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Cognitive Radio Network's Performance Comparison in Different Channels

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Abstract—

In this paper, a comparison between the performance of Cognitive Radio systems with Energy Detection in various channels such as AWGN and Rayleigh with various modulation schemes such as DPSK, QAM, and MSK are presented. A comparison between probability of detection in simulation and theory has been obtained.

Keywords— DPSK, QAM, MSK & AWGN

I. INTRODUCTION

Now a days there is a transition from voice only communications to multimedia communications. As a result of this the need for higher data rates is also increasing. The current frequency allocation schemes adopt fixed or static allocation methods. But the increasing need for higher data rates cannot be accommodated by the existing methods [10]. Therefore, new techniques that offer new ways for exploiting the available frequency spectrum are required.

One of the new techniques gaining attraction is Cognitive Radio [11}. [I2J. [13}. It provides an efficient solution for exploiting the available spectrum. Some of the frequency bands are not occupied entirely and are not always used. Cognitive Radio makes use of these frequency bands during unoccupied time and area. This helps in avoiding congestion and increases spectrum efficiency. Cognitive Radio is defined in many ways. FCC defines Cognitive Radio in the following way. "A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously acijust its radio operating parameters to modify system operation. such as maximize throughput. mitigate interference. facilitate interoperability and access secondary markets[I]. "

The ability to measure, sense and learn is an important component of cognitive radio. It should also be aware of the parameters to use the radio channel. Some of them are radio channel characteristics, spectrum and power availability, radio's operating environment, user requirements, local policies and other parameters. In cognitive radio, two types of users are considered, primary users and secondary users. The primary users are be defined as the licensed users who are having high priority over a specific part of the spectrum. The secondary users are unlicensed users and are given low priority over spectrum usage. The secondary users have to exploit the spectrum such that they do not cause interference to primary users. Therefore secondary users need to have cognitive radio capabilities. It helps to check whether the spectrum is occupied by primary users or not. Spectrum opportunity is defined as a band of frequencies not used by primary user of that band at a particular time in a particular geographical area [1 1], and is available for the cognitive users. Spectrum sensing is the task of obtaining awareness about the spectrum usage and existence of primary users in a geographical area. Generally, spectrum sensing is considered as measuring the spectral content or radio frequency energy over the spectrum. But, when cognitive radio is considered, spectrum sensing involves obtaining the spectrum usage characteristics across multiple dimensions such as time, frequency, space and code. Moreover, it involves determining signal type occupying the spectrum including the modulation, carrier frequency, bandwidth, etc. Three methods of spectrum sensing are Transmitter Detection, Receiver Detection, and Interference Temperature Management. Of the above three methods transmitter detection is important as it is used widely. The different types of transmitter detection methods are Energy detection [14], [15], [18], Cyclo-stationary based detection and Matched filter detection. The conventional energy detector measures the energy associated with the received signal over a specified time period and a bandwidth. The decision of an energy detector is feasible even when little prior knowledge of the transmitted signal is available. The decision statistic of an energy detector is a measure of the received signal energy after proper filtering, sampling, squaring and integration.

Cyclo-stationary based detection exploits primary user transmission using cyclo-stationary feature of received signals [16]. The analysis is based on spectral correlation function. It differentiates noise from primary user's signals. It is computationally complex and needs long processing time, degrades performance [5].

Matched filter detection is an optimum method when some knowledge of the transmitted signal is known [17]. The knowledge of primary user signaling features required for spectrum sensing. The major drawback is that CR requires dedicated receiver for every primary user [4].

In this paper, Energy detection is considered as it is advantageous over other methods because of its simplicity in implementation. In Energy detection method, the presence of primary user is detected by comparing the output of the energy detector (M) with a threshold (AE) which depends on the noise floor. The Energy Detection problem had been explained by many authors and they all tried to improve the performance at low SNR values [6] and also for different fading and shadowing conditions [7] and also under various other factors [18]. We consider the energy detection problem for different modulation schemes under various fading schemes such as AWGN and Rayleigh channels. The modulation schemes considered are BPSK, QAM, MSK and a comparison is made.

The rest of the paper is organized as follows. Section II explains the system model and notations. Section III gives the expressions for Pd and Pf for AWGN channels. Section IV gives the expressions for Pd and Pf over fading channels. Section V gives the numerical results and simulations for the AWGN and Fading channels with various modulation schemes.

II. SYSTEM MODEL

The main notations that are used in the paper are listed below for reference after which the system model is mentioned.

- s(n) : signal waveform. w(n) : noise waveform which is modeled as a zero-mean white Gaussian random process.
- AE : energy threshold used by the energy detector.
- T: observation time interval, seconds.
- W : one-sided bandwidth (Hz), i.e. positive bandwidth of the low-pass (LP) signal.
- u=TW: time bandwidth product.
- fc: carrier frequency.
- Pd: probability of detection.
- Pt: probability of false alarm.
- Pm = 1- Pd: probability of missing.
- Ho: hypothesis 0 corresponding to no signal transmitted.
- HI: hypothesis 1 corresponding to signal transmitted

The received signaly(n) takes the form

y(n) = h(n)* s(n) + w(n) (1) where h(n) represents the impulse function of channel.

Two Hypotheses [4] formulated are

Ho: y(n)=w(n) (2) HI: y(n)=h(n)* s(n)+w(n). (3) The decision metric has been formulated as

M=!:I y(n)1^2 (4) The probability density function (PDF) of M can then be written as Ho

(5) where r (.) is the gamma function and Iv (.) is the vth-order modified Bessel function of the first kind.

