SPECTRUM OCCUPANCY MEASUREMENT AND ANALYSIS AT OSUN STATE UNIVERSITY CAMPUS, OSOGBO, NIGERIA

HAMMED OYEBAMIJI LASISI[1], BOLATITO FATIMAH ADERINKOLA*[2], FUNMILOLA MARGARET ADEAGBO[1]

[1]*Department of Electrical and Electronic Engineering, Osun State University, PMB 4494, Osogbo, Osun State, Nigeria*

[2]*Department of Electrical and Electronic Engineering, the Federal Polytechnic, PMB 231, Ede, Osun State, Nigeria*

Abstract: The rapid growth of new wireless communication applications and services has increased the demand for effective radio spectrum usage. However, present spectrum allocation policy has left some bands unoccupied. Through spectrum measurement, unoccupied spectrum can be identified and reallocated to unlicensed users without interfering with licensed users. This paper presents spectrum occupancy measurement of UHF TV bands from 470 MHz – 870 MHz conducted at six different locations in Osun State University, main campus, Osogbo. The results revealed that the spectrum occupancy values for the locations considered are: 16.6%, 11.9%, 18.9%, 23.1%, 17.7% and 19.4% respectively for locations 1, 2, 3, 4, 5 and 6. Only 17.9% of the spectrum, on the average, is effectively utilized. This indicated that large portion of the spectrum is unoccupied, and cognitive radio, stands a good chance of being deployed in the examined bands.

Keywords: spectrum, energy detection, analyser, measurement, duty cycle

1. INTRODUCTION

The radio frequency (RF) spectrum is a finite (3 kHz to 300 GHz), scarce but non-exhaustible resource in wireless communication system. The demand for this resource has been growing rapidly with the dramatic development of the mobile telecommunication industry in the last decade. However, the present spectrum allocation policy which pre-allocate the spectrum for authorised user has made some bands to have heavy traffic on them while others are left unused leading to huge waste of spectrum resources. Many research efforts, by academia, scientist and telecommunication engineers, on the improvement of the bandwidth and efficient use of the available ones had been documented by many researchers. More so, TV band has gotten a lot of interest because of the prospective use of the unoccupied spectrum, if any, to improve spectrum utilization opportunistically.

One of the most significant approaches for providing regulators, academics, and engineers with the foundation data of current and future spectral occupancy information is to conduct a spectrum occupancy measurement campaign. The analysis of measurement data will not only provide spectrum administrators with actual spectrum utilization, allowing them to allocate spectrum more efficiently, but it will also provide technical assistance to the concerned authorities in developing cognitive radio (CR) management and future spectrum allocation policies [1]. Several spectral occupancy survey and measurements have been carried out nationwide.

*Corresponding author, email: fattyade2307@gmail.com
doi.org/10.29081/jesr.v28i1.007

In China, [2] carried out spectrum occupancy measurement at a single location in Chendu using a Rohde & Schwarz FSU high performance spectrum analyser. Their goal is to get the data of spectrum for future modelling of the spectrum and result revealed that there exit idle spectrum band which can be employed by the CR.

With four measurement locations in South China, [3] used a digital wideband receiver to measure simultaneous spectrum from 20 MHz to 3 GHz. The results of the experiments revealed that there is a substantial amount of spectrum available for CR applications. In Beijing, [4] carried out a 24 hour spectrum measurement campaign. Their purpose is to learn more about Beijing's radio frequency distribution scenario and determine the frequency bandwidth that dynamic spectrum access devices can use. As a result of the measurement, it was discovered that only about 13.5% of the spectrum in Beijing is being utilized.

In the United State of America, USA, spectrum occupancy measurement was conducted from 140 MHz to 1000 MHz in the rural western Montana [5]. Their goal was to see if they could make very sensitive broadband spectrum measurements using equipment and processes that could be used in remote areas. The findings show that there is a huge amount of unused spectrum accessible in big rural and isolated areas of the United States that lack meaningful cellular service. In Grand Forks, North Dakota, USA, a Universal Software Radio Peripheral (USRP) was used to conduct an experiment on the radio spectrum, proposing a scanning technique in comparison to autocorrelation and energy detection, over a frequency range of 824 MHz – 5.8 MHz [6]. In several frequencies of the radio spectrum, the spectrum occupancy was found to be less than 20%.

