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# Analysis of Spectrum Occupancy of Active FM Band within Federal Polytechnic Ede Northern Campus

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**Abstract: Campaign measurement for the Analysis of Spectrum Occupancy of the Active FM Band was carried out at some strategic four locations of Federal Polytechnic Ede Northern campus Nigeria, for the spectrum availability evaluation of the frequency modulation band for an average of 8 hours period. The band range of the FM is 88- 108 MHz ,with some emphasis made on the Frequency Modulation (FM) radio stations within Osun and neighboring state. Spectrum is a very scarce resource and its availability is a major factor that determine the effectiveness and performance of many broadcasting radio stations coupled with cognitive radio opportunistic usage. The methodology implemented in this work is an energy detection approach with the 5 dB threshold taken into consideration above the noise floor to determine the spectrum availability or unavailability. The quality of the signal will be determined by the threshold setting of allowing the availability of the quality signal above the threshold and disallowing the availability of noise. The conclusion taken from the result is that an average of 37.15 % of the FM band was occupied in all the four locations to give an inference of 12.67 MHz band unoccupied out of the 20 MHz band allocated for the Frequency Modulation.**

**Keywords**: Cognitive radio Noise threshold, Spectrum Occupancy, Duty Cycle, Frequency Modulation.

## 1. INTRODUCTION

The desire for limitless services with frequency spectral frugality exposes man to the choice of having to seek for novel and more techniques of managing the frequency spectrum, which is a finite resource with limitless demands. Part of these techniques is the frequency reuse, which culminates into spectral occupancy and spectral efficiency among others that looked into the measurement rate of the frequency utilization [7]. It is pertinent to determine the true behavior of the real spectrum usage in an environment to enable deployment and development of future wireless communication system and to put into the usage the unused and underutilized frequency spectrum.

The aim of this paper is to provide an in-depth analysis of the spectrum measurement of active FM band (88-108) MHz within the four different locations of Federal Polytechnic Ede Northern campus. In other to determine the duty cycle, an adaptive energy detection threshold technique was employed with a modified duty cycle considering the space variables.

A hypothesis based model for energy detection, for a received signal y(k), the transmitted signal x(k) are given as:

$$H_0: y(k) = w(k) \quad (1)$$

$$H_1 : y(k) = h.x(k) + w(k) \quad (2)$$

Where:

$H_O$ and $H_1$ represents the hypothesis equivalents to “signal absence” and “signal presence” respectively.

$w(k) =$ additive white Gaussian noise (AWGN) with zero mean and variance $r^2{}_n$ and

$h =$ the amplitude of the channel gain.

## 2. SPECTRUM SURVEY REVIEW

Selected research work that deals with spectrum occupancy are highlighted as follows; some work was performed on spectrum measurement campaign over a rich diversity when the research work concludes that the occupancy levels observed perceived by secondary users depends on the locations in consideration with significant variations in reduced physical areas [4].

In the work of [5], an average occupancy rate of 62.22 % was discovered in the Spectrum Occupancy of GSM 900 Downlink of Active GSM Operators in Ilorin Metropolis research work, with an inference of 7.46 MHz unoccupied.
(Rizza..Loquias, Guzman, G.Hilaro, & S.Marciano, 2019) works on the quantitative analysis of spectrum measurement of the UHF TV band within range of (470-698) MHz, in the Western segment of the Philipine Nautical Highway Systems. A geo-location database approach was used to characterize and quantify the spectrum occupancy with an 80 % capacity threshold of ITU-R standard.

Spectrum selected window from 400 -6000 MHz band in greater Melbourne area in Australia was looked into by [1], where analysis on the utilization of Dynamic Spectrum Access in different bands of the spectrum was done , and a conclusion was reached that ,a potential exploitation of the radio spectrum could be achieved by taking the advantage of the available spectrum hole for the benefit of cognitive radios without interference to the incumbent spectrum user.

