Analysis of Cognitive Radio Spectrum Sensing Techniques over Nakagami-m Fading Channel

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Abstract: As the demand of wireless communication increases exponentially, with the same ratio scarcity of spectrum also originates. To overcome this spectrum scarcity a novel approach, Cognitive Radio (CR) shows development of an opportunistic and promising technology. This paper explores implementation and analysis of the CR spectrum sensing techniques such as Matched filtering, Energy detection and Cyclostationary feature detection on MATLAB platform by simulation. We analyze performance of these techniques over, Nakagami-m fading channel with AWGN channel for both the BPSK and QPSK modulation.

Keywords: Cognitive Radio, Spectrum sensing, Energy detection, Matched filtering, Cyclostationary feature detection, Nakagami-m fading channel, AWGN channel, BPSK, QPSK

I. INTRODUCTION

Cognitive radio (CR) is an excellent development to treat the scarcity of spectrum. As the wireless communication is spreading its application exponentially at commercial as well as domestic level, dynamic spectrum allocation play an effective role to reduce the problem of spectrum scarcity [1]-[10]. In our implementation we show the performance of cognitive radio spectrum sensing techniques like Energy detection, Matched filtering and cyclostationary feature detection over the Nakagami m-fading channel. Individual performance of each sensing techniques analyzed for both BPSK and QPSK modulation. We plot the curve for SNR vs Decision accuracy for each sensing techniques although combine analysis also done for both BPSK and QPSK modulation techniques over Nakagami-m fading channel.

This paper organized as, first section introduced to our work. Matched filtering, Energy detection and Cyclostationary feature detection techniques briefly introduces in the section second, third and fourth respectively with their basic mathematical expressions. Nakagami-m fading channel discussed in the section five. Section six shows the performance of discussed spectrum sensing techniques individually. Finally section seven concluded the inferences drawn from our work.

II. MATCHED FILTERING

Matched filtering is an optimum and most promising method of spectrum sensing. It require prior knowledge of primary user signals like operating frequency, modulation type, packet format, bandwidth and pulse shaping etc. Matched filter is a linear filter which performs coherent detection of primary user (PU) signals. In its operation it performs correlation of received primary user signal with the filter impulse response to check the spectrum is busy or idle. Although its performance might be week in the absence of suitable desired primary user information. [1] - [4].
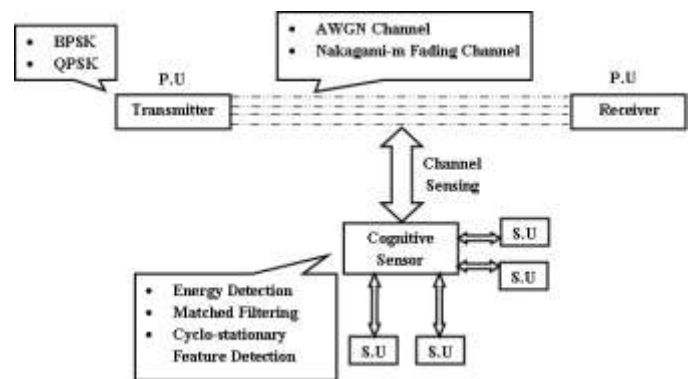

Figure 1. Cognitive environment over propagation channels

As the PU signal passes through the matched filter, it produces a peak in its output to show the presence of PU signal over sensed spectrum. At the same time it increases the signal component and decreases the noise component to maximize SNR [12].

$$Y(n)= \sum_{k=-\infty}^{+\infty} h(n-k)z(k)\ldots\ldots\ldots..(1)$$

Where z is 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 [1], [2], [3], [9].

