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Implementation of Spectrum Sensing Algorithm Based on Television White Space Scenarios for Spectrum Aggregation Applications

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Abstract: *With the proliferation of mobile devices and diverse mobile applications, wireless operators are experiencing phenomenal growth in the demand for mobile services around the world. These demands have led to the technological responses such as the advancement in radio access, coding and modulation schemes as well as spectrum (carrier) aggregation and cognitive radio capabilities. The aspect of spectrum or carrier aggregation uses cognitive radio technology that implements the dynamic spectrum access for spectrum utilization by sensing and using the underutilized spectrum on co-primary basis without interference to the primary users. In this work, an energy-based, non-parametric TVWS spectrum sensing algorithm was implemented in MATLAB environment. The developed sensing algorithm was aimed at finding free TVWS frequency channel(s) that would be used during spectrum aggregation of channels from TVWS and LTE-A spectrums. The chosen free channel would be configured as the component carrier two (CC2) at the configuration management platform of the TVWS eNode B. The result showed the instantaneous TV channels statuses; free, busy and interfered by computing the PSD expressed in dB while the estimated received power level in dBm for free channels was computed for the UHF range from channel 21 through channel 69. The detectable TV signals' threshold value was set at -114 dBm. In the ten simulation five cycles carried out, the developed algorithm instantaneously selected channels: 68,34,48,60 and 28 corresponding to the centre (carrier) frequencies of 850MHz, 578MHz, 690MHz, 786MHz and 530MHz, would be dynamically configured as the component carrier two (CC2) in the TVWS eNode Bs during spectrum aggregation process.*

Keywords: LTE-A, PSD, TVWS, UHF

I. INTRODUCTION

Spectrum or rather bandwidth being a scarce commodity in communications, through cognitive radio capabilities of wireless networks, it is possible to access and perform spectrum/carriers aggregation with the underutilized frequency bands (channels) of the Radio Frequency Spectrum in order to increase the bandwidth for the network users ([1], [2], [3],). One of such underutilized spectrum bands is the Television (TV) broadcast band with frequencies from 52 MHz to 862 MHz which lies just below the wireless communication spectrum band on the Radio Frequency Spectrum [4]. The underutilized bands are as a result of bands vacated by analogue television users usually referred to as the Television white space (TVWS) during Digital Switchover process (DSO) [3]. For Region 1 which comprises of Africa, Europe, former Soviet States, Middle East and Islamic Republic of Iran, this process (DSO) is expected to be fully completed by 2020 as mandated by the International Telecommunication Union–Radio Section (ITU-R) ([5], [6], [7]). Meanwhile the IEEE 802.22 standard has provided framework for the use of TVWS for wireless communication using Cognitive Radio (CR) capabilities not only for the freed analogue UHF channels but also to the entire frequency spectrum from channels 21 to 69 provided it does not interfere with the primary users. That means that, the Secondary User (SU) uses the TVWS channel only when the channel is absolutely free from licensed Primary User (PU) usage.

In order to avoid any harmful interference to primary services in TVWS, secondary users (SUs), named as White Space Devices (WSDs) in TVWS, should have the knowledge of spectrum occupancy. Two approaches have been proposed to make SUs aware of the spectrum occupancy namely; spectrum sensing and geolocation database [8]. In a typical wireless network, spectrum sensing is carried out by cognitive radio at base stations (eNode Bs). In this process, the cognitive radio continuously scans through the spectrum, detect free frequency channel (s) for use and automatically switch to another free channel (s) within the unlicensed spectrum when a primary user is detected [9]. The free frequency channels sensed in this way are used during the extension of LTE-A network to operate in TVWS through spectrum aggregation process. Sensing techniques can be classified as either parametric (signal specific) or non-parametric (blind). A parametric technique is a type of sensing that detects signals in a channel based on specific features of the signal like the detection of an incoming pilot signal of known frequency. On the other hand, the nonparametric sensing technique is a technique that does not rely on specific features of the signal like the Energy and Eigen value detections techniques [1]. One of the common hardware tools used in spectrum detection is the universal software radio peripheral (USRP) device in collaboration with frequency analyzers [3]. Spectrum sensing requires SUs to have the capability to detect spectrum holes that are not occupied by primary users (PUs) and also to mitigate the effect of unlicensed users like Public Making and Special Events (PMSE) devices such as wireless microphone that operate mostly on an unlicensed basis ([1], [10])..The other approach is the geolocation database where the service provider issues vacant TV information to subscribers which include channel location and time. However in this method, the PMSE cannot be detected and also it uses theoretical propagation models instead of actual measurements when computing the power received levels. This might result in errors during vacant channel status. Therefore, the geolocation service providers combine the two methods while providing services to their subscribers. ([8], [11]).

Spectrum Aggregation (SA) is defined as the ability to concurrently access spectrum opportunities by a radio or a set of radios in a different band through the use of technology [12]. In simpler terms it is the aggregation of component carriers (CC) of a wireless network from frequency channels of different spectrum bands. The component carriers (CC) refer to individual frequency carrier to be use during Carrier Aggregation (CA) or Spectrum Aggregation (SA). An example of SA is the aggregation of components carriers from LTE-A and TV spectrums on the Physical Layer (PHY) of Open System Interconnection (OSI) communication layers as shown in Fig.1

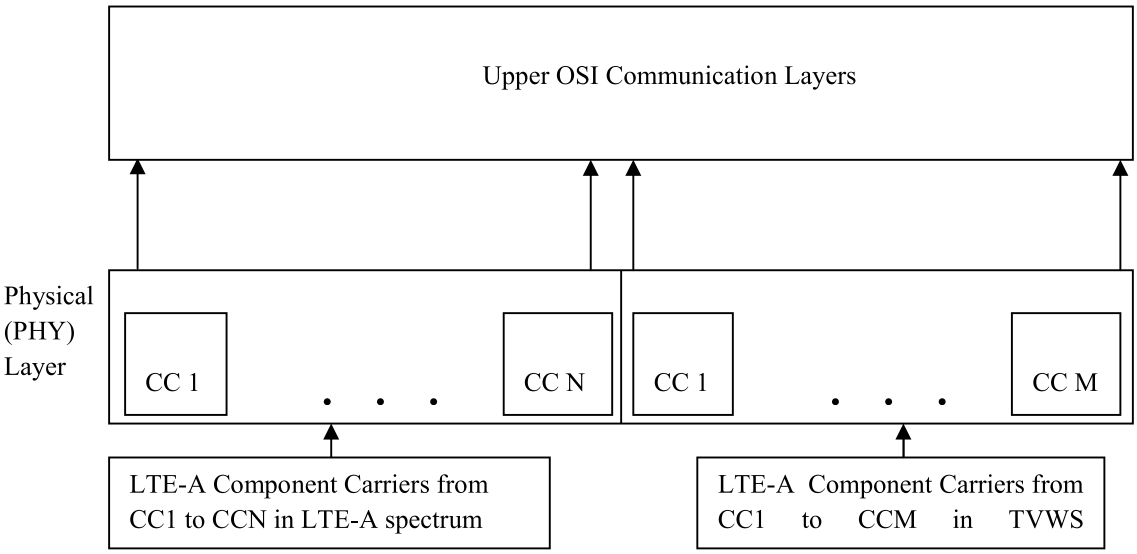

Fig. 1: Block Diagram of Spectrum Aggregation of LTE-A and TVWS.

