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Estimation of Best Spectrum Sensing Concept in Cognitive Radio Networks

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Abstract*—: Cognitive radio is a versatile and sharp radio system learning that can naturally recognize accessible divert in a remote range and change correspondence parameters empower more data to run at the same time. Psychological radio is estimated as a point towards which a product characterized radio stage ought to create. The significant elements of CR incorporate Spectrum detecting, Spectrum portability, Spectrum choice, Spectrum sharing. Range detecting frames the base of subjective radios and is one of the principle strategies that empower the intellectual radios to improve the range use. Range detecting is for the most part done in the recurrence and time area. In this paper we will analyze about and investigate four noteworthy range detecting systems to be specific Energy detection, Matched filter spectrum detection, Cyclostationary spectrum detection and Waveform based spectrum detection. In view of the similar outcomes we can appraise the best spectrum detection for remote portable applications.

Index Terms: Cognitive radio; energy detection; cyclostationary detection; spectrum sensing; matched filter detection, waveform detection.

I. INTRODUCTION

The theory of cognitive radio was proposed by Joseph Mitola in a seminar at the Royal institute of technology in Stockholm in 1998 and published the same in 1999. It is a novel approach in wireless communication which will increase the wireless spectrum utilization. A cognitive radio [1] network design includes elements matching to both the unimportant user (secondary user) and the main user (primary user). The unimportant system is self-possessed of a set of users which have or do not have a minor base station, all of which are provisioned with Cognitive Radio function.

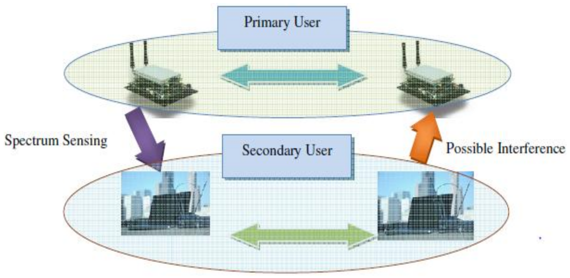

Fig.1.Cognitive Radio Network

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Spectrum sensing [2] is the process of regularly monitoring an exact frequency band, aiming to recognize if a primary user is present or absent. A major test conducted in cognitive radio network suggests the secondary user needs to spot if the primary user is using the approved spectrum and exit the spectrum as soon as required to avoid interfering with the primary user. .

The Cognitive Radio facilitates the procedure of locating spectrum holes which are nothing but empty frequency bands. This type of spectrum sensing may not need complicated signal processing. A spatial spectrum hole is a band which is not used by the Primary User at some spatial regions; and therefore can be used by Secondary Users as well as others.

The conditions of power spectra of inward RF is classified into three distinct types,

- White spaces: This indicates absence of primary users and utilization without limits.
- Gray spaces: This indicates presence of primary users but the interference power doesn't go above interference temperature value (fixed threshold).
- Black spaces: This indicates high usage by the primary user. Therefore the secondary users will have to use an interference cancellation technique for communication.

II. ANALYSIS OF VARIOUS SPECTRUM SENSING METHODS& RESULTS

A. *ENERGY DETECTION*

Energy detection is the most broadly perceived technique for its low computational and execution complexities. It is a great degree fundamental strategy in which the recipients needn't waste time with any data on the primary user's signal [3]. The energy detector's output is compared with a threshold for detecting a signal.

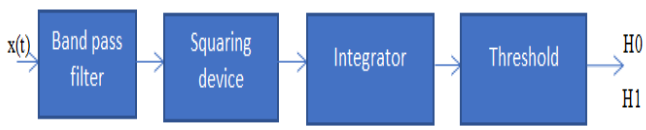

Fig.2. Signal processing in energy detection

In this technique as shown in Fig.2, the input is accepted by the BPF of the data transfer capacity W and is incorporated after some period interim; the yield of the square of an integrator is formerly contrasted with a predefined edge. The objective of this examination is to find the presence or nonappearance of the authorized client.

The estimation of beginning can set to be flexible or settled in view of the states of the channel. Energy detection spectrum sensing is otherwise known as Blind Signal detector, on the grounds that it disregards the structure of the signal.

