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Conference Paper · November 2017

DOI: 10.1109/NIGERCON.2017.8281890

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Spatial Variability Analysis of Duty Cycle in GSM Band

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Abstract: **The introduction of new kinds of technological products, applications and services that rely on wireless communications has resulted into an upsurge in global mobile data traffic. There is, therefore, a need to investigate the efficient utilization of the limited available radio spectrum. In this paper, we examine the spatial variation of spectrum occupancy (i.e. duty cycle) in the GSM 900 MHz band within Kwara State, Nigeria. Experimental results show that there is a very high spatial variance in duty cycle from one location to the other with mean occupancies of 1.67% and 17.76% in rural and urban locations respectively. It is worthy to mention that some rural locations recorded 0% duty cycle. Therefore, the telecommunication industry in Nigeria should adopt useful techniques to maximize the scarce radio resources, especially for rural areas.**

Keywords: *Duty Cycle; GSM band; Rural; Urban; Spatial*

I. INTRODUCTION

Efficient spectrum utilization is very crucial to addressing the challenges of spectrum usage management. The introduction of new types of technological products, applications, and services that involve wireless communications has exponentially increase the demand for the limited radio spectrum. These products and services include smart phones, tablets, and other applications of Internet of Things (IoT). However, the limited available radio spectrum for wireless communications have been largely reported to be significantly underutilized as there is a high level of wastage in the licensed spectrum band. Thus, it becomes highly necessary to develop useful techniques that will enhance dynamic and efficient spectrum utilization. This will cater for the exponential growth in global mobile data traffic.

In an attempt to find a lasting solution to the observed spectrum scarcity problem, the Cognitive Radio (CR) approach was introduced [1]. CR is a smart radio which has a complete knowledge of its environment. It is also capable of adjusting its working parameters in response to the changes in the environment. The basic underlying idea of CR is to give room for unlicensed users to access some unoccupied licensed bands temporarily or spatially in a favorable, non-interfering and symbiotic manner [2]. In recent time, spectrum occupancy measurement and survey has experienced a rapid growth in Africa, Asia and Europe [3-6]. However most of the researches have not significantly considered the spatial variation of duty cycle in the uplink and downlink frequencies of the GSM bands. Martin B.H. in [7] examined how the spatio-temporal properties of spectrum holes affect the basic communication need of a secondary spectrum user. In order to meet the required communication need of a secondary user, it is necessary to clearly consider the impact of the spatio-temporal properties of spectrum holes on the use decision by future secondary users. Also, Babalola et al. [8-9] studied the temporal variation of duty cycle in the TV band. This was achieved by measuring the spectrum occupancy across the frequency range of 48.5 MHz – 870 MHz in Kwara state, Nigeria. The work indicated that the TV bands are not fully utilized and, in future, it might be a very promising band for the deployment of software defined radio (SDR). Faruk et al. [10] conducted a large scale spectrum survey in the rural and urban locations spanning 50 MHz- 6 GHz. The work gave detailed analysis of the spectrum usage in the locations studied. However, most of the previous spectrum occupancy campaigns were based on measurements obtained in the UHF, VHF, TV and other higher bands. This work therefore, examines the spatial variability of duty cycle in selected rural and urban areas in Ilorin Kwara State, Nigeria. The paper also presents spectrum measurement and analysis in 9 different locations (rural and urban) in Ilorin, Kwara state, Nigeria. This research aimed at investigating the spatial variability analysis of duty cycle in GSM bands considering both the uplink and downlink.

II. METHODOLOGY

A. *MEASUREMENT SETUP*

The measurement setup and settings used are identical for the rural and urban locations. The setup consists of a spectrum analyzer, a data storage device, and a laptop. Agilent N9342C Handheld Spectrum Analyzer (HSA) capable of measuring from 100 KHz to 7 GHz (tuneable to 9 kHz) was used. The device uses energy detection to directly measure received signal level in dBm. It is also capable of displaying the spectrograph of signals. It also has both inbuilt and external GPS (global positioning system) location features. A storage device was used to save the log files generated by spectrum analyzer. The measurement setup at the locations is shown in Fig 1.

