognitive radio is to use the spectrum's empty channels to ease traffic congestion in congested areas. This software defined radio relies heavily on accurate spectrum detection. Fading also shouldn't be used to restrict or hinder interaction. Spectrum sensing is only relevant to frequency spectrum in cognitive radio. Observing a licenced user's unused spectrum is critical to the success of the cognitive radio idea. [11]-[12]. As a result, the primary user is continuously sensed to allow SU channel movement to another part of the spectrum in the event that the prime user commences transmission. This is a must.

This necessitates achieve this type with the lowest possible error rate. The crux of the problem is the detection threshold. Under the worst scenario, this should take into account the interference. The ability to correctly detect the principal user is critical for future spectrum analysis and decision-making procedures [11]-[12]. This is defined as dynamic bandwidth management. There are several spectrum sensing methods that are used for spectrum sensing, including: Detection of Matched-Filters: If CR has previous knowledge of the PU, the matched-filter (also known as coherent detector) might be considered a best sensing approach. It's incredibly precise since it maximises the signal-to-noise ratio (SNR) received.

Cyclostationary Feature Detection Implementing a Cyclostationary Feature Detector is a dynamic spectrum technology that can distinguish the modulated signal from additive noise. If the mean and autocorrelation of a signal are both a function of frequency, it also seems to be cyclostationary. Using the information embedded in the PU signal that is not included in the noise, cyclostationary feature identification may identify PU objects from the background at very low Signal - To - noise (SNR) [10]-[12].

Energy Detection: Because of its limited calculation and implementation complexity, detection method is the most prevalent method of spectrum sensing. The receivers are not required to know anything about the principal users. The primary signal is simply treated as noise by an energy detector (ED), which determines the existence or existence of the primary signal based on the energy of the connotations [05]-[07]. Table I compares the results of various research projects in cognitive wireless spectrum sensing.

II. PROPOSED METHODOLOGY

Figure 1 shows the model of the system for a MIMO-OFDM based transmitters with Mt antennas and a receiver with Mr antenna. MIMO-OFDM transmitters can be used as a primary user to indicate busy channels or as a secondary user to represent idle channels for detecting purposes. MIMO-OFDM transmitters is treated as another CR user attempting to communicate with the MIMO-OFDM transmitter CR receiver for reconstruction purposes. Signals pass via the IFFT block first in a traditional MIMO-OFDM based CR model before being sent by numerous transmitting antennas.

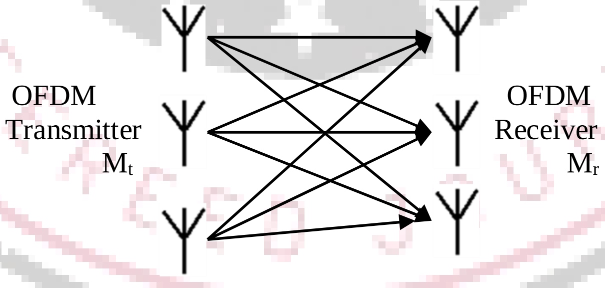

Figure 1: MIMO-OFDM Transmitter and Receiver

MIMO-OFDM transmitters can be used as a primary user to represent busy channels or as a secondary user to represent idle channels for detecting purposes. MIMO-OFDM transmitter is treated as another CR user trying to engage with the MIMO-OFDM transmitter CR receiver for restoration purposes. Signals pass via the IFFT block first in a traditional MIMO-OFDM based CR model before being sent by numerous transmitting antennas. Because wavelets are localised in both time and frequency, whereas the typical Discrete wavelet transform is only localized in frequency, the IFFT block is substituted with the IDWT block in this study.

