SIMULINK BASED SPECTRUM SENSING

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***Abstract*—** There is an explosion in the field of communication technology today with the advent of numerous services being offered by various vendors. The available spectrum today is very limited and highly congested. Moreover, static allocation and assignment to a particular party leads to inefficient usage as it cannot be put to use incessantly. Also, the allocation is made for a specific technology and henceforth companies cannot utilize it for new services or techniques. Cognitive Radio is an upcoming area of research which addresses these concerns. Cognitive Radio makes use of Dynamic Spectrum Access wherein the complete spectrum is used by different users as and when they are available. This requires a spectrum sensing to detect available parts of the spectrum. This paper explores Simulink based Energy Detection which is a method under spectrum sensing and compares its performance with cyclostationary method under the high noise scenario. The research work also compares the performance of the system under various noise models such as Gaussian, Rayleigh and Rician.

Keyword- Cognitive radio, Spectrum sensing, FFT, Energy detection, Cyclostationary, Noise models.

I. Introduction

For the past few years, radios have been evolving and getting smarter. The communication systems that are in use today are able to adapt and alter in varying hostile conditions, depending on diverse variables to maintain connectivity. For example, 3G devices change their output power to make sure that power imbalances between different users do not take place. A cognitive radio is one such adaptive device and is considered to be very smart with decision making capabilities[1]. It is known to be an artificial brain capable of making decisions to sense, share and mobilize the channels in the spectrum. This also aids in analyzing the spectrum [2].

Dynamic Spectrum Access is often used alongside Cognitive Radio. Dynamic Spectrum Access involves sharing of the spectrum between the primary and secondary users [3]. The primary or licensed user is given priority as they hold the license. The secondary user is given permission to make use of the spectrum whenever the primary user is not active. The moment the primary user accesses the spectrum, the secondary user has to shift to an unused portion of the spectrum.

Cognitive Radio can find applications in various fields ranging from the military to the public safety domain. There is a mixture of centralized and decentralized networks, heterogeneous systems that need to interoperate with each other. Many of these systems need to be deployed in extremely hostile conditions. Networks might need to use varying amounts of bandwidth either temporarily or for longer durations. Cognitive Radio makes initial deployment easier by facilitating self-configuration of networks wherever possible with suitable architectures [4]. In places where rapid deployment is a necessity, any reduced manual configuration is a welcome move.

Spectrum Sensing is a key aspect of Cognitive Radio. Our objective is to utilize the empty channels in the spectrum to reduce the traffic in congested areas. Proper sensing forms the backbone of this software defined radio. Also, communication should not be marred by fading. Spectrum sensing in cognitive radio is applicable to radio frequencies only. Observing the unused spectrum of a licensed user is crucial to a cognitive radio. So, the primary user is sensed perpetually to allow channel mobility to another part of the spectrum; in case the primary user intimates to transmit[5]. This calls for an efficient hardware with negligible error percent. The threshold for detection forms the crux. This should be in consideration of the interference in the worst - case scenario. In sensing the primary user correctly, future spectrum analysis and decision making processes are assisted. It can be said as managing the spectrum dynamically[6].

Spectrum sensing methods are energy detection based, matched filter detection based and cyclostationary-feature[7]based. Cyclostationary feature detection is concerned with cyclically varying property or the periodicity in signal pattern. This periodicity is exhibited by primary user signal and hence can be taken advantage of, for our estimation analysis. The cyclostationary behavior preordained can be used to establish the probability of the presence of the signal[8]. This work tries to achieve sensing of this loose spectrum based on energy detection method and cyclostationary method including various noise models into consideration.

Section II deals with the motivation of the works and section III deals with the Simulation mode. Section IV deals with discussion and results and finally section V concludes the paper.