Fig. 1. Agilent N9342C Spectrum analyzer

B. MEASUREMENT LOCATIONS

The measurement was outdoors at specific rural and urban locations in Kwara state, Nigeria. Table I shows the measurement sites and type of environment considered, with their respective coordinates. Table II shows the frequency bands considered.

TABLE I: LOCATIONS VISITED

Location	**Type**	**Coordinate**	**Identifier**
Adio village	Rural	4°29'42"E 8°46'40"N	LOC 1
Malete Village	Rural	4°31'16"E;8°38'49"N	LOC 2
Alamote Village	Rural	4°29'42"E 8°22'34"N	LOC 3
Odo Oke Village	Rural	4°31'55"E 8°17'09"N	LOC 4
Lagiki, Village	Rural	4°33'02"E 8°16'46"N	LOC 5
University Quarters, Ilorin	Urban	4°38'47"E 8°27'49"N	LOC 6
University of Ilorin, Ilorin	Urban	4°67'60"E 8.48'74"N	LOC 7
Pipe Line	Urban	4°35'07"E 8°27'57"N	LOC 8
Kwara Stadium	Urban	4°32'29"E 8°28'36" N	LOC 9

TABLE II: SERVICE BANDS CONSIDERED

Service Bands	Frequency range (MHz)	Bandwidth (MHz)
GSM 900 UL	835-915	80
GSM 900 DL	925-960	35

III. DATA COLLECTION AND PROCESSING

The analyzer was used to collect all the raw data in a matrix form with element of the received signal power $P\ (f_i\ ,\ t_j)$ (in dBm). Where f_i represents the frequency and t_j records the time slots. An external hard drive was used to receive the collected data which was later examined and sorted on a computer system. The received data was later processed using the Microsoft Excel. Evaluation of the occupancy statistics involves three steps: raw data input, setting of the threshold, and computing the average duty cycle of each channel. The received power levels at the antenna output that have not been processed are regarded as the raw data inputs. Duty cycle implies how often the signal is observed when sampling a specific band [7]. It is expressed as the percentage of time a frequency band or channel is occupied over a given period as shown in equation (1)

$$\textit{Duty}\ \text{Cycle} = \frac{\text{Signal Occupation period (n)}}{\text{Total Observation period (m)}} \times 100\% \qquad (1)$$

Where *n* is the signal duration and *m* is the period of observed measurement. When given a time series, *t* of channel power measurements the duty cycle can be calculated as:

$$\textit{Duty}\ \text{Cycle} = \frac{n}{m} t \times 100\% \qquad (2)$$

IV. RESULTS AND DISCUSSION

The results of the various occupancy measurements in the GSM 900 MHz DL for both the rural and urban locations in Ilorin Kwara State are shown in Table III. In Table III, a duty cycle of 0.07% was obtained for LOC 1 (rural), a significant increase (6.9%) was observed in LOC 2. LOCs 4 to 5 were completely unoccupied with duty cycle of 0%. The reason for this spatial variation is that LOC 2 being a rural area has experienced technological developments including being the host to a state university in Kwara state, Nigeria. The results show that the GSM 900 MHz band is slightly occupied in LOC1 and most occupied in the LOC 2, while all other rural locations were completely unoccupied.

For urban locations, LOCs 6 and 7 exhibit high occupancy level. But a quite higher occupancy rate of 19.28% and 34.69% were observed in LOCs 8 and 9 respectively. This is because the locations considered 8 and 9 are residential and commercial areas within the metropolis, as such high activities are expected. Average occupancies of 1.67% and 17.76% were recorded in the rural and urban locations and overall of 10.55% in all locations. Fig 2 shows the cumulative distribution function of the received signal strength for six locations, three rural and three urban. LOC 6 is recorded to have the best signal quality based on this metric. This results indicate that higher duty cycle does not directly mean better signal quality, as the duty cycle is a measure of occupancy (i.e. when the received signal exceed the threshold value defined). Therefore, values of –60 dBm and -90 dBm could mean the same occupancy. In other words, methodology in computing the duty cycle metric did not cater for temporal variation of the received Signal Level (RSS)L.

