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Simulation of Cognitive Radio Using Periodogram

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Abstract

A limited and precious resource like the available spectrum has been put to a lot of limitations by the exceeding demand of wireless applications. Recent study has shown that some frequency bands in the spectrum are mainly unoccupied most of the time, while some are less occupied, whereas few bands are over utilized. This leads to spectrum underutilization. Cognitive radio is one such technique to overcome such spectrum underutilization. It refers to a technique in which secondary user searches for a free band to operate in while primary user is not using its licensed band. A function that enables the cognitive radio to search for the free bands is called Spectrum sensing. It helps to detect the spectrum hole so that they can be utilized by secondary user. In this paper simulation of cognitive radio is done using the energy detector spectrum sensing which is also called periodogram. This paper also highlights the effect of SNR and attenuation on the detection capability.

Keywords: Cognitive radio, Spectrum sensing, Energy detection.

1. Introduction

The enormous success of ISM bands has brought criticism to the traditional process where the bands are allocated to a single user and exclusive license is issued to a single entity within a geographical area and hence other devices are prohibited from transmitting significant power within these bands [1].

Recent studies show that after around ten years the majority of frequency bands which are suitable for mobile communication systems will be entirely engaged and hence there is an urgent need for new solutions. A possible solution coming up is the use of “Cognitive Radio” technology which is a radio or system, which has the ability to sense and is fully aware of its functioning situation and can regulate its operating parameters. This technology seems like a promising solution in order to use the available spectrum on the frequency band efficiently.

The Cognitive radio is a radio which adapts to the environment conditions by analyzing, observing and learning, and makes use of this analysis for future decisions. The main motive of cognitive radio is to improve the spectrum usage of the cellular network by allowing the secondary users to access the licensed bands which are temporarily unused by the licensed users (Primary users) in such a way that secondary users do not cause any interference to the primary users. In this paper, Section 1 gives introduction about the cognitive radio and Section 2 contains detailed definition of cognitive radio, Spectrum sensing techniques have been explained in section 3, section 4 shows the simulation of cognitive radio, Results are shown in section 5 and section 6 concludes the discussion showing the scope for future work.

2. Cognitive Radio

Cognitive radio has been defined differently by different by various researchers. It is defined as "A radio that employs model based reasoning to achieve a specified level of capability in radio-related domains" by the author in **[2]**. Cognitive radios have been proposed as a possible solution to improve spectrum utilization by enabling opportunistic spectrum sensing and sharing. Its technological capabilities allow cognitive radios(CRs) to dynamically seek and access unused portions of the radio spectrum , and thus improve resource utilization **[3]**.The main constraint for the opportunistic secondary devices is to guarantee non-interference to the primary system. When the secondary user/ cognitive radios access the band which is currently unused by the primary user the it has to take care that when the primary user returns then it should switch bands before causing any interference to the primary user. Hence efficient Spectrum sensing is required to fulfil this criterion for interference free spectrum sharing.

Mainly four functions are performed by the cognitive Radio-

(1)- It continuously searches for spectrum holes or white spaces as shown in Figure1; this function is known as Spectrum Sensing.

(2)- After the spectrum hole is found, it selects the appropriate white space for accessing, this is called spectrum management.

(3)- It allocates this channel to the secondary user till the primary user is not using it, this is called Spectrum Sharing.

(4)- Cognitive user vacates the channel when the licensed user is detected; this is known as spectrum mobility.

