Assessment of TV White Spaces Availability in Southern Nigeria (A Case Study of Ugbowo, Benin City)

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***Abstract*—**TV white space refers to TV channels that are not used by any licensed services at a particular location and at a particular time. Ultra high frequency (UHF) band spectrum has very good wireless radio propagation characteristics. In this paper, a comprehensive quantitative assessment of TV white space in the 470-870MHz band for urban area of Edo state in south-south region of Nigeria was presented using an inexpensive RF Explorer and the readings were presented using graph plots through the aid of touchstone PC spectrum analyzer software. The result shows that over 58% of the 50 channels assessed in this area were underutilized. Yet, we have high alarming rate of spectrum scarcity by the communication industries. Most of the smart devices competing for these scarce spectra can be deployed to these unutilized spectra at low or no cost thereby freeing most of the spectrum bands.

***Index Terms*—** Spectrum, TV White Space (TVWS), Frequency, South-South Nigeria, Rural area, Internet

I. INTRODUCTION

TELEVISION White Spaces (TVWS) refers to unused portions of spectrum in the television (TV) bands, such as guard bands between broadcasting channels and channels freed up by the transition from analogue to digital TV broadcasting [1].

TV white space technology is a promising one in the current scenario to provide broadband connectivity to rural areas. Internet connectivity is scarce in areas with low population density due to environmental obstacles, distance from major Internet Service Providers, and lack of financial incentives. This results in expensive and complex networks leaving the rural communities with little options. While traditional Wi-Fi weakens over rugged terrain, the TV band can penetrate buildings and terrains with good signal strength. Also they provide larger coverage and greater bandwidths which allow these channels to be used for delivering broadband internet access in areas that aren't easily accessible by cable at much lower costs than optical fiber or conventional wireless networks. These frequencies can be made available for unlicensed use by secondary users at locations where the spectrum is not being occupied by licensed users. This leads to more efficient use of the existing spectrum. However the incumbent user is protected from any interference from the unauthorized ones. The secondary user must vacate the band once the primary user arrives. The systems operating in the TV bands are analogue TV with sensitivity value of -94 dBm, digital TV with sensitivity of -116dBm and wireless microphone with -107 dBm [2]. In this regard, Federal Communications Commission (FCC) in the United States of America (USA) announced a threshold of -114 dBm as the criteria for TVWS [3]. The logic behind this is to utilize the unused spectrum of the incumbent systems for secondary access so that white space devices with low power can utilize this spectrum without causing interference with the incumbent systems. The unused Broadcast TV channels vary sparingly from one location to another. The TVWS will have the flexibility to sense, operate and log on to unused TV White Space channels. This is possible with the use of a database that houses unused channels called geo-location database technology [4]. This paper is aimed at investigating and assessing TV white space availability in Ugbowo area of Benin City to provide internet connectivity in less densely populated area.

This paper is structured as follows: Section II presents TV whitespaces trials in the developing world and the potential benefit of TVWS; Section III presents the equipment employed to perform the measurement, NBC licensed stations in Edo State and the method of data collection deployed. Section IV presents data analysis and results. Section V presents discussion from the work and finally Section VI highlights the main conclusions derived from this study and describes the planned future work.

II. LITERATURE REVIEW

2.1 TV White Space Trials around the World

There has been increasing interest in telecommunications use of "TV white spaces" in the UHF bands that have commonly been used for television broadcasting. In more and more countries, this interest is fueled by the now inexorable move towards digital terrestrial television broadcasting, the consequential and looming end of analogue terrestrial television broadcasting, continuing growth in internet usage and increasing demand for wireless broadband access. USA already has a number of certified database administrators and is the front runner in the deployment of TVWS based networks. United Kingdom (UK) and Singapore are also hastening in the deployment process. United Kingdom (UK) has had a number of pilot deployments pertaining to the use cases of Smart City, Rural Broadband, Wi-Fi Hotspot coverage, machine to machine communications (M2M), sensor networks etc. Singapore has deployed many smart grid solutions based on TVWS and is undertaking many pilot deployments for a number of use case scenarios [5]. In this paper the pilot deployment of Accra, Cambridge UK and Kenya are herein after considered.

2.2 Accra TVWS pilot network

In March 2014, Spectra Link Wireless, under authorization from the Government of Ghana's National Communications Authority (NCA), and in collaboration with the Meltwater Entrepreneurial School of Technology (MEST) deployed a pilot network to offer free wireless broadband access for its community of Entrepreneurs in Training.