II. MOTIVATION

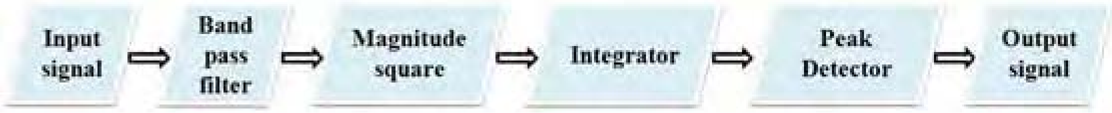

Fig. 1. Traditional energy detection

Fig. 1. defines the general energy detection method. In Energy Detection, the signal is passed through a band pass filter to weed out unwanted signals [9]. The magnitude of this signal is then squared. This magnitude squared signal is then integrated by an Integrator. A peak detector detects the peak magnitude [10]. The signal thus obtained is then used to devise hypothesis. The energy detection method is known to be the simplest approach to sense the spectrum which analyses the received signal to check if primary users are present. Any information transmission or reception involves energy [11]. If the received signal energy crosses the set threshold, the primary user is assumed to be present and hence the spectrum is occupied. If the received signal energy does not exceed the threshold, the primary user is considered absent and the secondary user is free to access the spectrum. The hypotheses are

H0: signal is absent = n(t) (only noise)

H1: signal is present= s(t) + n(t) (signal + noise)

Fig.2. Block diagram of cyclostationary method

Fig. 2. provides the block diagram of cyclostationary method. This method of detecting primary user transmission utilizes the cyclical varying property of the received signal [12]. The signal periodicity or mean and correlation characterize cyclostationarity [13]. The algorithms pertaining to cyclostationary recognize the user signal and noise. The usage of cyclic correlation functions instead of power spectral density is a favorable aspect of this method [14].

Additive white Gaussian noise (AWGN) is a channel model which has a constant power spectral density.It comes from various natural sources and it is due to the addition of white noise.The AWGN channel is suitable for various satellites and deep space communication links but not for terrestrial links.

Rayleigh distribution is a continuous probability distribution which arises when the overall magnitude of a vector relates to its directional components. Rayleigh distribution naturally occurs once the velocity is divided into its orthogonal 2-dimensional vector components. Rician noise is characterized by the Rican factor "k", characterized by $K=m2/2\sigma2$ where $m=m12+m22$.

In Rician noise, it is a tedious process to separate signal from noise. Wherever there is low signal-to-noise ratio the presence of Rician noise is problematic. It not only causes random variations, but also reduces image contrast [15]

III. SIMULINK MODEL

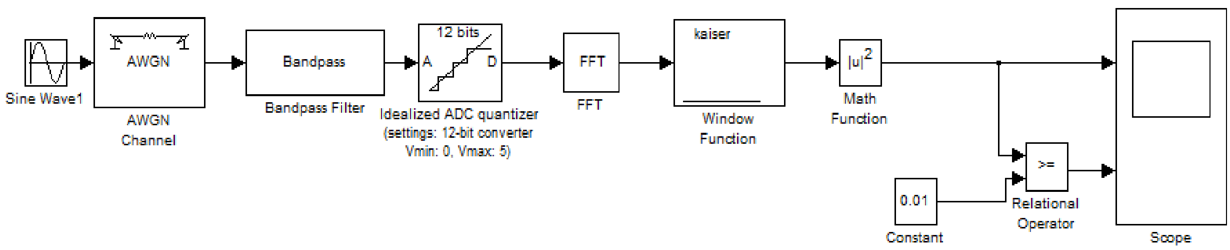

Fig. 3. Simulink model

Fig. 3. gives the Simulink based model for energy detection using FFT. Here, the analog signal is first filtered through a bandpass filter and then converted into a digital signal. A 12-bit ADC quantizer (Vmin = 0V, Vmax = 5V) is used. This output is then passed through an FFT to get the corresponding coefficients. The signal is converted from time domain to the frequency domain by the FFT block. The required band of frequencies is allowed by a Kaiser window. The magnitude of the received signal is then taken and it is squared. A minimum amount of signal is considered to be noise or unwanted signal disturbances. Hence, depending on environmental

and device parameters, a minimum tolerable limit is fixed as a threshold. The received signal is assumed to be present if and only if this threshold is crossed. This is done with the help of a relational operator which is placed in the comparator diagram.