In this paper, the focus is to implement an energy based spectrum sensing algorithm based on the TVWS scenarios for spectrum aggregation applications. The remaining pat of the paper is organized as follows;, review of related works is discussed in Section II, TVWS scenarios and algorithm implementation are dealt with in Section III, the results and discussions are displayed in Section IV and finally, the conclusion is drawn in Section V.

II. REVIEW OF RELATED WORKS

[13] has presented a parametric online learning algorithm for spectrum sensing. The algorithm looked for optimum decision signal threshold to decide the presence of a Primary User (PU) The performance of the proposed algorithm

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was tested over non-fading and different fading channels for low signal-to-noise ratio regime with noise uncertainty. The results showed performance improvement with high probability of detection and low false alarm when compared with the matched filter-based spectrum sensing method. Public Making and Special Events (PMSE) signals were not considered in this work which could lead to PUs interference. Also it was not applied to TVWS channels that are temporal and spatial in nature.

Also, [14] employed the use of Deep Learning Networks (DLN) based on Long Short Term Memory (LSTM) to sense spectrum. The LSTM used feature learning from spectrum data. The DLN was trained using several features of the signals and the performance of the proposed sensing technique was validated with the help of an empirical testbed setup using Adalm Pluto. The testbed was trained to acquire the primary signal of a real world radio broadcast taking place using FM signals Experimental data showed that even at low signal to noise ratio, the algorithm performed well in terms of detection and classification accuracies when compared with the existing machine learning techniques such as ANN, DNN, Random forest, SVM, and Gaussian Naive Bayes. Some initial data were needed but issues like PMSE with no prior notice might cause interference to the PU.

Similarly, [15] improved upon the Convolutional Neural Network (CNN) sensing algorithm by using Deep Convolutional Neural Network (DCNN) which enhanced feature extraction. This method transformed the spectrum sensing problem into the image binary classification which trained the DNN model through residual learning and extracted the deep image features. The testing data was input into the model and the spectrum sensing through image classification was completed. The result showed that the proposed algorithm provided high detection probability with low false alarm at low Signal-to- Noise Ratio (SNR) when compared with the CNN and SVM. Also, the issues of PMSE and the characteristics of TVWS channels were considered.

Lastly, [16] presented an energy based spectrum sensing algorithm termed as energy detection with entropy. This method addressed the energy based spectrum sensing techniques challenges affected by noise instability at low SNR. During the implementation, non cooperative energy based spectrum sensing with entropy was carried out using MATLAB simulation tool. The result showed that at the SNR of -18 dB the proposed algorithm has a probability of detection of 0.4818 while the Conventional Energy Detection algorithm presented a value of 0.4063. This means that the proposed algorithm has improved by 18.58% when compared with the Conventional Energy Detection algorithm. Temporal and spatial variability of the TVWS spectrum were not considered.

III. TVWS SENSING SCENARIOS AND ALGORITHM IMPLEMENTATION

The TVWS channels that are used in this work are the ultra high frequency (UHF) channels comprising of channel 21 through channel 69 with their corresponding carrier frequencies representing $C_{total}\ channels$. The channel sensing is done using the energy based nonparametric detection technique. The energy of a channel is estimated by computing the power spectral density (PSD) of generated signal(s) in a channel. This sensing technique computes energy of each channel during a simulation time cycle thereby leading to the UHF channels to be categorized into three scenarios namely; free, busy and interfered channels. The bandwidth of any TVWS channel is 8MHz which can be represented as channel lower (f_L) and upper frequency (f_H) limits and centre (carrier) frequency (f_C).

3.1 Free TVWS Channel

A channel is free when the computed PSD of the TVWS channels is less than or equal to PSD_{free} as shown in equation (1). PSD_{free} is the minimum noise margin power of about 0dB [17].

$$Computed\ PSD\ of\ n\ channels \leq PSD_{min} \quad \dots (1)$$

The developed algorithm in Figure 8 chooses any TVWS channel within PSD_{free} candidates W and allocate the channel n such that $n \epsilon W$ ($W \subset C_{total}\ channels$) with the least received signal power PSD_{min} for secondary use based on the LTE-A bandwidths [18]. This because there might be many PSD_{free} UHF channels during a simulation cycle. PSD_{min} is the minimum detectable power threshold level of a frequency channel at a point and is usually expressed as the signal received power level (RxLev) in dBm. The value for PSD_{min} is -114 dBm [19]. Figs. 2 and 3 demonstrate this scenario. Fig. 3 shows a free channel with minimum power received level is detected while Fig. 4 shows a secondary user is instantaneously allow to occupy the channel for aggregation use.

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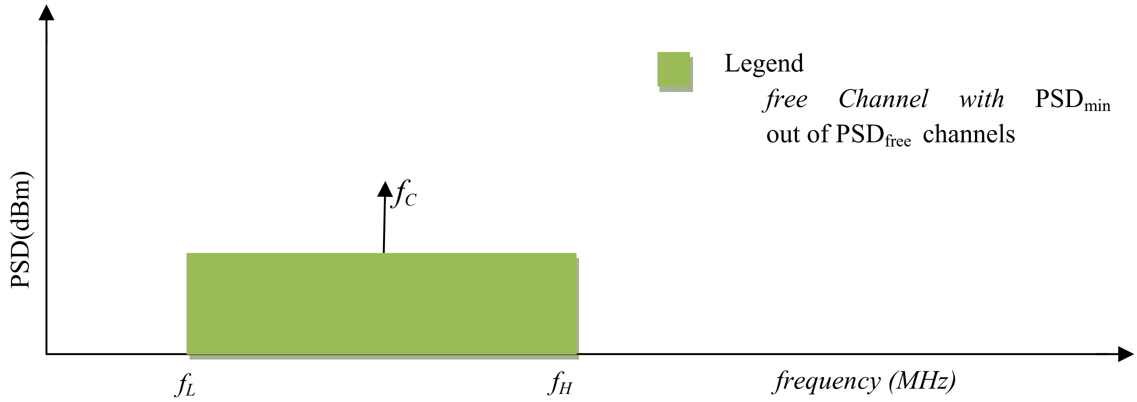