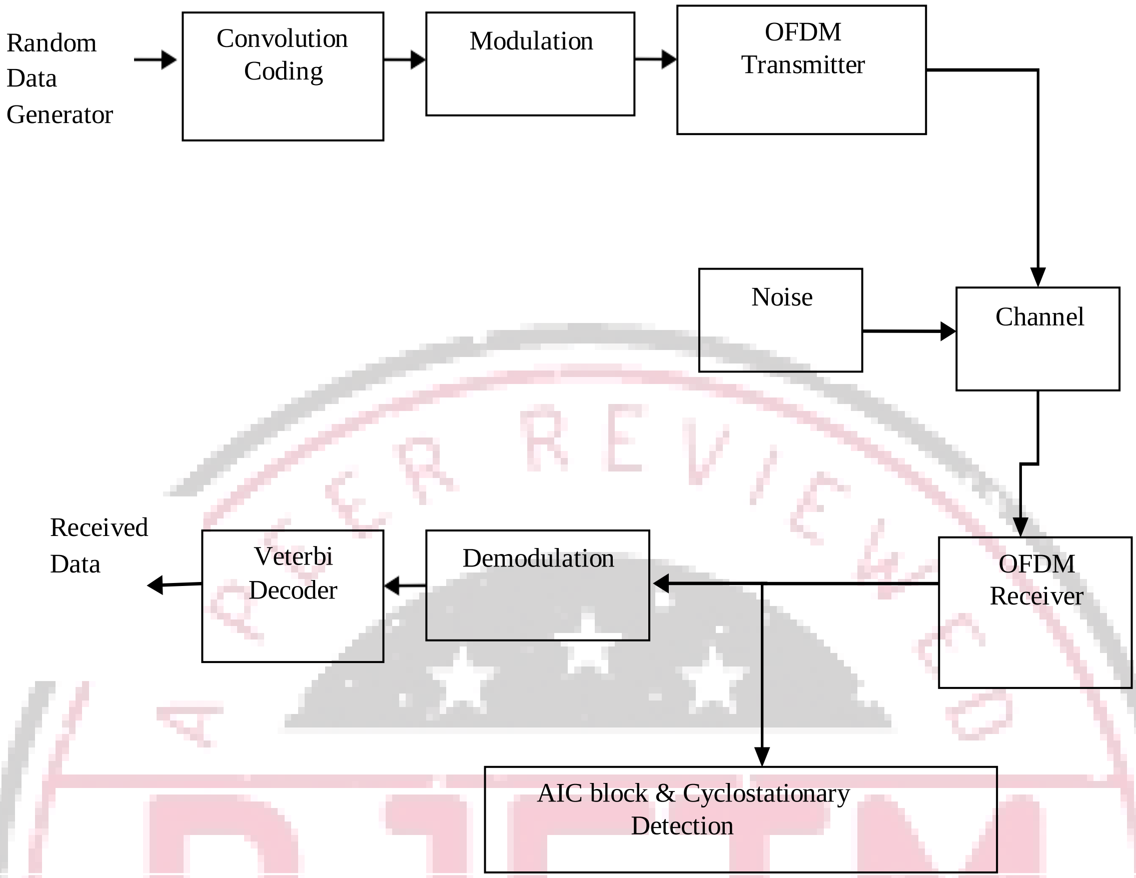

Fig 2:- Flow Diagram of Transceiver for MIMO-OFDM

After passing through into the IDWT block, the signal is given a cyclic prefix before being broadcast. The received signal at the antennas is first recombined with a mixing vector and then sent for deconvolution in the proposed paradigm. A cyclostationary model is also included in this developed framework in order to determine whether the signal received is from the primary or secondary user. If the primary user sends a signal, the CR user instantly exits the channel. If the signal received from the transmitter was intended for the CR receiver, it recreates it. The MIMO-OFDM-based transmitter and MIMO-OFDM-based receiver are the two most important components of the model presented in Figure 2.

OFDM Transmitter:-

Let x denote the reference voltage that will be sent over MIMO using Mt and Mr antennas. For the mth subcarrier, x=[x1(m), x2(m)........xMt(m)] and for the ith transmitting antenna, xi=[xi(1), xi(2), xi(Ns)].