In [6], research works on radio spectrum usage in Samsun, where extensive measurements were carried out at 115 locations on GSM bands using RF explorer 6G Combo as an equipment. Deduction from the work resulted in the the calculation of eight different threshold from -40 dBm to -75 dBm ,where 8.5 % and 82% spectrum average occupancy of GSM 900 band was arrived at for -40 dBm and -75 dBm threshold respectively indicating only 39 locations occupied and 76 locations unoccupied.

In [10], investigation was carried out on the spectrum occupancy of the Palestinian FM ,UHF and GSM bands by using the low cost software defined radio (SDR) device RTL-SDR, based on the findings that UHF band is under-utilized ,a dynamic spectrum access based on cognitive radio (CR) was suggested to improve spectrum utilization for wireless communication. The work was concluded with three Cognitive radio concept of utilizing unoccupied spectrum ,namely as ; interweave cognitive radio concept for UHF band , underlay cognitive radio concept of WCDMA for underlay approach with GSM, overlay Cognitive radio concept for OFDM sharing and coexistence approach with GSM were proposed [2].

In [12], research work was carried out on spectrum survey to provide useful data for spectrum regulation and planning for dynamic spectrum sharing. To optimize the utilization of the frequency spectrum, a modern option of dynamic spectrum sharing approach of cognitive radio is suggested. A comparison of different bands was done, Short term and Long term Measurement was carried out using Duty cycle, and concluded experimentally that frequency spectrum is heavily underutilized in most of the frequency bands. A deep analysis of Wi-Fi (ISM) was performed and the possibility of channel switching to maximize wireless traffic was found to increase the data throughput .Investigation on the spatial variation of spectrum occupancy which is also known as the duty cycle in the GSM 900 MHz band in Kwara state, Nigeria. Experimental results indicated that, there is a very high spatial variance in the duty cycle from one area to another with mean occupancies of 1.67 % and 17.76 % in rural and urban areas respectively, with overall of 10.55 % for all areas under consideration [8].
The deduction from the work the advised the telecommunication industries in Nigeria to adopt a beneficial techniques to optimize the scarce radio resources in the licensed bands of the rural areas.
In [9], research work was carried out on 2.4 GHz Industrial Scientific and Medical (ISM) bands in two different locations for opportunistic LTE operation. The selection of the accurate parameters for the analysis is greatly dependent on both the systems operating in the channel as well as the characteristics of the system intending to operate in the channel without harmfully interfering with the incumbent users.

In [3], a research work titled ‘’Spectrum Occupancy Measurements in the TV and CDMA Bands’’ embarked on 24 hours outdoor measurement of spectrum occupancy in both rural and urban areas of kwara state for the frequency range of 48.5 MHz -880 MHz. The outcome of the result obtained shows that, the mean average duty cycle for CDMA band and TV bands 1-4 in rural and urban areas are 12.02% and 2.58% together with 3.13% and 0.25 % respectively. The deduction from the outcome of the result is that, in both rural and urban areas, CDMA bands are less utilized when compared with TV bands.

In [2],another work named ‘’Short-Term Variation of Duty Cycle in the VHF and UHF Bands’’ carried out another 24 hours outdoor measurement in rural and urban areas for a period of 24 hours in Kwara state ,Nigeria for a rage of frequency of 48.5- 880 MHz. The result arrived at for duty cycle, indicate that , TV band 3 was the most occupied band in rural and urban areas, with occupancy up to 20.26 % and 37.27 % respectively. The

mean average of the duty cycle obtained in urban area is 12.02 % compared to 2.58 % in the rural areas. The conclusion drawn from the result is that ,an ample opportunity for deployment of software defined radio for another more relevant utilization of the spectrum.

## 3. MATERIAL AND METHOD

### 3.1 Measurement Locations:

Spectrum campaign measurements was carried out to determine the spectrum occupancy of active FM radio spectrum services at four different locations within the Federal Polytechnic Ede Northern campus. Details of the locations are shown in Table .