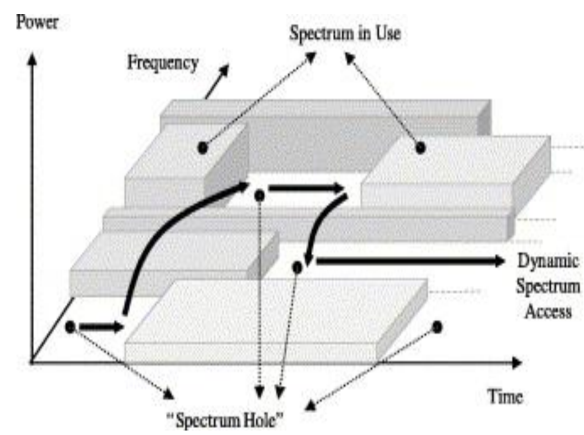

Figure 1: Spectrum holes and spectrum in use

3. Spectrum Sensing

The present literature of spectrum sensing is still in its development stage.

Spectrum sensing problem can be put together as a binary hypothesis testing, with two hypotheses –

$$H_o: y[n] = w[n]; n= 1, 2... N$$

$$H_1: y[n] = x[n] + w[n]; n= 1, 2... N$$

Where, H_o states that received signal samples y[n] correspond to noise sample signal w[n] and hence, primary signal is not sensed to be present in the spectrum band. H_1 indicates the presence of some primary users signal x[n]. N denotes the number of samples gathered during sensing period.

Ideally the spectrum sensor would select H_1 to show the presence of primary users and H_o otherwise. In practice spectrum sensing algorithms fall into mistakes, which are classified as missed detection and false-alarm, which may be defined as-

Probability of missed detection, P_{MD}

This is the probability when a primary user is detected to be inactive while it is actually active, is called the probability of missed detection. Higher value of P_{MD} leads to higher interference because in this case the secondary user will assume that the spectrum is free while the spectrum is actually utilized by the primary users.

$$P_{MD} = P(H_o/H_1)$$

Probability of detection, P_D

The probability of detection is the probability that the primary users are detected to be present while they are actually present, to avoid any interference from the secondary users if they are trying to access the spectrum. A high value of P_D will lead to efficient use of the spectrum without causing interference to the primary user [4].

$$P_D = P(H_1/H_1), \text{ or}$$
$$P_D = 1 - P_{MD}$$

Probability of False alarm, P_{FA}

It is defined as the probability of detecting that primary user is present while it is actually inactive, and this leads to inefficient utilization of the spectrum, because even if the spectrum is free, the secondary user will assume that it is occupied by the primary user and hence will not be able to utilize the spectrum. A low value of P_{FA} is expected to increase the channel reuse capability when it is free [4].

$$P_{FA} = P(H_1/H_o)$$

A number of different approaches have been proposed for identifying the presence of transmission signal.

The Various techniques employed for Spectrum sensing are **[2]**-

(1) Energy Detection

Energy detection based approach also known as periodogram, is the most widely used techniques because of its low implementation complexities **[5]**. This method is more general because in this the receiver does not need any information about the primary users signal.

The detection of the signal is based on the output of the energy detector compared to the threshold which depends on the noise [6]. The major challenge of this technique is selection of the threshold for detection of primary users and the inability to differentiate between noise and interference from primary users, and also its poor performance under low SNR values.

(2) Matched Filter Detection

Matched-filtering is known as the optimum method for detection of primary users when the transmitted signal is known **[7]**. It is known as the finest technique for detection of primary users because it maximizes the SNR of the received signal in existence with additive Gaussian noise. It is done by correlating the unknown signal with the known signal to detect the known signal in the unknown signal.

(3) Cyclostationary feature detection

Cyclostationary feature detection is a method for detecting primary user transmissions by using the Cyclostationary features of the received signal **[8]**. Cyclic correlation function is used for detecting signals present in a given spectrum, instead of the power spectral density (PSD).

The algorithms based on Cyclostationary detections can differentiate between noise and primary users signal.

4. Simulation of Cognitive Radio

This paper shows the simulation of periodogram which is done using MATLAB simulation. The proposed model shows 5 primary users where each user's message is modulated by using amplitude modulation. Summation of five primary signals shows the transmitted signal. Periodogram method is used to estimate the power spectral density of the transmitted signal. Using this Cognition process is displayed among the primary users and secondary users. Figure 2 shows all the 5 primary users as present.