Fig. 3: Sensed free TVWS channel

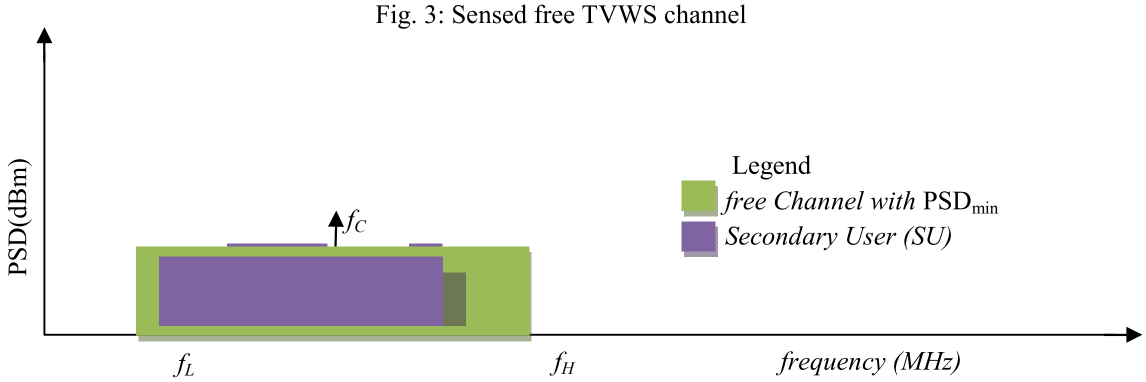

Fig.4: Sensed free TVWS channel with Secondary User Allocation.

3.2 Busy TVWS Channel

A channel is said to be busy when there is presence of primary user on a TVWS channel. In this case the algorithm in Figure 8 computes the PSD and compares it with threshold value PSD_{Int}. The threshold value PSD_{Int} is the channel power in dB that is greater than the noise power margin (PSD_{free}) in dB. If the computed PSD of the prospective TVWS channel is greater than PSD_{Int}, then such TVWS channel would be classified as busy channel and be ignored at that scanning cycle. The mathematical formulation of this situation is shown in equation (2).

$$PSD_{free} < PSD\ (scanned\ channel) > PSD_{int} \quad \dots (2)$$

Fig. 5 shows the algorithm senses the TVWS channel but is already occupied with a primary user. The developed algorithm classifies this type of channel as busy channel(s).

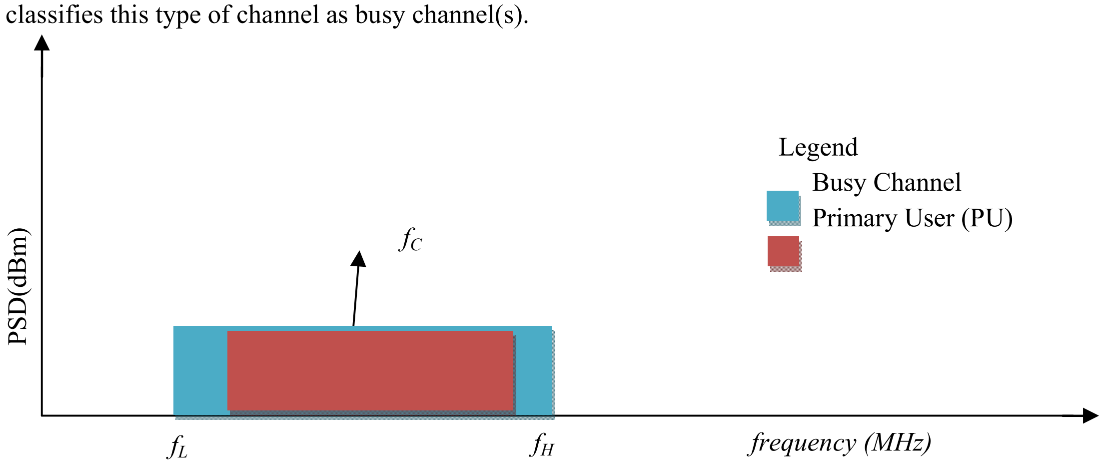

Fig. 5: Sensed Busy TVWS Channel with Primary User

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3.3 Interfered TVWS Channel

An interfered channel is a situation where a TVWS channel is being occupied for secondary use (spectrum aggregation) but a primary user (either analogue or digital TV users) for that channel has been tuned 'ON' to use the channel. Because the primary users have legitimate right to use their licensed TV channel, the secondary user has to vacate the channel immediately. That would happen when equation (3) is satisfied.

$$PSD_{free} < PSD\ (scanned\ channel) \leq PSD_{int} \qquad \ldots (3)$$

The algorithm would classify that channel as an interfered channel and immediately switchover to a free channel for continuous secondary user operations. Fig. 6 showed a channel is allocated for secondary use but a primary user is put 'ON' to use the channel. The developed algorithm removes the secondary user from the channel.

