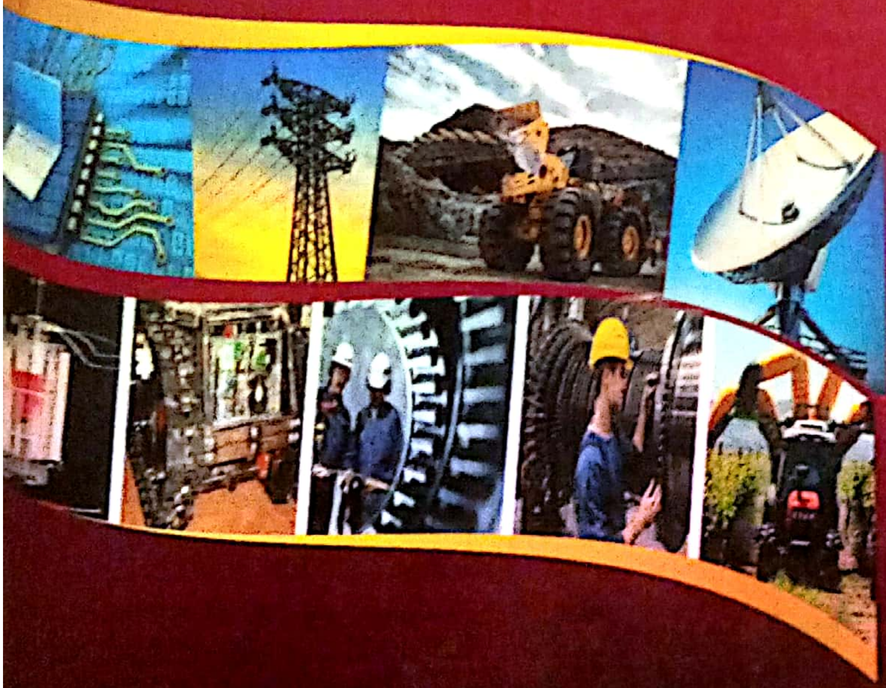
# FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY &
SCHOOL OF INFRASTRUCTURE, PROCESS ENGINEERING AND TECHNOLOGY

## 3rd INTERNATIONAL ENGINEERING CONFERENCE IEC 2019

**THEME** THE ROLE OF ENGINEERING AND TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

# BOOK of PROCEEDINGS



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**EDITED BY**

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# FORWARD

The School of Engineering and Engineering Technology, Federal University of Technology, Minna, organized the 1st and 2nd International Engineering Conference in 2015 and 2017 respectively. With the emergence of the new School of Electrical Engineering and Technology and the School of Infrastructure, Process Engineering and Technology, the two schools came together to organize this 3rd International Engineering Conference (IEC 2019) with the theme: **"The Role of Engineering and Technology in Sustainable Development" considering the remarkable attendance and** successes recorded at the previous conferences. The conference is aimed at offering opportunities for researchers, engineers, captains of industries, scientists, academics, security personnel and others who are interested in sustainable solutions to socio-economic challenges in developing countries; to participate and brainstorm on ideas and come out with a communiqué, that will give the way forward. In this regard, the following sub-themes were **carefully selected to guide the authors' submissions to come up with this communiqué.**

1. Engineering Entrepreneurship for Rapid Economic Growth.
2. Regulation, Standardization and Quality Assurance in Engineering Education and Practice for Sustainable Development.
3. Solutions to the Challenges in Emerging Renewable Energy Technologies for Sustainable Development.
4. Electrical Power System and Electronic as a Panacea for Rapid Sustainable Development
5. Promoting Green Engineering in Information and Communication Technology
6. Reducing Carbon Emission with Green and Sustainable Built Environment
7. Artificial Intelligence and Robotics as a Panacea for Rapid Sustainable Development in Biomedical Engineering
8. Petrochemicals, Petroleum Refining and Biochemical Technology for Sustainable Economic Development.
9. Advances and Emerging Applications in Embedded Computing.
10. Traditional and Additive Manufacturing for Sustainable Industrial Development.
11. Emerging and Smart Materials for Sustainable Development.
12. Big Data Analytics and Opportunity for Development.
13. Building Information Modeling (BIM) for Sustainable Development in Engineering Infrastructure and Highway Engineering.
14. Autonomous Systems for Agricultural and Bioresources Technology.