Mathematical Model

Energy range = $|x(\omega)|^2 (t_2 - t_1)$….(5)

$V_T = \sqrt{2\sigma_n^2 log\left(\frac{1}{P_{fa}}\right)}$ ….(6)

$$V_T(\omega) = \int_{t_1}^{t_2} V_T\, e^{-j\omega t}\, dt = j\frac{V_T}{\omega}\left[e^{-j\omega t}\right]_{t_1}^{t_2}$$

$$= V_T\left[\frac{e^{-j\omega t}}{-j\omega}\right]_{t_1}^{t_2} = \frac{V_T}{\omega} e^{j\left[\frac{\pi}{2} - \omega(t_2 - t_1)\right]}$$

$$|V_T(\omega)|^2 = \frac{V^2}{\omega^2}(t_2 - t_1) \;....(7)$$

$$P_{fa} = 10^{\frac{V_T^2}{2\sigma_n^2}} \;....(8)$$

Where:

σ_n^2 = Power of noise

V_T =Threshold Voltage

ω =Angular frequency

P_{fa}=False alarm probability

$$W_i = \sum_{i=1}^{n} LL_i \;....(9)$$

$$W_{x..N} E_j = Y_j E_j ; j = 1 \; to \; M \;....(10)$$

$$Signal\ power = \frac{1}{P}\sum_{i=1}^{P} Y_i \;....(11)$$

$$Noise\ power = \frac{1}{M-P}\sum_{i-P+1}^{M} Y_i \;....(12)$$

a. Simultion

The energy detection spectrum model was implemented using NS2.The following results were observed. The plot showed a gradual decrease in the complementary region of convergence (fig. 3) and steep increase in SNR for varying false alarm probability (fig. 4).

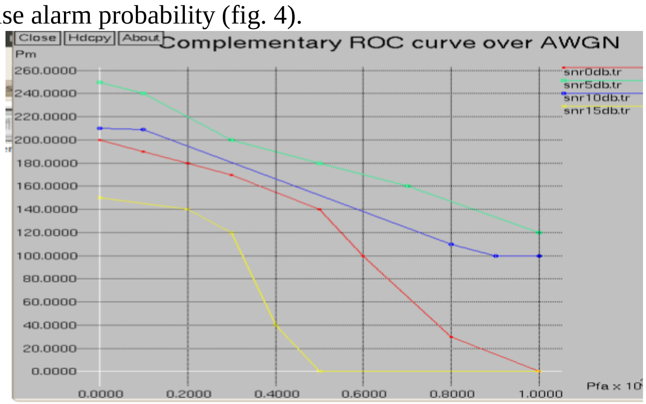

Fig.3. Complementary ROC curve over AWGN

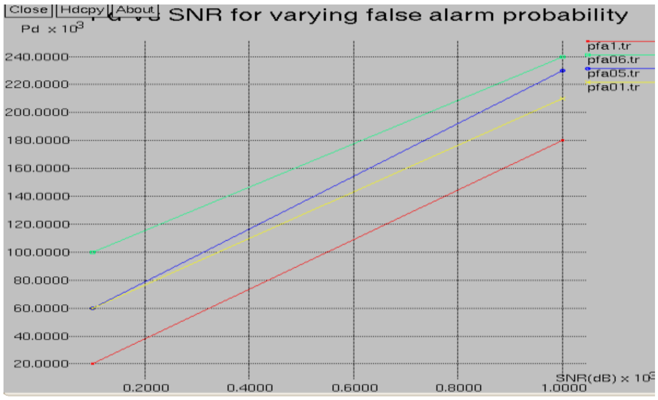

Fig.4. Plot for varying false alarm probability

B. MATCHED FILTER DETECTION

In matched-filter detection, the dynamic threshold is used to recover the spectrum-sensing effectiveness and provide better performance in cases of poorer SNR [4]. Integrating matched-filter detection with spectrum sensing better manages the use of the spectrum, although this requires prior knowledge of the signal to be detected. Thus, the received signal is demodulated and the matched-filter method is applied. The time it takes for this method of detection is a lot shorter than with any other method. It decides if the signal is present or not by accentuating the new signal after filtering and suppressing the noise at the same time. There will be a sharp contrast between the noise and the signal and the output will show a large peak if there is a presence of a signal. . In the event that the signal is missing, no such pinnacle will show up. Therefore by maintaining the probability of error to a minimum, we can decide if a signal is present or absent using matched filter. Matched filter has the advantage of decreasing the noise component and increasing the signal component at the same instant. . This is clearly proportional to boosting the signal amplitude to the commotion adequacy proportion at some moment at the yield. It demonstrates more helpful in the event that we go for square of amplitudes. Consequently the coordinated channel is outlined such that it will expand the proportion of the square of signal amplitude to the square of the noise amplitude, where Y (t) is the usual indicator across the t^{th} subcarrier, H(t) is the channel co-efficient of the t^{th} subcarrier, and N(t) is the noise across the t^{th} subcarrier.

