Co-channel and Adjacent Channel Interference in Cognitive Radio Multi-User Environment

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Finding vacant channels is one of the prime requirements of cognitive radio networks. The influence of devices operating in the adjacent channels is also to be considered especially when their signals are not properly cut off at the required cutoff frequencies. Also the effect of co-channel devices operating at a distance needs to be taken into account. This analysis is carried out in this work. It gives an idea of which channel can be used by cognitive radios at a given location and offers scope for proper planning by cognitive radios.

***Keywords*—Cognitive radio users, co-channel interference, adjacent channel interference, Bit Error Rate, Frequency Offset Factor, Roll off Factor.**

I. INTRODUCTION

The concept of cognitive radio has become popular in the recent times because of its promise of using the bandwidth efficiently. Across the globe, in many countries, wireless frequencies are already allotted for various purposes to different organizations. Of late, it was found that many of these frequencies are underutilized or inefficiently used by those organizations. It was also found that about 70% of the bandwidth of these allotted frequencies are wasted [1]. On the other side, there is hardly any bandwidth left to new services in the range of upto 2 Gigahertz, to be used conveniently by the present day electronic transceivers. This gave rise to the idea of making use of that idle bandwidth using opportunistic spectrum access mechanism. This mechanism is also called as dynamic spectrum access. As its name suggests, it tries to use the channels when the licensed user of it has not occupied it [2]. It should also take care that the channel needs to be vacated whenever the licensed user wants it for his operation. For this to happen properly, the opportunistic user should carefully observe the spectrum on continuous basis.

It also requires the knowledge of how much of the observed power can be considered as the 'presence of licensed user'. In this work, an analysis is carried out to draw conclusions on the presence of licensed user based on the signal power observed at various frequency ranges. As the opportunistic user does not know whether it is due to the primary user using the channel at distant location or a small quantity of power spill off from the adjacent devices [3] [4], the opportunistic user should take care to analyze it properly to arrive at a conclusion to occupy that channel or not.

Most of the times it may not be possible to know the type of a signal and the modulation technique used by the licensed user. Hence, received signal strength indicator (RSSI) is used as a prime indicator to know the activity of licensed users [5]. In general if a very low energy which is in the range of typical noise energy is observed with given channel, it can be considered that the channel is vacant [6]. There are exceptions in some cases where the signal is intentionally transmitted at low power levels like the case of CDMA, where multiple users transmit in the same channel but each of them at very low power levels. In these types of systems the power level is close to the noise level. However as there are multiple such devices sharing the channel in these kinds of systems, their combined power level is more than the usual noise level that is observed. So this can be considered as a probable presence of licensed users.

In fact the opportunistic user does not even know whether the observed energy in the channel is due to the licensed user or due to another opportunistic user like him who has occupied the channel prior to him. Also a smart opportunistic user can mimic the primary user to make the opportunistic user that has occupied the channel to vacate it [7] [8] . Hence care should be taken to avoid these kinds of misplays also.

The main aim of this work is to find best suitable channels for cognitive radio users by considering both co-channel and adjacent channel interferences. Part-II of the paper describes the popular Primary User detection techniques. Analysis carried out is described in part-III and part-IV illustrates the simulation results. Conclusion and future scope are given in part-V.

II. COMMONLY USED PRIMARY USER DETECTION TECHNIQUES

There are so many ways to detect the presence of primary users. If the signal detected by the SU is y(t), then it can be represented as [9].

$$y(t) = \begin{matrix} n(t)\ldots\ldots\ldots\ldots\ldots H_0 \\ x(t)+n(t)\ldots\ldots\ldots H_1 \end{matrix} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where n(t) is noise, H_0 and H_1 are hypotheses of absence or presence of PU signals and/or other SU signals respectively. Energy detection is the simplest method of detection. In this technique, the energy of the sensed signal is compared with a threshold and if the sensed signal is greater than the threshold then it will be concluded that the primary user is present, otherwise absent. The average energy of observed signal is

$$y = \frac{1}{N}\sum_{t=1}^{N} y(t)^2 \text{ --------------------- } (2)$$

Where
N= number of samples

Here selection of threshold is crucial. If threshold is very high then it results in misdetection of primary user, which shouldn't occur. On the other hand if threshold is very low then noise may also be treated as presence of primary user i.e false alarm, which results in missing the spectrum access opportunities. The main limitation of this technique is its performance is good only when SNR is high.

If the SU has prior knowledge of PU signals then matched filter detection or coherent detection [10] is used. Here the received signal is convolved with the filter whose impulse response is time shifted mirror image of reference signal. It needs very less sensing time, but requires the prior knowledge of PU signals, which may not be possible in real time. The convolution of received signal and impulse response of the filter can be expressed as

$$z(n) = \sum_{k=-\infty}^{\infty} h(n-k).y(k) \text{ -------------- } (3)$$

Z (n) will be maximum if signal is present and minimum for its absence.