III.   ENERGY DETECTION

Please Energy detection is very simple and effective spectrum sensing technique. It is most popular and economic due to its simplicity. It is based on non-coherent detection and does not need prior knowledge of structure or signal format of PU signal. The energy detector calculates the signal energy over the desired spectrum and compares it with pre calculated threshold energy level. If the calculated energy level is found to be greater than threshold energy level, it is considered as desired spectrum is busy with PU signals. The desired spectrum is said to be free or idle when energy detector found energy level over the desired spectrum is less than threshold energy level. Now CR engine can offer this spectrum to Secondary User (SU) [1]-[4], [7], [9], [10], [11], [13] .

$$S_N(x) = \frac{1}{N}\sum_{n=-1}^{N} s(n)^2 \ldots\ldots\ldots..(2)$$

Here $S_N(x)$ is energy calculated by energy detector. The threshold energy level Th calculated by using decision parameter D as

$$D = \frac{P_{avg}}{P_m} \ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Where P_{avg} is average power while P_m is mean power

$$T_h = \frac{\max (D)+\min (D)}{2}\ldots\ldots\ldots\ldots... (4)$$

$$X(n) = \begin{cases} N(n) & H_0 \\ S(n) + N(n) & H_1 \end{cases} \ldots.. (5)$$

Hypothesis H_0 shows the absence of PU signal over desired spectrum while H_1 indicates spectrum is sharing PU information.

IV.   CYCLOSTATIONARY FEATURE DETECTION

Cyclostationary or repeating features of any communication signal are the underlying properties of that signal, which can be used for its detection over the communication channel. Autocorrelation and cyclic spectral density of primary user (PU) signal exhibits periodicity introduced in the signal format. Cyclostationary feature of PU signal characterized by

periodicity like, sine wave carriers, pulse trains, repeating sequences, spreading, hoping sequences, or cyclic prefixes. Receiver performs signal detection over communication channel by exploiting the cyclic features of PU signal while these cyclic features of PU are previously stored in the memory of cognitive engine. This spectrum sensing technique does not require frequency or phase synchronization of signal while performs better than energy detection technique in for low signal to noise ratio (SNR). However this technique has higher degree of complexity than other popular spectrum sensing techniques as it makes large calculation [1], [2], [4], [8].
The received signal is given by

$$X(n)= s(n)+w(n) \ldots\ldots..\ldots..(6)$$

The cyclic spectral density (CSD) function of a received signal can be calculated as

$$S(f,\alpha) = \sum_{\tau=-\infty}^{\infty} (R_Y^\alpha)(T)e^{-2j\pi fT} \ldots\ldots.. (7)$$

Where cyclic autocorrelation function (CAF) given by

$$(R_Y^\alpha)(T)=E[y(n+\tau)y(n-\tau)]e^{2j\pi\alpha n} \ldots\ldots\ldots..(8)$$

Here α is the cyclic frequency. CSD function exhibits its maximum values, when fundamental frequency of transmitted signal x(n) is equal to the cyclic frequency [2], [3].

V. NAKAGAMI-M FADING CHANNEL

In the practical wireless communication, multihope and multipath transmission is the most occurring scenarios. Nakagami-m fading channel is the most suitable fading environment to summarize such types of propagation path [14]. It is more accurate and better than the Rayleigh and Rician fading channel as it has m diversity path. Probability density function of Nakagami-m fading channel is given by

$$f(P_r)\frac{P_r^{2m-1} 2m^m}{(m-1)!P_r^{2m}} exp \frac{-m}{P_r^2}P_r^2 \ldots\ldots..(.9)$$

Where P_r is the Nakagami distribution envelope and m is shape factor, which is given by

$$m=\frac{\overline{P_r^2}^2}{[P_r^2 -\overline{P_r^2}]^2} \ldots\ldots\ldots...(10)$$

For $m=1$ its performance gets equivalent to Rayleigh fading channel [13], [14]. Nakagami distribution comprehends direct components with the reflected and scattered component of original transmitted signal.

VI. RESULTS AND ANALYSIS

We simulate our work on MATLAB to analyze performance of CR spectrum sensing techniques over the Nakagami-m fading

channel and AWGN channel. Analysis done by observing plots, SNR Vs Decision accuracy (Detection probability) for BPSK and QPSK modulation technique. This work done for Matched filtering, Energy detection and Cyclostationary feature detection spectrum sensing technique.
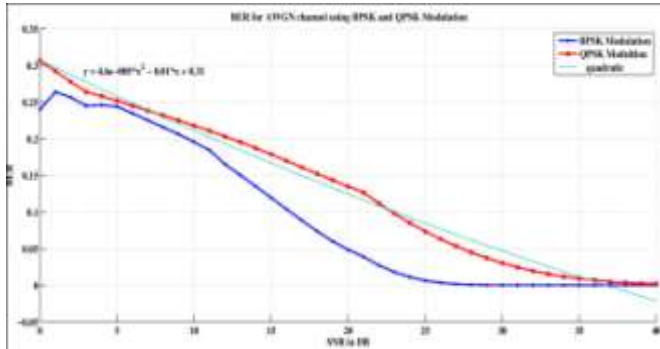