Data samples are modulated using the QPSK, BPSK, and 64-QAM modulation schemes . After that, IDWT is performed using the following equation:

$$d(k) = \sum_{m=0}^{\infty} D_m^n \, 2^{\frac{m}{2}} \psi(2_k^m - n)$$

Where D^n are the wavelet coefficients and ψ(t) is the wavelet functional for each sub - (number k, $0 \le k \le N-1$) with reduced factor m times and displaced n times. The wavelet-coefficients are used to characterize signals in terms of scale, location, and time. The process is reversed at the receiving end. The information is sent through a noisy channel. Rayleigh fading with AWGN noise is the channel. This transmission's equation is as follows:

$$x' = x + n$$

Where x is the sending signal and n denotes the noise introduced into the channel. Noise is added to the new signal. As a result, the recipient Mr will get x′ .

***OFDM Receiver*:**

The impulse response is subsequently processed by the j-th receive antenna's merging vector. Let's write the merged vector as s(j). Then, as illustrated in Figure 4, the s(j) is transmitted to the AIC block, which is utilised to compressing the sparse signal, and the LFSR generates a pseudorandom pattern to use as a modulator.

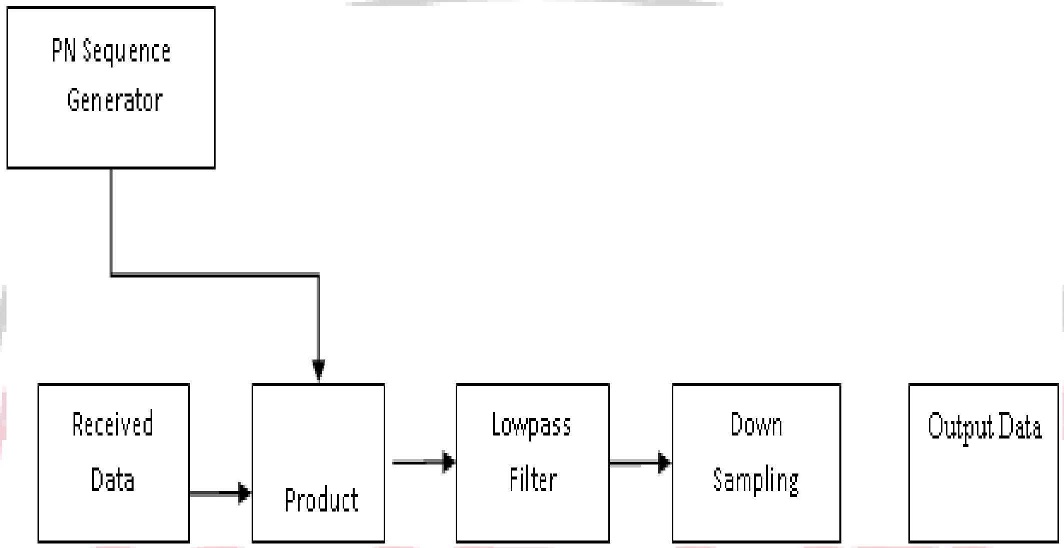

Fig 3:- AIC Block Diagram

After that, the modulated signal is sent through a low pass filter. After passing through with a low pass filter, the input is down sampled to extract the non-zero discrete values from the scanty signal. The AIC block functions as a compressive sampler, with the difficulty of the optimization problem growing significantly with the length of the signal.

Cyclostationary Detection:

The signal produced from the AIC block is regarded as cyclo-stationary. Since it uses the cyclic correlation function to detect the presence of signal in a particular spectrum, the cyclostationary features extraction method is also known as the spectral correlation method. Cyclo-stationary processes have periodicity in statistical properties such as mean and autocorrelation. CR can detect random signal in the presence of noise by employing periodic statistics of the principal user waveform. The spectral correlation function is used to extract these features. The basic block diagram of the cyclo-stationary based detection method is shown in Figure 4.