In the United Kingdom, high-resolution spectrum occupancy measurements and analysis were carried out for 2.4 GHz wireless local area network (WLAN) signals by [7]. Their goal is to build models to accurately detect spectrum holes and anticipate their occurrence, as well as idle time windows (ITWs), in order to determine the best spectrum allocation based on unlicensed users' needs and/or to optimize spectrum utilization. The results demonstrated that, in addition to the generalized Pareto distribution, Gamma and lognormal distributions may be utilized to characterize the idle state of a 2.4 GHz WLAN channel. [8] used four broadband antennas to measure spectrum occupancy at the University of Hull in the United Kingdom, covering the frequency range of 30 to 3000 MHz. Overall, the results showed that spectrum usage is persistently low, and that there is a considerable quantity of spectrum that might be used for future CR development. In Turkey, [9] conducted outside spectrum occupancy assessments at a distinct locale in the Faculty of Engineering building, Selçuk University, Konya, Turkey. The Rigol DSA 1030 spectrum analyser was used to do the measurements, which covered the frequency range of 30 MHz to 3000 MHz. MATLAB software was used to perform measurement controls, data collection, and analysis. The occupancy rate for the TV band 470 MHz–790 MHz is 8.49 percent, while the total occupancy rate for the entire examined spectrum (30 MHz–3000 MHz) is 7.63 percent, according to the findings. [10] conducted spectrum occupancy measurement with focus on cellular and TV broadcasting bands. The purpose was to look into the availability of white spaces in Malaysia for opportunistic CR access. The results revealed that the majority of the assigned TV bands are only 15% utilized.

The spectrum occupancy measurement in rural and urban areas of Kwara state, Nigeria were performed by [11] for 24 hours, with an emphasis on the TV and CDMA bands. The results showed that CDMA bands are less used in both areas as compared to TV bands, which have a very low average occupancy of 12.02% in urban areas. Similarly, an outside assessment of spectrum occupancy was reported in both rural and urban areas of Kwara state, spanning the frequency range of 2.4 GHz to 2.7 GHz [12]. The findings revealed that the examined band is vastly underutilized, with upper and lower occupancy values of 22.56% and 0% in urban and rural contexts, respectively. In Ikeja, Lagos State, Nigeria, [13] explored the spectrum use in the 700 MHz–2200 MHz frequency band. The frequency range that was measured was separated into many continuous sub-bands. According to the results of the measurement, the analogue TV band has a used spectrum value of 49.5% which implies that a considerable portion of the spectrum that has been assigned is inactive and so underutilized.

This paper presents results of measurement campaign of UHF TV bands of 470 MHz to 870 MHz in Osun State University main Campus, Osogbo, Nigeria using energy detection techniques.

2. EXPERIMENTAL SETUP

In this paper, energy detection technique was employed where an investigational measurement was set up in a chosen geographical location. Though, wireless frequency is very wide but only UHF TV bands from 470 MHz – 870MHz were considered.

2.1. Measurement setup and location

Spectrum utilization varies with geographical scenario, thus the measurements were conducted in February 2021 at six different sites within Osun State University main campus, Osogbo. Table 1 depicts the geographical locations for the measurement and their corresponding coordinates.

Table 1. Measurement locations.

Location	Coordinate	Identifier
Engineering Complex	4° 36’ 13’’E, 7° 45’ 40’’N	Location 1
Health Sciences	4° 36’ 16’’E, 7° 45’ 27’’N	Location 2
Library	4° 36’ 09’’E, 7° 45’ 31’’N	Location 3
Administrative Building	4° 36’ 04’’E, 7° 45’ 42’’N	Location 4
Auditorium	4° 35’ 52’’E, 7° 45’ 26’’N	Location 5
URP Building	4° 35’ 55’’E, 7° 45’ 22’’N	Location 6

Figure 1 shows the set up used for the measurement in all the locations. It consists of Agilent N9342C Handheld Spectrum Analyser which can measure from 100 KHz to 7GHz. It measures the received signal strength in dBm directly using energy detection. Global positioning system (GPS) location functions are also available on the analyser. A telescopic whip antenna, RH799 wide band antenna capable of detecting signals from 70MHz – 1GHz with 180 degrees tilt angle adjustable, was connected to the analyser. The spectrum analyser's log files were saved in real time using a data storage device.

