Autocorrelation Based Spectrum Sensing in Wi-Fi and LTE-LAA Co-Existence for 5G Systems Using USRP

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***Abstract*— Wi-Fi network is intended to work in unlicensed range just where it speaks with other Wi-Fi hubs. It utilizes a convention called Carrier-Sense Multiple Access/Collision Avoidance (CSMA/CA) which utilizes transporter detecting methods to stay away from crash by sending information just when its calculations sense channel to be "idle" for the transmission. Presence of both Wi-Fi and small cell LTE in unlicensed band (especially 5GHz), prompting their conjunction is a hotly debated issue for research now a days. We go for coexistence of LTE and Wi-Fi to utilize auxiliary or primary client's unused range. For clear channel evaluation, CSMA/CAA in Wi-Fi utilize both energy detection as well as channel sensing techniques whereas LTE-LAA employs just energy detection method. Energy detection is most usually utilized and straightforward spectrum sensing method yet it has numerous downsides moreover. As a technique for signal detection, energy detection experiences a few downsides. In the first place, to improve detection reliability, expanded detecting time is required. Also, there is a base SNR beneath which no signal can be recognized. Noise uncertainty brought by different elements (e.g., temperature changes, surrounding impedance, what's more, separating), is unavoidable and prompts blunders when setting the edge for signal detection. Because of all these reasons we are utilizing autocorrelation-based spectrum sensing strategy for better outcomes. Examination being completed in LabVIEW using USRP and gives better understanding of our work.**

***Index Terms* — Autocorrelation, spectrum sensing, USRP, LTE-LAA, Wi-Fi.**

I. INTRODUCTION

In this universe of arising innovation, with more headways and accessibility of communication services, number of clients working on hand-held gadgets are quickly expanding. Utilization of high-data transmission applications like web-based video, sound and webcasting by such enormous number of clients bring about a subsequent transmission capacity shortage and expansion in versatile information traffic. For giving each client a superior organizing experience by improving the throughput and information rate, we accentuate more on utilization of 802.11 Wi-Fi or small cell LTE network. However, high infiltration zones with colossal number of portable clients have expanded interest, and from here emerges the essential for time sharing of unlicensed range between Wi-Fi and LTE.

Wi-Fi network is intended to work in unlicensed range just where it speaks with other Wi-Fi hubs by a period sharing system dependent on Distributed Coordination Function (DCF) and with non-Wi-Fi networks utilizing Dynamic Frequency Selection (DFS) and Energy Detection (ED) method. Wi-Fi utilize a convention called Carrier-Sense Multiple Access/Collision Avoidance (CSMA/CA) which utilizes transporter detecting methods to stay away from collision by communicating information just when its calculations sense channel to be "idle" for the transmission. It utilizes the strategies like DCF to forestall impact by carrying out arbitrary back-off time component which relies upon the size of contention window and appropriate time slots allotment openings. On the opposite side, in the event that we talk about LTE, today, we as a whole are encircled by 4G LTE innovation. With expansion in number of versatile clients, their requests for better throughput and high information rate should also improve. Thus, to give a presentation lift to mobiles clients LTE totals the utilization of both authorized and unlicensed groups for the greatest benefit. For the downlink correspondence (DL), carrier aggregation is utilized by consolidating both authorized and unlicensed spectrum for a superior client experience and satisfying their every request. For uplink correspondence (UL), it utilizes its licensed bands only. With respect to coexistence for unlicensed LTE, there are two specifications: LTE Unlicensed (LTE-U) and LTE Licensed Assisted Access (LTE-LAA). This LTE-LAA has been created by 3GPP. Both of these details vary in the manner that LTE-LAA carries out Listen-Before-Talk (LBT) mode though LTE-U has nothing to do with LBT. LTE-U chips away at obligation-based methodology additionally called as Carrier Sense Adaptive Transmission (CSAT) which is utilized for getting LTE channels by changing OFF and ON lengths. LBT system utilized in LTE-LAA works in comparative design as CSMA/CA accomplishes for Wi-Fi. It is a detecting method which initially senses its current circumstance and communicates information just when it can discover a free channel to work on. At the point when a coexistence occurs between LTE-LAA and Wi-Fi, it ought to be in such a way that it will not influence the throughput and inertness of any of Wi-Fi and LTE-LAA, rather it ought to act as a boost for the overall performance. In this manner we can give an ideal meaning of “fair access or coexistence". In this undertaking, rather than utilizing energy detection strategy for spectrum detecting we are going to work with autocorrelation-based sensing method.

