# AN ASSESSMENT OF UHF (470-670) MHz BAND SPATIAL OPPORTUNITY FOR COGNITIVE WIRELESS COMMUNICATION SERVICES

Adegboyega Kifli ADEBAYO[1, 3*], Hammed Oyebamiji LASISI[1], Kehinde Olukunmi ALAWODE[1], Nazmat Toyin SURAJUDEEN-BAKINDE[2]

[1]Department of Electrical and Electronic Engineering, Osun State University, Osogbo, Nigeria
[2]Department of Electrical and Electronics Engineering, University of Ilorin, Kwara State, Nigeria
[3]Department of Electrical and Electronics Engineering, Federal Polytechnic Ede, Osun State Nigeria
adebayo.adegboyega@federalpolyede.ed.ng, hammed.lasisi@uniosun.edu.ng,kehinde, alawode@uniosun.edu.ng, deenmat@unilorin.edu.ng

**Keywords**: Spectrum utilization profile, Cognitive wireless communication, Ultra High Frequency, Spatial Opportunity, Cognitive radio, Spatial Opportunity, Primary User Interference Probability, Estimated Spectrum Utilization, Primary user, Secondary user.

**Abstract:** *The research aimed to assess UHF (470-670) MHz band services in Osogbo metropolis, Nigeria, using a model deployed for a measurement campaign. Four locations were assessed: Firestation, Uniosun campus, National Control Centre (NCC), and Fountain University campus. Energy Detection approach was used for data capture and analysis. The metric of assessment included carrier to interference ratio (CIR), spatial opportunity, Average Primary User Interfering Probability (PUIP), and estimated spectrum utilization. The primary receiver had a carrier to interference ratio of 75.86197 dB, while the secondary receiver had a ratio of 79.66266 dB. Computed Spatial Opportunities for deployment of UHF (470-670) MHz for Secondary System was 37.26% at 1.1km distance from the transmitter. The best interference manageable location was found at the NCC with the lowest primary user interference probability. The estimated spectrum utilization for the locations was 52.88 for the Firestation, 46.51 for Fountain University, 50.03 for Uniosun, and 47.79 for the NCC.*

## 1. INTRODUCTION

Several works have been carried out on spatial spectrum utilization and opportunity. In [1], in 2015, on spatial spectrum utilization efficiency metric for Spectrum Sharing Systems, a new metric called *spatial spectrum utilization efficiency* (SSUE) was introduced for evaluating the efficiency of reusing the TV spectrum. The model, consists of a single primary transmitter network and multiple secondary networks transmitting outside the noise limited grade B contour. The result shows a typical low power TV transmitter of 1 kW and 4 W secondary users, the minimum and maximum achievable spectrum efficiency limits for primary networks are 28% and 54%, when the PU height are 100 m and 600 m respectively.

In [2], work was carried out on a Hybrid Spectrum Opportunity Extraction Scheme for Cognitive Wireless Communication. An adaptive spectrum extraction decision mechanism for Cognitive Radio Networks was developed to increase spectrum efficiency usage for GSM band of 900 and 1800 using Long Short-Term memory (LSTM) approach.

The result shows that the root mean square error (RMSE) of the channel vacancy duration of GSM 900 and 1800 was 14.29 5 to 28.57 % and primary user interference probability decreased by more than four-fold with 50 % increase in spectrum utilization.

Spatial Opportunity is an advantage of spectrum availability created by the primary (licensed) user for the secondary (cognitive) user to utilize without causing harmful interference to the primary transmission. The reason for this is to utilize the vacant or unused spectrum of the incumbent systems by the secondary users for deployment into white space devices [3].

This paper is structured as follows: Section 2 presents the review of spatial opportunity; section 3 presents the specification of the equipment deployed for the measurements and method of data collection and the algorithm for the assessment of spatial opportunity prediction for UHF (470-670) band. Section 4 presents data analysis and results. Section 5 presents the conclusion from this study and the future work planned.

## 2. LITERATURE REVIEW OF SPATIAL OPPORTUNITY

In [3], a quantitative assessment of TV white space of band (470-870) MHz was investigated, where it was discovered that 58 % of the 50 channels assessed were underutilized. It was suggested that the unutilized bands could be deployed with no or low cost for smart devices applications.

In [4], research investigated spatial white space availability of VHF/UHF band between 56 to 806 MHz using alternative spectrum management and techniques for adequate utilization of TV white space. An algorithm was developed to predict the service contour to decide the availability of the tv white spaces. It was found that keep out distance varies as a function of operating frequency and propagation characteristics.

In [5], spatial variability of duty cycle of GSM Band 900 was investigated within Kwara state Nigeria. The spatial variation of spectrum occupancy in terms of duty cycle of the band was analyzed. Result shows that an average of spectrum occupancy of 1.67 % and 17.76 % were discovered for rural and urban locations respectively. This indicates that the rural areas radio resources can maximize the for better deployment and usage.

In [6], the short-range cognitive radio system to be located within the service area of the primary system was investigated where spatial opportunity was discovered in the secondary system for possible deployment usage. The difference between the path loss created by the primary and secondary system was analyzed. It was clarified that different antenna heights of the primary and secondary systems can affect the variation of path-loss coefficient.

In [7], investigation was carried out on the availability of TV white space in Ondo state radio vision television station in Akure, south western, Nigeria. The measurements was carried out on (470-960) MHz band. The result of the research shows that 71.05 % of the 38 channels were unutilized and a deployment for security surveillance was suggested for the available unutilized bands.

In [8], a Terrestrial –Digital Video Broadcasting (DVB-T) spectrum measurement to study the variation of the received signal power in the TV channels frequencies was investigated. A DVB-T band with intelligent devices was suggested for mobile cognitive radio users without depreciating the quality of service of the primary users. A short distance communication like car-to car data transfer and self-driving vehicles was suggested.

In [9], investigation was carried out on (470-860) MHz in European Union with a Hidden Node Margin (HNN) sensing approach. It was revealed that mean occupancy of 32 % with a standard deviation of 18 was achieved with an occupancy threshold of -75 dBm at 8 MHz. Top occupancy of 84% for the bandwidth was achieved from different repeaters overlap due to lack of obstacles.