**Table 1: Locations under consideration for research work**

| LOCATION | NAME | COORDINATES |
|---|---|---|
| 1 | ADMINISTRATIVE BLOCK | $7.733^{O}$N, $4.424^{O}$E |
| 2 | APPLIED SCIENCE | $7.731^{O}$N, $4.422^{O}$E |
| 3 | ELECT-ELECT DEPARTMENT | $7.729^{O}$N, $4.420^{O}$E |
| 4 | LIBRARY | $7.727^{O}$N, $4.418^{O}$E |

The map of the measurement locations is shown in figure 1

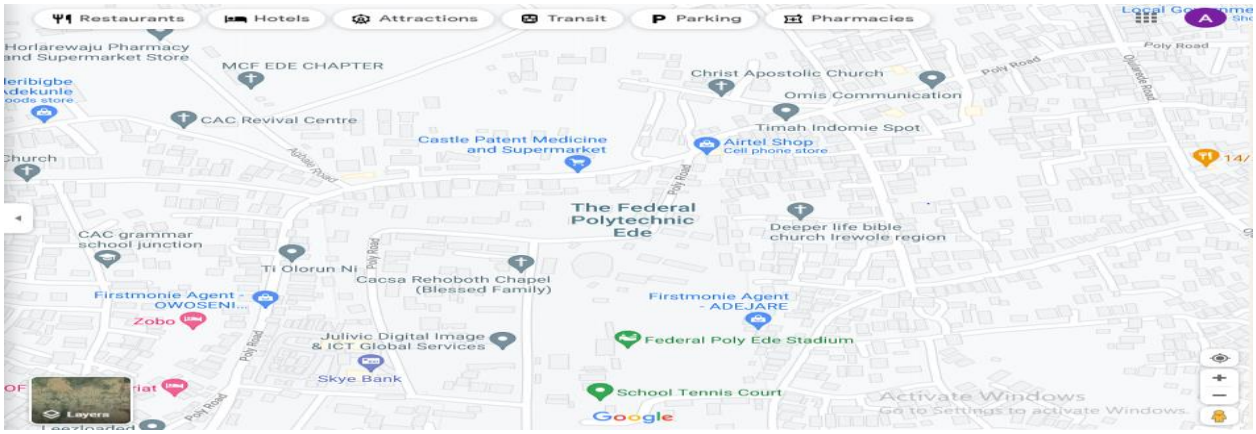


**Figure 1: Map of Federal Polytechnic Ede North campus where all the four locations are sited.**

### 3.2 Spectrum Band

Table 2 indicates the Frequency Modulation radio spectrum service under consideration in this research work with the relative allocated spectrum band

**Table 2: Radio spectrum services in the chosen spectrum band (88-108) MHz**

| Radio Spectrum Services | Allocated Band (MHz) | Bandwidth (MHz) |
|---|---|---|
| FM Band | 88 - 108 | 20 |

### 3.3 Set-up of the Measurement Equipment

Campaign measurement setup should be able have the ability to sense both strong and the weak signals within the frequency range of the signal field strength metre, also known as spectrum analyzer. This set up comprises of an energy detector, a field strength analyzer (BK PRECISION 2640) with 100 KHz – 2.0 GHz frequency range, Omni directional antenna, an android based Global Positioning System (GPS) and a strong storage device embedded within the laptop (Toshiba model) . The GPS allows the capturing of different locations coordinates within the polytechnic spectrum measurement. Table 3 indicates the summary of the parameters of the BK PRECISION 2640 field strength signal analyzer as captured from the instructional manual.