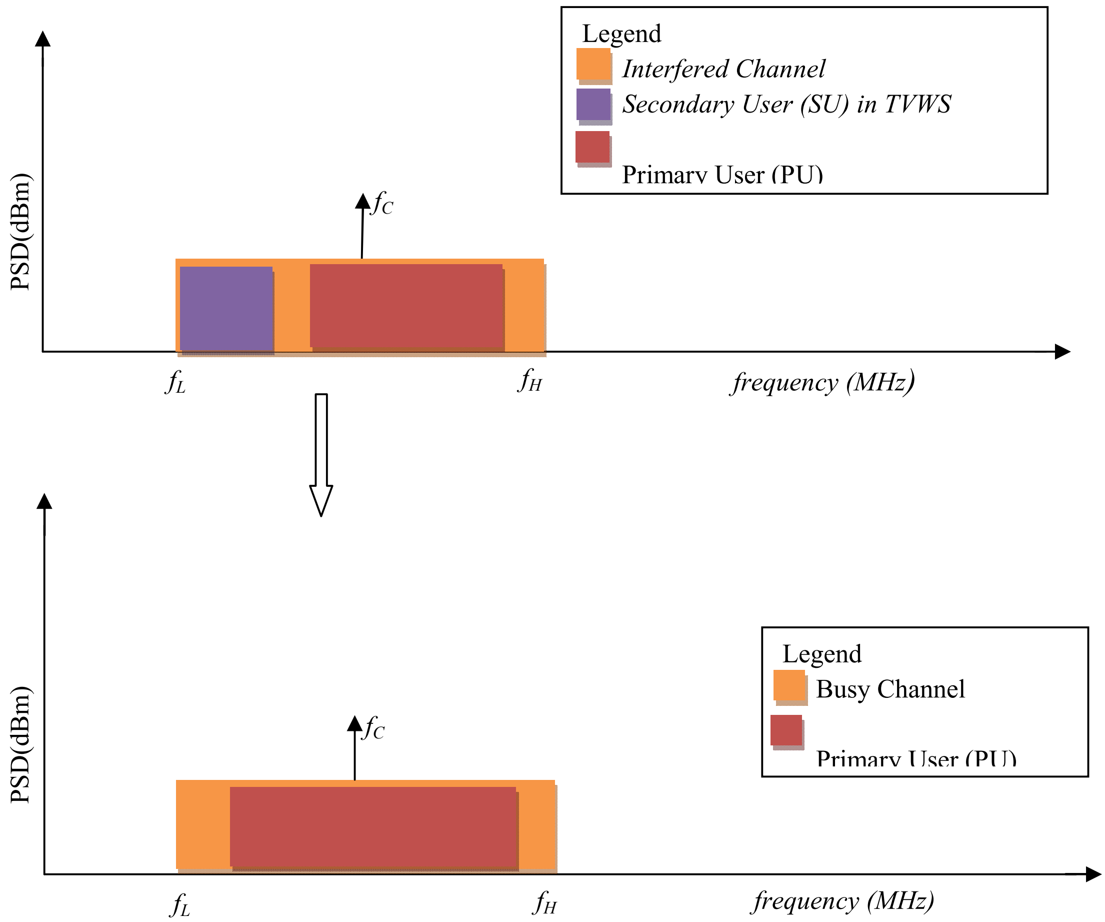

Fig. 6: Sensed interfered TVWS channel with Primary User

The flowchart for the proposed TVWS sensing algorithm is presented in Fig. 7 where the computed PSD of received signals of each channel was compared with the Threshold values. The algorithm has been implemented to allocate TVWS channel during Spectrum Aggregation Deployment (SAD based on the channel scenarios discussed namely; busy, interfered or free. With reference to flowchart of Fig.7, the PSD_{int} , PSD_{free} and PSD_{min} were earlier own discussed.

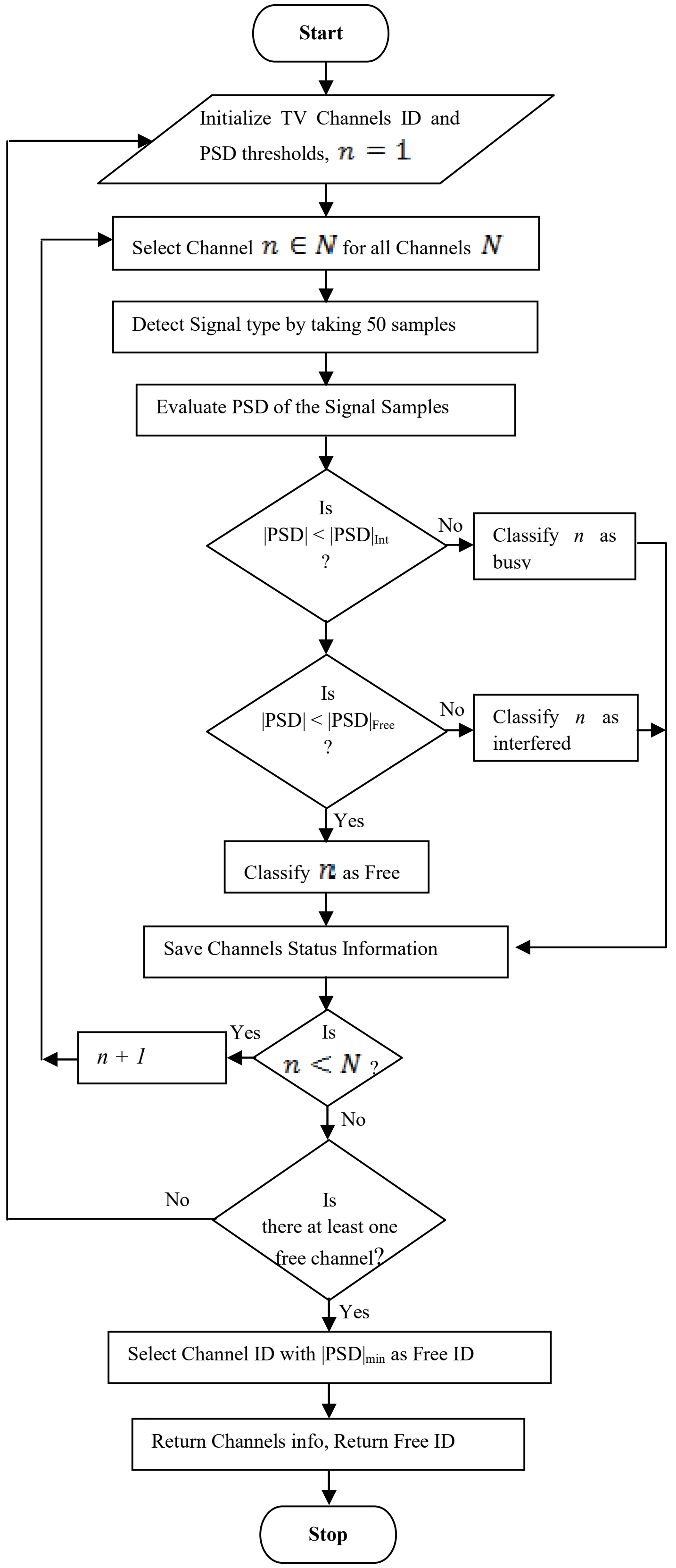

Fig. 7: Flowchart of TVWS Sensing Algorithm

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Table 1: Channel Sensing Simulation Parameters

Parameter	Values
Channel Numbers (UHF)	21 - 35,39 - 69
Channel Centre Frequencies	(474 – 860) MHz
N	512
M	64
k	50
PSD_{min}	-114 dBm
PSD_{int}	18 dB
PSD_{free}	1.7 dB
FFT size	1024
Window Type	BT

IV. RESULTS AND DISCUSSION

This section presents the results and discussions showing the status of the TVWS channels based on the simulation scenario and the received power level in dBm of the prospective free channels with computed minimum received level. The result for five simulation cycles showing the channels ' condition as free, busy or interfered are shown from Figs. 3 to 6. . Similarly for each simulation cycle, the computed received power level in dBm is shown.