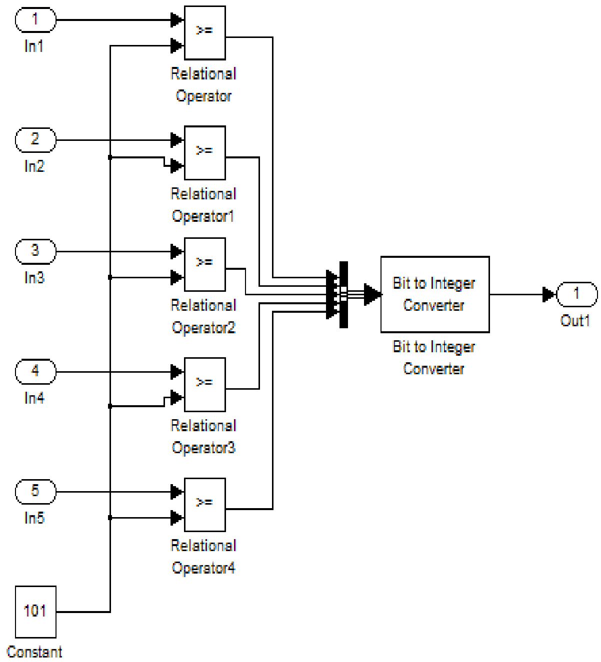

Fig. 4. Comparison of threshold.

Fig. 4. shows the threshold comparison of various users. The energy detection blocks are replicated for as many users as required (five in this case) and the results are studied. In this case, the threshold [16] is set to a decimal value. The output from the relational operator and the bit values from all five users are concatenated together to form a consensus. The veracity of detection is upgraded as the number of users is increased . As the users pool their resources, the threshold is reduced [17].

In cyclostationary method the sinusoidal signal is filtered using notch filter and converted to digital using idealized ADC quantizer. This signal is then strengthened by squaring magnitude after passing through FFT block. Such a signal is then shaped by windowing and this signal is correlated after which the decision is made. The cyclostationary and energy detection designs are observed in the absence of noise as well as in the presence of noise; particularly low and high noise levels in case of energy detection.

IV. Discussion and Results

The results are plotted and concluded using Simulink. In Fig. 5., the first five axes represent the five users. The sixth axis displays the output from the comparator after comparison with the threshold.

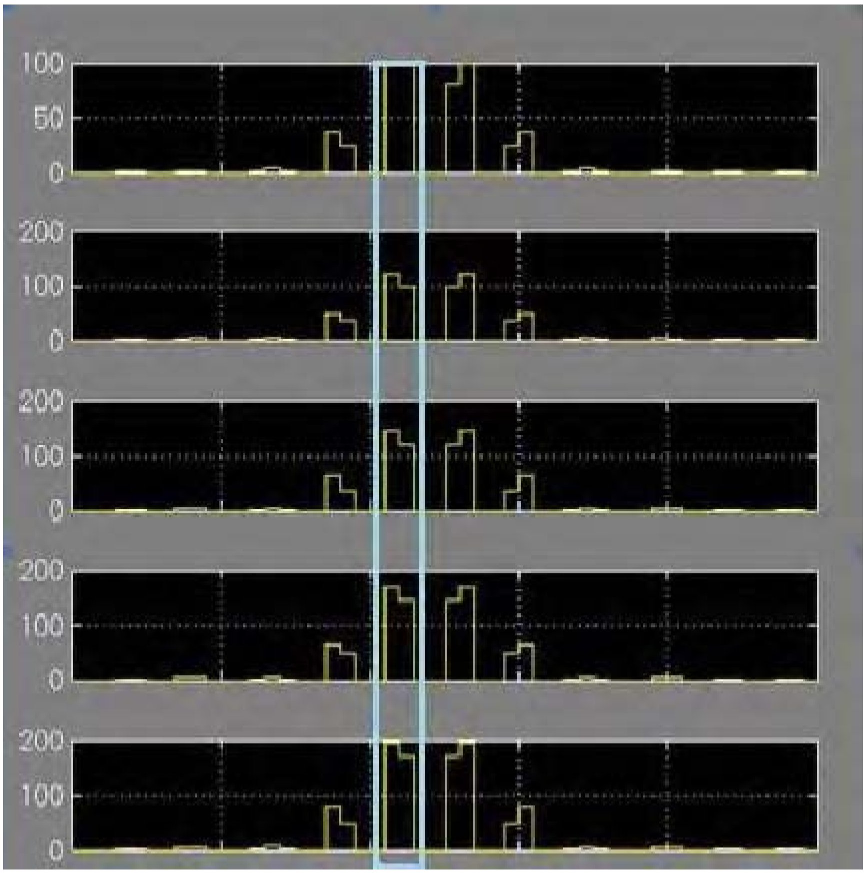

Fig. 5. Simulink output of energy detector with m=5

Here the y axis indicates the threshold. It is set as 101. It is evident that apart from the first user, the second, third, fourth and fifth users exceed the threshold of 101. From the figure it can be interpreted as the first user being present whereas the second, third, fourth and fifth users are idle.