### 2.1 Benefits of Spatial Opportunity Deployment for Cognitive Usage Devices [3]

#### 2.1.1 Rural and Urban Deployment

Wireless broadband with greater range of operation can be easily deployed for local area network for internet services for rural and urban areas for a municipal broadband network for better quality of signal service.

#### 2.1.2 Enterprise and Education video conferencing

Video conferencing from far distance for institutional learning for middle school and higher institutions) and enterprise benefits for private and governmental agencies can easily explore from the deployment

#### 2.1.3Mesh and Ad-hoc Networks

Internet backhauls facilities for internet and ad-hoc mesh wireless network that will give a smooth and quality signal for browsing and wireless communication will be easily available.

#### 2.1.4 Public Safety Communications

Emergency or public safety communications can also be achieved from the spatial opportunity deployment of the uhf band services for cognitive usage, where an emergency line free of any charges will available for public complaint to governmental or security agencies for prompt response to the call of the citizens in need of assistance or rescue mission.

2.1.5 Security Surveillance

Security surveillance devices like perimeter video surveillance and wireless are monitoring devices and home usage can be easily deployed by the spatial
opportunity scenario.

## 3. METHOD

Measurement campaign carried out for the spectrum occupancy of four different locations within Osogbo metropolis in Nigeria: namely; Fire station (longitude 7.8545ºN, latitude 4.5457ºE) Fountain University campus (longitude 7.7437ºN, latitude 4.5460ºE) , National Control Centre (longitude 7.8026ºN, latitude 4.5786ºE) and Uniosun campus (longitude 7.7616ºN, latitude 4.6012ºE). The band spectrum is (470-670) MHz band that give a bandwidth of 200 MHz for frequency of operation. The data gathered was analyzed with Microsoft excel and was analyzed with spatial equations from [2] and [10] to deduce the spatial opportunities for the UHF (470-670) MHz band services.

### 3.1 Specification of the Measuring Equipment

The equipment used for the measurement setup is a spectrum analyzer that must be able to detect all types of signals, regardless of strength, within the designated frequency range. This calls for the use of a more advanced and sensitive spectrum analyzer. The specification of the field strength analyzer utilized for data capturing is (BK PRECISION 2640 with variable parameters, 500ms sweep time, 50 input impedance, variable resolution bandwidth, 3.125Hz resolution, maximum accuracy of 3ppm and minimum accuracy of 1.5 ppm and 0.1GHz -2.0 GHz frequency range) and an Android-based global positioning system (GPS) to record all coordinates of chosen locations within Osogbo metropolis are all part of the experimental setup.

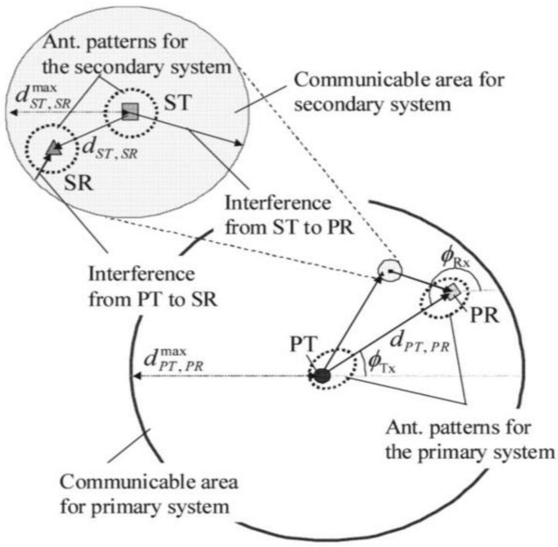


Fig. 1 Coexistence between the Primary and Secondary Systems [2] and [10]

In the assessment of spatial opportunity, two inferences need to be considered (i) Interference from the primary transmitter (PT) to the secondary receiver (SR), $I_{PR}$ and (ii) interference from the ST to the PR, $I_{SR}$. The spatial opportunity is evaluated by the definition of the service coverage area shown in Figure 1 where the signal from a specified transmitter gets to the $R_X$ with a carrier-to-noise-ratio (CNR) beyond a specified threshold [2]. In the service area, both the Primary (PT/PR) and the secondary (ST/SR) system coexist. The beams of both the PT,$\varphi_{TX}$ and PR, $\varphi_{RX}$ were perfectly coupled. The ST and SR seek for spatial opportunity to communicate without interfering with the incumbent users PT and PR.
The coexistence between the primary and secondary systems, assuming,${R_{TX,RX}}^{min}$ is the least amount of received power needed to accomplish the purpose Carrier-to-Noise-Ratio (CNR) at the service edge region as stated in Eqn. (1) from [2] and [10].

$${R_{TX,RX}}^{min}[dBm]=G_{TX,HPA}+G_{TX,ANT}+F_{TX,BW(\varphi TX)}-L\left({d_{TX,RX}}^{max}\right)+F_{RX,BW(\varphi RX)}+G_{RX,ANT} \quad (1)$$

$G_{TX,HPA}$ is the transmitter's power, $G_{TX,ANT}$ and $G_{RX,ANT}$ are the transmitter and receiver antenna gain respectively. $F_{TX,BW(\varphi TX)}$ and $F_{RX,BW(\varphi RX)}$ are the normalized response of antenna pattern for direction $\psi_{TX}$ *and* $\psi_{RX}$ in the horizontal plane at Tx and Rx and BW is the 3dB value of beamwidth. Then, CNR at the edge of the communicable area, for a receiver noise power of $G_{RX,LNA}$ is determined using Equation (2) according to [2] and [10].

$$CNR_{TX,RX}{}^{min} = R_{TX,RX}{}^{min} - G_{RX,LNA} \quad (2)$$

Secondary Transmission (ST) is simply evaluated when the SR is situated in the service area of the ST and the ST is randomly located in the PT service area. Utilizing the carrier-to-interference ratio (CIR) parameter, the evaluation can be evaluated. When the following circumstances are met, secondary transmission will not be possible:

(i) The primary system is dangerously interfered with by the secondary transmission;
(ii) The primary interference at the receiver results in an unsatisfactory target quality.