Figure 2. BER over AWGN channel using BPSK and QPSK modulation

Figure 2 shows the BER over AWGN channel for BPSK and QPSK modulation. BER decrease rapidly as SNR increase for BPSK modulation as compared to QPSK modulation while curve for QPSK modulation showing linearity as compared to curve for BPSK modulation Figure 3 shows the BER over Nakagami-m fading channel for BPSK and QPSK modulation. BER is almost constant over the whole SNR range for both the BPSK and QPSK modulation. It is important to observe that for QPSK modulation BER is very low. It can be considered as errorless transmission.
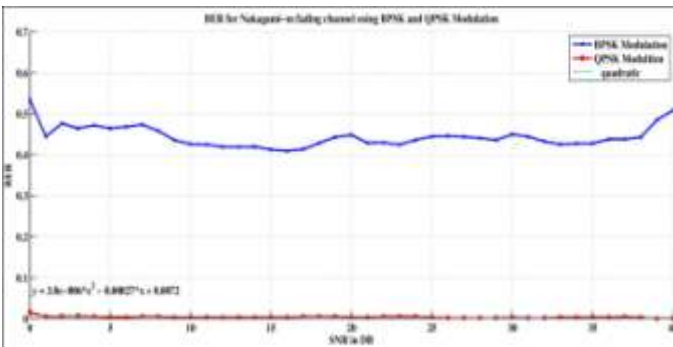

Figure 3. BER over Nakagami-m fading channel using BPSK and QPSK modulation

A. *Matched Filtering*

Performance of Matched filtering technique calculated over AWGN channel and Nakagami-m fading channel for both BPSK and QPSK modulation

Figure 4. Decision accuracy of Matched filtering technique over AWGN and Nakagami-m fading channel using BPSK modulation
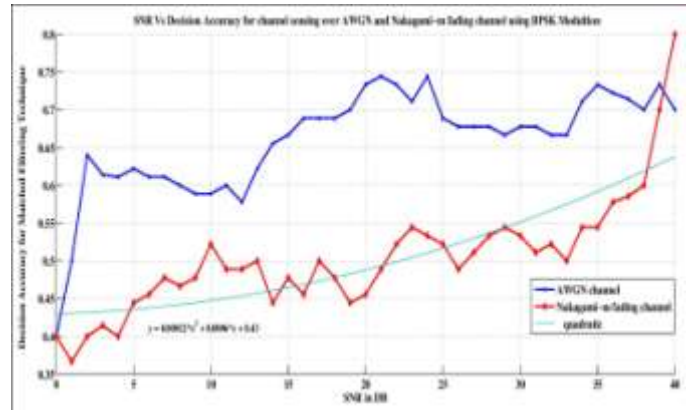

Figure 4 and figure 5 shows decision accuracy of Matched filtering technique over AWGN channel and Nakagami-m fading channel for BPSK modulation QPSK modualtion respectively. Matched filtering technique offering better performance over AWGN channel rather than Nakagami-m fading channel for BPSK modulation, while for QPSK modulation, Nakagami-m fading channel gives better performance than AWGN channel for low SNR values. It is also observed that for high SNR values performance over both the channel gets equivalent.
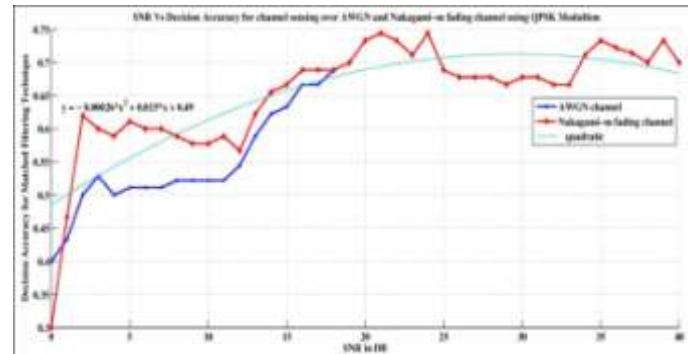