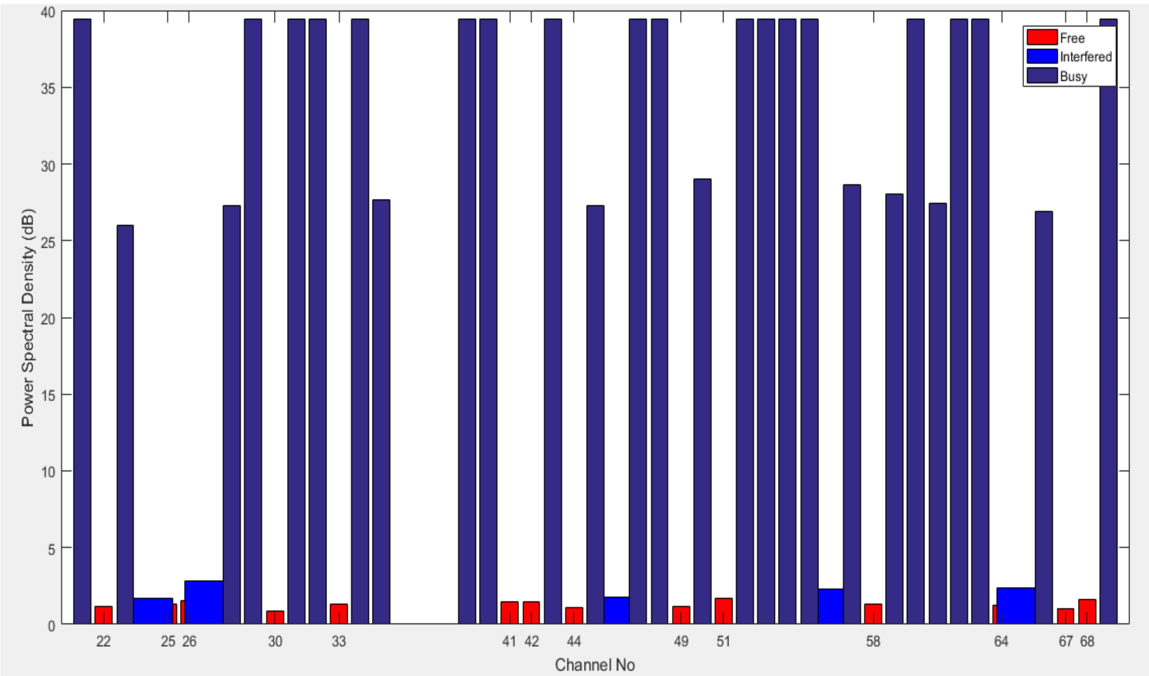

Fig. 8: TVWS Channel Sensing Status for simulation number 1

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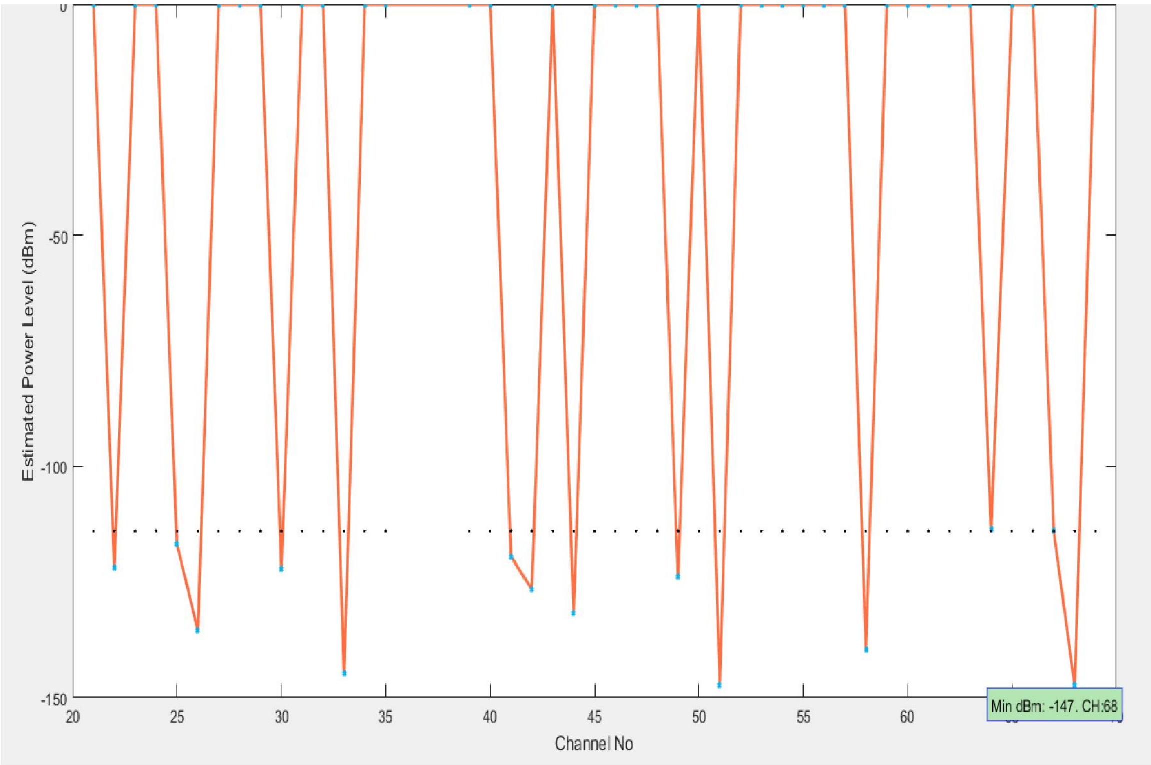