II. Related Work

Spectrum sensing is one of the common techniques used today to check whether the given spectrum is free or not. There are various spectrum sensing techniques which have been proposed in last few years. Examples of such techniques include energy detection (ED) [14], matched filter (MF) detection [15, 16], cyclo-stationary feature detection (CSD) [16-18], and covariance-based detection [19]. [12] a broad survey of the essential cognitive radio innovation with complete cognitive cycles and highlights are introduced and different parts of various spectrum sensing plans are modeled.[13] Introduced FPGA execution of an autocorrelation-based spectrum sensing which is able to do conquering DC offset and frequency offset issues is introduced.

For clear channel evaluation, CSMA/CAA in Wi-Fi utilize both energy detection as well as channel sensing techniques whereas LTE-LAA employs just energy detection method With the 3GPP Release 13 [6], LTE/Wi-Fi co-existence turned out to be major domain for research work and an area of great interest. In one of initial works on this topic, from a radio source management which was working to examine 5GHz LTE/Wi-Fi co-existence [7] reveals that LTE do affect the Wi-Fi in co-existence scenarios so their fair access needs to be handled carefully. In [9], LTE and Wi-Fi co-existence performance analysis by proper simulation also proved that in a co-existence scenario while performance of LTE is very less affected, Wi-Fi approach is mostly obstructed by LTE transmissions and as a result Wi-Fi has to wait in listen mode most of time. So, Wi-Fi performance gets devastated to a greater extent as compared to LTE in co-existence scenario. In [8], an experimental set-up was used to carry out research in LTE-LAA and Wi-Fi co-existence which discussed impact of carrier sensing thresholds. Other main conclusion of this research work was asymmetry in back-off parameters which are used in LTE-LAA and DCF standards which Wi-Fi use. This asymmetry is a topic of careful examination. Other issue is the recommended values of sensing thresholds. Let us take an example, Wi-Fi uses -62dBm ED threshold to detect non-Wi-Fi nodes but with this threshold Wi-Fi can interfere with signals weaker than -62dBm and is very hazardous for performance. So according to this research, various factors impact fairness of co-existence like sensing threshold, contention window size and transmission duration.

[9] revealed the problems which arise due to asymmetry of channel bandwidth between LTE-LAA and Wi-Fi. Depending on where bandwidth of LTE-LAA is situated with respect to 20 MHz Wi-Fi channel, Wi-Fi performance has a noticeable effect of low bandwidth (1.24 or 5 MHz) LTE transmissions. In [10], Rochman et al. by extensive simulation examined the effect of energy detection threshold on LTE-LAA and Wi-Fi and also proved that the total throughput can improved if both LTE-LAA and Wi-Fi works on a -82dBm sensing threshold value. On the other side, in [11] Qualcomm through proper simulation work explored the co-existence of Wi-Fi with both LTE-U as well as LTE-LAA and proved that without degrading the Wi-Fi performance we can make both LTE and Wi-Fi to share the same unlicensed spectrum and can achieve a fair throughput gain.

III. AUTOCORRELATION BASED SPECTRUM SENSING

In spectrum sensing primary users (PUs) seldom involves the whole authorized spectrum dispensed to them. The ensuing unused space between the channels could be utilized by auxiliary clients which are secondary users (SUs). The spectrum sensing algorithms ought to be prepared to dependably recognizing the PU. A few spectrum detecting techniques had been presented since the beginning of cogitative radio (CR).

Among them, energy detection (ED) procedure is the most normally utilized calculation. It is basic and utilizes signal's energy to recognize the presence of PU. But it presents genuine impediments with its powerlessness to differentiate the type of signals and poor performance in areas of low Signal to noise ratio (SNR). For great spectrum detecting, we can misuse any properties that exist in the signal that are absent in the noise. One such property is the autocorrelation of the signal samples. Orthogonal frequency division multiplexing (OFDM) is the adjustment utilized in many remote innovations like wireless local area network (WLAN), long term evolution (LTE), digital video broadcast – terrestrial (DVB-T), ultrawideband (UWB) and so on Autocorrelation based range detecting utilizes the innate cyclo-stationarity in OFDM signals. In each OFDM block, a specific number of signal samples at the end are repeated at the start of the block. This repeated information portion is known as the cyclic prefix (CP) and this records for the cyclo-stationarity.