Figure 5. Decision accuracy of Matched filtering technique over AWGN and Nakagami-m fading channel using QPSK modulation

Figure 6 shows individual performance of Nakagami-m fading channel for both BPSK as well as QPSK modulation. This channel offer better performance for QPSK modulation rather than BPSK modulation.
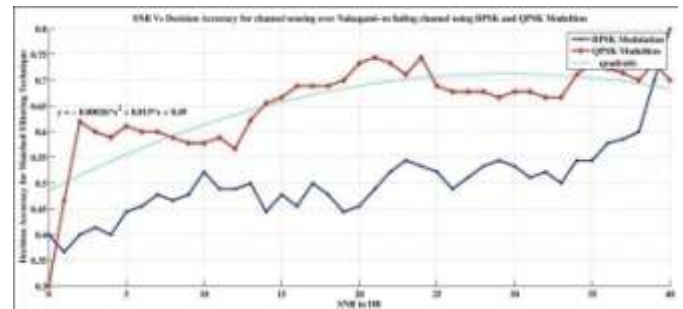

Figure 6. Decision accuracy of Matched filtering technique over Nakagami-m fading channel using BPSK and QPSK modulation

B. Energy Detection

Decision accuracy for energy detection technique showing good results over AWGN channel with respect to Nakagamim fading channel for both the BPSK and QPSK modulation. It can be analyze in figure 7 and 8. However Nakagami-m fading channel offer better performance for QPSK modulation as shown in figure 9.
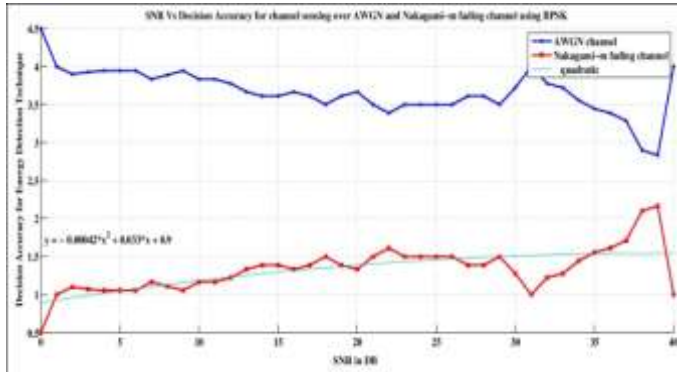

Figure 7. Decision accuracy of Energy Detection technique over AWGN and Nakagami-m fading channel using BPSK modulation
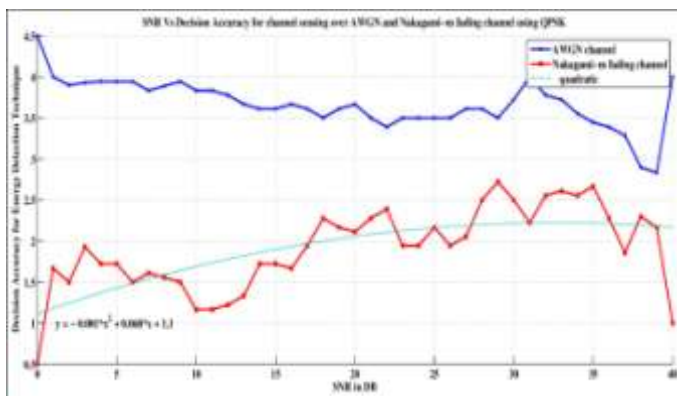

Figure 8. Decision accuracy of Energy Detection technique over AWGN and Nakagami-m fading channel using QPSK modulation
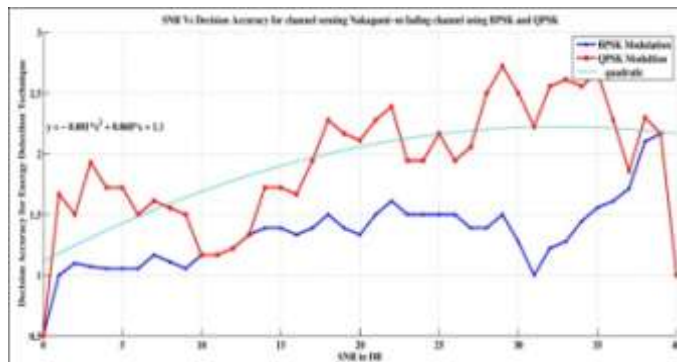