If CIR at PR is $CIRI_{PR}$, then the following equations provide its value when there is a small-scale fading effect $L_{SF(t)}$ given in Eqns. (3) and (4) from [2] and [10].

$$CIRI_{PR}(dB) = R_{PT,PR} - R_{ST,PR} \quad (3)$$

$$CIRI_{PR}(dB) = G_{PT,HPA} + G_{PT,ANT} - L\left(d_{PT,PR}\right) - L_{SF,PT,PR(t)} - G_{ST,HPA} - G_{ST,ANT} + L\left(d_{ST,PR}\right) - L_{SF,ST,PR(t)} - F_{PR,BW(\varphi_{ST,PR})} \quad (4)$$

$G_{PT,HPA}$= Primary transmitter's power, $G_{ST,HPA}$= Secondary transmitter's power, $G_{PT,\ ANT}$ = Primary transmitter's antenna gain, $G_{ST,\ ANT}$ = Secondary transmitter's antenna gain, $L\left(d_{PT,PR}\right) =$ Estimated path-loss between the primary transmitter, $L\left(d_{ST,PR}\right) =$ Estimated path-loss between the secondary transmitter, $L_{SF,PT,PR\ (t)}$ = small scale fading effect between the primary transmitter and primary receiver and $L_{SF,ST,PR\ (t)}$ = small scale fading effect between the secondary transmitter and primary receiver.
Next, for each attempt to randomly find ST in the PT service area, a flag variable $NC_{SR}(i) = 1$ is used if $CIRI_{SR} > \lambda_{SR}$, a defined value. If not, it is zero. The antenna response of the PR in the direction of ST is taken into

Consideration by the term $F_{PR,BW(\varphi_{ST,PR})}$.

The value of CIR at SR, if $CIRI_{SR}$ is present, when there is a small scale fading effect $L_{SF(t)}$ is supplied in Eqns. (5) and (6) from [2] and [10].

$$CIRI_{SR}(dB) = R_{ST,SR} - R_{PT,SR} \quad (5)$$

$$CIRI_{SR}(dB) = G_{ST,HPA} + G_{ST,ANT} - L\left(d_{ST,SR}\right) - L_{SF,ST,SR(t)} - G_{PT,HPA} - G_{PT,ANT} + L\left(d_{PT,SR}\right) - L_{SF,PT,SR(t)} - F_{PT,BW(\varphi_{PT,SR})} \quad (6)$$

Furthermore, each time ST is randomly located in the PT service area, the flag variable $NC_{PR}(i) = 1$ is set if $CIRI_{PR} > \lambda_{PR}$, a defined value. If not, it is set to zero. The antenna response of the SR in the direction of PT is taken into consideration by the term $F_{PT,BW(\varphi_{PT,SR})}$.

The signals from ST and PT, respectively, represent the desired and interfering signals. The placements of PR, ST, and SR are chosen at random for every try. The ratio between the total number of attempts $N_{total}$ and the number of attempts with either $CIRI_{PR}$ or $CIRI_{SR}$ larger than the specified thresholds. This ratio is known as the spatial opportunity for $I_{PR}prob_{PR}$ when taking into account PT and SR, or the spatial opportunity for $I_{SR}prob_2$ when taking into account ST and PR. The two scenarios were evaluated by Eqns. (7) and (8), respectively [2] and [10].

$$I_{PR}prob_{PR} = \frac{\sum_{i=1}^{N_{total}} NC_{PR}}{N_{total}}(i) \quad (7)$$

$$I_{SR}prob_{SR} = \frac{\sum_{i=1}^{N_{total}} NC_{SR}}{N_{total}}(i) \quad (8)$$

Where both $I_{PR}$ and $I_{SR}$ are considered, Eqn. (9) from [2] and [10] gave the overall spatial opportunity.

$$I_{total}\, prob_{total} = \frac{\sum_{i=1}^{N_{total}}[NC_{PR}(i), NC_{SR}(i)]}{N_{total}} \quad (9)$$

**(1) Estimated Spectrum Utilization:** For efficiency of spectrum utilization $\eta_{SU}$, two types of spectrum decision schemes are compared: one based on MLNN spectrum prediction, and the other on study of spectrum occupancy statistics.

The ratio of empty slots found by the cognitive user to empty slots that are available in the system for a given amount of time is known as spectrum utilization. This appears in Eqn. (10).

$$\eta_{ESU} = \frac{number\ of\ vacant\ slot\ detected}{total\ number\ of\ vacant\ slots\ in\ the\ Nspectrum\ fragments} \times 100\% \quad (10)$$

**(2). Primary User Interfering Probability (PUIP):** is the proportion of the channel slots an SU utilizes while a PU is transmitting. The communication of a false alert is the cause of this. The PUIP is expressed in Eqn. (11)

$$PUIP = \frac{Total\ number\ of\ collision\ slots}{Total\ number\ of\ PU\ activity\ slots} \quad (11)$$

Table 1 shows the algorithm for the assessment of spatial opportunity prediction in UHF (470-670) MHz band services.

Table 1: The Proposed algorithm of assessment of spatial opportunity prediction for spectrum occupancy of UHF (470-670) MHz Band Services in Osogbo Metropolis