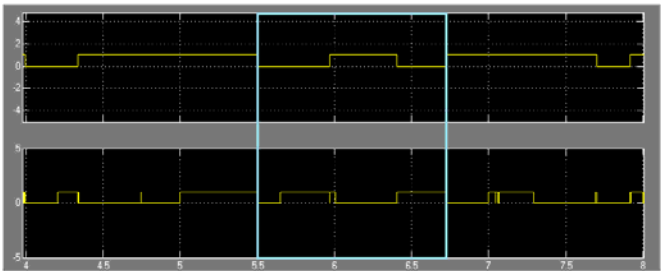

Fig. 6. Comparison of cyclostationary and energy detection method

Fig. 6. enunciates the comparison of cyclostationary and energy detection under noisy condition. The first and second axes denote energy detection and cyclostationary methods under heavy noise circumstance respectively. It can be observed that the cyclostationary method is unaffected by the noise. Though energy detection method usually performs well, it misdetects the presence of primary in the presence of heavy noise.

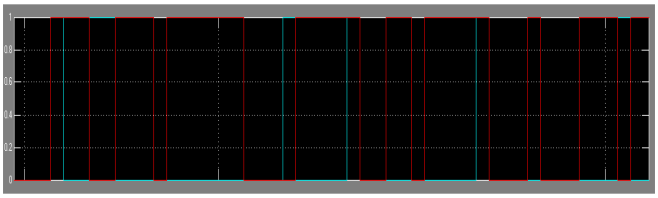

Fig. 7. Gaussian model

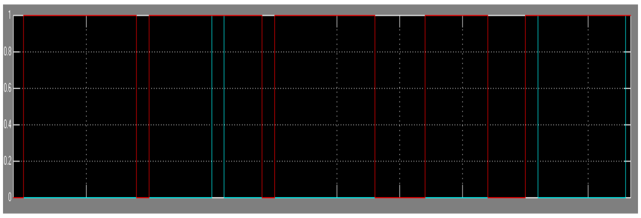

Fig. 8. Rayleigh model

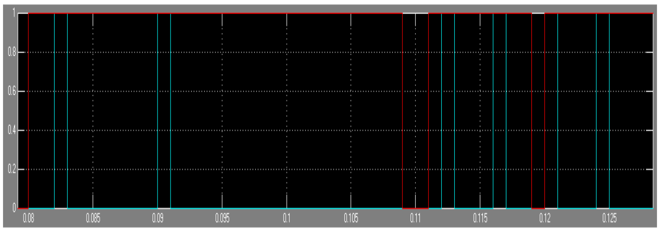

Fig. 9. Rician model

Fig. 7. shows the output of energy detection method with Gaussian noise in the channel. From the graph it can be concluded that the performance of the system degrades in the presence of noise. The red colored line indicates the presence of the primary users and the blue colored line indicates the presence of noise.

Fig. 8. gives the output of energy detection method when the signal undergoes Rayleigh fading. From the graph it is clear that the performance of the system is degraded badly. In this case the noise source dominates and as a result probability of detection decreases.

Fig. 9. shows the output of the energy detector method when the signal passes through the Rician channel. The performance of the system is degraded very badly when compared to the previous cases. The error rate increases and hence the probability of detection decreases.

V. Conclusion

This paper has implemented Simulink based spectrum sensing. The energy detection is carried out for five users. The presence or absence of the primary user is decided based on the threshold. Despite the energy detection method's desired performance, it is observed to give degraded results in the presence of noise which is overruled by the cyclostationary method. Also, the performances under various noise models have been implemented. The error is less in case of AWGN noise when compared to other noise models. The detection, cyclostationary and noise model analysis techniques used would be very helpful in the design of practical cognitive radio networks.

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