The purpose of the pilot with MEST has been to test the efficiency of using TV white spaces for Internet radio networks, in an urban environment that presents multiple sources of interference. The network has been successfully tested on channels adjacent to active television channels, over a 10 km link, with no interference observed [6].

2.3 Cambridge UK Deployment

The Cambridge White Spaces Trial was designed to help Ofcom translate its proposals for license-exempt access to white space spectrum into a secure enabling framework which protects the licensed services as well as enabling innovation. It was also intended to help illustrate the potential for white spaces to service a number of key applications [7].

CRFS used a network of its RFeye® spectrum monitoring nodes, together with its Data Analysis System (DAS) software tools, to survey and analyze the TV white space in and around Cambridge. The survey consisted of three elements: fixed site monitoring, mobile monitoring, and a demonstration of transmitter location. Fixed site monitoring was carried out at five sites in the Cam-bridge area. The monitoring extended over several months from August to November 2011. A large amount of data was collected: spectrum scans were captured every few seconds, at a frequency resolution of 20 kHz. The results from the trial show that spectrum use was reasonably stable over a time scale of months, with some digital switchover-related activity being apparent. The spectrum between the digital multiplexes was substantially clear, with most of the detected narrowband signals accounted for by analogue TV transmissions, which were in the process of being phased out at the time of the trial. A small number of low level narrow band signals were detected that have yet to be identified [6] - [7].

Among the conclusion of the monitoring was that:

1. The UHF white space channels, at the time of monitoring, were mostly clear of harmful interference, although a small number of potential narrowband interferers were detected. Digital and analogue TV signals were detected, including low power signals from distant transmitters.
2. The data produced by the network of fixed and mobile monitoring nodes provided an extremely useful, evolving picture of the "RF terrain", and was seen as an essential complement to the geo-location databases used to control spectrum access for TV White Space Device.
3. The wideband (10 MHz to 18 GHz and above) capabilities of the CRFS monitoring nodes provide an opportunity for exploring and evaluating other potential "white space" bands.

2.4 Kenya TVWS Pilot

Microsoft Corp., in collaboration with the Government of Kenya (Ministry of Information and Communications), Mawingu Networks (previously Indigo Telecom), and Jamii Telecom Limited, and with support from the Communications Authority of Kenya (CAK), are conducting a pilot project delivering low-cost wireless broadband access to previously unserved schools, healthcare clinics, government offices, and some small businesses near Nanyuki, Kenya. Launched in 2013, the network utilizes Adaptrum and 6Harmonics TV white spaces and solar-powered base stations to deliver broadband access and create new opportunities for commerce, education, healthcare and delivery of government services. To maximize coverage and bandwidth, while keeping costs to a minimum, the project is using several complementary spectrum bands available to license-exempt devices, including 13 GHz, 5 GHz, 2.4 GHz, and TV white spaces band spectrum. The Mawingu project has successfully demonstrated the technical viability of this model of delivery, with interference free point to multi-point coverage of up to 14 kilometers from TV white spaces base stations operating at only 2.5 Watts power (EIRP measurement). The TV white space base stations have achieved speeds of up to 16 Mbps on a single 8 MHz TV channel at distances of up to 14 kilometers [8].

2.5 *Malawi TV White Space commercial pilot*

The University of Malawi, in collaboration with the International Centre for Theoretical Physics in Trieste and Malawi Communications Regulatory Authority, has roll out TV white spaces pilot project in the city of Zomba, in southern Malawi. The pilot, which kicked off in September 2013, has connected several institutions, school, hospital, an airport and a research facility [10].

2.6 The potential benefits of TVWS [4]

2.6.1 Rural and Urban Broadband Deployment:

The excellent propagation characteristics of the UHF spectrum band as compared to the unlicensed 2.4 or 5 GHz bands, allow for wireless broadband deployment with greater range of operation (including the ability to penetrate buildings, weather, and foliage) at lower power levels. Hence, the TVWS could be used to provide better broadband connectivity in less densely populated areas. Hundreds of urban centers across the nation are already deploying first generation wireless local area networks to provide broadband access to residents. Use of the TVWS for such municipal broadband networks could increase the quality of service and decrease the deployment costs for these networks.

2.6.2 Education and Enterprise Video Conferencing:

The TVWS could be used to give local high schools and middle-schools the same multimedia capabilities obtainable to major university campuses: mobile, high-speed Internet access for every student and teacher with a laptop or portable wireless device.

2.6.3 Mesh and AdHoc Networks:

The TV white spaces could be used to enhance mesh networking. Self-configuring, ad-hoc mesh wireless networks avoid disruption or failure by re-routing around node failures or congestion areas, thereby enabling more robust and reliable communications. Mesh networks could be used as backhauls to provide Internet connectivity.