1. Implement Data Capturing of the band with BK precision2640 spectrum analyzer
2. Carry out spectrum sensing with energy detection approach and deduce power spectrum densities $P(t_i, f_j)$ over a period of 48 hours
3. Analyze the data with Excel sheet application into matrix form $Z = \begin{Bmatrix} P(t_1 f_i) & P(t_1 f_j) \\ P(t_1 f_i) & P(t_1 f_j) \end{Bmatrix}$
4. Create a decision threshold $\lambda_{TH} = \eta Z(f) + p_i$ And apply the hypothesis rule for each entry in 3: $I_{ED}(t_i f_j) = \begin{cases} 0, if P(t_{i,} fj) < \lambda_{TH} \\ 1, if P(t_{i,} fj) \geq \lambda_{TH} \end{cases}$
5. Evaluate the average spectrum duty cycle and acquire spatio-temporal variations of duty cycle across all the four locations within specified period of 48 hours and within the specified band limit for each link using $\Delta(loc, t, f) = \frac{1}{N_{time} N_{freq}} \sum_{i=1}^{N_{time}} \sum_{j=1}^{N_{freq}} I_{ED}(t_i, f_j)$
6. From 5, deduce the Channel Vacancy Durations (CVD) according to $CVD_l = t_s(1-\mu_m)$
7. Set up a threshold for the channel vacancy duration $CVD_{THR}$
8. If CVD $\geq CVD_{THR}$, move to 9, if not go back to 6.
9. Test for the existence of spatial opportunity using carrier-to-interference –ratio (CIR)
10. Evaluate and determine the communicable service coverage area for primary and secondary system users
11. Arbitrarily generate the locations of PR, ST and SR within the service coverage area
12. For a Secondary user transmission, determine $CIRI_{PR}$, $CIRI_{SR}$ and check if $CIRI_{PR} \geq \lambda_{PR}$ and if $CIRI_{SR} \geq \lambda_{SR}$ respectively.
13. Check if the allowable numbers of trials have been achieved, if no repeat step 9-12 and if yes proceed to 14.
14. Determine the probabilities where $CIRI_{PR} \geq \lambda_{PR}$ and if $CIRI_{SR} \geq \lambda_{SR}$ are satisfied
15. Evaluate the Estimated Spectrum Utilization (ESU) using Equation 10
16. Evaluate Primary User Interference Probabilities (PUIP) using Equation 11
17. End

# 4.0 RESULTS AND DISCUSSION

## 4.1 SPATIAL OPPORTUNITIES OF COEXISTING PRIMARY AND SECONDARY WIRELESS SYSTEMS

### 4.1.1 Variation of Carrier-to –Interference-Ratio for Randomly changing locations of PR, ST and SR

The variation of Carrier-to-Interference-Ratio as sensed by Primary Receiver (PR) and Secondary Receiver (SR) respectively of the link primary transmitter (PT) and primary receiver (PR), secondary transmitter (ST) and secondary receiver (SR) and secondary transmitter (ST) and primary receiver (PR). Spatial opportunities occur when CIR values threshold is set at 45 dB for PT and PR while the CIR value of 30 dB threshold was implemented for spatial opportunity of ST and SR.

### 4.1.2 (470-670) MHz UHF Variation of Carrier-to –Interference-Ratio for Randomly changing locations of PR, ST and SR

The analysis of the variation of carrier-to-interference ratio are given in Figure 2 and Figure 3. Figure 2 indicates the (470-670) MHz UHF Primary Receiver Carrier-to- Interference-Ratio in dB versus Number of trials at antenna transmitter height of 30m, with the highest carrier-to-interference-ratio of 75.86197 dB that occur at trial number 160000 while the lowest carrier-to –interference ratio of -26.4927 dB occur at trial number 15800.

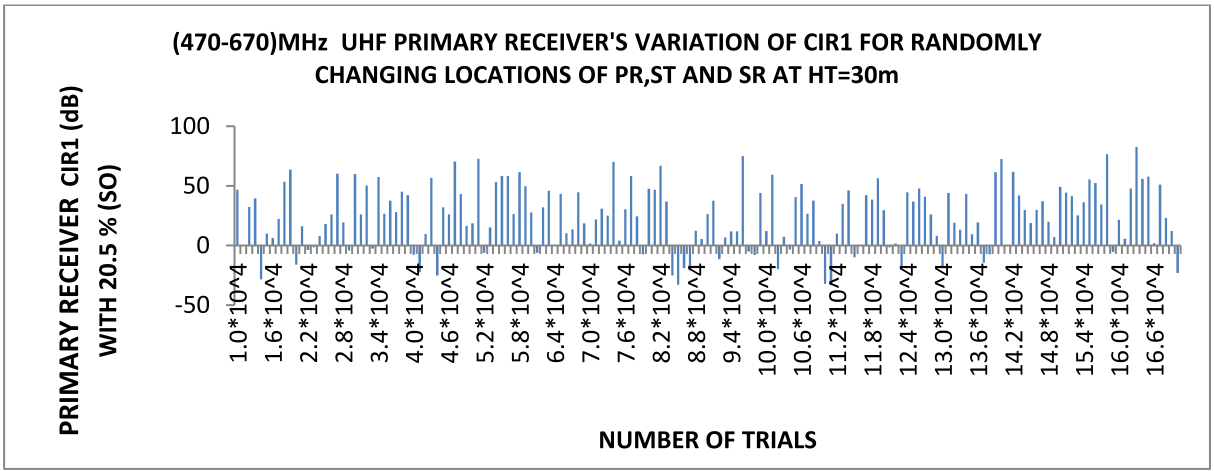


Fig. 2: (470-670) MHz UHF Primary Receiver's Variation of CIR1 for randomly Changing Locations of PR, ST and SR at antenna height of 30 m

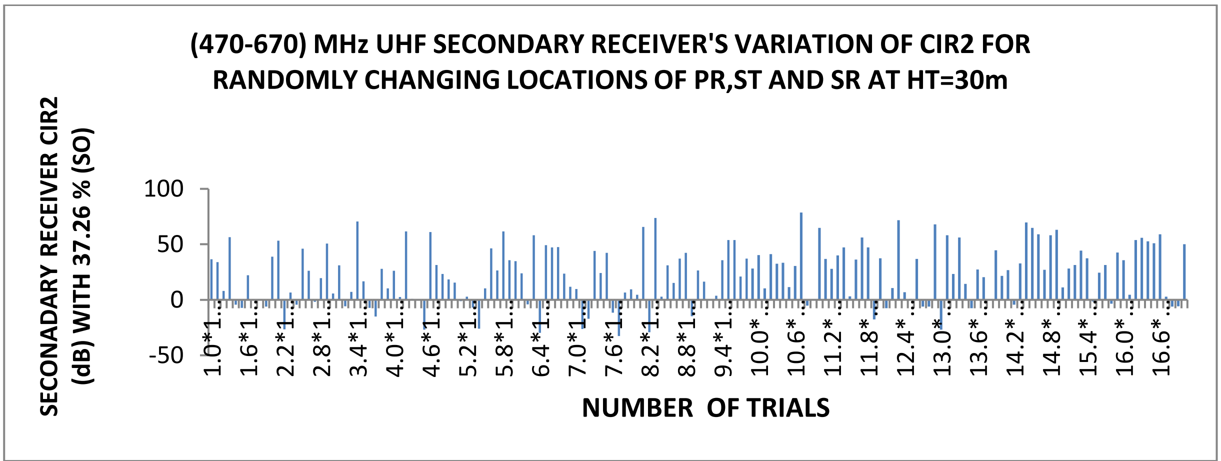


Fig. 3: (470-670) MHz UHF Secondary Receiver's Variation of CIR2 for Randomly Changing Locations of PR, ST, and SR at antenna height of 30m

