An Insight into Spectrum Occupancy in Nigeria

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Abstract

The rapid evolution in wireless communication which has led to the development of several standards has also brought about a perceived spectrum scarcity. Studies have shown that contrary to popular belief concerning spectrum scarcity, most of the allocated spectrum is heavily underutilized. This has led to several spectrum occupancy measurements mostly in the US, Europe and recently Asia to ascertain the utilization level of the allocated spectrum. These measurements will help in determining which bands will be suitable for the deployment of cognitive radio technology. In this paper, an indoor spectrum occupancy measurement conducted within the region of 700 MHz to 2.5 GHz in Abuja, Nigeria is presented. The results obtained indicate that large portion of the allocated spectrum is underutilized which could be considered for the deployment of cognitive radio paradigm in the near future.

Keywords: *Cognitive radio, spectrum occupancy, wireless communication, Abuja*

1. Introduction

The rapid development of wireless standards and bandwidth hungry technologies has led to a perceived shortage of spectrum. In order to satisfy the growing demand for new spectrum, the spectrum management policy needs to be changed. Currently, the administrative or command and control approach to spectrum management has proven to be ineffective [10]. Several spectrum occupancy measurements carried out all over the world [2-9] mostly in USA and Europe with very few found in Africa have buttressed the fact that the assigned spectrum bands are underutilized. The idea of sharing the spectrum between a primary user (PU, the entity the spectrum was assigned to) and a secondary user (SU, the user that uses the spectrum opportunistically without interference)by using dynamic spectrum access techniques is what mainly cognitive radio is all about[7].The concept of Cognitive radio was first introduced by Mitola [1] in 1999. He described cognitive radio as a smart radio that has a full understanding of its environment and can also adapt its operating parameters to adapt to changes in the environment. The importance of spectrum occupancy measurements cannot be underestimated. The knowledge of the utilization level of the spectrum bands will help researchers to conceive (devise) spectrum models that could be used to predict future utilization. It could also help policy makers in determining which bands have low occupancy: this will go a long way in determining the bands that are suitable for dynamic spectrum access. Spectrum usage is dependent on location, time, measurement conditions, and equipment [2]. While spectrum monitoring tends to provide detailed information on conformity with laid down rules pertaining spectrum usage which a spectrum planner uses to ascertain the level of compliance and also to confirm the effectiveness of current planning system, spectrum measurements on the other hand tend to quantify the performance of the measuring band. It should be noted that the utilization level of a particular band cannot be extended to other bands or other locations [11]. In [3], Kishor Patil *et. al* conducted a spectrum occupancy measurements in the frequency band from 700MHz to 2700MHz in an outdoor scenario in suburban Mumbai, it was found that the spectrum occupancy of the entire band to be roughly 6.62%. In [12], a measurement campaign was performed in Guangdong province in china which also showed a low occupancy. Shared Spectrum Company has performed many measurement campaigns in several American cities which also showed low spectrum occupancy. [4] De Francisco, R et al. and Miguel Lopez-Benitez et. al performed spectrum occupancy measurement in Netherlands and Spain respectively. The results were similar to what was obtained in other campaigns. [5,6]. Other measurements conducted [7-9] also proved that the spectrum utilization level is low.

In this paper, a spectrum occupancy measurement was performed in the region of 700MHz-2.5GHz in a predominantly residential district of Abuja, Nigeria. The measurements were conducted indoors and the bands with low utilization levels were identified. Each band was monitored for 12 hours daily. From 9 am to 9 pm. The statistics obtained can also prove valuable to policy makers in managing this precious resource.

The remainder of the paper is organized as follows; in section II the equipment used in the measurement setup are described. In section III we shall present the results obtained from the measurements and analysis of those results. Section IV concludes this paper and suggests potential future research areas.

2. MATERIALS AND METHOD

2.1 Measurement Setup

The measurement setup used consists of an Aaronia AG HF-6060 V4 spectrum analyzer with a range of 10MHz-6GHz, an Aaronia AG OmniLOG 90200 antenna with a range of 700MHz to 2.5GHz, a laptop system that is connected to the spectrum analyzer via a USB cable, and an MCS software specially designed to run on Aaronia AG spectrum analyzers. The setup is connected as shown in figure 1. MATLAB software package was used to process and analyze the data and the results presented in later sections.