The conference editorial and Technical Board have members from the United Kingdom, Saudi Arabia, South Africa, Malaysia, Australia and Nigeria. The conference received submissions from 4 countries namely: Malaysia, South Africa, the Gambia and Nigeria. It is with great joy to mention that 123 papers were received in total, with 0.9 acceptable rate as a result of the high quality of articles received. Each of the paper was reviewed by two personalities who have in-depth knowledge of the subject discussed on the paper. At the end of the review process, the accepted papers were recommended for presentation and publication in the conference proceedings. The conference proceedings will be indexed in Scopus.

On behalf of the conference organizing committee, we would like to seize this opportunity to thank you all for participating in the conference. To our dedicated reviewers, we sincerely appreciate you for finding time to do a thorough review. Thank you all and we hope to see you in the 4th International Engineering Conference (IEC 2021).

**Engr. Dr. S. M. Dauda**
Chairman, Conference Organizing Committee

## ACKNOWLEGEMENT

The Chairman and members of the Conference Organizing Committee (COC) of the 3rd International Engineering Conference (IEC 2019) wish to express our gratitude to the Vice Chancellor and the management of the Federal University of Technology, Minna, the Deans and all staff of the School of Electrical Engineering and Technology (SEET) and the School of Infrastructure, Process Engineering and Technology (SIPET) for the support towards the successful hosting of this conference. We also thank the entire staff of the university who contributed in one way or the other. We are sincerely grateful to you all.

# Spectrum Occupancy Measurement in the VHF Band- Results and Evaluation in the Context of Cognitive Radio

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ABSTRACT
In this paper the results of spectrum occupancy survey in the context of Cognitive Radio was presented. In Cognitive Radio, secondary unlicensed users are allowed to opportunistically use the primary licensed users' bands with the understanding that there will be no interference i.e Secondary Users (SU) quits at the arrival of Primary Users (PU). A 24-hour measurement survey was carried out at the centre of Minna metropolis in Niger State, Nigeria covering a frequency range of VHF (30-300MHz). Aaronia HF 6065 V4 spectrum analyzer was used for data collection. Results show that the band allocated for Aeronautical Navigation has the highest spectral occupancy of 39.83% followed by the FM band with occupancy of 12.90% while the frequency band meant for Aeronautical Mobile and Space Operation has occupancy of 4.73% and TV Broadcasting 0.09%. The average occupancy of the VHF band is 14.39%.

Keywords: *Cognitive Radio, FM, Primary Users, Secondary Users, VHF*

## 1 INTRODUCTION

The rise in the demand for wireless devices and wireless communication technology has resulted to the scarcity of the finite radio spectrum. Several wireless services and applications like satellite radio broadband, Wi-Fi internet connections and Bluetooth devices have contributed to the heavy demand of the spectrum. Several regulatory bodies worldwide including the Federal Communications Commission (FCC) of the United States of America (USA) have discovered that lots of frequency bands in the radio frequency spectrum is currently under-utilized. Therefore, the implication is that most spectrum that are allocated are not fully utilized (Barau *et al.,* 2013). This has led to inefficient use of this natural resource (Weiss and Jondral 2004). In the current policy, unlicensed users are disallowed from accessing the spectrum even when they are not utilised by the primary users (Saladhine *et al.,* 2017). Cognitive Radio is envisioned to solve the problem of spectrum scarcity by gaining an understanding of the dynamism of the spectrum occupancy of the frequency band (Barnes *et al.,* 2013; Barnes and Maharaj, 2011).

According to Mitola and Maguire (1999) Cognitive Radio is a radio that senses the environment and adapt its operating parameters to changes in the environment. The essence of Cognitive Radio is to assess the free frequency bands so as to improve on the usage of spectrum opportunistically. It has been generally accepted as a standard solution to spectrum scarcity and under-utilization due to the ineffective way of spectrum allocation to Primary User (PU). To effectively deploy Cognitive Radio, there is the need to have correct and accurate understanding of the allocated spectrum.

Several spectrum occupancy measurement campaigns have been conducted all over the world (Juarez *et al.,* 2016 and Wiles *et al.,* 2016). The study reveals heavy underutilization of spectrum. Few of the campaigns focused on some specific frequency bands while others focused on power received in dBm or percentage of spectrum utilization such as duty cycle (Lima and Mello 2013). Spectrum measurement campaigns is important so that spectrum occupancy samples on pre-selected frequency bands can be obtained such as in cellular bands or TV bands (Eltom *et al*., 2018).

However, there is still a general lack of the understanding of the spectrum occupancy in Africa and in particular in Nigeria. According to Kliks *et al.,* (2013), spectrum occupancy measurement information for a particular location is not applicable for other locations. Therefore, this work presents results of an outdoor spectrum occupancy measurement in Minna metropolis, Niger State, Nigeria with focus on the Very High Frequency (VHF) band of 30-300MHz).