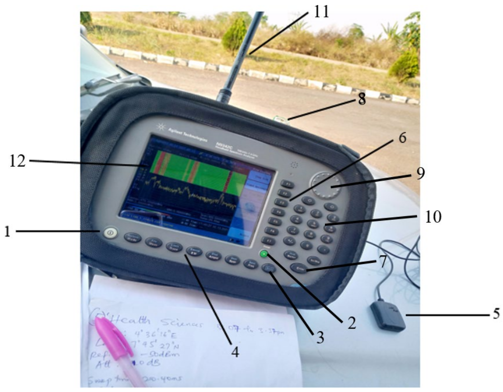

Fig. 1. Measurement setup:
1—power button; 2—preset; 3—shift; 4—function keys; 5—external GPS locator; 6—softkeys; 7—enter; 8—USB flash drive; 9—knob; 10—alphanumeric keys; 11—RH799 wide band antenna; 12—screen for displaying spectrum traces and status information.

Since the accuracy of the measurement results is closely connected to the measurement parameter settings, the spectrum analyser was configured as shown in Table 2.

Table 2. Spectrum analyser configuration.

Parameter	Value
Resolution Bandwidth (RBW)	3 MHz (Automatically set by the SA)
Video Bandwidth (VBW)	3 MHz (Automatically set by the SA)
Sweep Time	20.40ms (Automatically set by the SA)
Sweep Type	Continuous
Reference Level	50 dBm
Preamplifier	ON
Impedance	50 Ω

2.2. Data collection and analysis

Data were generated and collected in comma-separated value (*.csv) file format and saved in the data storage device for further processing. The analyser received a total of 1500 frames per band per location, with 461 frequency points measured per received frame.

To estimate the spectrum occupancy, based on energy detection techniques employed, the noise floor N_f of the received signal energy P_r has to be determined and then compared with a predefined threshold. The noise floor helps to reduce noise and correctly estimate the utilization. It was calculated using equation (1):

$$N_f = \frac{1}{N} \sum_{r=1}^{N} P_r \quad (1)$$

where N_f is the average power of specific frequency point, N is the number of frequency points of the received frequency power, and P_r is the received power of specific frequency in a given time slot. Setting the decision threshold helps to ensure a reliable estimation of spectrum occupancy. M-dB criteria was employed and the **t**hreshold value (γ) was set using equation (2):

$$\boldsymbol{\gamma} = N_f + M \quad (2)$$

where M is a margin chosen as 5dB according to ITU-R [14]. However, the value of γ should not be too low to avoid overestimated spectrum occupancy i.e. high probability of false alarm (P_{fa}) and should not be too high to avoid underestimated spectrum occupancy i.e. low probability of detection (P_d).

The spectrum occupancy rate is the most important metrics to measure the utilization of spectrum. Let $\mathbf{S}_{(f_r,\, t_r)}$ be the spectrum occupancy in each measurement frequency as seen in equation (3):

$$\mathbf{S}_{(f_r,\, t_r)} = \begin{Bmatrix} \mathbf{0}, & \boldsymbol{P_r} < \gamma \\ \mathbf{1}, & \boldsymbol{P_r} \geq \gamma \end{Bmatrix} \quad (3)$$

where P_r is the received power spectral density in dBm, measured in frequency point f_r and at time index t_r, and γ is the decision threshold. If $\mathbf{S}_{(f_r,\, t_r)} = \mathbf{1}$**,** the frequency is occupied, otherwise, the frequency is unoccupied.

The duty cycle of a band is the average spectrum occupancy, and is computed as in equation (4). It provides useful information on spectrum availability by frequency band, time, and place:

$$\mathrm{D}c = \sum_{i=1}^{N} \frac{\mathrm{S}_{(f_r,\, t_r)}}{N} \quad (4)$$

where Dc is the duty cycle for specific frequency of a given location at a given time, N is the total number of time samples for a frequency point.