**Table 3: Specification of the BK PRECISION 2640 Field Strength Meter (Spectrum Analyzer) used**

| Parameter | Variables allocated |
|---|---|
| Frequency range | 100 kHz -2 GHz |
| Accuracy | ±3 ppm display:±1.5 ppm |
| Resolution | 3.125 Hz |
| Resolution bandwidth | Variable |
| Input impedance | 50 Ω |
| Sweep time | Min 500 ms |

Source: BK Precision


**Figure 2: The measurement Set-up on the field**

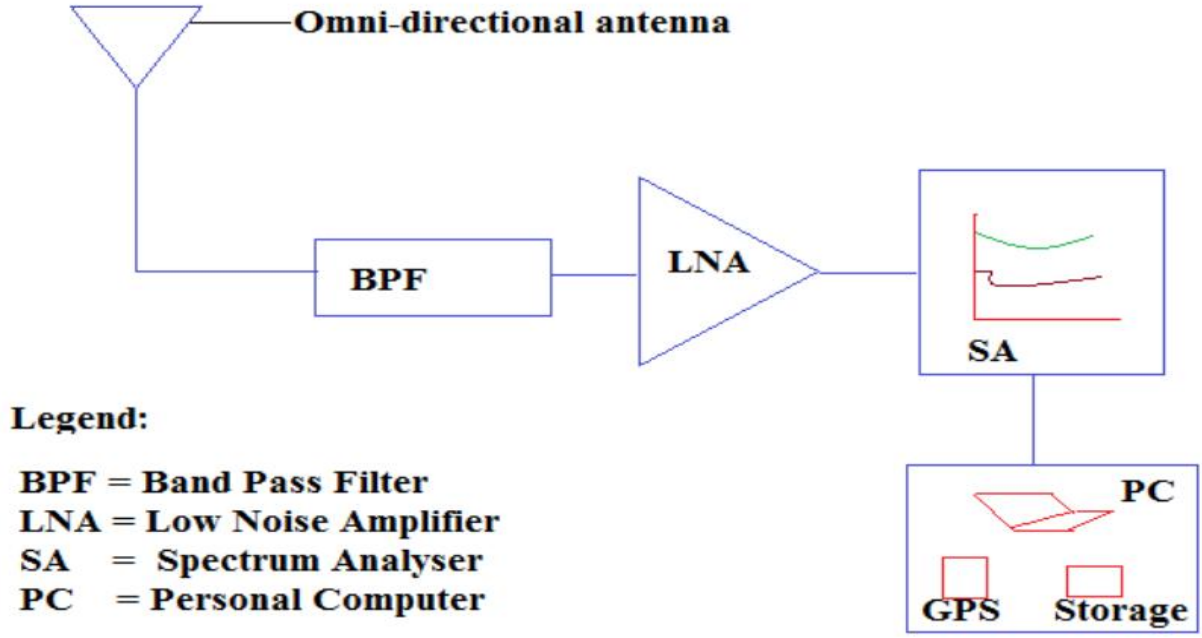


**Figure 3: The diagramatic measurement Set-up**

The methodology approach is based on energy detection due to its simplicity of computation mechanism.

### 3.4 Resolution Bandwidth (RBW), Frequency Bin Size and Decision Threshold

The accuracy of spectrum occupancy is determined by the frequency size bin that is a bit lower than the signal bandwidth, because a greater frequency size bin than the signal bandwidth can give overestimation of the spectrum utilization. Also a narrower RBW assist the reduction of the noise floor and smooth operation of the signal frequency system. A resolution bandwidth of 12.5 KHz was implemented as a better trade-off between the detection capacity shown in the duty cycle and the time taken to measure indicated by the sweep time of the average spectrum analyzer.

The duty cycle is computed in equation (3) according to [5].

$$\text{Duty Cycle} = \frac{Signal\ Occupation\ period}{Total\ observation\ period} \times 100\ \% \quad (3)$$

Selection of the decision threshold determines the duty cycle functions, due to the fact that a high decision threshold resulted to underestimation of the actual occupancy rate because of misdetection of the faded primary transmission, while a low decision threshold results into overestimation because of the noise samples beyond the threshold.

The criteria used in setting the decision threshold according to [5] is the Variable $m_i$-dB criteria in setting the decision threshold. The threshold $m_i$-dB is placed above the noise level determined by the matched load placed across the spectrum analyzer, depending on the band. The variable $m_i$-dB criteria will be applied because the noise variance σX(f) and the maximum noise level can be vary from one band to another depending on the measurement set-up, therefore a constant $m_i$-dB threshold above the entire frequency range being measured is not accurate. The decision threshold $\lambda_k$ in dB is computed in equation (4)

$$\lambda_k = \mu X(f) + m_i \quad (4)$$

*where* $\mu X(f)$ *is the average noise level*

## 4.0 RESULTS AND DISCUSSION

### 4.1 RESULTS

1. The ten frequency modulation (FM) radio stations in Osun state under consideration and their respective allocated frequencies are shown in table 4.