## 2 METHODOLOGY

The description of the measurement location and the equipment used are described in the following sub-sections.

## 2.1 MEASUREMENT LOCATION

A careful choice of a measurement location is essential for a good spectrum measurement campaign. The location site chosen has an impact on the spectrum occupancy measurement. In general, according to Sanders (1998), a site for spectrum measurement demands that:

1. Transmitters around the measurement location are minimal to avoid intermodulation and saturation challenges.
2. Minimal impulsive noise due to vehicular movements and electrical machines which can increase the signals received.

Bearing in mind these conditions, the spectrum occupancy measurement site for this work was chosen to be the Abuja Electricity Distribution Company (AEDC) office located at the centre of Minna town in Niger State, Nigeria. The google map of the site is shown in Fig. 1 while the Geographical Coordinates are shown in Figure 2.


Figure 1: Google Map of Measurement Location


Figure 2: Geographical Coordinates of the Site

## 2.2 MEASUREMENT EQUIPMENT

The setup of equipment used for measurement in this work includes a calibrated Aaronia Spectran HF-6065 V4 spectrum analyzer. The range of the spectrum analyzer is 10MHz to 6GHz and an Omni directional antennae with a range of 10MHz to 3GHz and a laptop connected via USB cable to the spectrum analyzer and an MCS software designed specifically to run on Aaronia Spectrum Analyzer. The equipment was powered with an 850VA inverter. The setup is as shown in Figure 3.

Figure 3: Equipment Setup

The full frequency measurement range of the study is 30-300MHz and was observed for 24 hours before band to band telecommunications spectrum occupancy analysis was carried out. As a result of the analysis, the occupied telecommunication bands were identified and the duty cycle and occupancy was measured. The parameter configuration of the spectrum analyzer is shown in Table 1.

TABLE 1: PARAMETER CONFIGURATIONS OF SPECTRUM ANALYZER

| Parameter | Value |
|---|---|
| Frequency Range of the Analyzer | 10MHz-6GHz |
| Frequency Range of the Antennae | 10MHz-3GHz |
| Frequency Range for the Study | 30-300MHz |
| Resolution Bandwidth (RBW) | 100KHz |
| Video Bandwidth (VBW) | 100KHz |
| Sample Time | 1ms |
| Detection Type | RMS |
| Sample Points | 5401 |
| Attenuation Factor | Auto |

## 2.3 DATA COLLECTION AND PROCESSING

The outdoor measurement was taken for 24 hours in the location. All raw data was collected by the spectrum analyzer in a matrix form as shown in Table 2 with $P_{i,j}$

being the elements of the received signal powers in dBm while the rows and the columns records the time slots and the frequency respectively. A total of Thirty Million Eight Hundred and Fifty Thousand Five Hundred and Twelve (30,850,512) data elements was recorded by the spectrum analyzer and saved file using .csv extension. Processing of the measurement samples was done with the aim of getting necessary parameters in order to measure spectrum occupancy.

TABLE 2: Matrix for the Power Spectrum Measurement

| Time/Frequency | 1 | → | 5,401 |
|---|---|---|---|
| 1 | **$P_{1,1}$** | ⋯⋯→ | **$P_{1,5401}$** |
| ↓ | ⋮ | ↘ | ⋮ |
| 5,712 | **$P_{5712,1}$** | ……….. | **$P_{5712,5401}$** |

The duty cycle is the same as the frequency occupancy rate and describes or quantifies how a particular frequency band is occupied by signal. According to Mehdawi (2013) and Paulson *et al.* (2018), the duty cycle shows how frequent signals are seen on a particular channel during a sample period and is obtained as shown in (1):

$$Duty\,Cycle = \frac{DD_{Tslot}}{N_{Tslot}} * 100\% \quad (1)$$

where $DD_{Tslot}$ is the number of time slots where received signal power is equal to or greater than the decision threshold and,

$N_{Tslot}$ is the entire time slot.

Spectrum power measurements was done by the Spectrum Analyzer at intervals of 50 kHz for the entire range of the 30 MHz to 300 MHz spectra span giving rise to 5401 trace points. Trace points determines the resolution. The higher it is the better the resolution.

In Energy detection, the determination of the decision threshold is very crucial. When the decision threshold is set too high, the entire spectrum is underestimated and many signals are missed. However, when the threshold is set too low, the spectrum is overestimated and even noise is seen as signals.

