Energy detection in Spectrum sensing in Cognitive radio over different Fading channels

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Outline

Cognitive Radio

Most of the frequency bands are only used for short time and left unused for the remaining time. We can overcome this problem through Cognitive Radio.
Radio spectrum can be categorised into two ways:
1) Licensed
2) Unlicensed

Cognitive Radio can operate in 3 modes:
1) Underlay
2) Interweave
3) Overlay

- In cognitive radio concept, spectrum sensing plays a vital role in improving the spectrum efficiency by giving information on to what extent the spectrum is being used.
- Spectrum sensing is the important as it has to sense the spectrum in a fading environment.
- There are some existing techniques used in cognitive radio.
  1) Spectrum sensing
  2) Spectrum Database

Spectrum Sensing

- To efficiently use the available radio frequency spectrum, the devices should be conscious of their respective surrounding Radio Frequency(RF) environment.
- Spectrum sensing is used to provide this information on the RF spectrum whether the spectrum is free or occupied.
- For fading channel, the input and output relationship is given as

$$y(t) = hx(t) + n(t)$$

where, y(t) is the received signal
h is the channel fading coefficient
n(t) is Additive White Gaussian Noise(AWGN)
x(t) is the primary user signal.

Spectrum sensing can be divided into two parts.
They are:

- Non-cooperative: Acts on it's own and decides based upon signal detection and pre loaded information. There are four methods to do spectrum sensing.
  - -Matched filter
  - -Energy detector
  - -Cyclo Stationary
  - -Waveform based
- Cooperative: CR devices share spectrum sensing information between themselves and decisions taken by the control unit or a mesh kind of network.

Limitations

Non cooperative:

- Parallel Sensing
- Sequential Sensing
- Waveform
- Matched Filter
- Cyclo stationary

Cooperative Sensing

- Cooperative sensing technique needs to intelligently combine inputs from various CR devices and ascertain the availability of spectrum holes.
- The accuracy of the algorithm is critical here as incorrect detection can inversely affect the performance of primary users in spectrum bands.
- Designing such a perfect algorithm is a challenge.

Spectrum sensing using Energy Detector

The energy detector measures the energy of the received signal to detect the spectrum's availability in a particular frequency.
The hypothesis test is as follows

$$H_0 \Rightarrow y = n$$

$$H_1 \Rightarrow y = hx + n$$

Hypothesis 0 (H_0) means the Primary User's signal is absent and Hypothesis 1 (H_1) means the Primary User's signal is present.

Energy Detector

At the energy detector, the received signal is multiplied by the factor $\frac{x^H}{||x||}$. Therefore,

$$\text{for} H_0, \bar{y} = \frac{x^H}{||x||} y = \frac{x^H}{||x||} n = \bar{n}$$

$$\text{for} H_1, \bar{y} = \frac{x^H}{||x||} y = h||x|| + \bar{n}$$

Let $|\bar{y}|^2$ be the energy of the $\bar{y}$ then,

$$|\bar{y}|^2 < E_t = H_0$$

$$|\bar{y}|^2 \geq E_t = H_1$$

Energy Detector

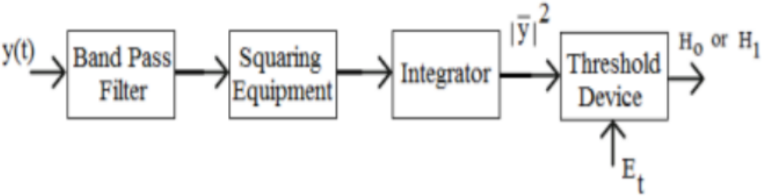

Figure 1: Block diagram of Energy Detector

Performance Parameters of Energy Detector

- Probability of Detection (P_D):The probability of detection indicates the probability that the signal is detected by the energy detector when the spectrum actually contains the signal. It is the probability that H_1 is detected as H_1.
- Probability of False Alarm P_{FA}:The probability of false alarm indicates the probability that the signal is detected by the energy detector when the spectrum is empty. It is the probability that H_0 is detected as H_1.