3. RESULTS AND DISCUSSION

Two subplots are used to describe each spectrum occupancy result for the frequency bands. The average received power against the measured signal frequency is shown in the first subplot. It showed the occupied signal's general waveform. The duty cycle, or spectrum occupancy rate, is plotted against signal frequency in the second subplot. This indicates how frequently the signal occupies a frequency band. The results of spectrum occupancy for the UHF TV band 470 – 870 MHz in each measurement location is presented in Figures 2 to 7.

Figure 2 shows the result of spectrum situations at location 1 of the measurement sites. The received power was compared with the decision threshold to give the actual occupancy as depicted by the second subplot. In this location, an average duty cycle of 16.6% was recorded, which implies that only this percentage of the spectrum was utilized at the time of measurement in this location.

The outcome of spectrum conditions at measurement location 2 is shown by the first subplot in Figure 3. To determine the actual occupancy, the received power was compared with the decision threshold. The actual spectrum occupancy at measurement location 2 is shown in the second subplot. This area had an average duty cycle of 11.9%, according to research. This means that just this proportion of the spectrum was used in this area at the time of measurement. When compared to location 1, this location's spectrum usage is extremely low.

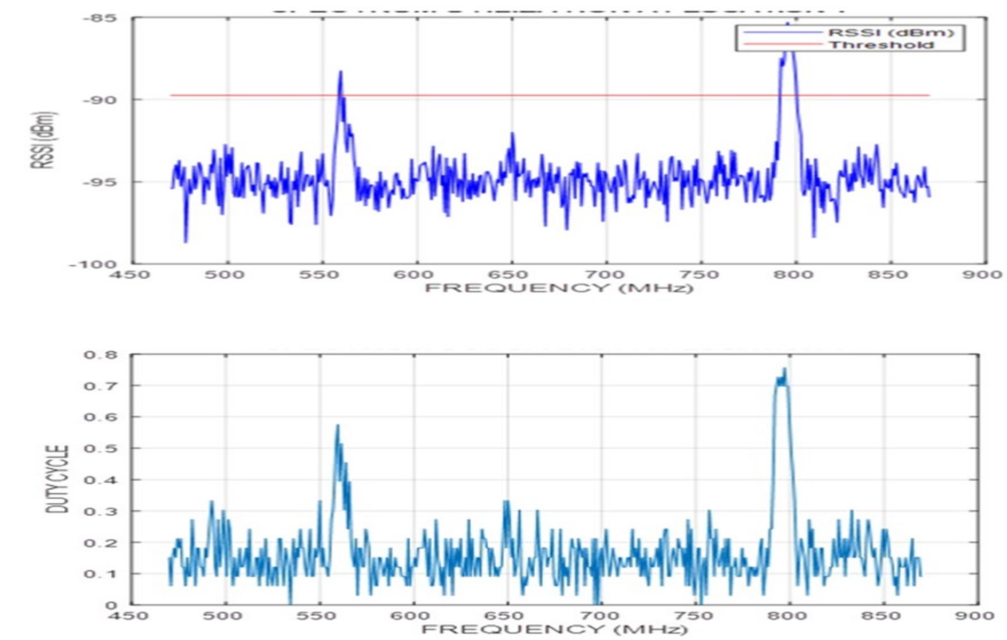

Fig. 2. Spectrum occupancy of location 1.