2.6.4 Public Safety Communication:

Public agencies can have access to spectrum in the TV band; this would improve the capacity and quality of their networks, as well as facilitate their expanded use for e-government and consumer services. In emergencies, the TVWS can also provide supplementary services to augment public safety communications.

2.6.5 Security Applications:

The good propagation and bandwidth characteristics of the UHF spectrum could enable enhanced video security applications for commercial, residential, and government purposes. Some examples of security applications using the white space devices include perimeter video surveillance, robust wireless secure area monitoring, and childcare monitoring in the home or in childcare facilities.

III. METHODOLOGY

3.1 Study Area

The area under scrutiny for the collection of feasibility-oriented parameters is situated in Ovia North, Edo state and its original name (with diacritics) is Ugbowo. Fig. 1 shows the Google map location of the measurement site and Table 1 shows the coordinate of the measured locations.

Figure 1: Google map of Ugbowo, Benin City. (Courtesy: Google Earth)

Table I: Coordinate of the Measured Locations

Site Name	Latitude	Longitude
Ugbowo (Urban Area)	6.405315	5.624839

3.2 Measuring Instruments/Equipment

1. Spectrum Analyzer (RF explorer 3G combo model)
2. A laptop equipped with touchstone RF spectrum Analyzer software.
3. Mini USB cable.
4. A global positioning system (GPS) receiver set
5. Power inverter.

3.3 NBC Licensed Stations in Edo State

The Table 2 shows the licensed TV station signal, their channels and frequency of operation that can be received within the study area.

Table II: TV Stations parameters in Edo State

S/N	Station	Channel	Frequency
1.	Edo Broadcasting Station	55	743.25MHz
2.	Independent Television	22	479.25MHz
3.	Silverbird Television	30	543.25MHz
4.	NTA Iruekpen	45	663.25MHz
5.	NTA Benin	7	189.25 MHz
6.	NTA Uzairue	41	631.25MHz
7.	Delta TV	23	487.25MHz

3.4 Measurements and Data Collection

The spectral analysis was carried out utilizing an Rf explorer 3G combo model, a handheld real time spectrum analyzer that graphically represents the magnitude of an input signal versus frequency within the full frequency range of the instrument. It is based on a highly integrated

Frequency synthesizer which offers high performance, compact size, low consumption and low cost. It is currently available at $269 online [9]

The RF Explorer was connected to window PC through the USB port for better visibility and other functionalities such as high resolution view, save screen shot image, print data and export to comma-separated values (CSV) for use in 3rd party tools such as excel [9]

Fixed site monitoring was chosen for the analysis; the monitoring extended over several hours for 24 hours; readings were taken using he spectrum analyzer to measure the received signal strength for all the 50 UHF channels (21 through 70) corresponding to 470 – 870 MHz with an Omni-directional antenna, a laptop and a GPS device for over 60 sweeps. The RF explorer antenna height is 2m above the ground, a span of 100MHz was used to enhance the visibility of the spectrum measured and the resolution bandwidth in the experiments was set to 178.57 KHz on the RF Explorer window client.

IV. DATA ANALYSIS AND RESULTS

The results obtained reveal the various TV stations signals that can be received within the study area. Table 1 shows the licensed TV station, their channels and Frequencies of operation. Some of the state mentioned in the table 2 above also share boundaries with Benin, where

Ugbowo is located. Measurement was carried out in Ugbowo area and environs in Edo State, and the results are shown in Fig. 2 and table 3.

Results for spectra coverage carried out for 470-570MHz is shown in Fig. 2.