Cyclo-stationary feature detection [11-12] checks for periodicity which is the distinguishing characteristic of signals but not the noise. It gives good results even for low SNR signals but the complexity of the circuit is high. It can be realized by analyzing the cyclic auto correlation function of received signal x (t), expressed as

$$R_y^{(\beta)}(\tau) = E[y(t) * y(t-\tau)e^{-j2\pi\beta t}] \text{---- } (4)$$

where E[.] is expectation operator used to find statistical average and β is cyclic frequency. $R_y^{(\beta)}(\tau)$ will be maximum for the presence of signal and minimum for its absence.

III. ASESSING THE RADIO ENVIRONMENT

Figure-1 is the typical environment diagram of the scenario considered here. As licensed users will always get good quality of service, the focus here is on the quality of service for secondary users. In this diagram multiple licensed users are shown to be transmitting. They are at different distances from the location of interest at which the opportunistic user is located. The multiple licensed users (interferers) shown in the diagram are considered to be occupying different channel frequencies. The opportunistic user should be capable of using any of these frequencies that are found to be free at various times. As discussed, these licensed users may not be transmitting all the times. So those unoccupied channels can be claimed by the secondary user. It can even claim those occupied frequencies also if that primary user is far away from this opportunistic user.

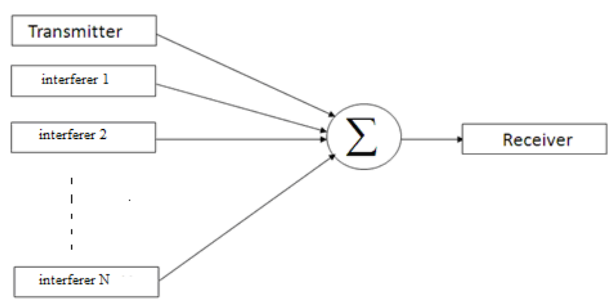

Figure- 1: Typical Environment Diagram

Co-channel interference is observed by varying the power of the co channel interferer. Adjacent channel interference is observed by varying the frequency of the interferer.

IV. SIMULATION RESULTS

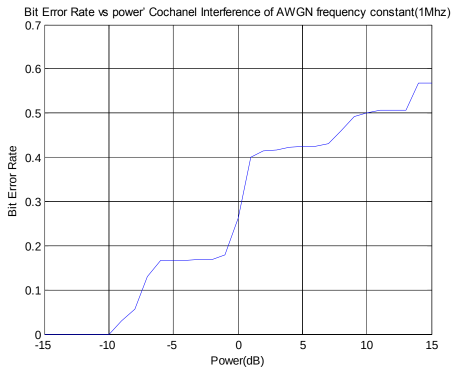

Figure-2: Bit Error Rate vs power in CCI

Figure-2 is the simulation result for the co-channel interference. It is observed here that by increasing power of the co-channel interferer (CCI), bit error rate also increases, as higher powers of another user operating in the same frequency increases the disturbance levels also.

Figure-3 is the simulation result of adjacent channel interferer (ACI) with equal power as the intended transmitter. Here we can observe that bit error rate decreases with increase in frequency offset i.e., the bit error rate decreases when the frequency difference between the intended transmitter and interferer increases.

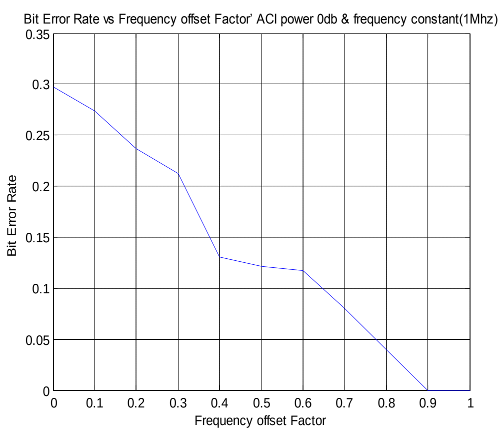

Figure-3: Bit Error Rate vs frequency offset factor in ACI

Figure-4 is similar to Figure-3 except for the interferer power being 3dB lesser than that of intended transmitter. Here we can observe that bit error rate is low compared to previous case. This is because of the fact that if the interfering user operates at less power bit error rate also will be less.