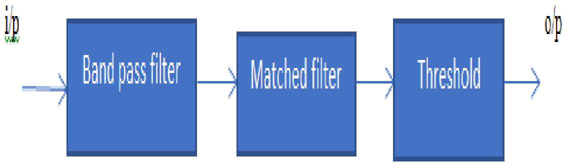

Fig.5.Signal processing in matched filter spectrum sensing

The Fig.5 of matched filter detection comprises three sections, i.e. band pass channel, coordinated channel and decision making.

Coordinated channel task is comparable to relationship in which the unknown signal is convolved with the channel whose impulse is the mirror and time shifted version of a reference signal.

The task of coordinated channel location is communicated as

$Y[n] = \sum_{k=-\infty}^{\infty} h\,[n-k]x[k]$....(13)

Where 'x' isn't the known signal and is convolved with the 'h', the impulse response of coordinated channel that is compared to the reference signal for expanding the SNR. The cognitive users must know the information from the primary users to detect spectrum holes using matched filter detection. This spectrum sensing technique is also very effective in the presence of certain level of noise.

Finally, in the SNR to determine whether the signal is absent or present; if the arriving signal is better than the threshold value, there will be a detection, otherwise not:

$s(t) = \{n(t)\}H0$....(14)

$s(t) = \{h * P(t) + n(t)H1\}$.....(15)

where S(t) is the secondary user, P(t) the primary user's transmit signal, n(t) is AWGN, h the breadth addition of the network, H0 = there's no primary user, and H1 = primary user is present.

b. System Model

We can express the composite OFDM modulated signal by:

$Z(t) = \sum_{K=0}^{N-1} \quad A(t)ke^{j2\pi k\Delta ft}$....(16)

An orthogonal signal satisfies the following condition: Tq .6f = 1. In between the symbols, a CP is added to avoid intersymbol interference (ISI). Therefore the modulated signal (OFDM) can then be expressed as:

$z_{cp}(t) = \sum_{K=0}^{N-1} \quad A(t)ke^{j2\pi k\Delta ft} + cp$....(17)

where Zcp (t) is the OFDM signal transmitted OFDM signal.

The signal received is given by :

$Y(t) = H(t)z_{cp}(t) + N(t)$z....(18)

where Y (t) is the received signal across the t^{th} subcarrier, H(t) is the channel co-efficient of the t^{th} subcarrier, and N(t) is the noise across the t^{th} subcarrier.

C. Simulation

After simulating the design of Matched Filter using NS2, the spectrum holes were detected efficiently in the presence of tolerable noise and the plot of time versus amplitude was obtained as shown in Fig.6.

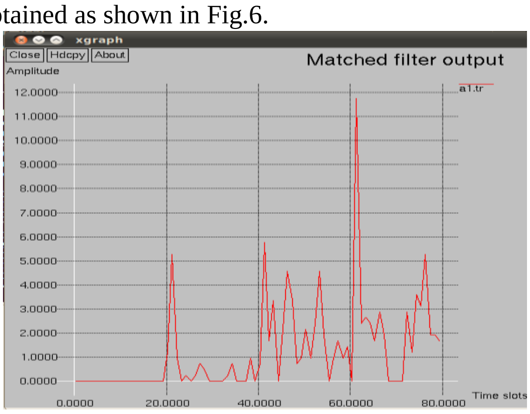

Fig.6. Plot of time slot versus amplitude for matched filter detection

C. CYCLOSTATIONARY DETECTION

Cyclostationary feature detection is a capable alternative particularly in situations where energy detection, portrayed straightaway is so useful. Be that as it may, this method requires a huge computational limit and altogether long perception times [5]. By the other side, the wide-sense stationary noise does not have any correlation. The modulated signal energy and noise energy are differentiated by a spectral correlation function to detect the presence of a primary user. This spectrum sensing is resistant to uncertainities caused by noise and exhibits better performance in low SNR regions. Although it needs prior knowledge of the characteristics of the signal, it has a key feature of differentiating the various types of primary signals from Cognitive radio transmissions. This will facilitate the elimination of requirement for synchronization in cooperative sensing.