**Table 4: FM radio stations in Osun state with respective centre frequencies and bandwidth**

| S/N | FM STATIONS | FM CENTRE FREQUENCY | FM BANDWIDTH (200 KHz TOLERANCE) |
|---|---|---|---|
| 1 | ORISUN FM | 89.5 | 89.3-89.7 |
| 2 | RAVE FM | 91.7 | 91.5- 91.9 |
| 3 | TIMSED FM IJEBU-JESHA | 94.1 | 93.9 – 94.3 |
| 4 | GREAT FM OAU CAMPUS | 94.5 | 94.3- 94.7 |
| 5 | RAY POWER OSOGBO | 95.1 | 94.9 -95.3 |
| 6 | GOLD FM ILESHA | 95.5 | 95.3-95.7 |
| 7 | ODIDERE FM IWO | 96.3 | 96.1-96.5 |
| 8 | CROWN FM ELEYELE ILE-IFE | 101.5 | 101.3-101.7 |
| 9 | UNIQ FM ILESHA | 103.1 | 102.9-103.3 |
| 10 | REDEEMERS UNIVERSITY CAMPUS FM | 103.5 | 103.3- 103.7 |
| 11 | LIVING SPRING FM (OSBC) | 104.5 | 104.3- 104.7 |

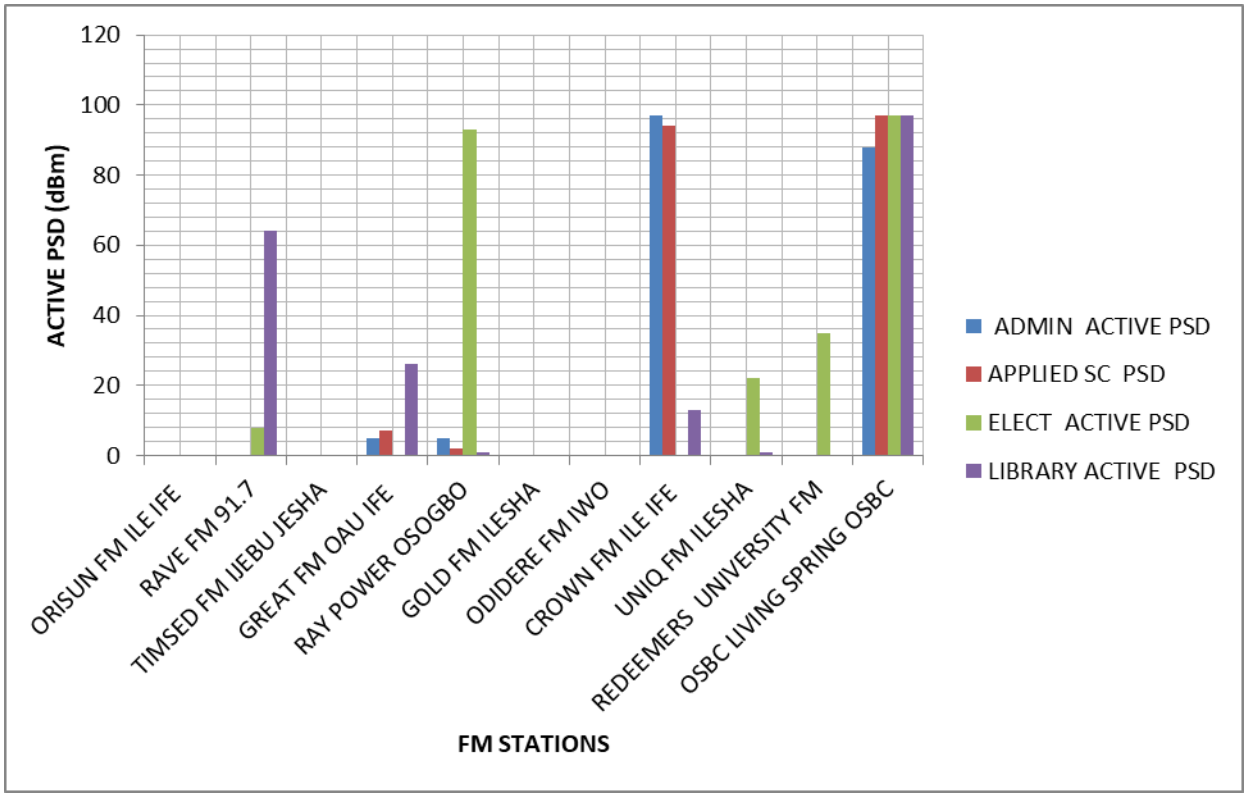