The idea of cyclo-stationarity changes with the sort of OFDM signal being utilized since various sorts of OFDM have distinctive CP lengths.

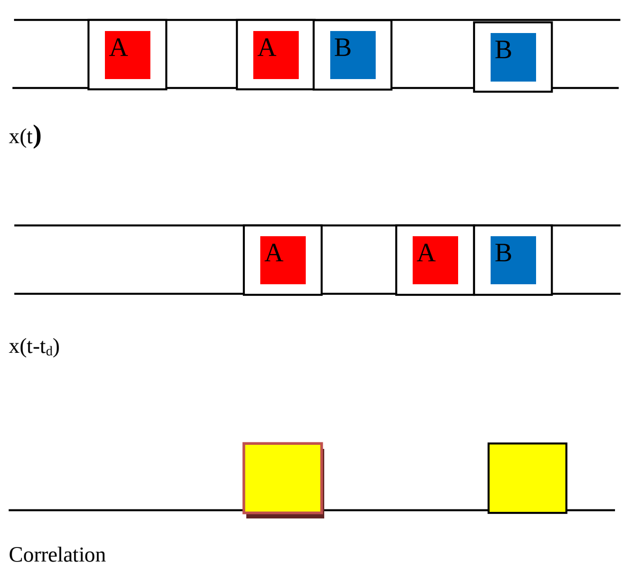

Fig. 1. OFDM frame structure and its correlation

IV. MATHEMATICAL MODELLING

Modulated sinc function is the autocorrelation function of band pass noise whose envelope has its initial zero intersection at 1/W, where W is defined as the bandwidth of the noise (sensing bandwidth too). Notwithstanding, the envelope of the autocorrelation function of the signal will go astray from a 'sinc', depending on the transmitted image rate, shaping of pulse, and modulation. At the point where the correlation is there in this signal, the initial zero intersection of the autocorrelation will occur at a bigger delay than that of the noise. To distinguish the deviation of the obtained waveform from noise, the envelope of the experimental autocorrelation work of the received signal is summed up to its first null τ = 1/W and this worth is utilized as a choice measurement to test the theory that an essential client is available, which deed with both the energy and autocorrelation of the received tests in signal handling, given a signal s(t), the consistent autocorrelation Rf(τ) is the constant cross-relationship of f(t) with itself, at slack τ, and is characterized as:

$$R_f(\tau) = \int_{-\infty}^{\infty} s(t)s'(t-\tau)\,dt$$

where s' addresses the complex conjugate. For a function which is real, s' = s. An Autocorrelation Function is one which is acquired by plotting the autocorrelation esteems that is obtained for different lags. An autocorrelation value which is near to one says that the signal is more correlated and it is less correlated when the value is close to zero. In spectrum sensing noise is a factor which enormously influences the quality of sensing. Also, when white Gaussian noise affects a signal, it is difficult to interpret it. Correlation will be very less and even can be negative for the very first lag it's the case of random noise as there hardly will be any similarity between two edges and samples. But periodic signal will have good correlation because of similarity between adjacent samples.

Autocorrelation based sensing technique is mainly used for analysis of the periodic nature of modulated signals which is mostly used in various communication systems applications as pulse trains, cyclic prefixes, sinusoidal carriers and spreading sequences. For wide sense stationary signal The mean and autocorrelation function will not be changing with time. Let the signal s(t) having constant mean $m_s(t)$ and autocorrelation function (ACF) which is function of time difference $t_2 - t_1$, $r_s(t_1, t_2)$ given as:

$$m_s(t) = E[\, s(t)] \qquad \_(1)$$
$$r_s(t_1, t_2) = E[\, s(t_1)\, ,\, s'(t_2)] \qquad \_(2)$$

Here E [.] represents the expectation of function variable. And

$$m_s(t) = K \qquad \_(3)$$
$$r_s(t_1, t_2) = r_s(t_2 - t_1) \qquad \_(4)$$

If $t_2 = t + \tau/2$, and $t_1 = t - \tau/2$, then equation becomes

$$r_s(t_1, t_2) = R_s(\tau) \qquad \_(5)$$

τ represents time constant. The spectral power density is given by Fourier transform of the time invariant autocorrelation function:

$$P_S(f) = \int_{-\infty}^{+\infty} R_s(\tau)e^{-j2\pi f\tau}d\tau \qquad \_(6)$$