The signal is processed through a filter in the cyclo-stationary detection block. A band pass filter is being used to pass a particular frequency band while rejecting frequencies from outside that range. The primary function of a filter in a transmitter is to keep the outgoing signal's bandwidth within the transmission band. The signal is then transformed to a digital signal. The process of transferring a large number of input values to a smaller set of values, such as reducing values to some unit of accuracy, is known as quantization. The signal is then transmitted through the DWT block, which converts the signal from time domain to frequency domain. Windowing is a technique for reducing unwanted oscillation inside a band.

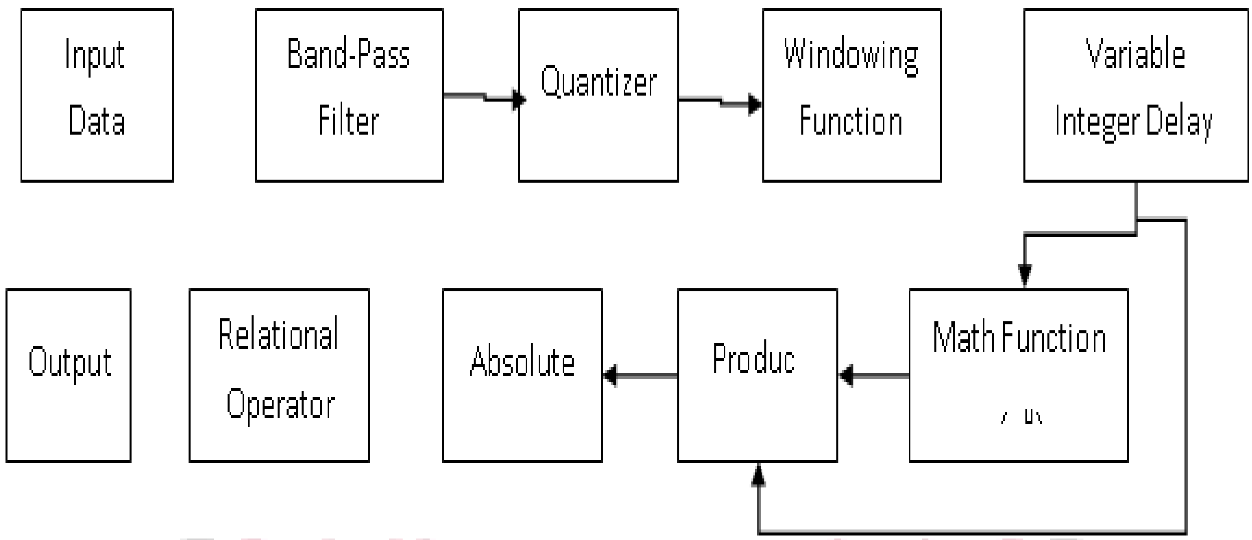

Fig 4:- Cyclostationary Detection Model

III. Result Analysis

False Alarm and Decision Threshold Relationship: The link between the false alarm P_f and the selection tolerance value is as following.

$P_f=(1-\lambda_t)^{M-1}$..................................(1)

Proof: When the noise in the network is additive white Gaussian noise, the detection threshold's Continuous Distribution Function (CDF) is as follows:

$F_\lambda = 1-(1-\lambda)^{-1}, 0 \leq \lambda \leq 1$ ....(2)

The false alarm Pf is calculated as

$P_f = [\lambda \geq \lambda t|H_O] = 1 - F\lambda$ ....(3)

Where H_o denotes the lack of a principal user.
The association between false alarm and selection cut-off has been proven by replacing the value of F into equation 3. So, threshold can be computed as:

$\lambda_f = P^{\frac{1}{M-1}}$ ....(4)