Figure 9. Decision accuracy of Energy Detection technique over Nakagami-m fading channel using BPSK and OPSK modulation

C. Cyclostationary feature detection

This technique is one of the more accurate spectrums sensing technique. Effect of noise is almost negligible on its performance. It can easily be seen in the figure 10 and figure 11. Decision accuracy over the whole SNR range is almost constant for both the channels and modulation techniques. Moreover Nakagami-m fading channel offer better and equivalent decision accuracy than AWGN channel for both BPSK and QPSK channel. It can be observed in figure 12.
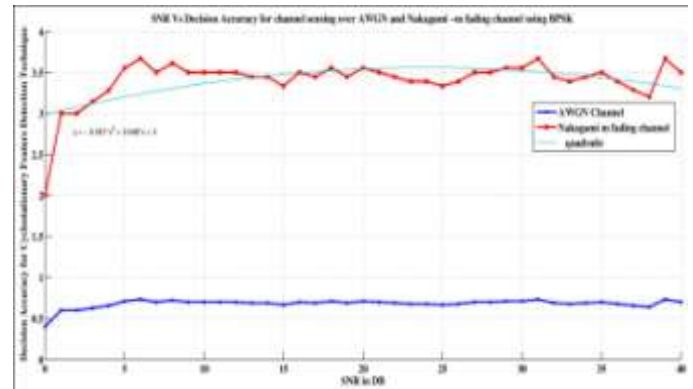

Figure 10. Decision accuracy of Cyclostationary Feature detection technique over AWGN and Nakagami-m fading channel using BPSK modulation
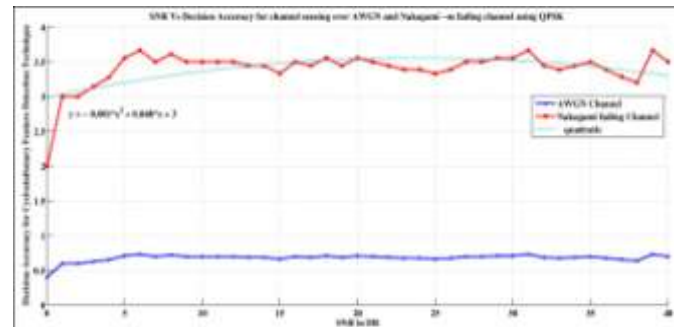

Figure 11. Decision accuracy of Cyclostationary Feature Detection technique over AWGN and Nakagami-m fading channel using QPSK modulation
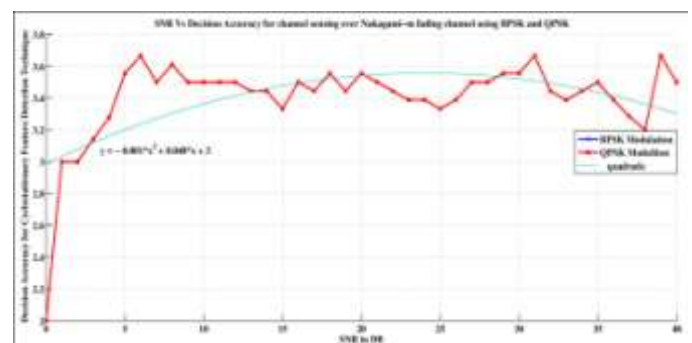

Figure 12. Decision accuracy of Cyclostationary Feature Detection technique over Nakagami-m fading channel using BPSK and QPSK modulation

VII. CONCLUSION

Cognitive Radio (CR) has emerged as a leading and promising technology of wireless communication. Exponential growth in wireless communication applications with spectrum scarcity demands dynamic spectrum allocation. Analysis of discussed work gives great results. We can concluded from all the results as Cyclostationary feature detection offers best performance than Matched filtering and energy detection technique over Nakagami-m fading channel for both the BPSK and QPSK modulation techniques. However these both the techniques performs good over AWGN channel for QPSK modulation.

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