If the signals are spectrally correlated then ACF can be represented as:

$$R_S(t,\tau) = \sum_\beta R_s^\beta(\tau)\, e^{-j2\pi\tau\beta} \qquad \_(7)$$

β represents correlated cyclic frequency. For periodic ACF β = K / T, where T is time period and K is any integer. $A_s^\beta(\tau)$ is autocorrelation function calculated as

$$R_s^\beta(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} R(t,\tau)\; e^{-j2\pi\tau\beta}dt \qquad \_(8)$$

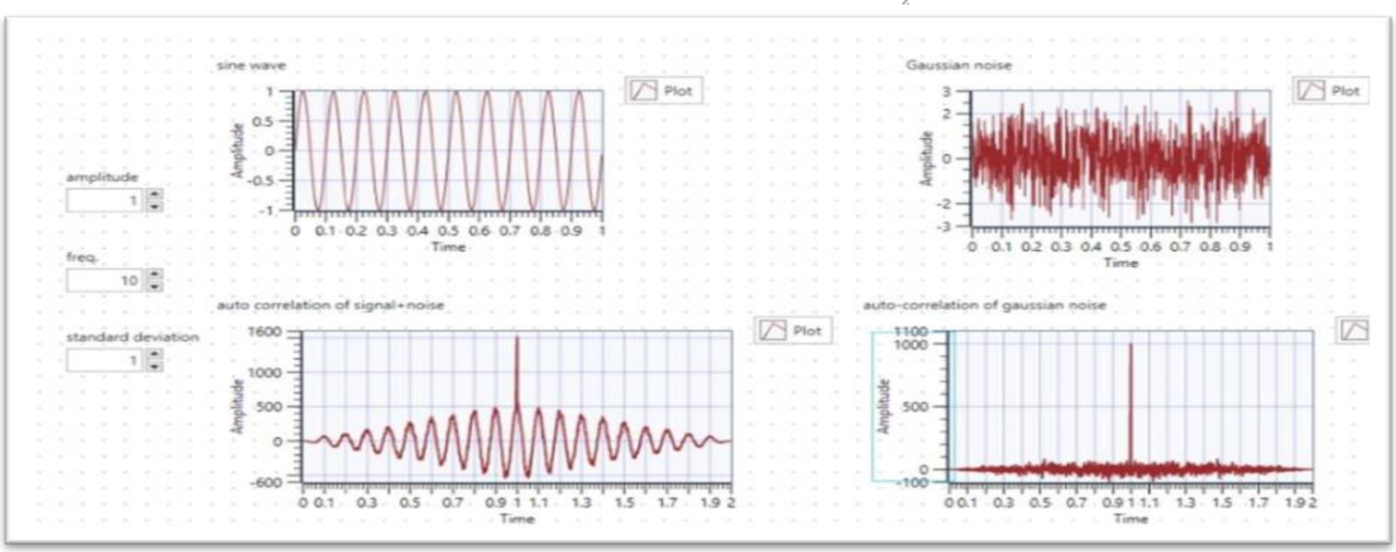

Fig. 2. (a) signal wave (b) Gaussian noise (c) autocorrelation of signal + noise **(d)** autocorrelation of noise

This can also be obtained from the signal $s(t)$ given as

$$R_S^{\beta}(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} s\left(t+\frac{\tau}{2}\right) s'\left(t-\frac{\tau}{2}\right) e^{-j2\pi\tau\beta}\mathrm{d}t \quad \_\ (9)$$

Then, the spectral correlation function can be calculated as the Fourier transform of ACF given as

$$P_S^{\beta}(\mathrm{f}) = \int_{-\infty}^{+\infty} R_S^{\beta}(\tau)(\tau)e^{-j2\pi f\tau}\mathrm{d}\tau \quad \_\ (10)$$

Eq. (10) correlates the spectral components of the signal $s(t)$. Since spectral correlation function is insensitive to additive noise. It does not contribute noise to the resulting function for any value of β because the spectral components of white noise are uncorrelated.