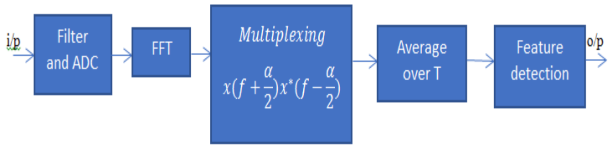

Fig.7. Signal processing of cyclostationary detection

a. System Model

In a cyclostationary signal, the autocorrelation should be a periodic function of time t. A zero-mean constant signal x(t) is called cyclostationary if its time varying autocorrelation function$R_{XX}(t,\tau)$is defined as,

$R_{XX}(t,\tau) = E[x(t)x * (t)]$....(19)

is periodic in time t for each lag parameter and it can be represented as a Fourier series

$R_{XX}(t,\tau) = \sum_{\alpha} \quad R_{XX}^{\alpha}(\tau)exp^{j2\pi\alpha t}$....(20)

The sum is calculated over integer multiples of fundamental cyclic frequency α. Hence we can define the cyclic autocorrelation function (CAF) as:

$R_{XX}(t,\tau) = (\frac{1}{T}) \int_{-\frac{T}{2}}^{\frac{T}{2}} \quad R_{XX}(t,\tau)exp^{j2\pi\alpha t}dt$....(21)

The Fourier transform of $R_{XX}(t,\tau)$ is called the cyclic spectrum (CS) which is describe as:

$S_{xx}^{\alpha} = \int_{-\infty}^{\infty} \quad R_{xx}^{\alpha}(\tau)exp^{-j2\pi\alpha t}dt$....(22)

The scanning of cyclic frequencies or the cyclic autocorrelation function determines if a signal is present or not. If the value is below the fixed threshold limit, the signal is assumed to be absent, otherwise the signal is said to be present.

The false alarm probability $P_{fa,CSD}$ for a given threshold $\gamma\gamma_{CSD}$is given as:

$P_{fa,CSD} = (1-\gamma_{CSD})^{(L-1)}$....(23)

Similarly, probability of detection is given$P_{fa,CSD}$ as:

$P_{d,CSD} = 1 - P_{CSF}(\gamma_{CSD}L, \sigma^2)$....(24)

b. Simulation

The simulation of cyclostationary design in NS2 exhibited curves as shown in Fig.8 below for a plot of no. of trials versus mean square error.

The curves showed decreasing and constant variations.

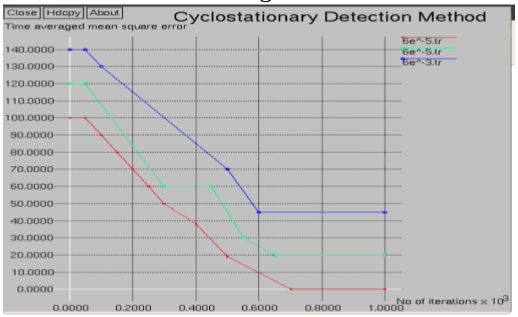

Fig.8. Plot of no. of trials versus mean square error for cyclostationary detection

D. WAVEFORM BASED SENSING

Systems which have knowledge of the signal patterns such as preambles, mid ambles, regularly transmitted pilot patterns, spreading sequences etc can use waveform based sensing technique. It is also known as coherent sensing [6].Applications related to edge detection in image processing are closely related to this type of spectrum sensing where the edges are detected using wavelets in the power spectral density of the channel. This technique exhibits better reliability and convergence time as compared with the energy detection technique.

As the signal patterns length increases the efficiency of the sensing algorithms also increases. In this technique, it is assumed that the time domain signal pattern is known and contains NB signal samples.

a. System Model

Consider the follow waveform sensing metric:

$S = RE[\sum_{n=1}^{NB} \quad x(n)s*(n)]....(25)$

For null hypothesis:

$$S = S_0 = RE[\sum_{n=1}^{NB} \quad \omega(n)s*(n)] \ldots .(26)$$

In the presence of primary signal,

S= $S_0 = \sum_{n=1}^{NB} \quad |s(n)|^2 RE[\sum_{n=1}^{NB} \quad \omega(n)s* (n)]....(27)$

Therefore Sensing Error Floor (SEF) can be estimated as,

$$SEF \; = Q(\sqrt{N_B \frac{\sqrt{SNR}}{\sqrt{(\alpha-1)SNR+\left(\frac{1}{2}\right)+\sqrt{1/2}}}})....(28)$$

b. Simulation

The waveform based spectrum sensing technique exhibits excellent performance even at low SNR as shown in fig.9.

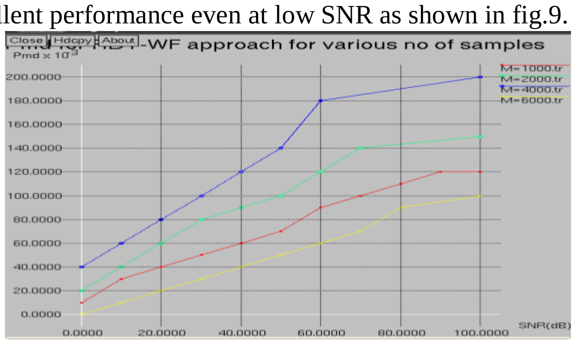

Fig.9. Performance plot of waveform based sensing at low SNR

III. CONCLUSION

In this paper, various spectrum sensing techniques are studied and analyzed. Fig.10 shows the comparison of different spectrum sensing methods with respect to sensing accuracy and complexity.