Receiver operating characteristics

- The ROC curve is created by plotting the True Positive Rate (TPR) against the False Positive Rate (FPR) at various threshold settings.
- The true-positive rate is also known as sensitivity or probability of detection. The false-positive rate is also known as probability of false alarm.

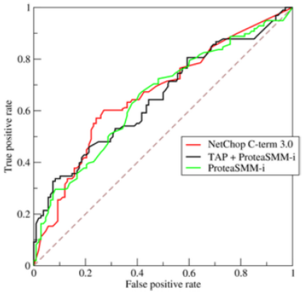

Figure 2: Receiver operating characteristic

Simulation Results

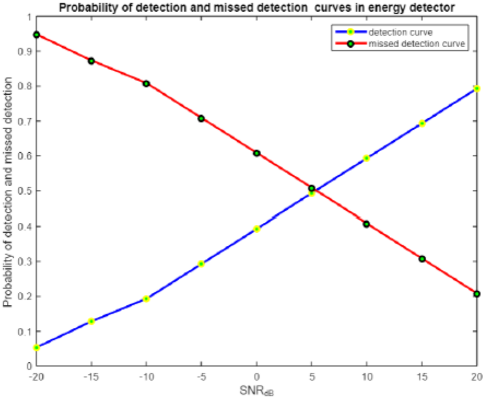

Figure 3: Probability of detection and missed detection curve in energy detector

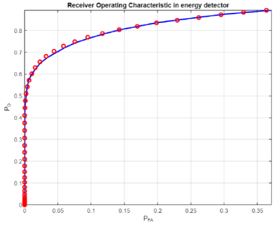

Figure 4: Receiver operating characteristics in energy detector

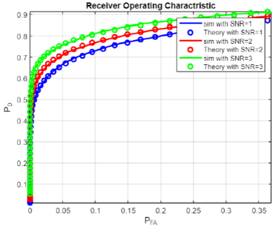

Figure 5: Comparison of receiver operating characteristics for SNR=1dB, SNR=2dB and SNR=3dB

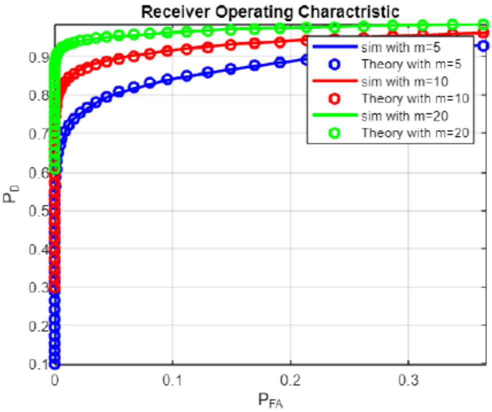

Figure 6: Comparison of Receiver operating characteristics for number of input signals m=5, m=10 and m=20

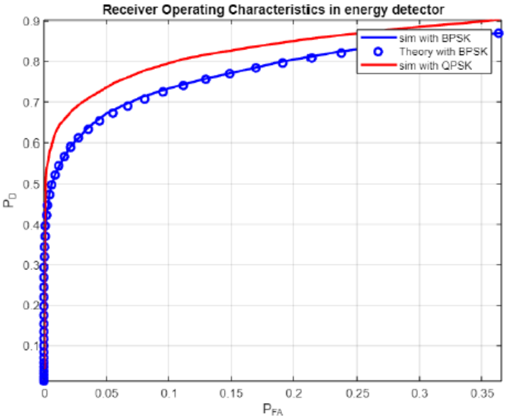

Figure 7: Comparison of Receiver operating characteristics for BPSK and QPSK signals in energy detector.

Conclusion

- From the simulation results, it can be concluded that the energy detector performs extremely good if the SNR of the received signal is high.
- Probability of detection increases with increasing the number of transmitted symbols.
- Probability of detection increases for QPSK on comparing with BPSK.
- The major drawback with energy detection method is that the poor performance under low SNR conditions and also no proper distinction between primary users and noise

Rayleigh fading

- The radial component of the sum of two uncorrelated Gaussian random variables will follow rayleigh distribution.
- Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver.