Figure 3 indicates the UHF (470-670) MHz Secondary Receiver Carrier-to- Interference-Ratio in dB versus Number of trials at antenna transmitter height of 30m, with the highest carrier-to-interference-ratio of 79.66266 dB that occur at trial number 104000 while the lowest carrier-to-interference-ratio of -22.7598 dB that occur at trial number 33000.

**4.2. Computed Spatial Opportunities for Specified locations**

Figure 4 to Figure 8 gave the analysis of computed spatial opportunities.

**4.2.1: (470-670) MHz UHF Computed Spatial Opportunities for Specified locations**

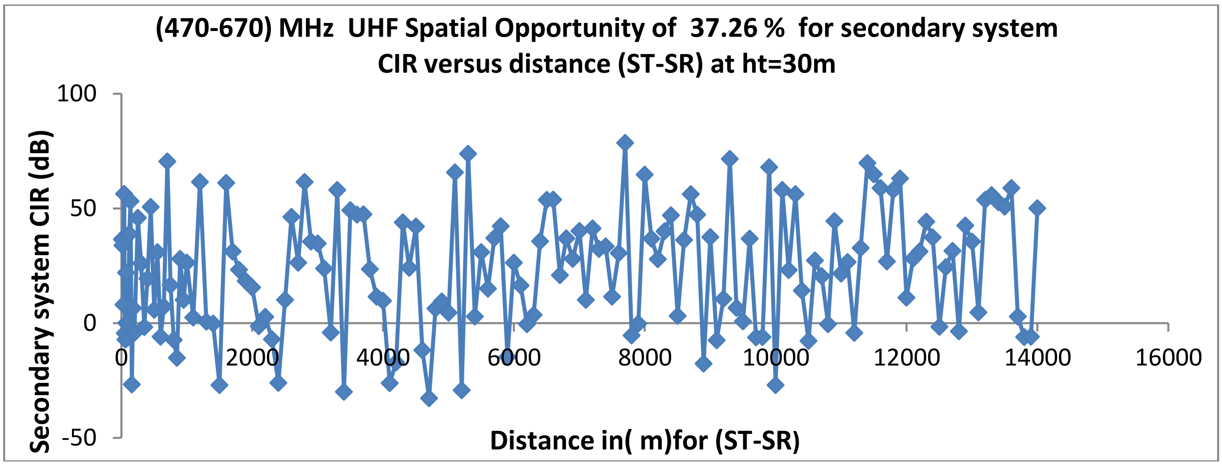


Fig. 4: (470-670) MHz UHF Spatial Opportunity of 37.26 % for secondary system CIR versus distance (ST-SR) at ht=30m

Figure 4: indicates the UHF (470-670) MHz Spatial Opportunity of 37.26 % for secondary system CIR versus distance (ST-SR) at ht of 30m, with the highest secondary system carrier-to interference ratio of 75.30371 dB that occur at 1.1 km location, while the lowest carrier-to interference ratio of -25.4865 dB occurs at 6.6 km location respectively for the secondary system to communicate when primary transmission is ongoing.

**4.3: Evaluation of Primary User Interfering Probability**

**4.3.1: (470-670) MHz UHF Evaluation of Primary User Interfering Probability for all four locations**

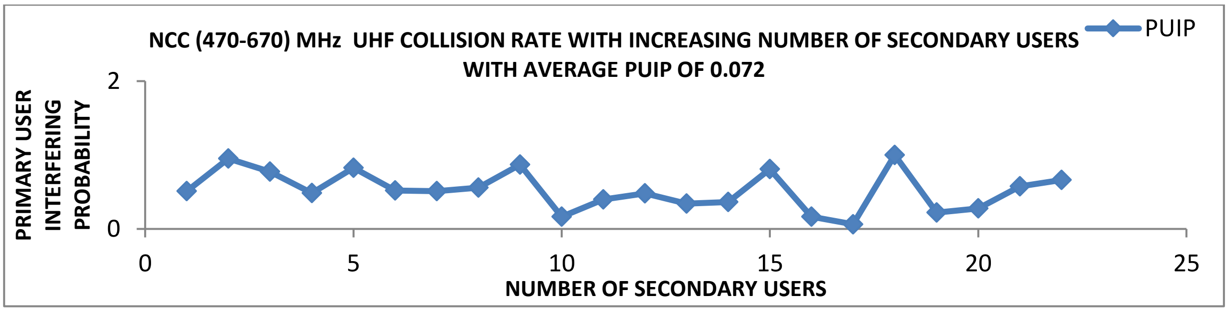


Fig. 5: National Control Centre (470-670) MHz UHF Primary User Interfering Probability versus Number of secondary users.

Figure 5 indicates the NCC UHF band Probability user interfering probability versus number of secondary users, with the highest user probability of 1 that occur at user's 18$^{th}$ while the lowest user probability of 0.167 occur at user 10$^{th}$ and the average Primary user interfering probability for all secondary users is 0.072.