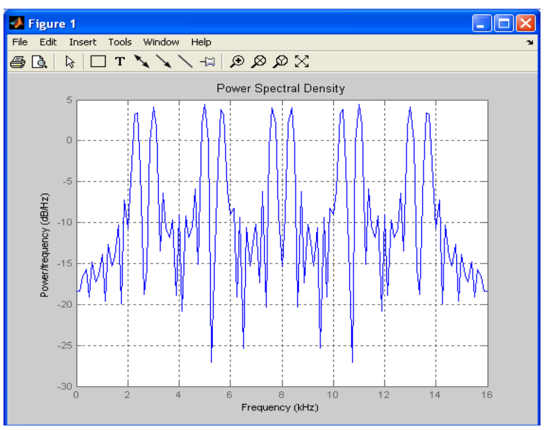

Figure 2: Power Spectral Density of 5 users.

The flow chart in figure 3 shows the complete flow of the process in Energy detection spectrum sensing or periodogram. This flow chart shows the working of periodogram to calculate the power spectral density of the transmitted signal using the amplitude modulation. At the end, the summed frequency is compared with the threshold value, and if threshold is less than the frequency then it assumes that primary user is absent and vice-versa if threshold is more than frequency.

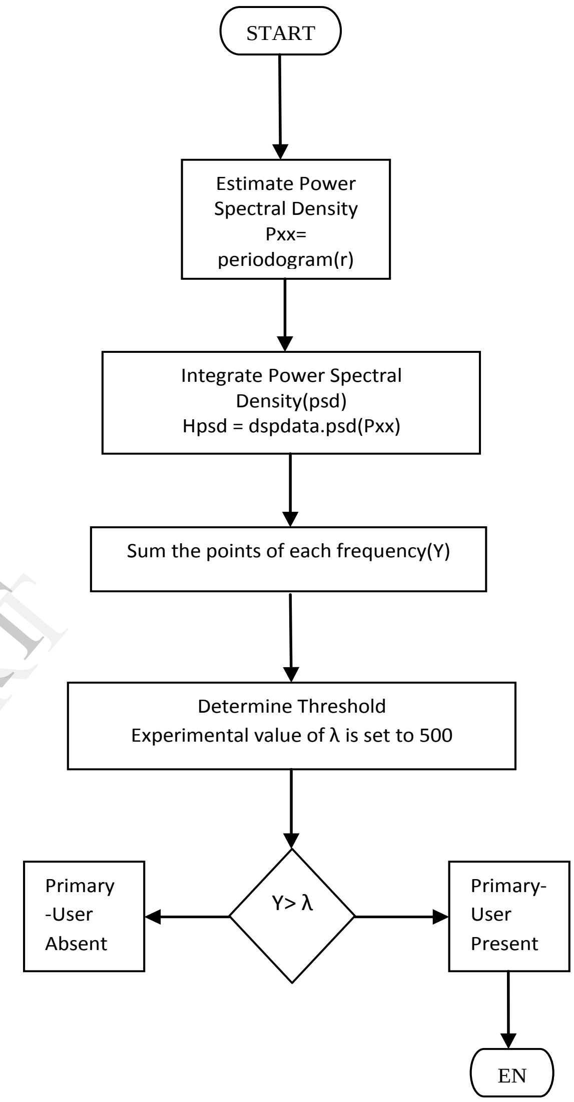

Figure 3: Energy detection sensing flow chart

5. Simulation Results

In this paper, energy detector spectrum sensing or periodogram is simulated in MATLAB using the periodogram. The following figures show the results of the simulation, Figure 4.1 showing all the 5 primary users are present.