Figure 1: Setup used for measurement

2.2 Location

The measurement was conducted indoors at Gwarinpa District a primarily residential district in Abuja, Nigeria. These measurements were conducted indoors as part of larger measurement campaign which we hope will provide an insight into the utilization level of the spectrum in Nigeria. Abuja is located at with a population of about 770,000 as at 2006. The measurements were taken from 9 am to 9 pm a duration of roughly 12 hours. The spectrum analyzer settings employed in this work are given in the table 1

PARAMETER	VALUE
Span	200MHz/300 MHz
Timing	500 ms
Resolution(samples)	51
Bandwidth Filter	200 KHz
Video Filter	200KHz

Table 1: Spectrum Analyzer Parameters used in conducting the measurement

2.3 Decision Threshold

In spectrum occupancy measurements, determining the decision threshold upon which a particular channel can be deemed as free or busy is very important especially when energy detection is employed. In energy detection, no prior knowledge of the signal is known therefore it's very important to correctly determine the threshold for accurate readings. Setting the threshold metric too high will lead to under estimation of the spectrum while low decision metric will lead to over estimation of the spectrum. The normal convention is to keep the decision metric some certain dB above the equipment's noise floor level. The noise floor for the setup was obtained by replacing antenna with a 50ohm resistor we can similarly measure the noise floor by removing the antenna and not replacing it with anything[]. In this work, a threshold of -76 dBm was used after the two methods were tested.

2.3 Spectrum allocation in Nigeria

Nigeria can be said to be arguably the leading country in Africa as far as spectrum deregulation and licensing are concerned. Since 1992, over 350 broadcasting licenses have been issued by the Nigerian Broadcasting Corporation (NBC) and over 300 licenses issued in the telecommunication sector by the Nigerian Communication Commission (NCC) [16]. Policy formulation and management of spectrum in Nigeria is determined by the several bodies. These include National Frequency Management Council, the Ministry of Information and Communication, Nigerian Communication Commission, and the Nigerian Broadcasting Corporation:

National Frequency Management Council: The National Frequency Management Council (NFMC) is the apex body for radio frequency spectrum management in Nigeria. Established by Section 26 of the Nigerian Communications Act 2003 and located within the Ministry of Information & Communications, NFMC is the primary sponsor and influence on the Government's frequency spectrum policies and legislation. The Council is responsible for the planning, coordination and bulk trans-sectoral allocation of radio spectrum to the regulatory bodies, namely the National Communications Commission, the National Broadcasting Commission and the Ministry, and acts as the focal coordinator of all frequency spectrum activities in Nigeria. The Council also advises the Minister on Nigeria's representation at international and multi-lateral frequency spectrum bodies. NFMC is chaired by the Minister of Information & Communications and consists of high-level representatives of the Ministries of Aviation, Transport, Science & Technology, NCC, NBC and the Security Services, and meets at least four times in a year [17]

Nigerian Communications Commission: NCC is the regulator of the telecommunications industry and has wide discretionary powers to plan, manage, assign and monitor the use of spectrum by commercial users of telecommunications services. The roles of NCC also includes: the encouragement of competition; the removal of market entry barriers; interconnection of new operators with incumbents; the monitoring of tariffs and quality of service; the protection of consumer rights; and the overall promotion of affordable telecommunications services. The Commission develops and publishes radio frequency regulations and standards for the industry.

National Broadcasting Commission: The Commission derives its powers from the NBC Act 38 of 1992 as amended by the National Broadcasting Commission Act 55 of 1999 and is the sole body charged with regulating the broadcast industry, setting broadcast standards and upholding equity and fairness in broadcasting. NBC assigns broadcast frequencies it receives from NFMC to private & public radio & TV stations, monitoring for compliance with administrative procedures, the broadcast code and technical standards. NBC processes applications for the ownership of all types of radio and television stations and has licensed over 350 operational stations in several categories including private, public, satellite, network, campus and community radio & TV stations. The Commission regulates broadcasting through 27 state & zonal offices and regularly publishes updates of the radio frequencies it assigns on its website [16].

Ministry of Information & Communications: The Ministry, through the Department of Spectrum Management, is responsible for the formulation and monitoring of communications policies, international treaties and national representation in international organizations, including the International Telecommunication Union (ITU), International Civil Aviation Organization (ICAO), International Telecommunication Satellite Organization (ITSO), International Maritime Organization (IMO), among others. With the establishment and increased legislative empowerment of both the NCC and NBC, MoIC's function has gradually been limited to the management and assignment of frequencies to Government and non-commercial users including the military, security services, diplomatic missions, voluntary organizations and non-profit groups. The Ministry raises revenue for the Government through the sale of amateur radio communication license application forms, issuance and renewal of licenses, and type-approval testing of radio communication equipment. MoIC is the secretariat of NFMC and acts as the custodian of all frequencies in Nigeria [16].