**Figure 4: FM Stations Active Power Spectral Density Distribution within 8 hours period.**

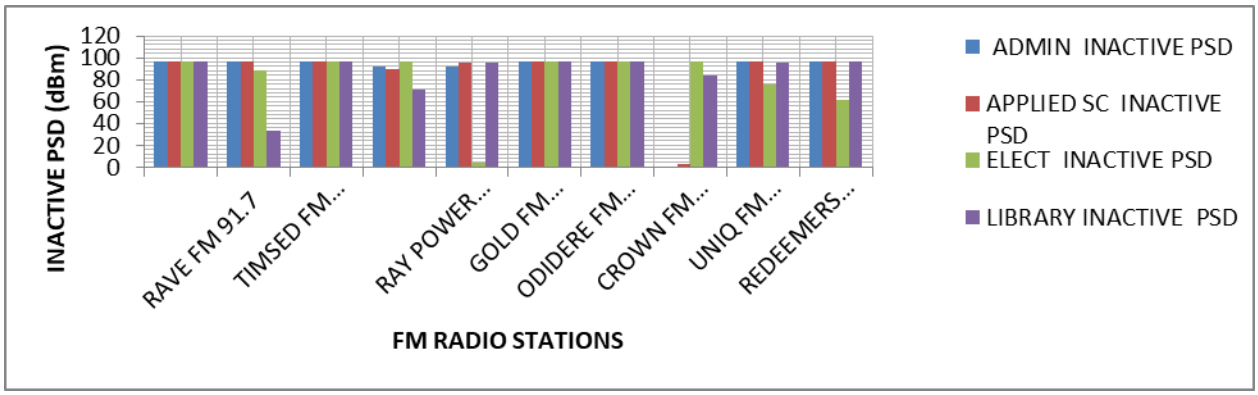


**Figure 5: FM Stations Inactive Power Spectral Density Distribution within 8 hours period.**

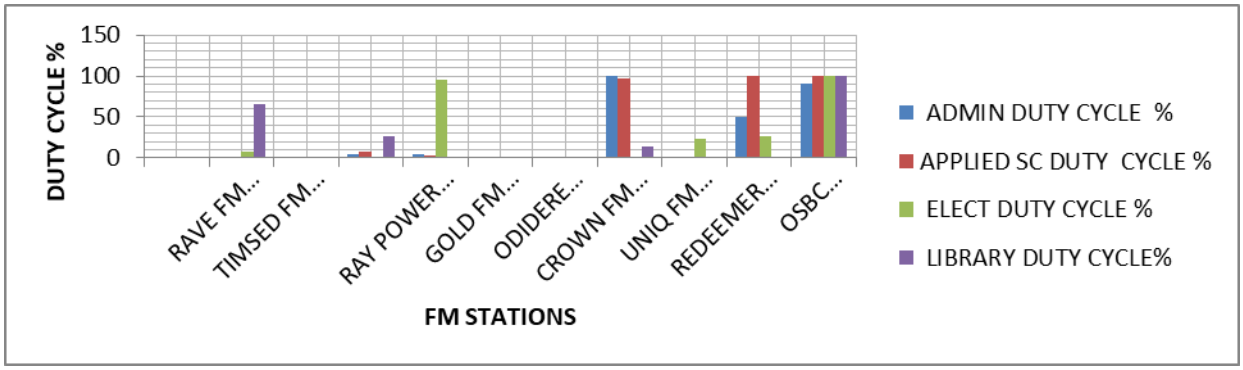


**Figure 6: FM Stations % Duty Cycle Distribution within 8 hours period**

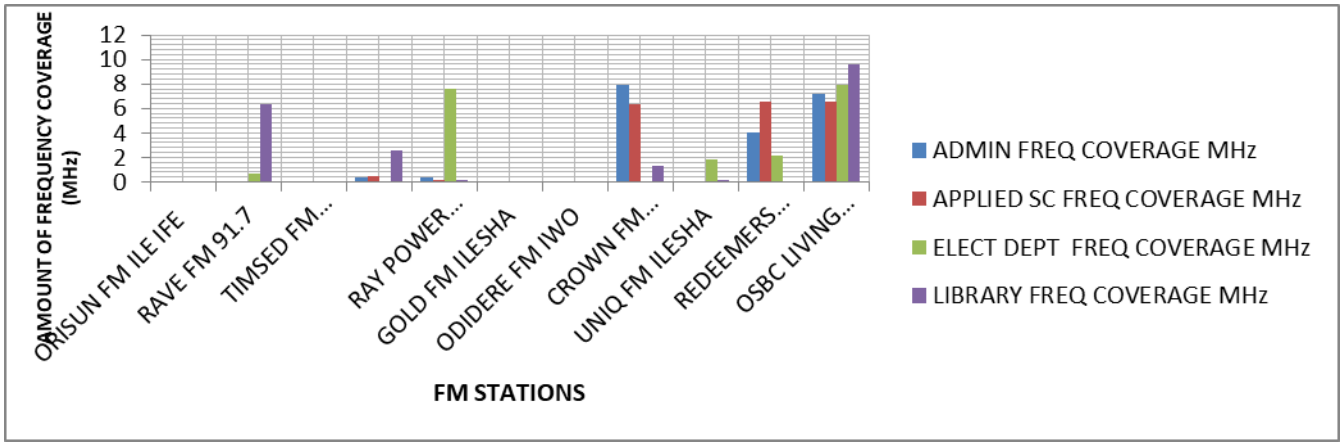


**Figure 7: FM Stations Spectrum Utilization Profile within 8 hours period**

## 4.2 DISCUSSIONS

In figure 4, it was observed that the 1st most active power spectral density occurred for all the four locations was 104.5 FM (OSBC) followed by 101.5 FM (CROWN) with active two locations and 95.1 FM (RAY POWER) and 91.7 FM (RAVE) with one locations each.

In figure 5,it was observed that the most inactive power spectral density occurred for all the four locations was ORISUN FM (89.5 FM) , TIMSED FM (94.1 FM) ,ODIDERE FM and GOLD FM (95.5 FM) with all having inactiveness for all the four locations within the time frame of the measurement.

In figure 6 and figure 7,it was observed that the 1st highest duty cycle occurred for all the four locations, for administrative block ,crown FM has 100 % duty cycle (in figure 6) inferring utilization profile of 7.95 MHz spectrum occupied (in figure 7) out of 20 MHz band, for Applied science OSBC FM also has 100 % duty cycle inferring another 6.53 MHz spectrum occupied, for Electrical Engineering Department and Library , OSBC FM has 100% duty cycle each with 7.89 MHz and 9.6 MHz spectrum occupied respectively.