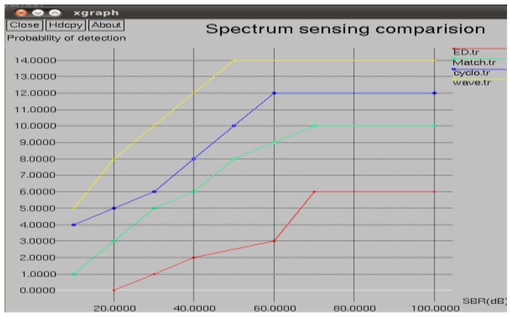

Fig. 10. Comparison of various spectrum sensing methods.

Waveform based spectrum sensing was found to be more robust than energy detection method and cyclostationary based methods. Though energy detection method is inexpensive and gives better performance, it is very limited in terms of accuracy. Therefore, we can conclude that waveform based technique is the best among these. However, based on the type of application, it is better to analyze all the techniques before deciding on a specific method.

REFERENCES

1. Simon Haykin, Peyman Setoodeh, “Cognitive Radio Networks: The Spectrum Supply Chain Paradigm”, IEEE Transactions on Cognitive Communications and Networking, vol. 1, Issue no 1, 2015.
2. Mohammad G. Khoshkhogh, Keivan Navaie, Halim Yanikomeroglu, “Optimal design of the Spectrum Sensing parameters in the overlay spectrum sharing”, IEEE transactions on Mobile Computing, vol. 13, no. 9, 2014.
3. Sheetal Kalambe, Padma Lohiya, P. Malathi, “Performance Evolution of energy Detection Spectrum Sensing technique used in cognitive radio”, International Conference on Signal Propagation and Computer Technology, 2014.
4. Thant Zin Oo, Nguyen H. Tran, Duc Ngoc Minh Dang, “An Opportunistic Matched Filter based MAC in Cognitive Radio Networks”, IEEE Transactions on Vehicular Technology, Volume: 65, Issue: 4, 2016.
5. Jarmo Lunden, Visa Koivunen, Anu Huttunen, “ Collaborative Cyclostationary Spectrum Sensing for Cognitive Radio Systems”, IEEE Transactions on Signal Processing, Volume: 57, Issue: 11, 2009.
6. Jaewoo So, R. Srikant, “ Improving Channel Utilization via Cooperative Spectrum Sensing with opportunistic feedback in cognitive radio networks”, IEEE Communicatins Letters, Volume :19, Issue:6, 2015.
7. K.Seshukumar, R.Sarvanan, M S Suraj, “ Spectrum Sensing Review in Cognitive Radio”, International Conference on Emerging Trends in VLSI, Embedded System, Nano Electronics and Telecommunication Systems, 2013.

8. V. Amrutha, K.V.Karthikeyan, "Spectrum sensing methodologies in cognitive radio networks", International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology, 2017.
9. Biao Sun, Qian Chen, Xinxin Xu, Yun He, "Permuted and filtered spectrum compressive sensing", IEEE Signal Processing Letters, Volume: 20, Issue: 7, 2013.
10. Jing Jiang, Hongjian Sun, David Baglee, Vincent Poor, "Achieving Autonomous Compressive Spectrum Sensing for Cognitive Radio", IEEE Transactions on Vehicular Technology, Volume: 65, Issue: 3, 2016.
11. Dafei Sun, Tiecheng Song, Bin Gu, Xi Li, "Spectrum Sensing and the utilization of Spectrum Opportunity Trade off in Cognitive Radio Network", IEEE Communications letters,Volume: 20, Issue:12, 2016.
12. Zhi Zhang, Xianbin Wen, Haixia Xu, Liming Yuan, "Sensing Nodes Selective Fusion Scheme of Spectrum Sensing in Spectrum Heterogenous Cognitive wireless sensor networks", IEEE Sensors Journal, Volume: 18, Issue:1, 2018.

V. AUTHORS PROFILE

Sharanya C received M.E. degree in Embedded Systems from Sathyabama University, Chennai. She is currently working as an Assistant Professor and is a part time PhD research scholar in Vels Institute of Science, Technology and Advanced Studies, Chennai. Her research interests include Wireless Networking, Spectrum Analysis, and Software Defined Radio etc. She is currently the Member of IEEE, Member of Institution of Electronics and Telecommunication Engineering (IETE), India and also has several memberships in electronics society and she has published several papers in national and international journals.

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