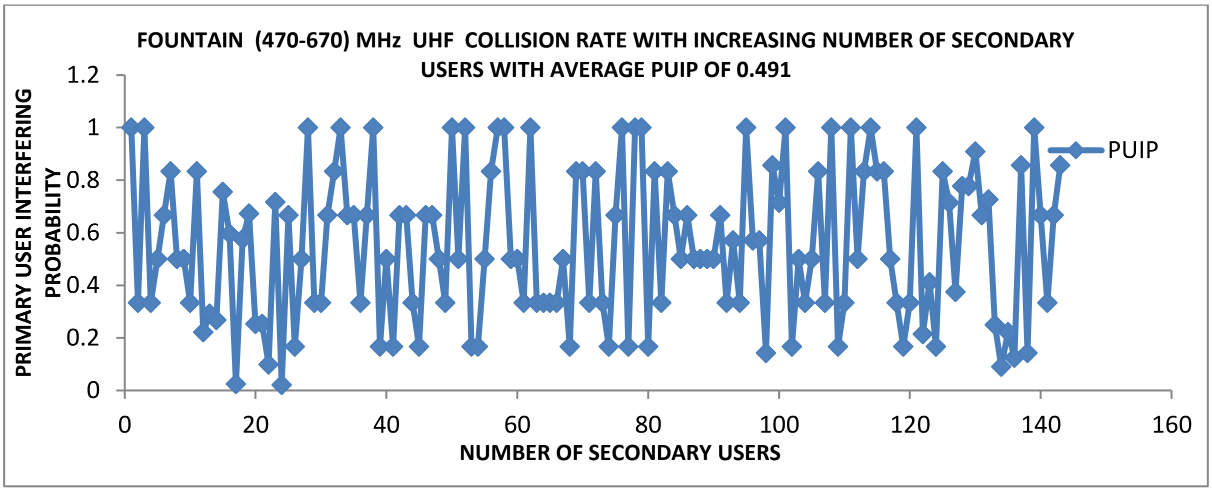


Figure 6: Fountain university campus (470-670) MHz UHF Primary User Interfering Probability versus Number of secondary users.

Figure 6 indicates the Fountain university First uhf band Probably user interfering probability versus number of secondary users, with the highest user probability of 1 that occur at user's 1st, 3rd, 28th, 33rd, 38th, 50th, 52nd, 57th, 58th, 62nd, 76th, 78th, 79th, 95th, 101th, 108th, 111th, 114th, 121th and 139th while the lowest user probability of 0.09 occur at user 134th and the average Primary user interfering probability for all secondary users is 0.491.

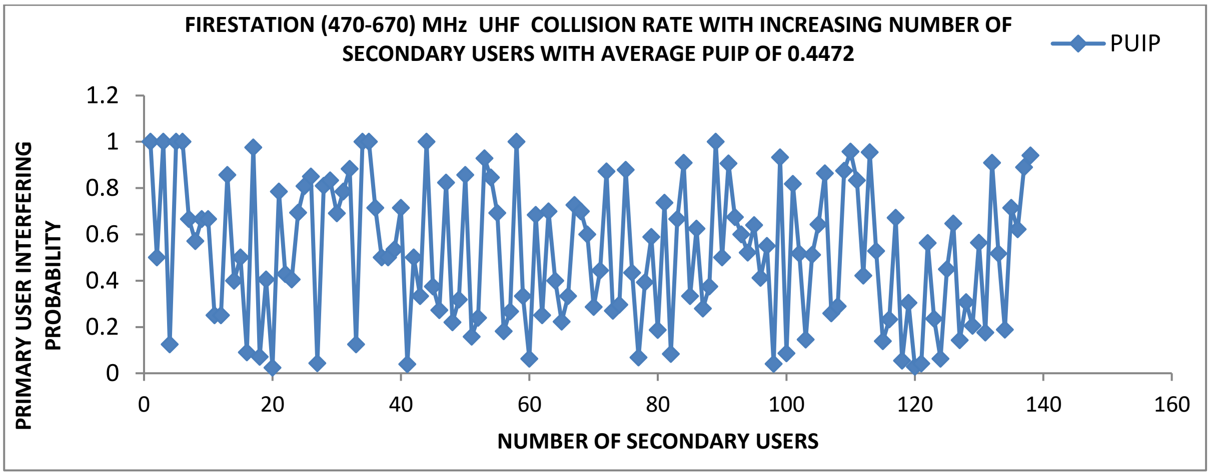


Fig. 7: Firestation (470-670) MHz UHF Primary User Interfering Probability versus Number of secondary users

Figure 7 indicates the Firestation (470-670) MHz uhf band Probability user interfering probability versus number of secondary users, with the highest user probability of 1 that occur at user's 1st,3rd,5th,6th,34th,35th,44th,58th and 89th while the lowest user probability of 0.188 occur at user 134th and the average Primary user interfering probability for all secondary users is 0.4472.

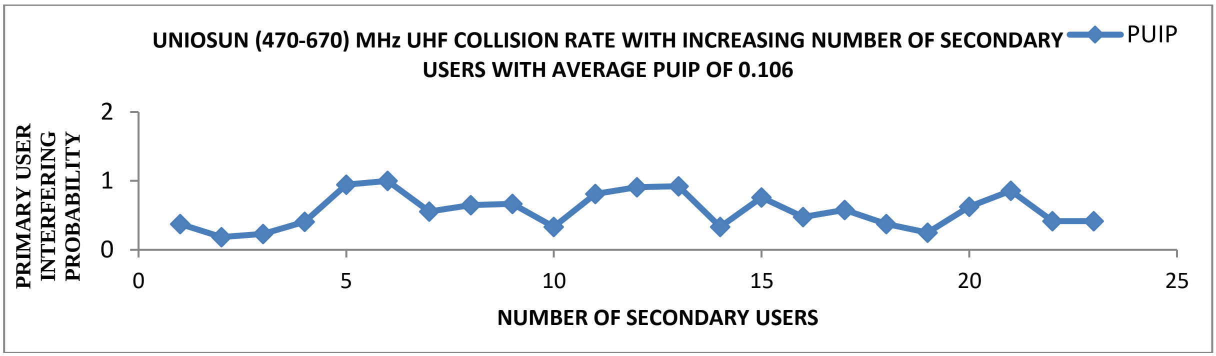


Fig. 8: Uniosun campus (470-670) MHz UHF Primary User Interfering Probability versus Number of secondary users.

Figure 8 indicates the Uniosun (470-670MHz uhf band Probability user interfering probability versus number of secondary users, with the highest user probability of 1 that occur at users' 6th while the lowest user probability of 0.185 occur at user 2nd and the average Primary user interfering probability for all secondary users is 0.106.