BAND	FREQUENCY RANGE	USAGE AND PLAN
800 MHz	790 – 806	Trunk Radio Services
900 MHz	890-960 MHz	GSM
1 GHz	1.35-1.525,1.579-1.772 1.805-1.91,1.96-1.99GHz	Rural Telecoms, GSM, Oil coy. Satellite broadcast, radio navigation services.
2 GHz	1.99-2.11,2.2-2.285, 2.305-2.32,2.345-2.36, 2.4- 2.5GHz	3G mobiles ,wireless local loop, satellite up/downlink, scientific, industrial and medical applications

Table 2: Spectrum Allocation Table for some services in Nigeria.

RESULTS AND DISCUSSION

The first band considered was the 700-1000MHz. It comprises the 800MHz band used for trunk radio services, emergency services, CDMA (fixed), 900 MHz for GSM and also the 470-960 MHz for analogue television broadcasting. [13]. In the VHF band there are 12 channels where as the UHF band consists of 49 channels making a total of 61 channels [14]. This band has the highest utilization level experienced at 26% due to the activities of the analogue broadcasting (part of it to be precise) GSM operations and the radio trunk services. CDMA technology employs the use of spread spectrum where by the signal power is very low almost the same with noise power. This makes the signal difficult to detect by the spectrum analyzer. The utilization level could be much more than the obtained value due to this factor.

Figure 2: Power level in dBm versus frequency (700-1000 MHz)

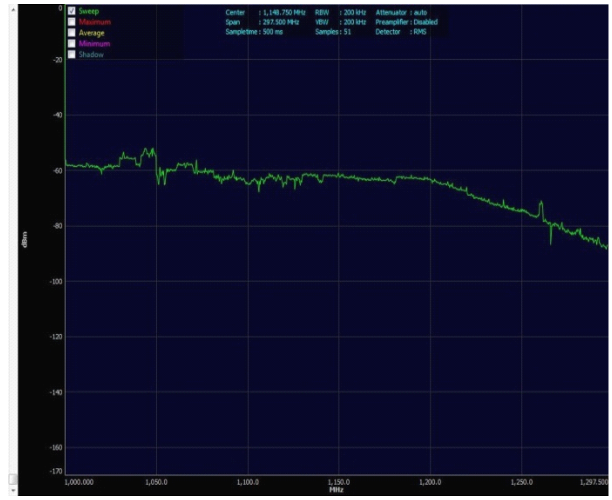

Figure 3: Power level in dBm versus frequency (1.1-1.3GHz)

Figure 4: Power level in dBm versus frequency (1.3-1.5GHz)

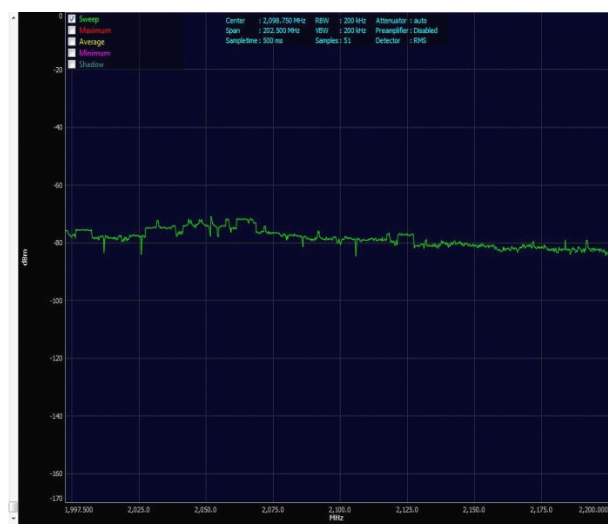

Figure 5: Power level in dBm versus frequency (2-2.2GHz)

IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 1, No 1, January 2013
ISSN (Print): 1694-0784 | ISSN (Online): 1694-0814
www.IJCSI.org

The 1000- 1500 MHz band is mostly used for microwave point to point communication [1350-1550MHz], government agencies and oil companies in the Niger delta region and Lagos [18].The 1000-1300 MHz and 1300-1500 MHz with a utilization level of 2.13 and 1.85 respectively are among the bands with the lowest utilization level. Apart from microwave point to point transmission observed around 1350-1450MHz; there is virtually no activity at all.

Above 1.5 GHz, majority of the utilization can be observed in the 3G mobile standards. With a utilization level of around 25.1% it has one of the highest utilization level amongst the bands considered for this work. In Nigeria, there are currently five mobile companies delivering 3G mobile services in Nigeria: MTN, Globacom, Airtel, Etisalat and Starcomms [15]. Networks employing UMTS use WCDMA technology as stated above, the spread spectrum nature of the signals where by the signals are modulated over a wide bandwidth thus making them having a noise-like character due to the very low transmission power makes them difficult to detect. This makes it difficult for the spectrum analyzer to determine such signals. Similarly, since the measurements' were conducted indoors, the ability of the antenna to receive signals might be hindered.