The noise levels are taken into consideration when the Energy Detection (ED) method is used to compute the proportion of the presence of signal in a particular band of interest. The decision threshold is taken as 10 dBm power above the average noise level. The ED method therefore does a comparison between the signals received in a particular frequency band of interest to a predefined threshold values. In a situation when the signal is lower than the threshold then the band is assumed to be idle and hence is available for use by Cognitive Radio.

## 3 RESULTS AND DISCUSSION

Analysis of the spectrum for some particular bands dedicated for specific services was done as shown in Table 3. The plot of Power Received (dBm) against Frequency (MHz) for the entire range of frequency measurement (30-300MHz) is shown in Figure 4.

TABLE 3: SERVICES ALLOCATED TO SPECIFIC FREQUENCY BANDS

| Services | Frequency Range (MHz) |
|---|---|
| FM Radio | 87.5-108 |
| Aeronautical Navigation | 108.05-137.95 |
| Aeronautical Mobile & Space Operation | 138-144 |
| TV Broadcasting | 174-230 |

Figure 4: Power Spectral Density Plot for 30-300MHz Frequency Range

Decision threshold plays a major role in determining the actual spectral occupancy in the frequency band under investigation. Whereas a high thresholds leads to underestimation of the spectrum a low threshold results in spectrum overestimation. When thresholds are extremely high signals in the occupied bands are missed. Likewise, very low thresholds are affected by noise hence assuming the frequency channel as not available. These scenario are shown in Figure 5. The Average duty cycle of 100% corresponds to a low decision threshold of -75 dBm for FM Radio, -81 dBm for Aeronautical Navigation, -81 dBm for Aeronautical Mobile and Space Operation and -87 dBm for TV Broadcasting. Also the Average duty cycle of 0%

corresponds to a high decision threshold of -57 dBm for FM Radio, -73 dBm for Aeronautical Navigation, -73 dBm for Aeronautical Mobile and Space Operation and -75 dBm for TV Broadcasting.

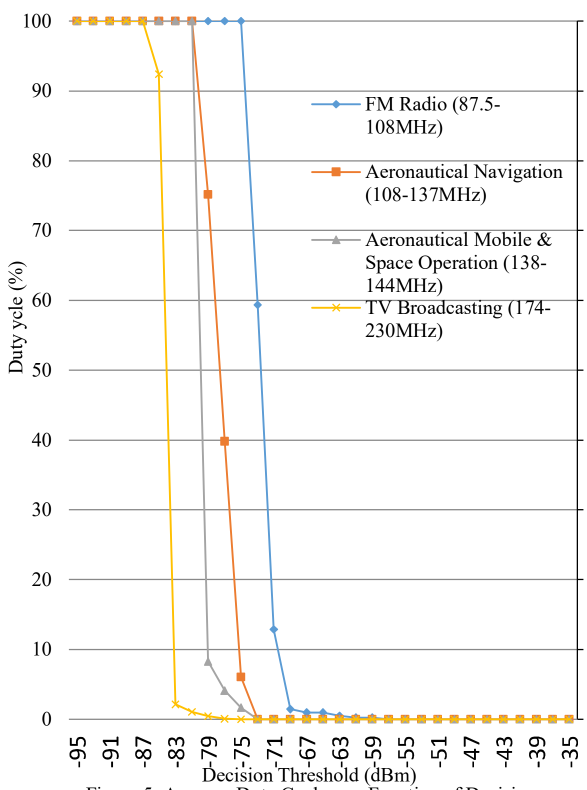


Figure 5: Average Duty Cycle as a Function of Decision Threshold

TABLE 2: AVERAGE DUTY CYCLE FOR SPECIFIED BANDS

| Services | Frequency range (MHz) | Bandwidth (MHz) | No. of trace points in bandwidth | Average Duty Cycle (%) |
|---|---|---|---|---|
| FM Radio | 87.5 – 108 | 20.5 | 411 | 12.90 |
| Aeronautical Navigation | 108.05 – 137 | 28.95 | 580 | 39.83 |
| Aeronautical Mobile & Space Operation | 138 - `144 | 6 | 121 | 4.73 |
| TV Broadcasting | 174 – 230 | 56 | 1121 | 0.09 |

Figure 6 to Figure 9 show the Power Spectral Density (PSD) Plots for FM Radio, Aeronautical Navigation, Aeronautical Mobile and Space Operation and TV Broadcasting which is averaged for the 24 hours measurement period. Figure 6 shows that there are some activities within the FM band with only about two broadcasting stations active and with a threshold of -71 dBm. Figure 7 reveals significant activities with a threshold value of -77 dBm within the band allocated for Aeronautical Navigation while Figure 8 shows minor activities with a threshold of -69 dBm within the band allocated for Aeronautical Mobile and Space Navigation. Figure 9 shows no significant activities within the TV Broadcasting band with a threshold of -61 dBm.