### 4.4: Evaluation of Spectrum Utilization

Figure 9 to Figure 12 gave the analysis of Evaluation of Spectrum Utilization.

### 4.4.1: (470-670) MHz UHF Evaluation of Spectrum Utilization for all four locations

Figure 9: indicates the NCC First uhf band spectrum utilization in percentage versus the number of available secondary users, with the highest spectrum utilization of 98.96 % that occur at secondary user number 31st while the lowest spectrum utilization of 0.867 % occur at secondary user number 82nd and the average estimated spectrum utilization for the whole secondary users is 47.79

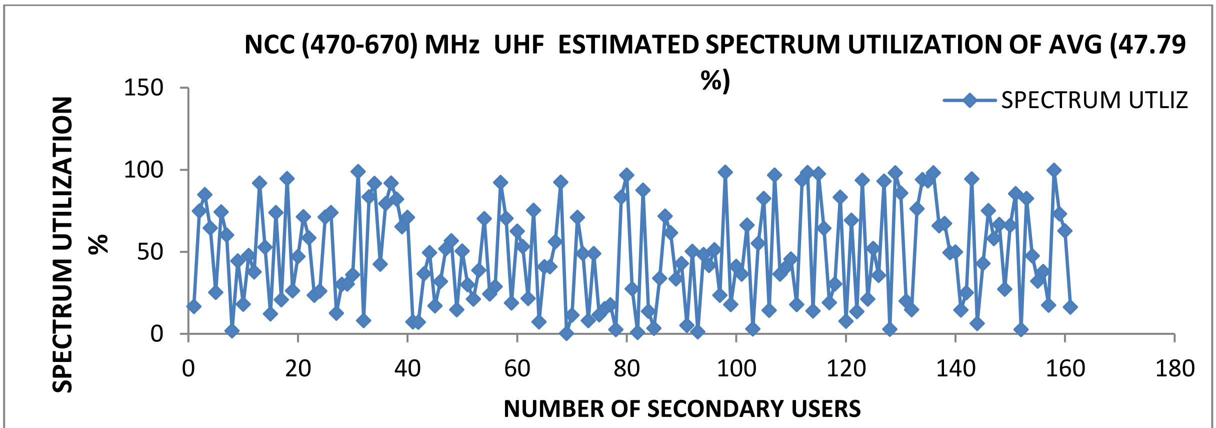


Figure 9: National Control Centre (470-670) MHz UHF Spectrum Utilization versus Number of secondary users%.

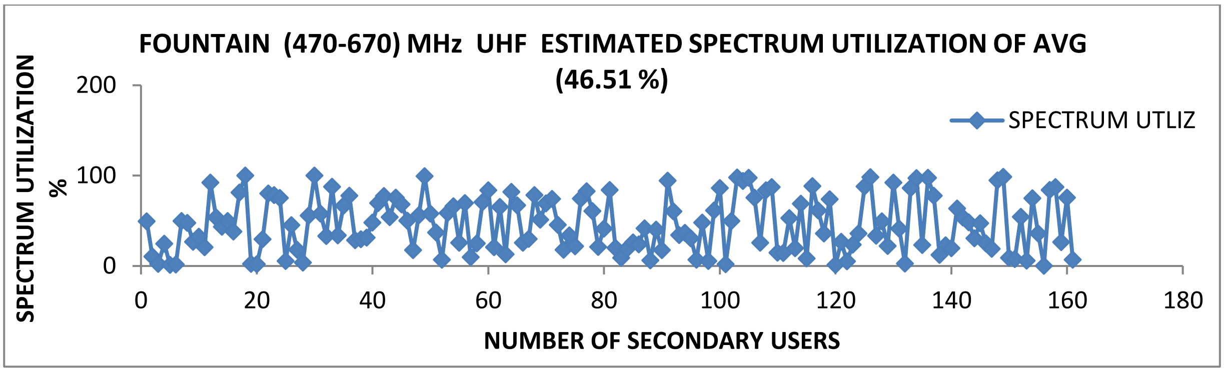


Fig. 10: Fountain University (470-670) MHz UHF Spectrum Utilization versus Number of secondary users

Figure 10: indicates the Fountain university uhf (470-670) MHz band spectrum utilization in percentage versus the number of available secondary users, with the highest spectrum utilization of 100 % that occur at secondary user number 18th and 30th while the lowest spectrum utilization of 1.23 % occur at secondary user number 120th and the average estimated spectrum utilization for the whole secondary users is 46.51 %.

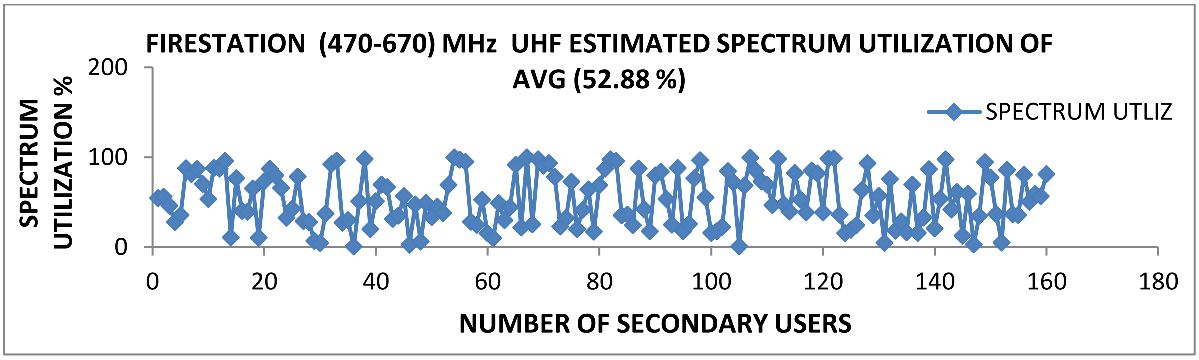


Fig. 11: Firestation (470-670) MHz UHF Spectrum Utilization versus Number of secondary users

Figure 11: indicates the Fountain university First uhf band spectrum utilization in percentage versus the number of available secondary users, with the highest spectrum utilization of 99.82 % that occur at secondary user number 54th while the lowest spectrum utilization of 2.78 % occur at secondary user number 46th and the average estimated spectrum utilization for the whole secondary users is 52.88 %.