Above 2.42 GHz, with 17% utilization, the ISM band shows considerable utilization but it could also provide some opportunity for secondary usage. As the measurement was done indoors it was able to detect much of the signals due to the short nature of signals in this band. Some activity on the satellite uplink and downlink bands were also detected at a frequency of 2.305-2.32 MHz and 2.335-2.36 MHz

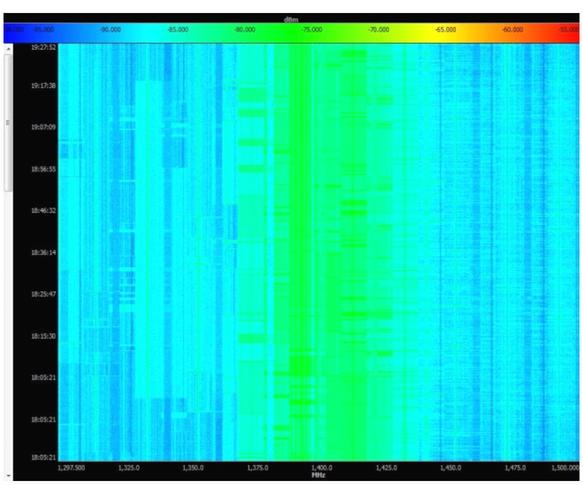
Figure 6: Waterfall of 1.3-1.5 GHz range

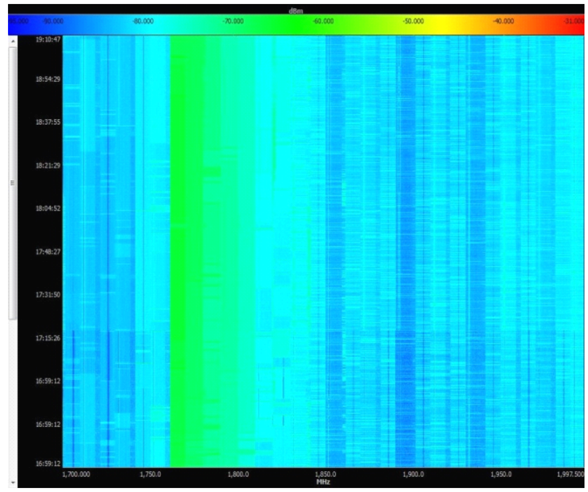
Figure 7: Waterfall of 1.7-1.9 GHz range

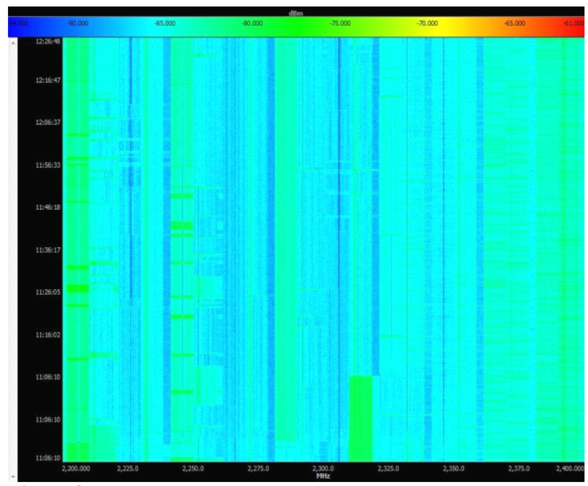
Figure 8: Waterfall of 2.2-2.4 GHz range

BLOCK	FREQUENCY RANGE(MHz)	DUTY CYCLE
1	700-1000	26%
2	1000-1297.5	2.13%
3	1297.5-1500	1.85%
4	1500-1700	12.7%
5	1700-1997	25.56%
6	1997-2200	0.45%
7	2200-2400	17.42%

Table 3: Summary of Spectrum Occupancy

CONCLUSION

In this work, an attempt was made to get the spectrum utilization level in Abuja the capital city of Nigeria. The 700-2500 MHz band was considered. The measurements were conducted indoors as part of wider planned measurements to be conducted. The results indicate abundant potential for CR deployment.. The cellular communication bands can be said to possess the highest utilization level at 26% and 25.56% for the bands containing the 2G and 3G cellular standards, while the 1000-1500 MHz and 2000-2200 MHz bands have the lowest utilization level as the results in table 3 indicate. These results will hopefully aid the academia and policy makers in formulating future policies for spectrum management. In the near future, further measurements would be taken to obtain a realistic picture of the utilization level. Similarly, measurements would be conducted in other locations both indoors and outdoors over a longer period of time to get a more detailed picture of spectrum usage in Nigeria

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