III. DETECTION AND FALSE ALARM PROBABILITIES OVER AWGN CHANNELS

In this Section we present the probability of detection and false alarm expressions for AWGN channel. The transmitted signal is affected only by Additive white Gaussian noise during transmission. The two probabilities that help to determine the performance of detection algorithms are Probability of Detection Pd and Probability of False Alarm Pta. Probability of Detection is the probability of detecting a signal on the considered frequency when it is truly present. Probability of detection is approximately computed by

(6)

where I.E is the threshold.

The probability of detection can be obtained from (5) using (4) as below.

Pd ═ Qm (flY,p:;) (7)

where Qm ( ) - generalized Marcum Q-function. Probability of False Alarm is the probability that the test incorrectly decides that the considered frequency is occupied when the signal is actually not present. (8) Using (4) we can evaluate (7) as follows.

PFr(m,AE/2)/r(u) (9)

r(.), f(.,.) – Complete, incomplete gamma functions. Threshold I.E is the balance between Pd and Pr. Probability of Miss Detection Pm which gives the probability of not detecting a signal when it is present in the considered frequency. Probability of miss detection is given by (10)

IV. AVERAGE DETECTION AND FALSE ALARM PROBABILITIES OVER FADING CHANNELS

This expression is derived in a different way from various previous work [9] in [2] by setting d^2=y

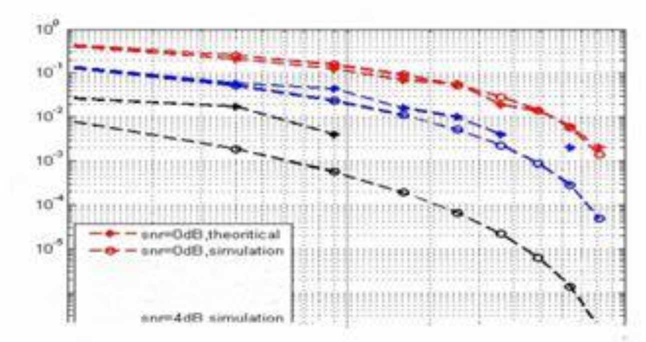

Fig2.Complementary ROC curves for Rayleigh channel at different snr values and **u** = 5

V. NUMERICAL RESULTS AND DISCUSSIONS

The simulation results are discussed under the following input and output parameters. The input parameters are the signal to be transmitted, the probability of missed detection and the probability of false alarm. For different values of known false alarm probabilities the threshold values are calculated. The probability of detection and hence the probability of missed detection are found based on the threshold values. The receiver is quantified by using the Receiver Operating Characteristic (ROC), which is the graph of Pd versus Pr, or equivalently by complementary ROC, a graph of Pm versus Pr. Fig! illustrates the complementary ROC for both theoretical and simulation under AWON channel for different SNR values. We can see that as SNR increases, the curve goes down indicating the improvement in the performance. Moreover it is observed that both theory and simulation coincide well for different SNR values.

In this section, a detailed discussion about the average detection probability over Rayleigh Channels has been presented. The expressions are in closed form [2]. They are actually obtained from the conditional Pd in the AWON case as in (8) over the SNR fading distribution. Pf will remain same for all channels as it does not depend on SNR values.

A. Rayleigh Channels

If the channel follows Rayleigh distribution, then the SNR y follows the PDF as shown below. (10)

—f.- —snr=2dB,lheoritical
10" —&—snr=2dB,simulation
-f.- -f(r)=dB,lheoritical
—&—
10.2 10'"
PI

Figl.Complementary ROC curves for AWGN channel at different snr values and 11= 10

Fig2 illustrates the complementary ROC for both theoretical and simulation under Rayleigh channel for different SNR values. In this case also, it is seen that as SNR increases the curve goes down indicating performance improvement. It can be seen that as false alarm probability decreases missed detection probability decreases. Comparing Fig.! and Fig.2, it is observed that for same values of snr and Pr, Pm values are higher in Rayleigh channel than in AWON. As a result, it can be observed that Pd is better in AWGN than in Rayleigh channels (Comparing Fig.l and Fig.2).

A comparison between Pd in simulation and theory has been obtained for all the channels namely AWGN and Rayleigh channels. It is observed that both theory and simulation coincide well for different snr values. The results for Rayleigh channel are also found to match with that of [2] when no modulation is done. values of Pm with MSK than QAM and about 4% than DPSK for Rayleigh

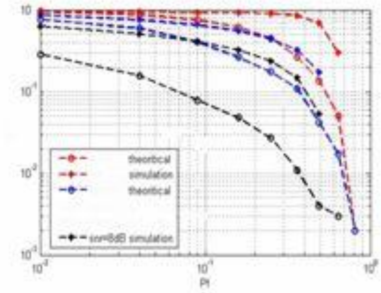

Fig3 shows the simulation result for different modulated transmitted signal over AWGN channel. From the graph it is clear that the performance of signal detection in Cognitive Radio is better for MSK. There is about 7% decrease in values of Pm with MSK than QAM and about 10% than DPSK.

Complementary ROC curves for AWGN channel at snr=OdB for different modulation schemes snr values and u = \0

VI. CONCLUSION

In this paper, a comparison between the performance of Cognitive Radio systems with Energy Detection in various channels such as AWGN and Rayleigh with various modulation schemes such as DPSK, QAM, and MSK is presented. A comparison between probability of detection in simulation and theory has been obtained. It was found that the theory and simulation value for different snr Coincide well for AWGN and Rayleigh channels. In case of AWGN channel there is about 7% increase in performance of MSK over QAM and 10% over DPSK. In case of Rayleigh Channel there is about 2.5% increase in performance of MSK over QAM and about 4% over DPSK for Rayleigh channel

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