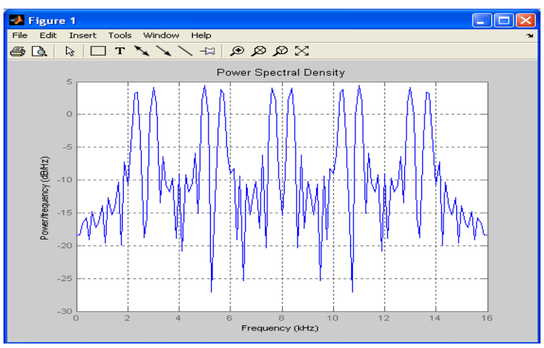

Figure 4.1: All five primary users are present

To explain the cognition process, here primary users are assumed to have frequencies 1,2,3,4 and 5 MHz. Figure 4.1 shows the Power Spectral Density (PSD) of the transmitted signal, we can see the frequency peaks for all the five primary users, which implies that all the 5 users are present.

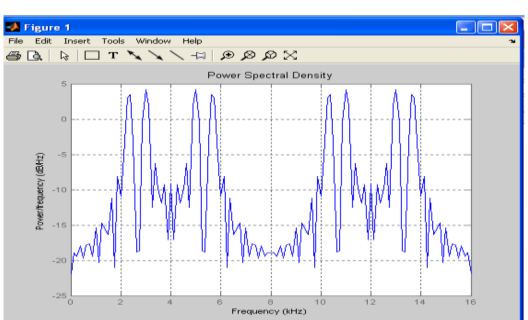

Figure 4.2: 3rd user is absent

When user 3 leaves the spectrum free then secondary user can access the band. Figure 4.2 shows that users 1, 2, 4 and 5 are present while 3 is absent because there is no frequency peak for it.

Effect of SNR is shown in the further figures, Figure 4.3a and 4.3b shows the PSD of the received signal when SNR is 40 db and 10 db respectively. Showing that when SNR is high, the distortion of signal is less as compared to when it is low. Hence, signal can be detected in a better way when SNR is as high as 40 db as when it is low as 10db.

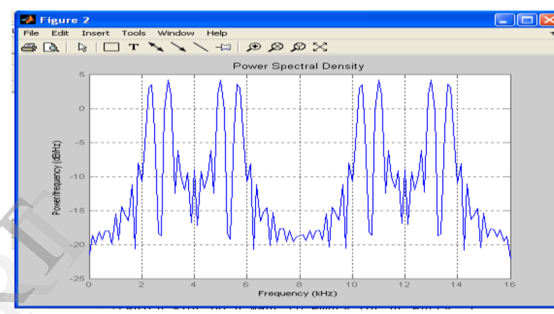

Figure 4.3(a): SNR = 40 db

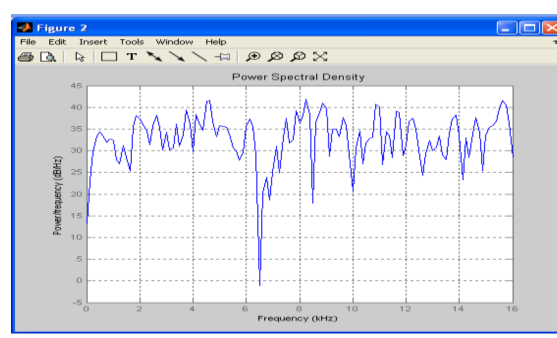

Figure 4.3(b): SNR = 10db

Figures 4.3c and 4.3d show the PSD of received signal when SNR is -10db and -40db, reflecting that the signal becomes more distorted when SNR is as low as -40db than when it is -10db, proving that when SNR values become low, it leads to distortion of signals and hence increasing the P_{FA} , as well as degrading the P_D, i.e., the performance of the Energy detector degrades as the value of SNR falls down.