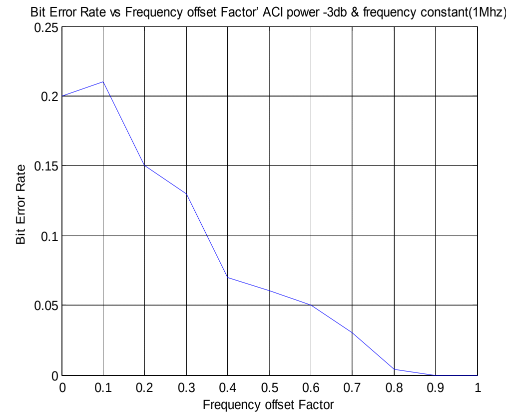

Figure- 4: Bit Error Rate vs Frequency offset factor in ACI

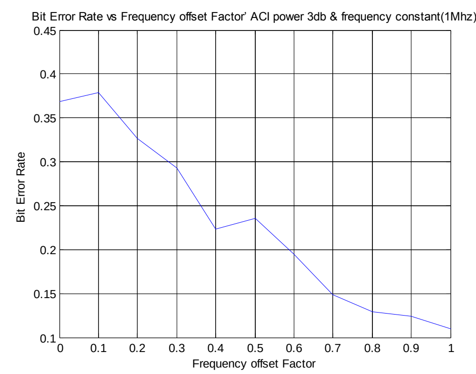

Figure-5: Bit Error Rate vs Frequency offset factor in ACI

Figure-5 is similar to Figure-3 but the interferer operates at 3dB higher power than the intended transmitter. Here we can observe that bit error rate is high compared to previous cases. This is because of the fact that if the interfering user is using high power, bit error rate will also be high.

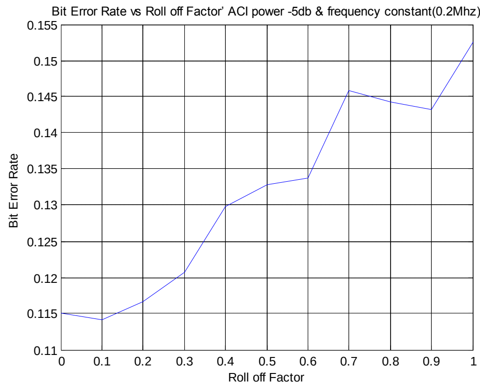

Figure -6: Bit Error vs Roll off factor in ACI

Figure-6 shows the simulation result of adjacent channel interference with power of -5dB and constant frequency offset of 0.2MHZ. We can observe that bit error rate is increasing with increase in Roll off factor. We know that if roll off factor is high, it means there is no sharp cutoff frequency and so the signal spreads into adjacent frequencies.

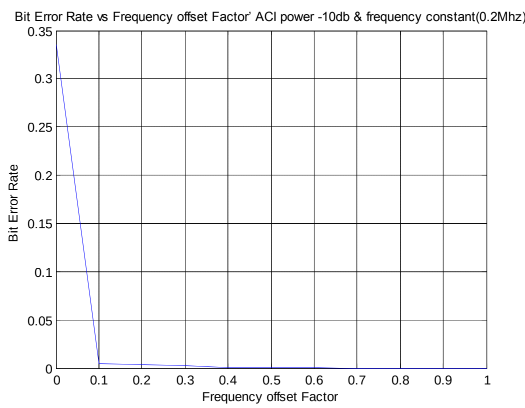

Figure-7: Bit Error Rate vs frequency offset factor in ACI.

Figure-7 shows the simulation result of Adjacent channel interference with power of -10db and constant frequency(0.2MHZ). Here it is observed that bit error rate is decreasing with increase in frequency shift. We know that if two users are using distant frequencies then there will not be a problem.

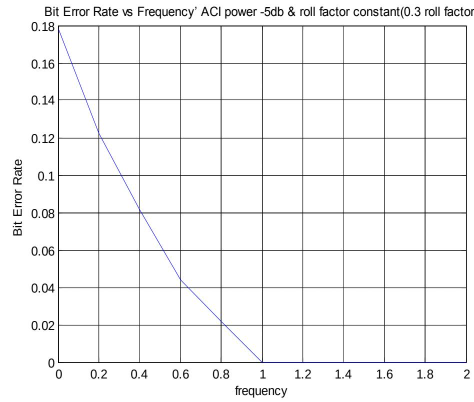

Figure-8: Bit error rate vs frequency shift in ACI

Figure-8 is similar to Figure-7 except for power is -3dB. Here we can observe that initial bit error rate is small compared to previous case. This is because of the fact that if the interfering user is using less power automatically bit error rate will be less.

V. CONCLUSION

Effect of interference to cognitive radio device is identified by simulating various scenarios of licensed users operating in the same channel and adjacent channels. Bit error rate is negligible when power of co-channel interferer falls to one tenth of the intended transmitter's power. In the case of interferer operating in adjacent channels, bit error rate is negligible when the frequency deviation is more than 1.2MHz when the power level of interferer is same as that used intended transmitter. Hence it suggests to consider the power levels and frequency deviations of other users before claiming the vacant channel. Bit error rate increases with increase in roll off factor. It gives an indication of not to use the channel that has adjacent channels with the improper filtering.

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