Relation between Probability (P_m) of misdetection and probability of detection (P_d):For the MIMO-OFDM basedcyclo-stationary detection, Probability of misdetection (P_m) is calculated as:

$$P_m = 1 - Q(\frac{\lambda_t\sqrt{N_s(M_r-1)\left(1-\frac{1+\gamma}{N_s\gamma}\right)}}{1+\gamma} - \frac{\sqrt{N_s}}{1+\frac{M_r-1}{N_s\gamma}})$$

Proof: Probability of detection (P_d) is calculated as:

$P_d = [[\lambda \geq \lambda_t|H_1]$

$$= Q\left(\frac{\lambda_t\sqrt{N_s(M_r-1)\left(1-\frac{1+\gamma}{N_s\gamma}\right)}}{1+\gamma} - \frac{\sqrt{N_s}}{1+\frac{M_r-1}{N_s\gamma}}\right) \quad ....(6)$$

Where Q(.) denotes the q-function, SNR at the receiver denotes the signal-to-noise ratio (SNR), and H_1 denotes the presence of the principal user.

The probability of misdetection(Pm) is:

$$P_m = 1 - P_d \text{ ....(7)}$$

Cumulative Distribution Function (CDF) and Decision Threshold Relationship: The relationship between the Continuous Distribution Function (CDF) and the decision lower limit is as follow:-

$$CDF=1-(1-\lambda_t)^{M-1},\ 0\leq \lambda_t \geq 1 \text{..............(8)}$$

In figure 5, the frequency of false alarm, Pf, is plotted against the predefined threshold, t. The probability of a false alert decreases as the number of samples increases, as seen in the graph.

In figure 6, the Cumulative Distribution Function, or CDF, is shown against the predefined threshold, or t. The likelihood of CDF grows as the number of samples increases, as shown in the graph.

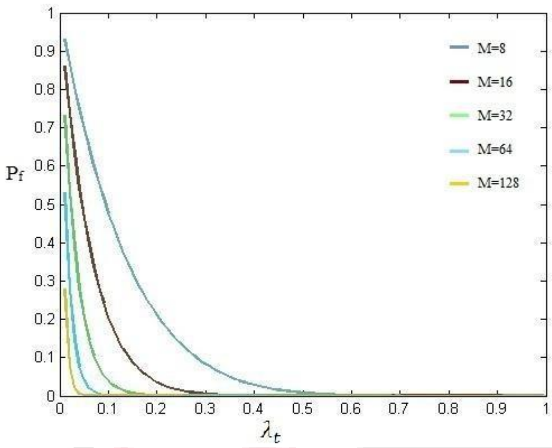

Figure 5: Pf vs λ_t

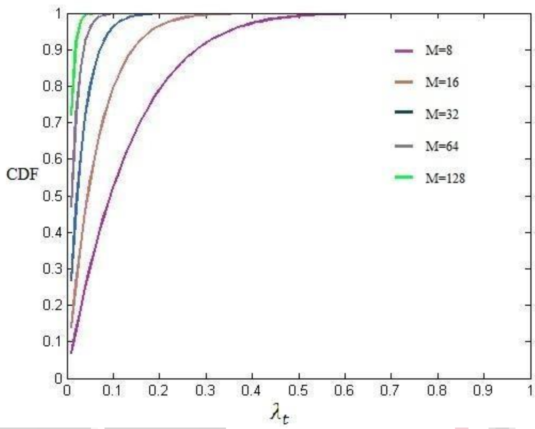

Figure 6: CDF vs λ_t

Probability of Detection (Pd)Evaluation :-

For performance assessment, Table I shows the Pd against SNR ratio. The present work in [1] is concluded based on comparative analysis. It has been discovered that when the SNR value increases, the proposed work achieved the best detection probability.

Table I: P_d Vs SNR Ratio

SNR(in db)	Proposed	Existing [1]
-15	0.9583	0.1
-10	1	0.3
-5	1	1
0	1	1
5	1	1
10	1	1

MSE Evaluation with Different Modulation Scheme :-

The mean squared error (MSE) of signal $\bar{x}$ and its estimate $\bar{x}'$ as:

$$MSE = E[\,\overline{(\bar{x} - x')^2}\,]$$

Where E[.] is the expectation operator

Figure 7 and 8 illustrates MSE Vs SNR for 2*2 and 3*3 MIMO OFDM respectively. From comparative analysis it is concluded that the minimum error is achieved by BPSK and 64-QAM modulation scheme.