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{\left(\frac{-r^2}{2\sigma^2}\right)} & \text{for } 0 \leq \text{r} < \infty \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where r is the envelope amplitude of Rx signal and $2\sigma^2$ is the power of the signal.

Simulation Results

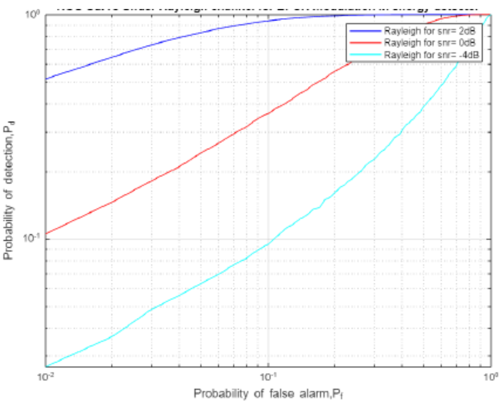

Figure 8: ROC Curve Under Rayleigh channels for BPSK modulation in energy detector.

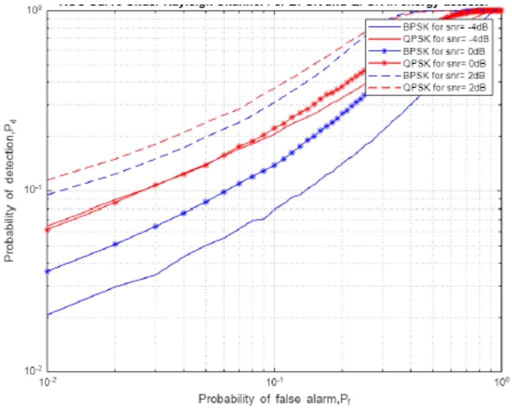

Figure 9: ROC Curve Under Rayleigh Channel For BPSK and QPSK in energy detector.

Conclusion

- We can observe that ROC improves for increasing SNR.
- ROC curve is improved for QPSK than BPSK.
- And also as the SNR is increasing difference between BPSK and QPSK curves is decreasing.

Rician fading

- Rician fading occurs when one of the paths, typically a line of sight signal or some strong reflection signals, is much stronger than the others.
- In Rician fading, the amplitude gain is characterized by a Rician distribution.
- Rayleigh fading is sometimes considered a special case of Rician fading for when there is no line of sight signal.

$$p(r_0) = \begin{cases} \frac{r_0}{\sigma^2} e^{\left(\frac{-r_0^2 + A^2}{2\sigma^2}\right)} I_0\left(\frac{r_0 A}{\sigma^2}\right) & \text{for } r_0 \geq 0,\ \text{A} \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Simulation results

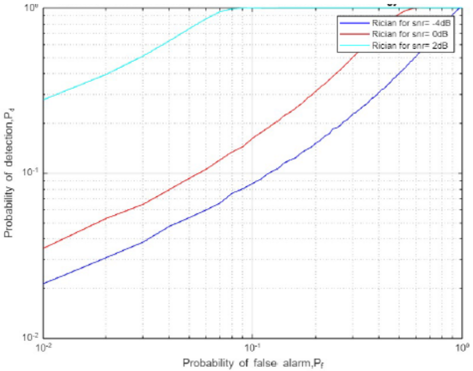

Figure 10: ROC Curve Under Rician channel for BPSK modulation in energy detector

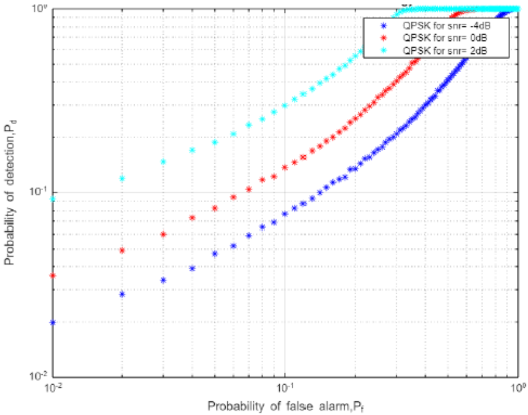

Figure 11: ROC Curve Under Rician Channel For QPSK modulation in energy detector

Conclusion

- We can observe that ROC curve improves as for increasing SNR.
- ROC curve improves for QPSK than BPSK.
- As the SNR increases the difference between QPSK and BPSK will decreases.
- The difference between QPSK and BPSK at particular SNR increases for rician compared to rayleigh fading.