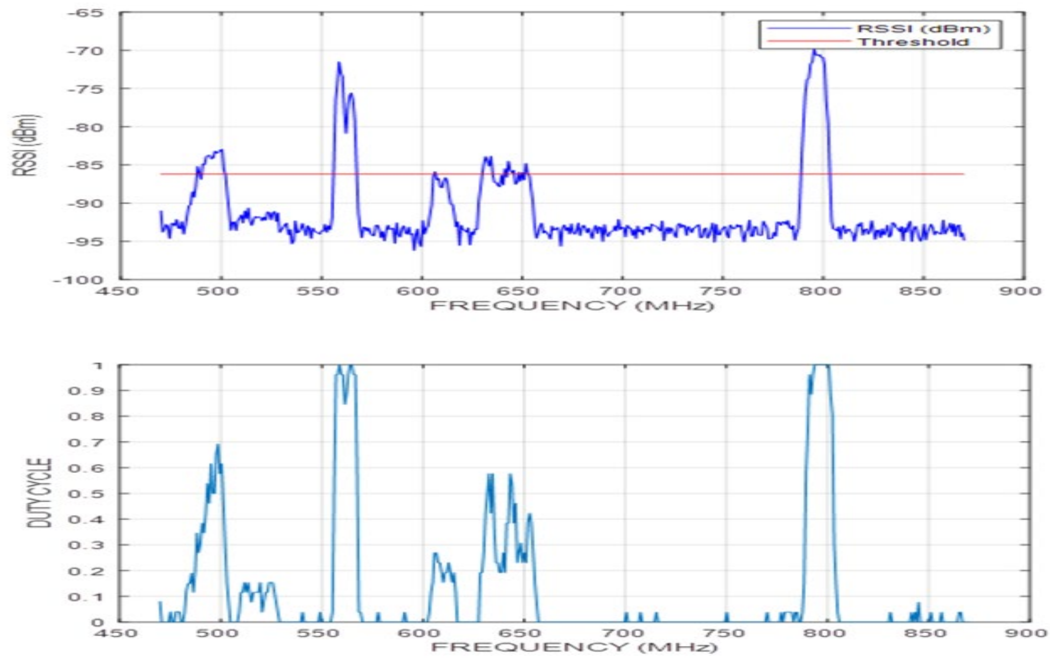

Fig. 3. Spectrum occupancy of location 2.

The outcome of the spectrum measurement at location 3 is shown in the first subplot of Figure 4, with a decision threshold of -84.68 dBm. The second subplot shows the resulting spectrum occupancy when the received power was compared to the decision threshold. An average duty cycle of 18.7 % was reported in this location, which implies that this portion of the spectrum was utilized in this locality. This result is somewhat higher than the values obtained in measurements 1 and 2.

The first subplot of Figure 5 presents the result of spectrum measurement at location 4. In this location, the decision threshold recorded was -83.67 dBm which was then compared with the received power in the location. The resulting spectrum occupancy of this location is as presented in the second subplot with an average duty cycle value of 23.1 % which is the highest value recorded so far. A greater percentage of the spectrum were occupied in this location.

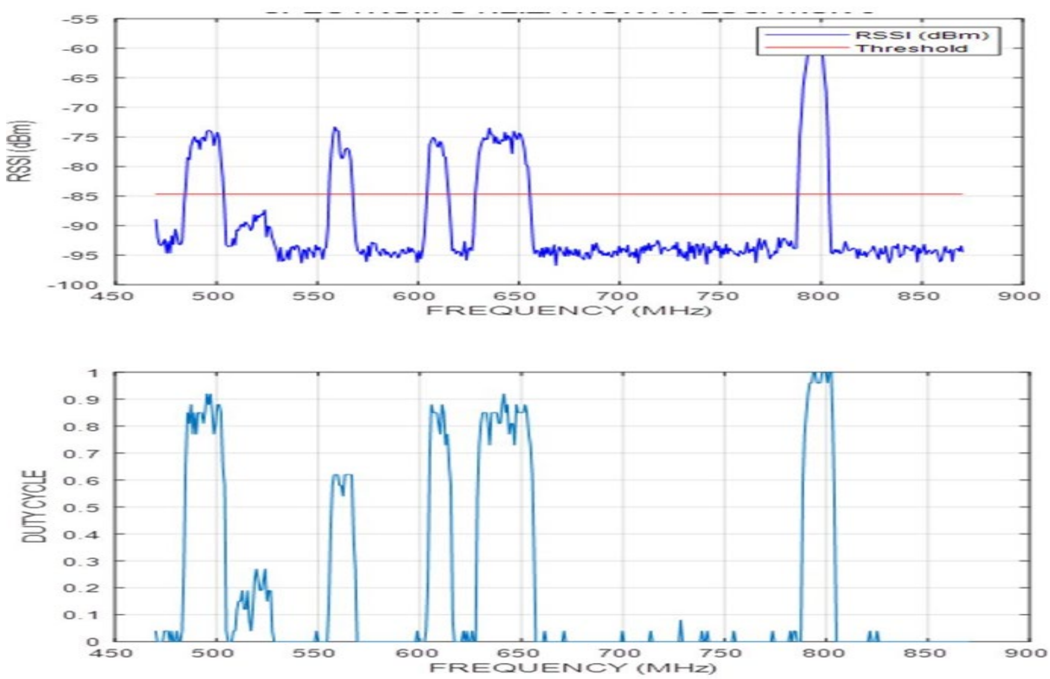

Fig. 4. Spectrum occupancy of location 3.