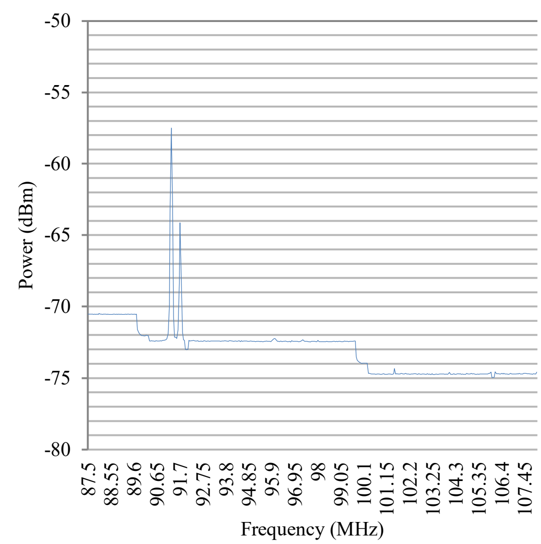


Figure 6: Power Spectral density Plot for FM Band

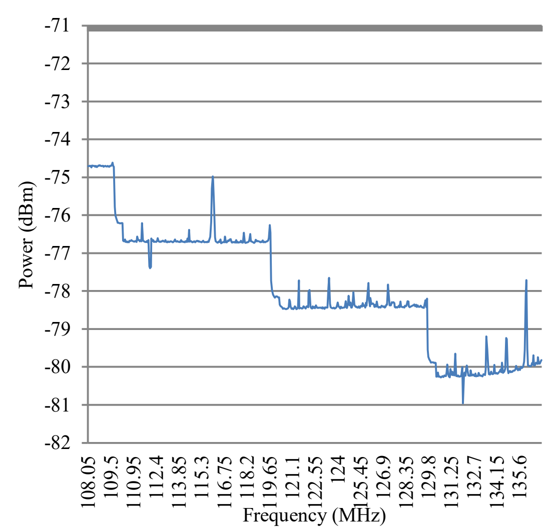


Figure 7: Power Spectral density Plot forAeronautical Navigation

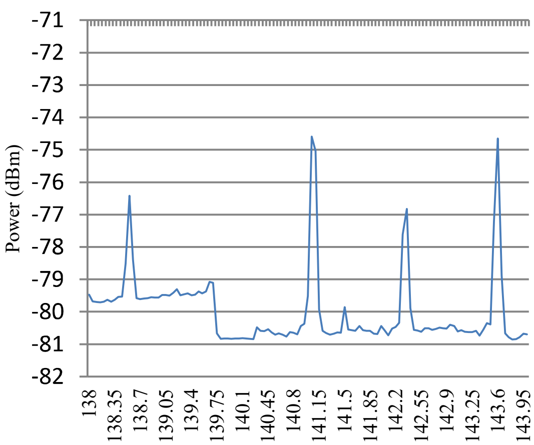

Figure 8: Power Spectral density Plot for Aeronautical Mobile & Space Operation

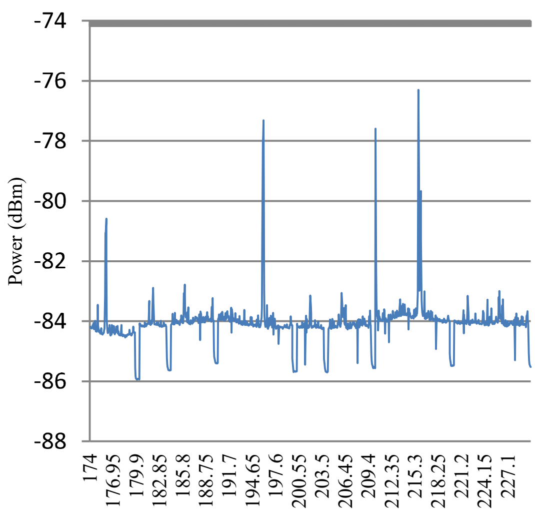

Figure 9: Power Spectral density Plot TV Broadcasting

## 4 CONCLUSION

Although several measurement campaigns have been done in many parts of the world, most of the campaigns focused on a wide band of frequency. This work focused on the narrow part of the VHF in the TV spectrum band. Spectrum Occupancy results show a very low occupancy particularly in the TV broadcasting sub band making the band appropriate for Cognitive Radio deployment.

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