Nakagami fading

- The sum of multiple independent and identically distributed (i.i.d.) Rayleigh fading signals have a Nakagami distributed signal amplitude.
- It describes the amplitude of received signal after maximum ratio diversity combining.
- After k-branch maximum ratio combining (MRC) with Rayleigh fading signals, the resulting signal is Nakagami with m = k.

- Nakagami pdf is:

$$f(r) = \frac{2}{\Gamma(K)}\left(\frac{K}{2\sigma^2}\right)^2 r^{2k-1} e^{\frac{-kr^2}{2\sigma^2}} \quad \text{for r} \geq 0$$

where, $\Gamma(.)$ is the Gamma function.

- Instantaneous receive power is Gamma distributed with k = 1, Rayleigh = Nakagami.

Simulation Results

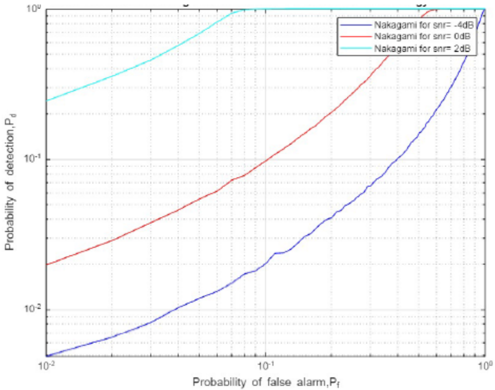

Figure 12: ROC Curve Under Nakagami channel for BPSK modulation in energy detector

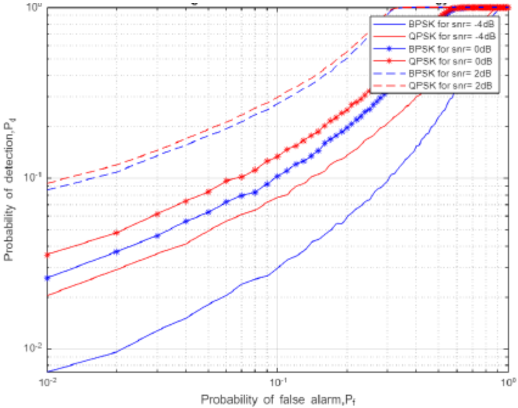

Figure 13: ROC Curve Under Nakagami Channel For BPSK and QPSK in energy detector

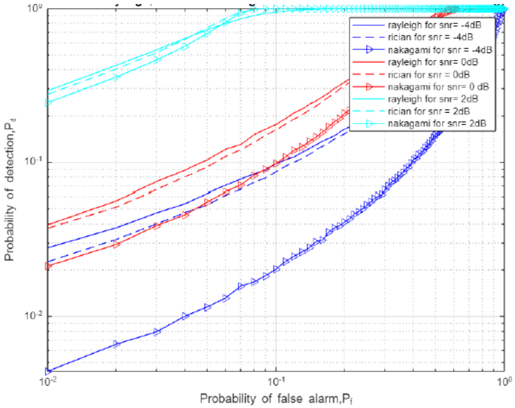

Figure 14: ROC Curve Under Rayleigh, Rician and Nakagami Channel for BPSK modulation in energy detector

Conclusion

- The difference between QPSK and BPSK at particular SNR is decreased when comparing with rayleigh at same SNR.
- Cognitive radio network depends upon channel distributions.
- We can observe that rayleigh fading has better performance compared to the rician and nakagami.
- Rician fading has better performance compared to nakagami.
- Nakagami channel has better performance than Rayleigh channel at low SNR value.

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THANK YOU