TABLE III: DUTY CYCLE RESULTS FOR GSM 900DL

Location	Location Type	Duty Cycle (%)	Average Duty Cycle Per Location Type	Average Duty Cycle
Loc 1	Rural	0.07	1.67%	10.55%
Loc 2	Rural	6.91		
Loc 3	Rural	1.39		
Loc 4	Rural	0		
Loc 5	Rural	0		
Loc 6	Urban	9.04	17.76%	
Loc 7	Urban	8.04		
Loc 8	Urban	19.28		
Loc 9	Urban	34.69		

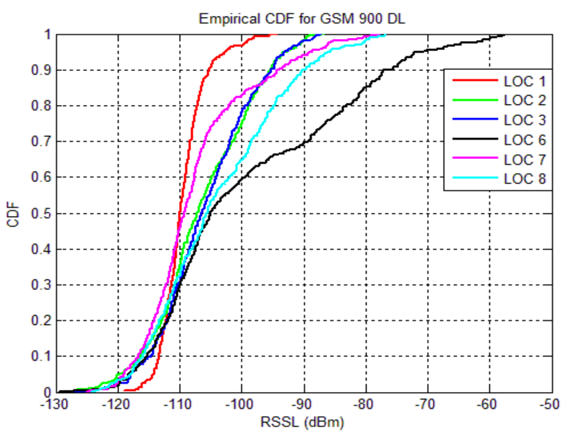

Fig 2: Cumulative Distribution for Received Signal Strength in the GSM 900 DL Band for selected Locations

In Figs. 3 and 4 we provide the spectrograms for the occupancy of LOCs 8 and 9 which are all urban locations to show the spatio-temporal variability of the duty cycle for the two locations.

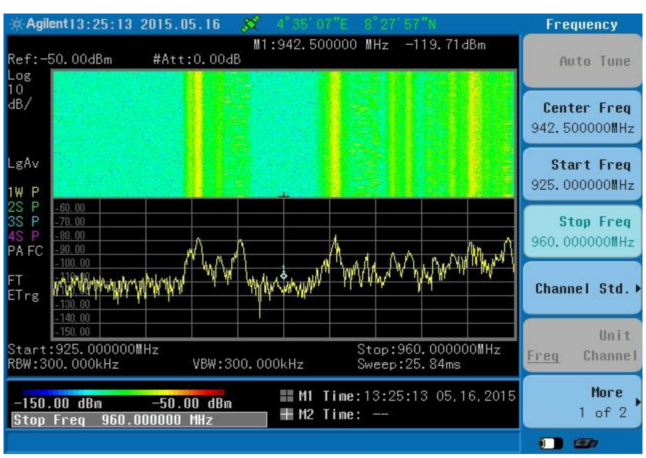

Fig. 3. Spectrogram for Location 8 (Pipeline)

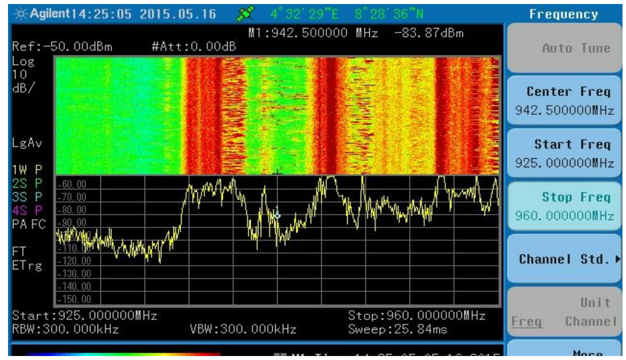

Fig. 4 Spectrogram for LOC 9, Kwara Stadium

VI. CONCLUSION

In this paper, we examine the spatial variation of duty cycle in the GSM band for specific rural and urban locations in Ilorin, Kwara State, Nigeria. The results show that the duty cycle varies from one location to the other with an average occupancies of 1.67% and 17.76% in the rural and urban locations and overall of 10.55% in all locations. Findings also indicate that higher duty cycle does not necessarily mean better signal quality and the methodology used in computing the duty cycle metric did not cater for temporal variation of the received signal strength. Therefore, the telecommunication industry in Nigeria should adopt useful techniques to maximize the scarce radio resources in the licensed bands, especially for rural areas.

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