Function can be normalized as

$$S_S^{\beta}(\mathrm{f}) = \frac{P_S^{\beta}(\mathrm{f})}{\sqrt{P_S^{0}(\mathrm{f}+\beta/2)P_S^{0}(\mathrm{f}-\beta/2)}} \quad \_\ (11)$$

This function is especially useful for identify correlated cyclic frequency and it simplifies the selection of threshold value for detection to perform spectrum sensing. In first, the spectral correlation function for a single value β and all frequencies f can be estimated using the Fourier transform of a cyclical autocorrelation estimate. In second, the Fourier transform of the signal is correlation product between the spectral components smoothed over time period.

V. Results and Analysis

To validate our auto-correlation based spectrum sensing, we use LabVIEW software and USRP and results have been presented in this section.

Signal that is to analysed or checked is passed to autocorrelation block. Then magnitude of autocorrelation is calculated and that is compared to threshold value for the detection purpose. As a result, we get detected frequency which is same as the frequency at which transmitter is transmitting signal and hence validate the code.

At the receiver side, we have designed a code for sensing the signal using autocorrelation-based technique. USRP is a software defined radio which can receive as well as transmit the signals. We are making our transmitter to send signal at 1.08 GHz. As we can see from the figure 4, at 1.08GHz it is showing that primary user has been sensed along with the detected frequency value. This detected frequency is same as that of the one at which we transmit our signal. It is also clear from the figure 5. If the primary user is absent then received signal has only noise components and as we know two adjacent noise samples are very dissimilar so their autocorrelation is very low. On the other hand, if the primary user is present then at that particular frequency autocorrelation value with be high as now received signal = noise +primary user signal. Because of this reason it is clear from figure 5 that autocorrelation magnitude peak is maximum at 1.08GHz which implies presence of primary user. This code has very accurately done the spectrum sensing and even detects in scenario of low SNR overcoming the disadvantage of energy detection.