Fig. 9: Received Power level for simulation 1

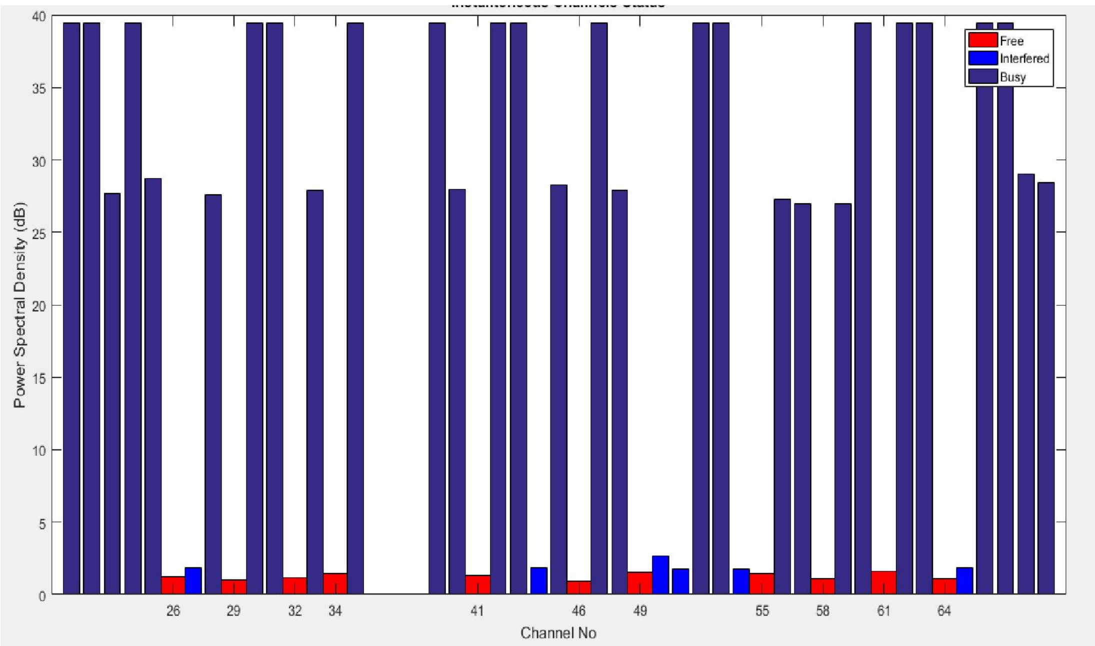

Fig. 10: TVWS Channel Sensing Status for simulation number 2

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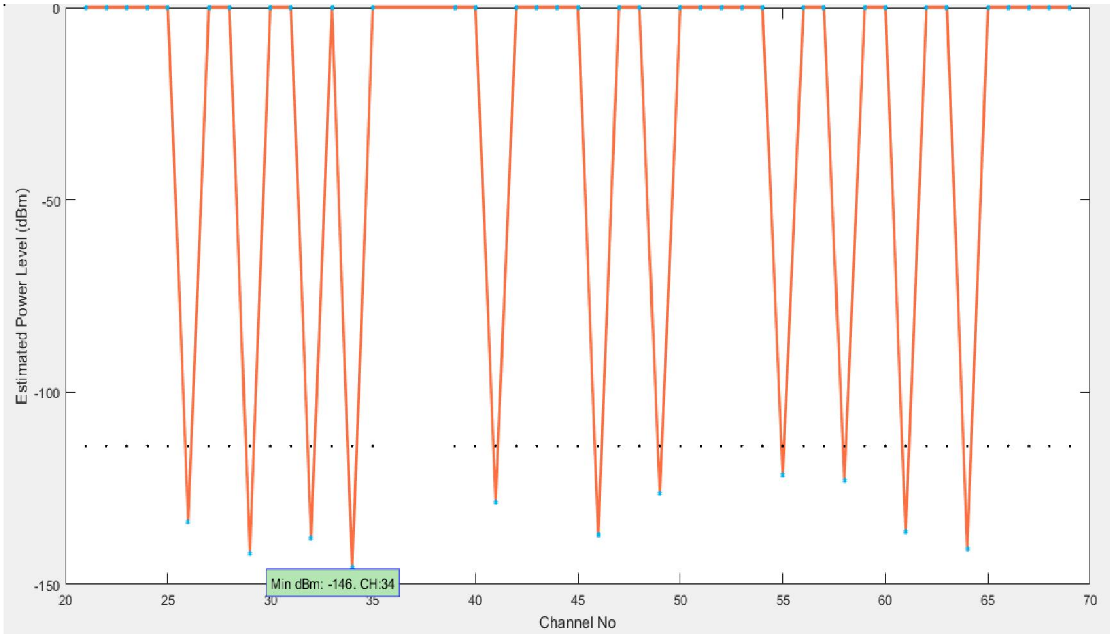

Fig. 11: Received Power level for simulation 2

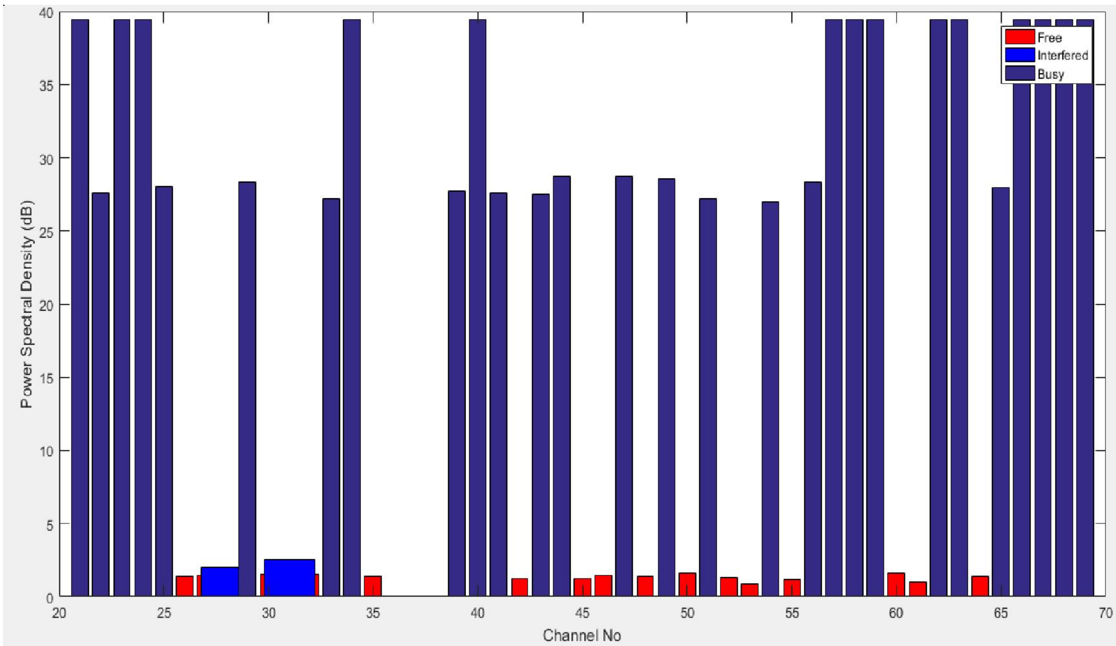

Fig. 12: TVWS Channel Sensing Status for simulation number 3

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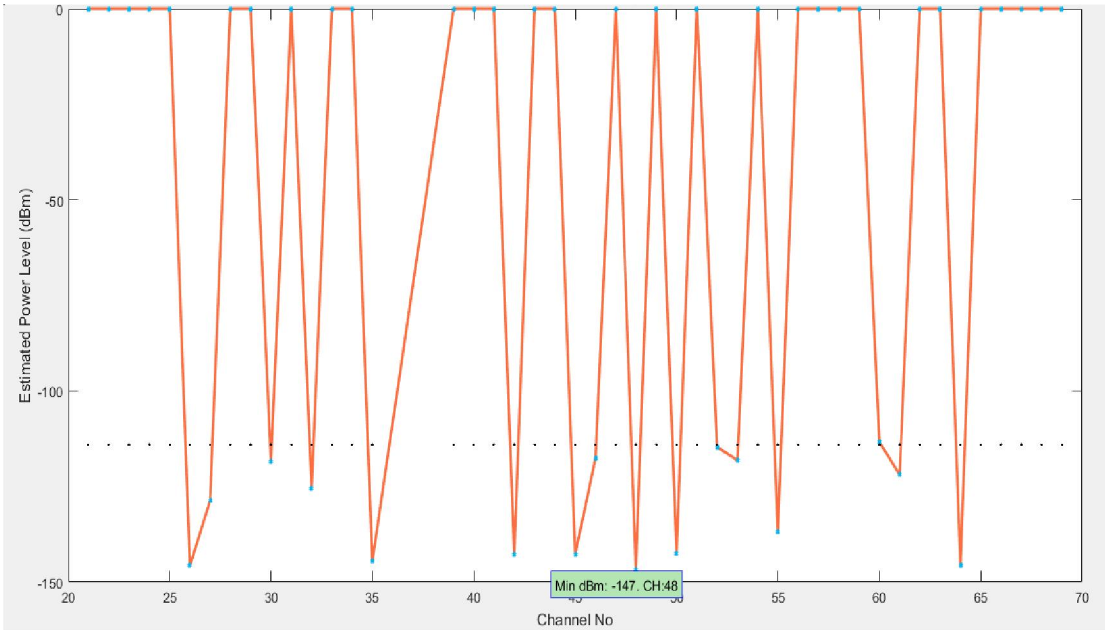