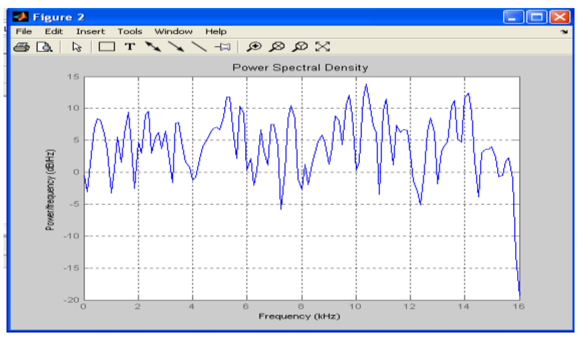

Figure 4.3(c): SNR = -10db

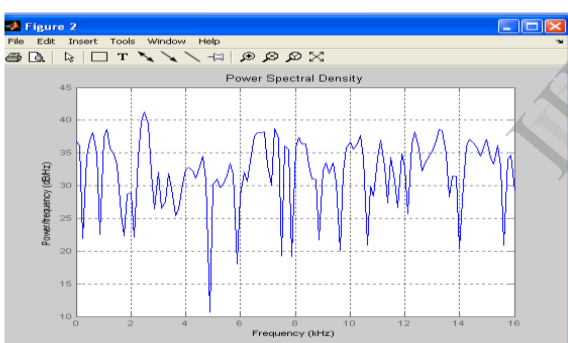

Figure 4.3(d): SNR = -40db

The following table shows the results for various values of SNR on the basis of which the above graphs have been created.

Table 1: Values of P_{FA}, P_D, P_{MD} for various values of SNR

SNR(SIGNAL-TO-NOISE RATIO)	P_{FA}	P_D	P_{MD}
-40	0.6	0.4	0.6
-35	0.4	0.4	0.6
-30	0.4	0.6	0.4
-25	0.4	0.6	0.4
-20	0.4	0.6	0.4
-15	0.2	0.8	0.2
-10	0.2	0.8	0.2
-5	0.2	0.8	0.2
-2	0.2	0.8	0.2
2	0.2	0.8	0.2
5	0.2	1	0
10	0.2	1	0
15	0	1	0
20	0	1	0
25	0	1	0
30	0	1	0
35	0	1	0
40	0	1	0

The following graphs show the change in probability of detection as the SNR increases, showing that the detection gets more effective as the SNR varies from -40db to 40 db.

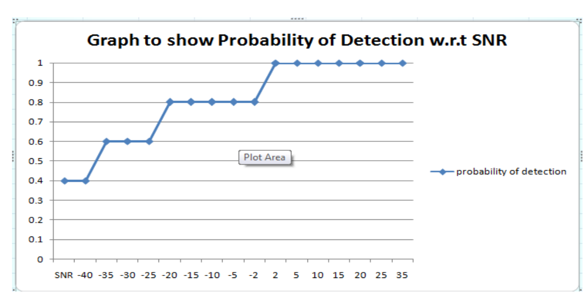

Figure 5: Graph between SNR and P_D

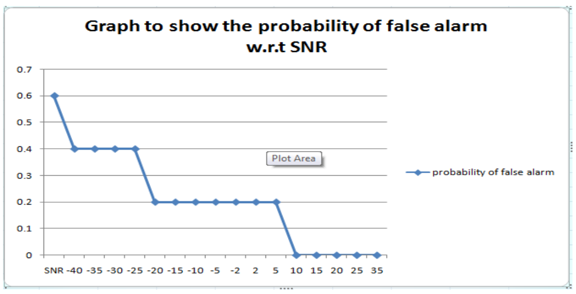

Figure 6: Graph between SNR and P_{FA}

Effect of attenuation on the transmitted signal is shown in the further figures, and the performance of energy detector is evaluated using different attenuation values.

Looking at figures 7a, 7b and 7c we can easily understand that increasing the attenuation leads to decrease in the signal amplitude.