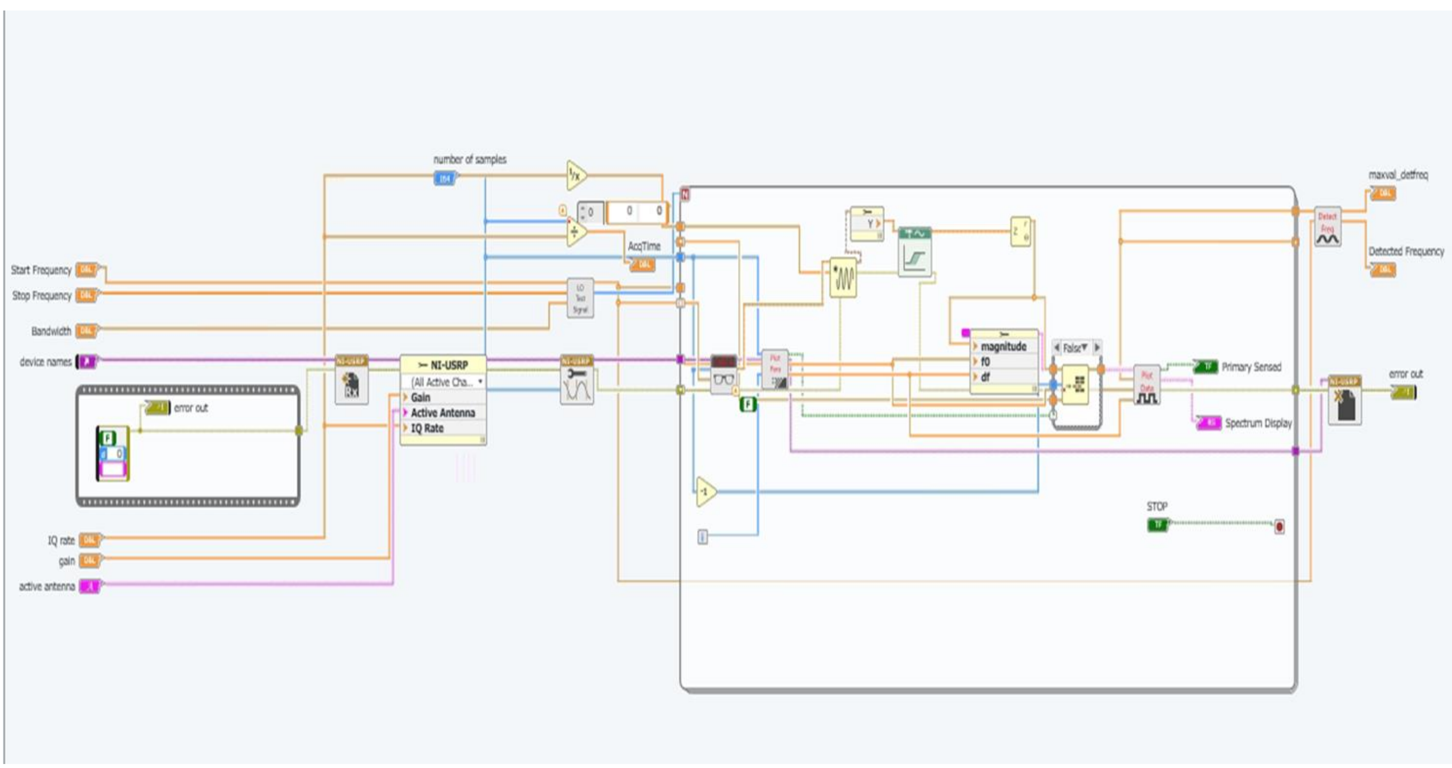

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Fig. 3. LabVIEW code for autocorrelation- based spectrum sensing

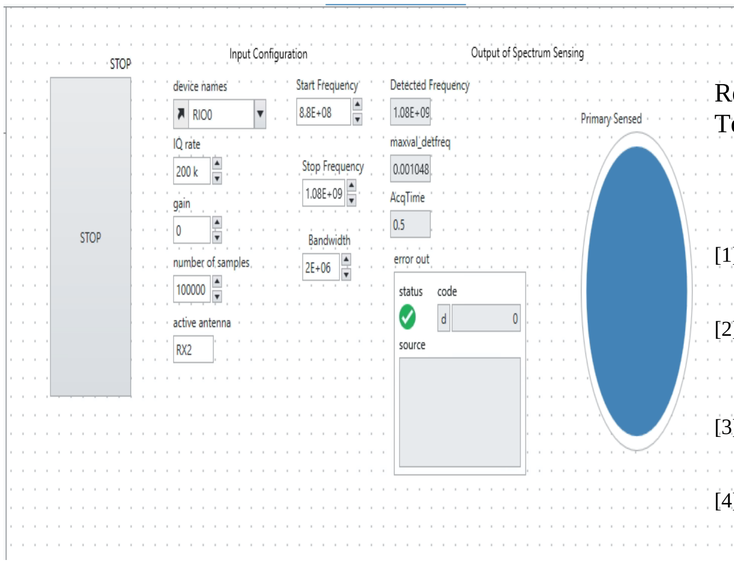

Fig. 4. Panel View in LabVIEW

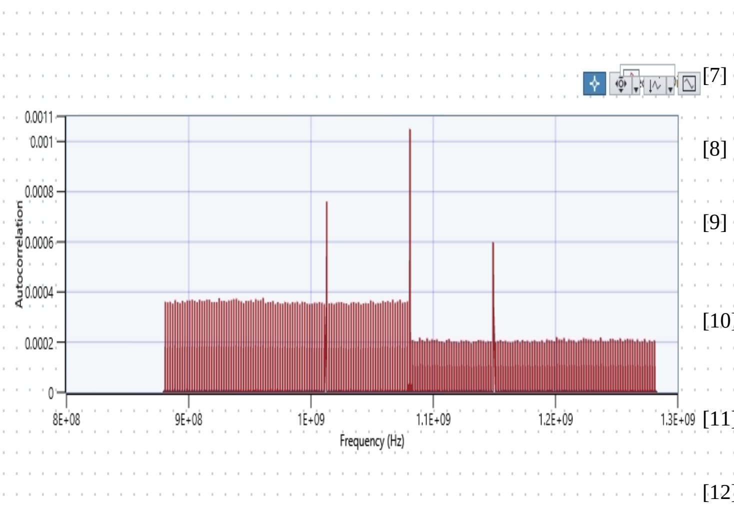

Fig. 5 Output plot between autocorrelation magnitude and frequency

VI. Conclusion

In this work, we have presented the autocorrelation-based spectrum sensing technique. While working with the energy detection scheme we faced various drawbacks like poor results in low SNR region so we switched to autocorrelated-based sensing technique. Output results show how accurately it can sense the presence of primary user and can distinguish between noise and true signal. Future work includes including this technique in LTE / Wi-Fi co-existence scenario case and present a new model analyze the performance with better accuracy.

VII. Acknowledgement

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