Fig. 13: Received Power level for simulation 3

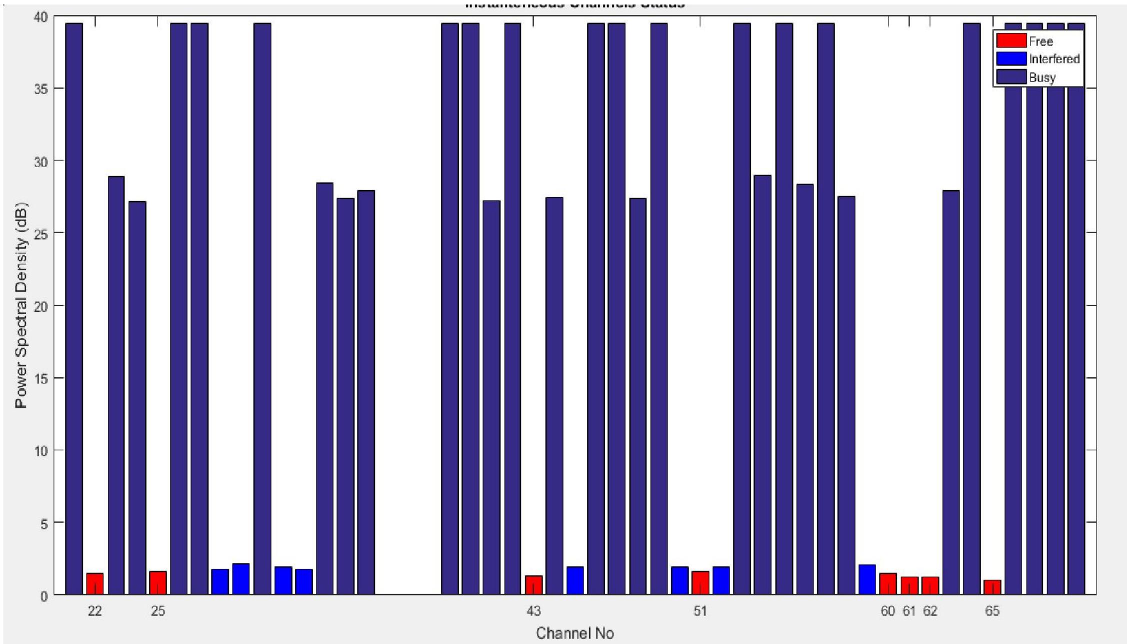

Fig. 14: TVWS Channel Sensing Status for simulation number 4

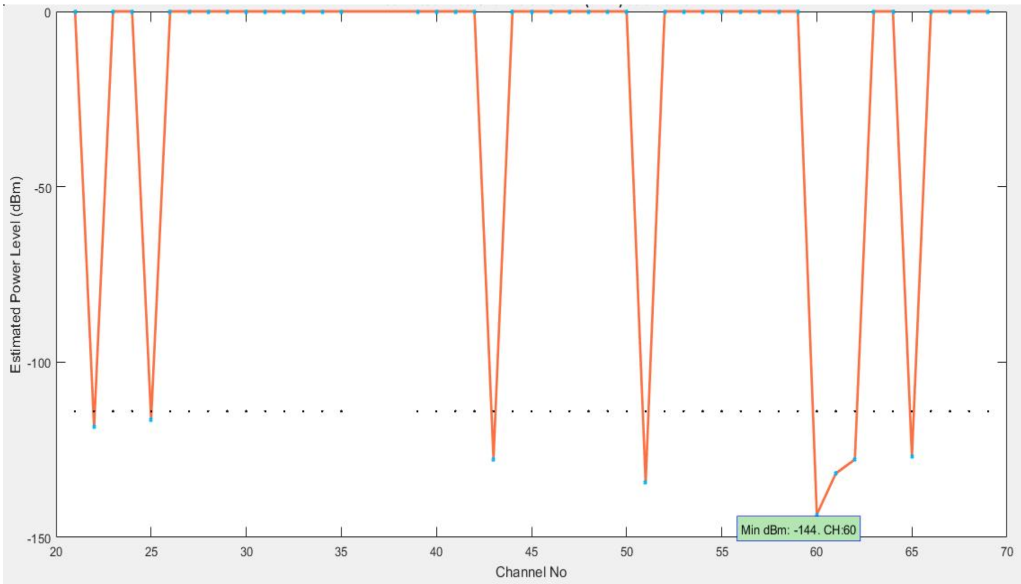

Fig. 15: Received Power level for simulation 4

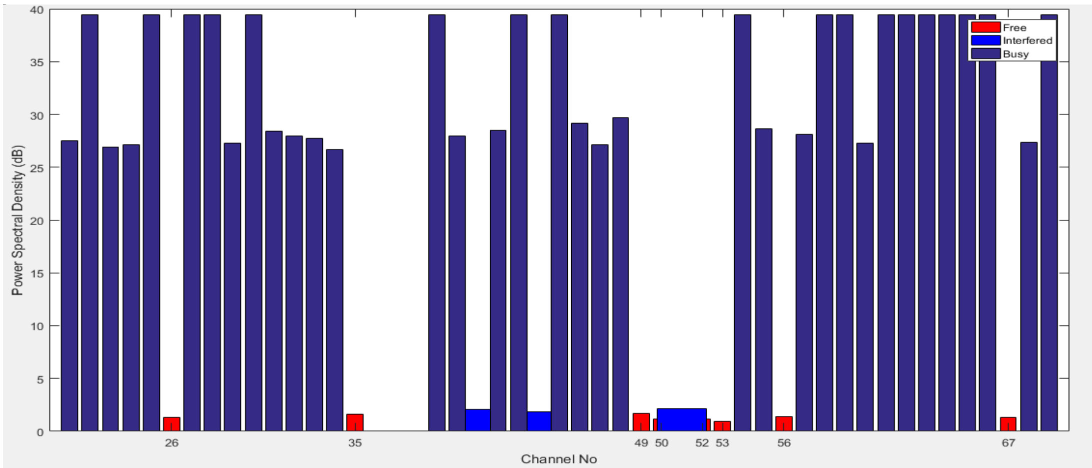

Fig. 16: TVWS Channel Sensing Status for simulation number 5

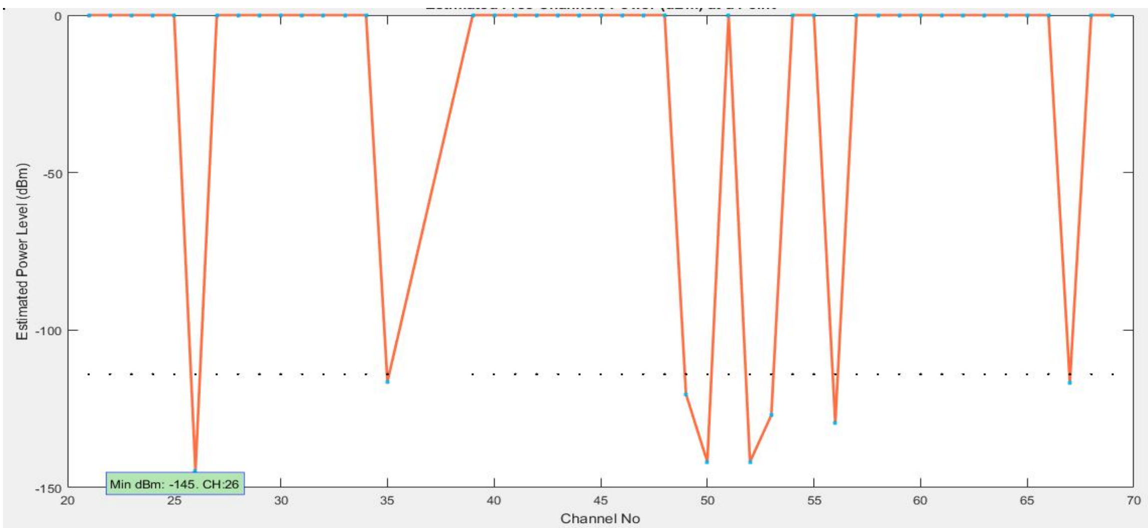

Fig. 17: Received Power level for simulation 5

Table 2: Result Summary of Simulation Test Cycles for Channel Sensing

Test Cycle Simulation number	Free TV channel Number with least Received Power Level (PSDmin)	Value of the Received Power Level (dBm)	Center Frequency (MHz)
1	CH 68	-147	850
2	CH 34	-145	578
3	CH 48	-147	690
4	CH 60	-144	786
5	CH 28	-145	530

Discussions

The main requirement of spectrum sensing is that a sensing device (eNode B system) should be able to detect the presence of (digital and analogue) TV signals and wireless microphone signals at a power received level (RxLEV) of −114 dBm [19]. This means that the overall average energy level of the signal at a point should lie above the threshold energy value of -114 dBm for occupied channels (busy or interfered) and below for the free channels. Table III showed the prospective channels with the least estimated power received levels (PSD_{min}), channel number and channel centre frequency for each of the ten simulation five cycles. The developed algorithm would dynamically choose this centre frequency as the component carrier two (CC2) when configuring the TVWS eNode B for the spectrum aggregation. Therefore, for the five simulation test cycles, channels 68,34,48,60 and 28 corresponding to the centre (carrier) frequencies of 850MHz, 578MHz, 690MHz, 786MHz and 530MHz, respectively as the chosen channels that are configured as CC2 during the spectrum aggregation

V. CONCLUSION

The proposed spectrum sensing algorithm for different TVWS scenarios has been implemented and simulated under MATLAB environment. The results indicated the status of the instantaneous TVWS channels that were busy, interfered or free based on the developed algorithm. UHF TVWS channels with signal received level less than -114 dBm were considered to be free candidates' channels qualified to be used for spectrum aggregation of TVWS channels. In this ten simulation test cycles, the developed algorithm instantaneously selected channels: 68,34,48,60, 28, 63, 35, 49, 24 and 31 corresponding to the centre (carrier) frequencies of 850MHz, 578MHz, 690MHz, 786MHz and 530MHz,respectively as channels with the minimum power received level (PSD_{min}) for each of the simulation cycle at a point and was dynamically configured as the component carrier two (CC2) in the TVWS eNBs during spectrum aggregation process

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REFERENCES

[1] IEEE 802.20 (2011) Part 22: Cognitive Wireless RAN Medium Access Control (MAC) And Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands, IEEE.
[2] Qualcomm Incorporated (2013). Extending LTE to Unlicensed Spectrum, San Diego, CA 92121 U.S.A.