Also in figure 6 and 7, the second highest duty cycle occurred for all the four locations, for administrative block ,OSBC FM has 90.7 % duty cycle (in figure 6) inferring utilization profile of 7.21 MHz spectrum occupied (in figure 7) out of 20 MHz band, for Applied science, the second most occupied station is CROWN FM also has 96.9 % duty cycle inferring another 6.33 MHz spectrum occupied, second most occupied station for Electrical Engineering Department and Library are RAY POWER FM and RAVE FM stations with 95.88 % and 65.98 % duty cycle respectively each, and inferences of 7.56 MHz and 6.34 MHz spectrum occupied respectively.

**TABLE 4: ESTIMATION OF THE OCCUPIED SPECTRUM BAND FOR FM RADIO STATIONS AT FEDERAL POLYTECHNIC EDE NORTH CAMPUS WITHIN 8 HRS OF CONSIDERATION.**

| FM STATIONS | CENTRE FREQUENCY ( MHz | ADMIN FREQUENCY COVERAGE (MHz) | APPLIED SCIENCE FREQUENCY COVERAGE (MHz) | ELECT DEPT FREQUENCY COVERAGE (MHz) | LIBRARY FREQUENCY COVERAGE (MHz) |
|---|---|---|---|---|---|
| **ORISUN FM** | 89.5 | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED |
| **RAVE FM** | 91.7 | UNOCCUPIED | UNOCCUPIED | 0.65 | 6.34 |
| **TIMSED FM** | 94.1 | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED |
| **GREAT FM OAU** | 94.5 | 0.41 | 0.47 | | 2.57 |
| **RAY POWER OSOGBO** | 95.1 | 0.41 | 0.14 | 7.56 | 0.1 |
| **GOLD FM** | 95.5 | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED |
| **ODIDERE FM IWO** | 96.3 | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED | UNOCCUPIED |
| **CROWN FM** | 101.5 | 7.95 | 6.33 | UNOCCUPIED | 1.29 |
| **UNIQ FM** | 103.1 | UNOCCUPIED | UNOCCUPIED | 1.79 | 0.1 |
| **REDEEMERS FM** | 103.5 | 4.02 | 6.53 | 2.11 | UNOCCUPIED |
| **LIVING-SPRING FM (OSBC)** | 104.5 | 7.21 | 6.53 | 7.89 | 9.6 |
| | **TOTAL FREQUENCY** | **20** | **20** | **20** | **20** |

LEGEND: 1ST MOST OCCUPIED , 2ND MOST OCCUPIED

## 5.0 CONCLUSION

In this research work the spectrum availability of the FM was observed in four selected locations at Federal Polytechnic Ede North Campus. The average spectrum availability for each of the four locations was determined and the analysis was shown in table 5. From the table the maximum occupied station for Administrative block is Crown FM with 39.75% of coverage with an inference of 7.95 MHz out of 20 MHz bandwidth, that of Applied science are Redeemers FM and Living spring (OSBC) FM with 32.65% of coverage each with an inferences of 6.53 MHz respectively for each FM, that of Electrical Engineering department is Living spring (OSBC) FM with 39.25% with an inference of 7.85 MHz and lastly for Library location the maximum occupied station is Living spring with 48% coverage with an inference of 9.6 MHz. out of the 20 MHz band allocated.

The computed average spectrum availability was looked into in terms of the 1st and 2nd most occupied FM band. For the Administrative block the 1st and 2nd most occupied FM band are Crown FM with 7.95 MHz and Living Spring FM with 7.21 MHz, for the Applied Science block Redeemer's FM and Living Spring FM have about 6.53 MHz respectively each as the 1st most occupied while Crown FM has 6.33MHz spectrum coverage as the second most occupied band , for the Elect/Elect Department block it was Living spring FM with about 7.89 MHz as 1st most occupied while Ray power FM has 7.56 MHz as the second most occupied band, finally for the Library block Living spring FM occupied 9.6MHz spectrum band as the 1st most occupied while RAVE FM has 6.34 MHz as the second most occupied FM band for the Library location.

The unoccupied spectrum could be utilized for cognitive radio network deployment in different areas like smart grid, emergency network, green technologies and TV white spaces benefits like spectrum re-farming to solve problem of spectrum scarcity across the globe.

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