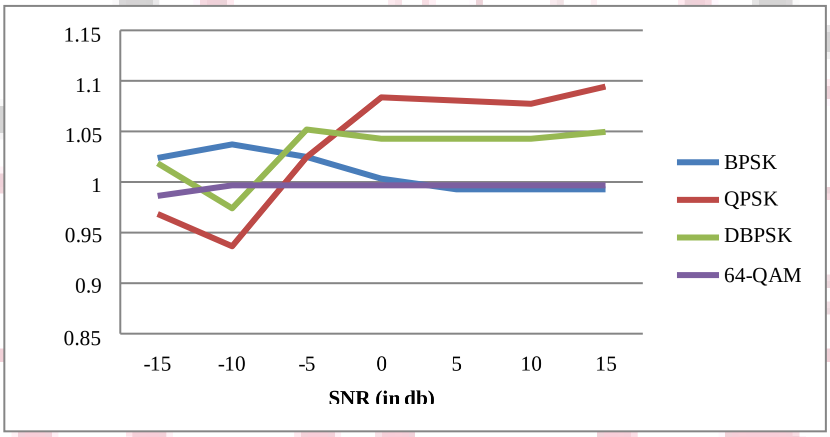

Figure 7: MSE Vs SNR for 2*2 MIMO OFDM

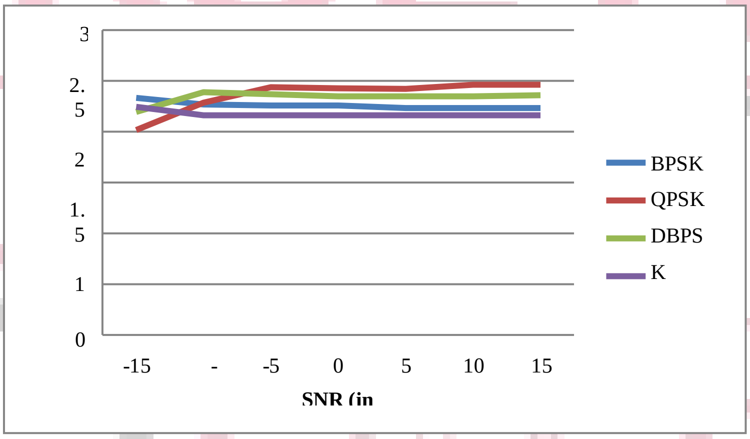

Figure 8: MSE Vs SNR for 3*3 MIMO OFDM

IV. *Conclusion*

In this article, a cyclostationary-based spectrum sensing detection method is constructed in Simulink. By comparing it to a decision threshold, Rayleigh fading and AWGN noise are used to efficiently detect the presence of the principal user. The AWGN noise model has an impact on minimum noise. Using a cyclostationary-based detection approach, the practical network may be constructed to make the most of the available spectrum. This approach has an advantage over other methods in that other methods, such as matching filter and energy-based detection, require prior knowledge of the principal user, whereas this method does not. From its intended CR emitter, a CR receiver. When analysing spectrum sensing in this study, the chance of false alert is employed. Similarly, different modulation schemes are used to analyse BER and MSE.

The goal of this research is to use signal processing techniques to detect and characterize spectrum sensing techniques for cognitive radio networks. The sensing has been examined for a few specific instances, and the supervisor has been notified of these behaviours for further action. In the future, bit error rates for various sensing methods can be examined and compared for improved outcomes. From its intended CR emitter, a CR receiver. When analysing spectrum sensing in this study, the chance of false alert is employed. Similarly, different modulation schemes are used to analyse BER and MSE.

V. References

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