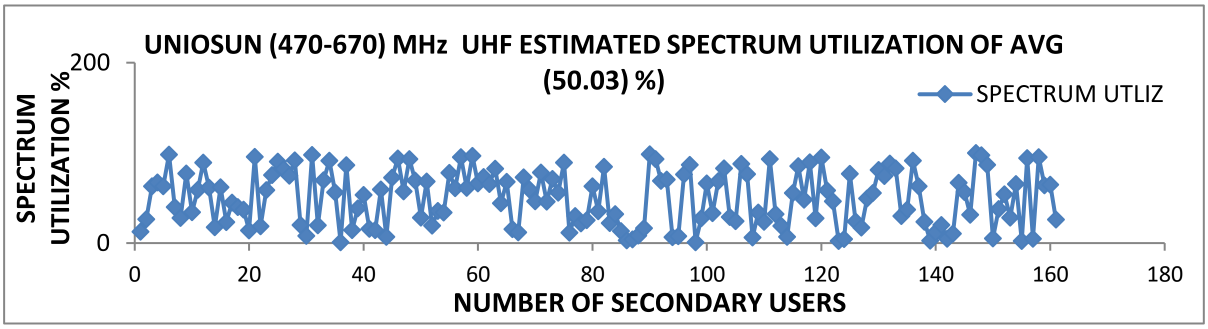


Fig. 12: Uniosun campus (470-670)MHz UHF Spectrum Utilization versus Number of secondary users

Figure 12 indicates the Uniosun (470-670) MHz uhf band spectrum utilization in percentage versus the number of available secondary users, with the highest spectrum utilization of 100 % that occur at secondary user number 147th while the lowest spectrum utilization of 6.25 % occur at secondary user number 108th and the average estimated spectrum utilization for the whole secondary users is 50.03 %.

## 5. CONCLUSION AND RECOMMENDATION

The paper investigated the assessment of the spatial opportunities created by the UHF (470-670) MHz band services for cognitive wireless communication services. The outcome of the result showed that, Firestation, Fountain university campus, Uniosun campus and National control center have an average estimated spectrum utilization of 52.88 %,46.51 % ,50.03 % and 47.79 % respectively, this implies that about 47.12% ,53.49%,49.97% and 52.21% of the stated bands of the same location can be deployed for cognitive usage and the location with the highest UHF (470-670) band utilization was Firestaion. Also, the average Primary user interference probability (PUIP) 0.4472, 0.491,0.106 and 0.072 implies that about 0.5528, 0.509, 0.894 and 0.928 probabilities of the band are interference free and the location with the lowest interference conflict of primary and secondary user during transmission occur at National Control Centre at 7.2 % interference. The computed spatial opportunity of 37.26 % for the specified locations which represent the advantage created for cognitive systems to communicate while there is transmission by the primary user of the band.

The result of the work will be useful for the broadcasting stakeholders in frequency allocation planning and possible deployment for emergency communications network and other cognitive usage that require necessary frequency allocation. In the future work, other bands will be subjected to the same process to create more opportunities for cognitive usage.

**Acknowledgement**

The Tertiary Education Trust Fund in Nigeria has provided support for research through the Academic Staff Training and Development program unit of the Federal Polytechnic Ede. The University of Ilorin's Department of Electrical and Electronics Engineering has made measuring instruments available for data-capturing, thanks to Engr. Professors Nazmat Toyin Surajudeen-Bakinde and A.Y. Abdulrahman.

## 6. REFERENCES

[1] Ayeni, A. A; Faruk, N; Surajudeen-Bakinde, N. T; Okanlawon, R. A; Adediran, Y.A"Spatial Spectrum Utilization Efficiency for Spectrum Sharing System" International Journal of Digital and Wireless Communication, 2015, pp. 44-51.

[2] Ehiagwina, F. O., Surajudeen-Bakinde, N., Afolabi, A. .., & Usman, A. M. (2022). A Hybrid Spectrum Opportunities Extraction Scheme for Cognitive Wireless Communications. *Telematics and Informatics Reports* , pp. (1-14).

[3] Stephen, U. Ufoaroh and Kebiru Abu., (2017). Assessment of TV White Spaces Availability in Southern Nigeria. International Journal of Electrical and Telecommunication System Research. Vol. 10, Number 10.

[4]Faruk, Nasir.,Ayeni, A. Adeseko., Adediran, Yinusa. A., (2013) . DTV Coverage and Protection Contour Estimation for Spatial White Space. IEEE international Conference on Emerging and Sustainable Technologies for Power ICT in a Developing Society(NIGERCON)

[5] Faruk ,Nasir., Imam-Fulani, Yusuf., Sikiru,Ismael. A.,Popoola,Segun. I., Oloyede, A.A.,Olawoyin, Lukman. A., Surajudeen- Bakinde, N.T., Sowande, A.O ., (2017). Spatial Variability Analysis of Duty Cycle in GSM Band. IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON)

[6] Nishimori, Kentario.,Taranto,Rocco. Di., Yomo, Hirroyuki.,Popovski,Petar (2007) .Spatial Opportunity for Cognitive Radio Systems with Heterogenous Path loss Conditions. IEEE conference paper

[7] Adefela, Adekunle. N.,Olasoji, Yekeen. O.,Adedeji, Kazeem B.,(2022) .Evaluation of TVWS availability : A Step Towards Frequency Utilization. Journal of Engineering Advancements. pp (50-56).

[8]. Csurgai-Horvath, Laszlo., Rieger, Istvan and Kertesz, Jozsef(2016). A Survey of DVB-T Spectrum Opportunities for Cognitive Mobile

Users.Journal Smart Spectrum Technologies for Mobile Information Systems.

[9] Fadda, M,.Popescu, V.,Murroni,M.,Angueira,P., and Morgade,J., (2015). On the Feasibility of Unlicensed Communications in the TV White Space:Field Measureents in the UHF Band.

[10] Nishimori, K. .. (2011). Cognitive Radio Operation Under Directional Primary Interference and Path Loss Models. *IEICE Transaction on Communication* , E94-B(5),1243-1253.