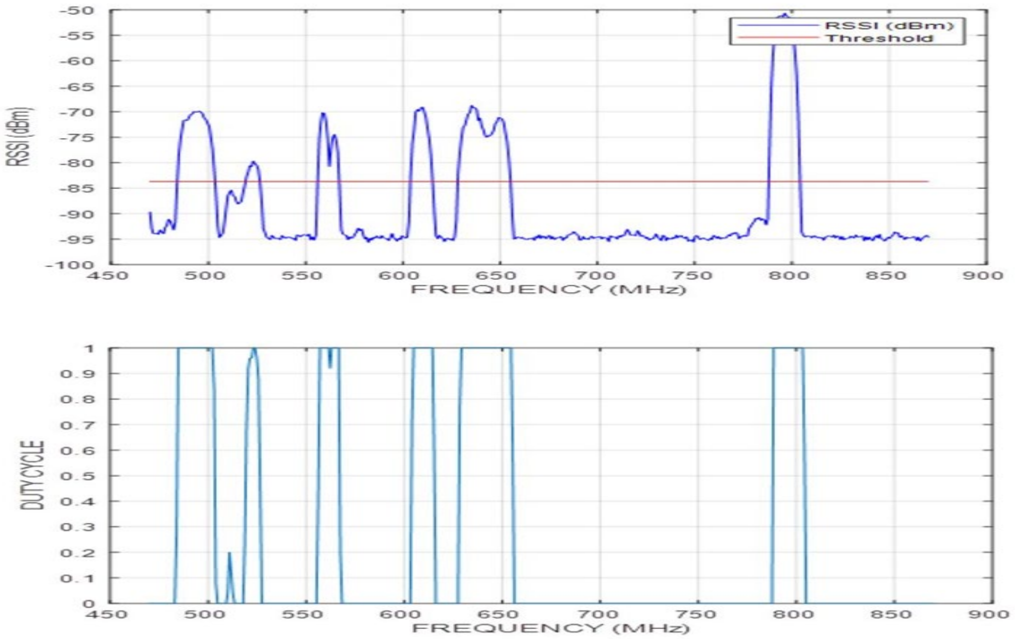

Fig. 5. Spectrum occupancy of location 4.

The spectrum measurement result of site 5 with a decision threshold of -85.14 dBm is as shown in the first subplot of Figure 6. Location 5 recorded an average duty cycle of 17.7 % with this choice threshold, and the consequent occupancy of the spectrum was plotted as shown in the second subplot.