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International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
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[3] Arslan, R., Haad A., Mahmood A.K., Haq I. & Mustapha S. (2015). Efficient Allocation of TV White Spaces for Cognitive Radio in Pakistan, International Journal of Computer Networks and Communications Security 3(3): 74-77
[4] Global System for Mobile communications Association (GSMA) (2017). Introducing Radio Spectrum. Spectrum Primer Series, London.
[5] Amana, E.I (2017). DSO Journey: The Story so Far, DSO Training for Staff of NBC Zonal office, Powerpoint Presentation, Ibadan Nigeria, www.digiteamnigeria.gov.ng
[6] Ukwela, F. (2017). The Concept of Digital Broadcasting, Free TV Newsletter, Cable Channel Nigeria Limited (CCNL), 1: 6-9.
[7] El-Moghazi, M., Whalley J. & Irvine J. (2013) European influence in ITU-R: The end of an era of dominance? 24th European Regional Conference of the International Telecommunication Society, International Telecommunications Society (ITS) Florence, Italy.
[8] Zhijin Q., (2016) Data-Assisted Low Complexity Compressive Spectrum Sensing on Real-Time Signals Under Sub-Nyquist Rate, IEEE Transactions on Wireless Communications, 15(2): 1174-1184
[9] Chakraborty, M., Bera R., Pradhan P., Pradhan R. &.Sunar S.(2010). Spectrum sensing and Spectrum shifting implementation in a Cognitive Radio based IEEE 802.22 Wireless Regional Area Network, International Journal on Computer Science and Engineering 2(4): 1477-1481 [11] Itoh K., Chen G., Clayboot W., & Sato T. (2002) A Handoff Algorithm Based on Combination of RSSI and Distance for Wireless Relay Networks IEEE Transactions on Vehicular Technology, 51(6):1460–1468.
[10] SACRA Project (2010) Spectrum & Energy Efficiency through multi-band Cognitive Radio, Seventh Framework Programme, European Commission – 249060, FP7-ICT-2007-1.1
[11] Telecommunication Engineering Center (TEC) (2008). Broadband Deployment through TV-White Space, Ministry of Communications and Information Technology, India.
[12] SOLDER Consortium (2014) Spectrum Overlay through Aggregation of Heterogeneous Dispersed Bands (SOLDER), D3.1 Initial Report, European Commission Information Society and Media
[13] Kenan k. & Ibrahim D. (2020).Spectrum sensing in cognitive radio networks: threshold optimization and analysis, Eurasip Journal of Wireless Communications and Networking, 255:1-19
[14] Nupur C., Kandarpa K. S., Chinmoy K., & Aradhana M. (2021). Design of an Novel Spectrum Sensing Scheme Based on Long Short-Term Memory and Experimental Validation, International Journal of Communications, 15:26-32
[15] Gai J., Xue X., Wu J. & Nan R. (2021). Cooperative Spectrum Sensing Method Based on Deep Convolutional Neural Network, Journal of Electronics & Information Technology, 43(10): 2911-2918
[16] Mustefa B. U., Ram S. S., Satyasis M.. & Davinder S. R. (2022). Improving Spectrum Sensing for Cognitive Radio Network Using the Energy Detection with Entropy Method, Hindawi Journal of Electrical and Computer Engineering, 2022:1-12