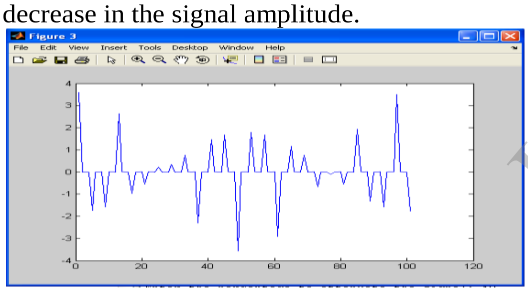

Figure 7(a): 10% Attenuation

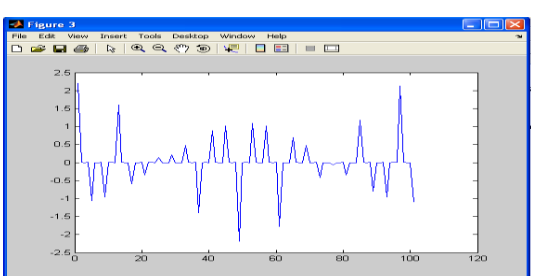

Figure 7(b): 45% Attenuation

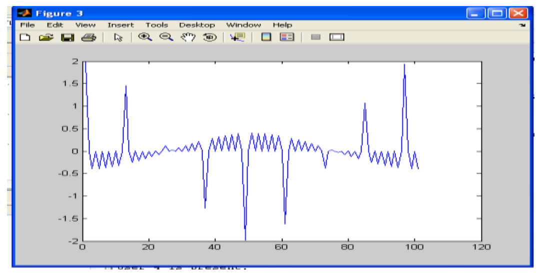

Figure 7(c): 60% Attenuation

Moreover, increasing the attenuation percentage leads to increase in the probability of missed detection, hence decreasing the probability of detection. The table and graph below show the effect of attenuation on the Probability of detection.

Table 2: Values of P_{FA}, P_D, P_{MD} for various values of attenuation percentage.

ATTENUATION	P_{FA}	P_D	P_{MD}
10%	0	1	0
15%	0	1	0
20%	0	1	0
25%	0	1	0
30%	0	1	0
35%	0	1	0
40%	0	1	0
44%	0	0.8	0.2
45%	0	0.6	0.4
50%	0	0.2	0.8
55%	0	0.2	0.8
60%	0	0.2	0.8

The following graph shows the change in the probability of detection with the change in the attenuation, showing that as the attenuation increases it leads to increase in signal distortion, leading to rise in probability of missed detection.

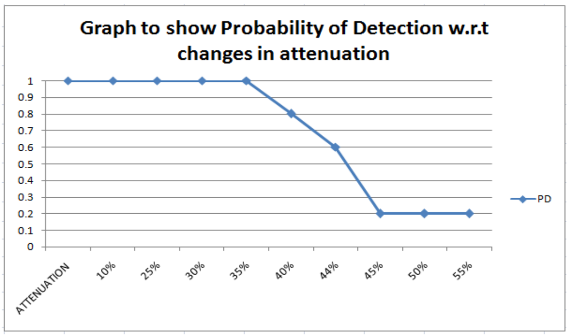

Figure 8: Graph between Attenuation and P_D

6. Conclusion and Future Work

In the proposed paper we are trying to show the effect of SNR and attenuation on the detection probability and probability of false alarm. From these graphs it is very clear that increasing the SNR will increase the probability that the users are properly detected, lowering the P_{MD} and P_{FA}. While, when the percentage of attenuation is increased, the P_{MD} increases which lowers the accuracy of detection, looking at the table, it is observed that till 44% attenuation the detection probability is up to the mark, while at 45% there is a drop in the detection probability, which is clearly due to distortion of signal that it couldn't be analyzed properly by the detector, giving out missed detections. Now, the motive here is to maintain the accuracy of the detection probability even above the 44% slab, till at least as far as 50% attenuation. This gives rise to another research paradigm, as to how to maintain the accurate detection till 50% attenuation, which based on our result starts getting lower after 45% attenuation.

7. References

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