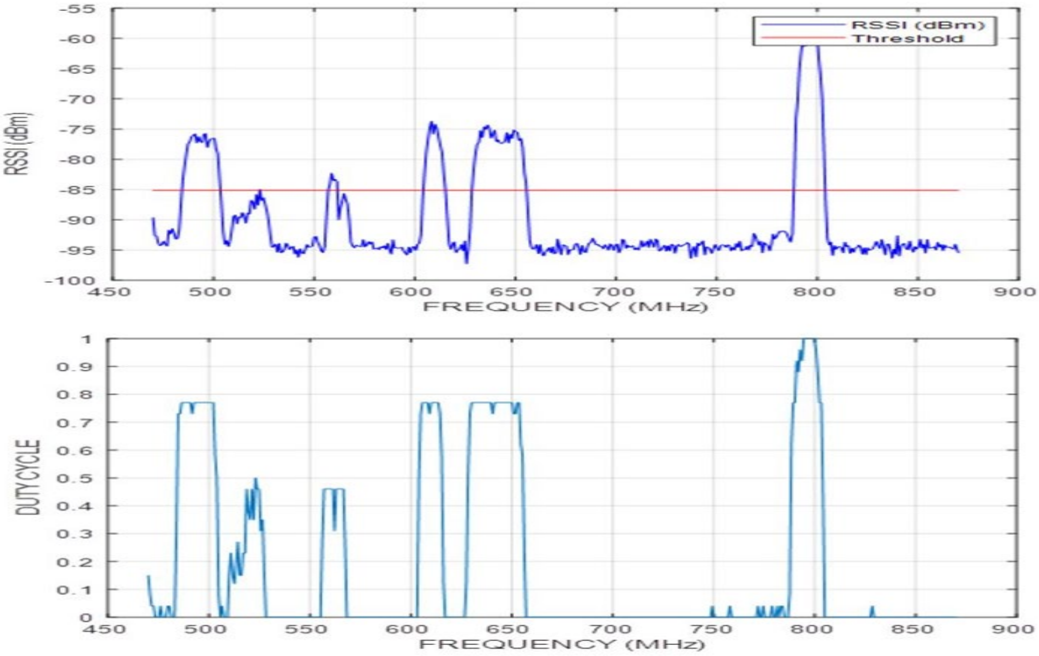

Fig. 6. Spectrum occupancy of location 5

Finally, the first subplot of Figure 7 shows the results of the spectrum measurement at site 6. When the average received power was compared to the decision threshold of -84.52 dBm, the average duty cycle was 19.4 %. The second subplot depicted the equivalent spectrum occupancy of location 6.

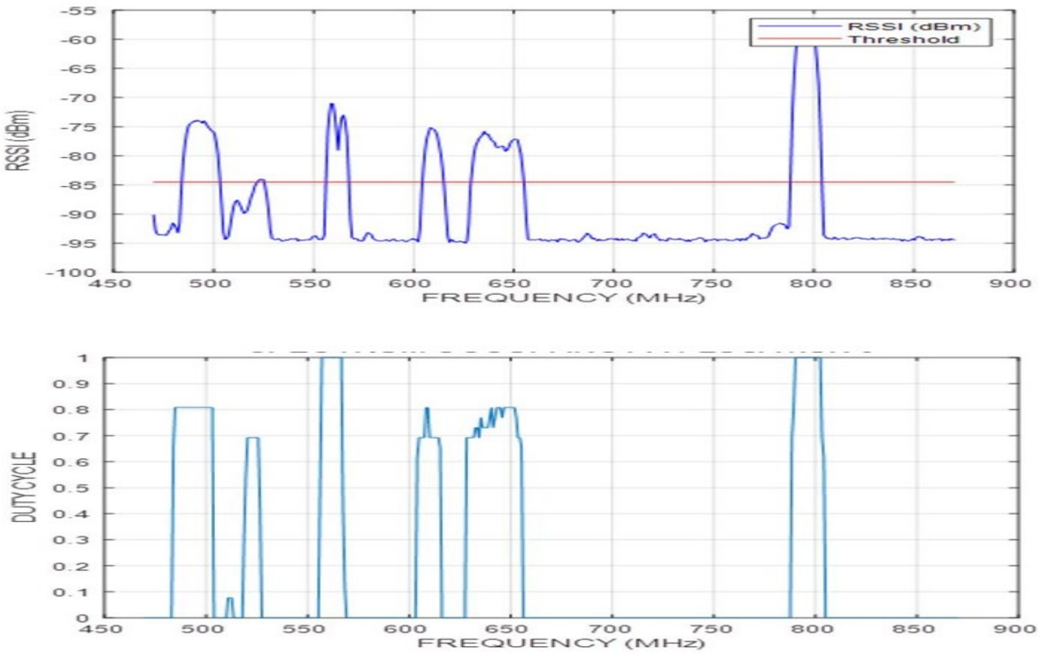

Fig. 7. Spectrum occupancy of location 6.

As can be seen from the Figures, all of the locations had lower spectrum occupancy values. In summary, the spectrum occupancy values for the locations considered in this research are: 16.6 %, 11.9 %, 18.9 %, 23.1 %, 17.7 % and 19.4 % respectively for locations 1, 2, 3, 4, 5 and 6. This implies that the spectrum is not uniformly utilized in all the locations. The overall duty cycle for all the locations revealed that only 17.9% of the spectrum is being utilized, thus a major portion of the spectrum is underutilized.

4. CONCLUSIONS

In this paper, spectrum utilization was investigated based on energy detection measurement technique. Measurements, spanning from frequency band 470 MHz to 870 MHz, were conducted at six different locations in Osun State University main campus, Osogbo at the busiest hours of the day. From the findings, typical percentage occupancy of the UHF TV spectrum varies from 11.9% to 23.1% with location 2 highly underutilized while location 4 is slightly utilized. Only 17.9% of the spectrum is used on average across all locations, according to the average duty cycle. This means that the spectrum is not being used effectively at the time and place of measurement. As a result of the low consumption shown by low occupancy, a major portion of the spectrum is underutilized as at the time of the measurement, and so there is ample opportunity for the deployment of new wireless technology applications in the examined band.

REFERENCES

[1] ZTE, Spectrum occupancy measurement and analysis, 2009. Available: www.zte.com.cn (25.05.2021).
[2] Han, Y., Wen, Y., Tang, W., Li, S., Spectrum occupancy measurement: focus on the TV frequency, 2nd International Conference on Signal Processing Systems (ICSPS), 2010.
[3] Yin, L., Yin, S.X., Wang, S., Zhang, E.Q., Hong, W.J., Li, S.F., Quantitative spectrum occupancy evaluation in China: based on a large scale concurrent spectrum measurement, The Journal of University of Posts and Telecommunication, vol. 19, no. 3, 2012, p. 122 – 128.
[4] Xue, J., Feng, Z., Zhang, P., Spectrum occupancy measurement and analysis in Beijing, International Conference on Electronic Engineering and Computer Science, 2013.
[5] Wiles, E., Hill, B., Anon da Silva, F., Negus, K., Measurement and analysis of spectrum occupancy from 140 to 1000 MHz in rural western Montana, 10th International Conference on Antennas and Propagation (EuCAP), 2016.
[6] Subramaniam, S., Reyes, H., Kaabouch, N., Spectrum occupancy measurement: an autocorrelation based scanning technique using USRP, 16th Annual Conference on Wireless and Microwave Technology (WAMICON), USA, 2015.
[7] Cheema, A.A., Salous, S., Spectrum occupancy measurements and analysis in 2.4 GHz WLAN, Electronics 2019, vol. 8, no. 1011, 2019, p. 1 - 14.
[8] Mehdawi, M., Rilley, N.G., Ammar, M., Fanan, A., Zolfaghari, M., Spectrum occupancy measurements and lessons learned in the context of cognitive radio, 23rd Telecommunication Forum (TELFOR), Belgrade, Serbia, 2015.
[9] Seflek, L., Yaldiz, E., Spectrum occupancy measurement at University Campus in Turkey, International Journal of Electronics and Electrical Engineering, vol. 5, no. 1, 2017, p. 1 - 6.
[10] Jayavalan, S., Mohamad, H., Aripin, N.M., Ismail, A., Ramli, N., Yaacob, A., Ng, M.A., Measurement and analysis of spectrum occupancy in the cellular and YV bands, Lecture Notes on Software Engineering, vol. 2, no. 2, 2014, p. 133 - 138.
[11] Babalola, O.D., Garba, E., Oladimeji, I.T., Bamiduro, A.S., Faruk, N., Sowande, O., Muhammad, M., Spectrum occupancy measurements in the TV and CDMA bands, International Conference on Cyber Space (CYBER-Abuja), 2015.
[12] Ayeni, A.A., Faruk, N., Bello, O.W., Sowande, O.A., Onidare, S.O., Muhammad, M.Y., Spectrum occupancy measurements and analysis in the 2.4-2.7GHz band in urban and rural environment, International Journal of Future Computer and Communication, vol. 5, no. 3, 2016, p. 142 - 147.
[13] Paulson, E.N., Adedeji, K.B., Kamaludin, M.Y., Popoola, J.J., Jafri, B.D., Sharifah, K.S.Y., Spectrum occupancy measurement: a case for cognitive radio network in Lagos, Nigeria, ARPN Journal of Engineering and Applied Sciences, vol. 12, no. 4, 2017, p. 951 – 955.
[14] International Telecommunication Union (ITU-R), Spectrum Occupancy Measurement and Evaluation Report ITU-R SM. 2256-1, ITU-R, 2016.