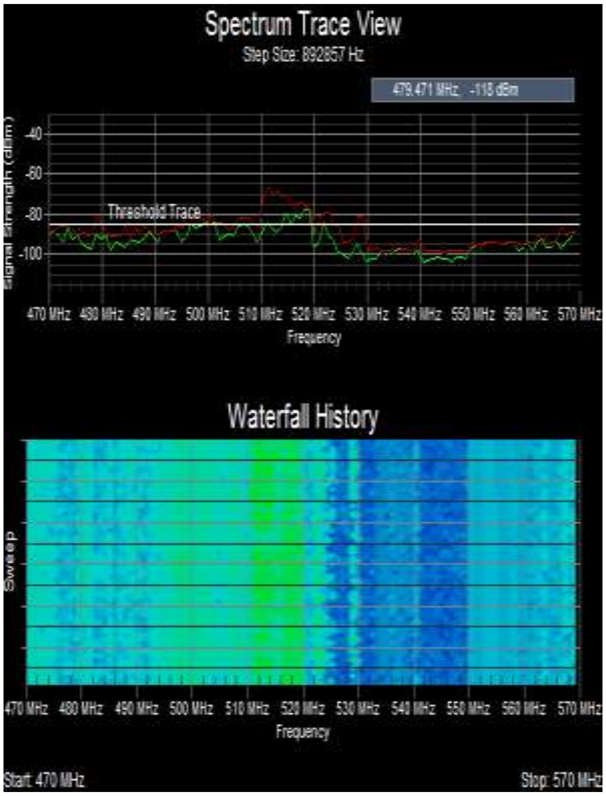

Figure 2: Spectral analysis plot for frequency span (470-570MHz)

TABLE III: Summary of 470-570MHz Spectrum Occupancy in Ugbowo

Frequency span	Channel no	Description	Status
470-478	21	TV Broadcasting Station	Occupied
478-486	22	Unoccupied	Free
486-494	23	TV Broadcasting Station	Occupied
494-502	24	TV broadcasting Station	Occupied
502-510	25	TV broadcasting station	Occupied
510-518	26	TV Broadcasting Station	Occupied
518-526	27	Unoccupied	Free
526-534	28	Unoccupied	Free
534-542	29	Unoccupied	Free
542-550	30	Unoccupied	Free
550-558	31	TV Broadcasting Station	Occupied
558-566	32	Unoccupied	Free

Total number of channels within 470-570MHz is 12; total number of occupied channels = 6;
Total number of unoccupied (whitespace) channels = 6; this shows that in this area 50% are occupied while 50% are free to be used by white space
Results for spectra coverage carried out for 570 to 670MHz is shown in fig. 3.

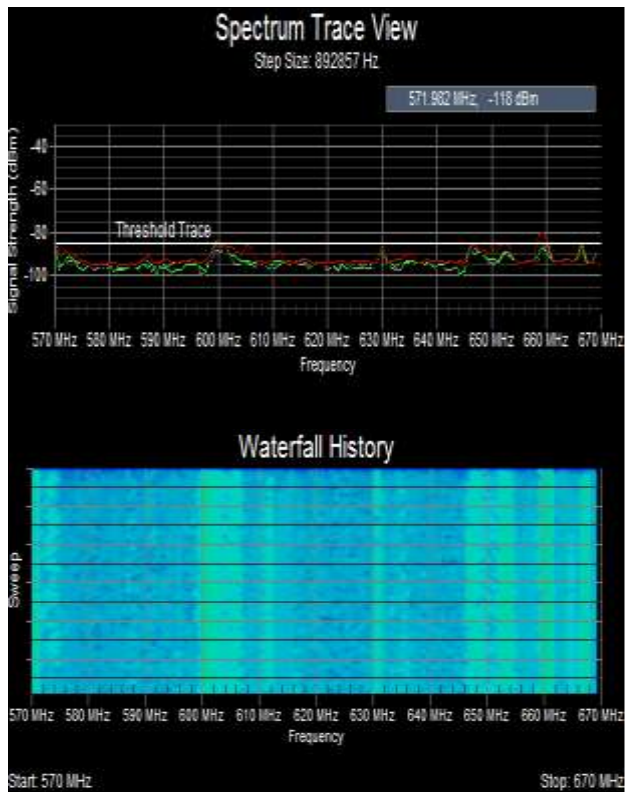

Figure 3: Spectral analysis plot for frequency range (570-670MHz)

TABLE IV: 570-670MHz Spectrum Occupancy Description

Frequency span	Channel no	Description	Usage
566-574	33	TV	Occupied

		Broadcasting Station	
574-582	34	Unoccupied	Free
582-590	35	Unoccupied	Free
590-598	36	Unoccupied	Free
598-606	37	TV Broadcasting Station	Occupied
606-614	38	TV Broadcasting Station	Occupied
614-622	39	Unoccupied	Free
622-630	40	TV Broadcasting Station	Occupied
630-638	41	TV Broadcasting Station	Occupied
638-646	42	Unoccupied	Free
646-654	43	TV Broadcasting Station	Occupied
654-662	44	TV Broadcasting Station	Occupied
662-670	45	TV Broadcasting Station	Occupied

Table 4 shows that the total number of channels investigated in the range was 13; total number of occupied channels = 8; Total number of unoccupied (whitespace) channels=5: This shows that in this area 62% are occupied while 38% are free to be used by white space.

The frequency occupancy for 670 to 770MHz range is as shown in fig. 4.

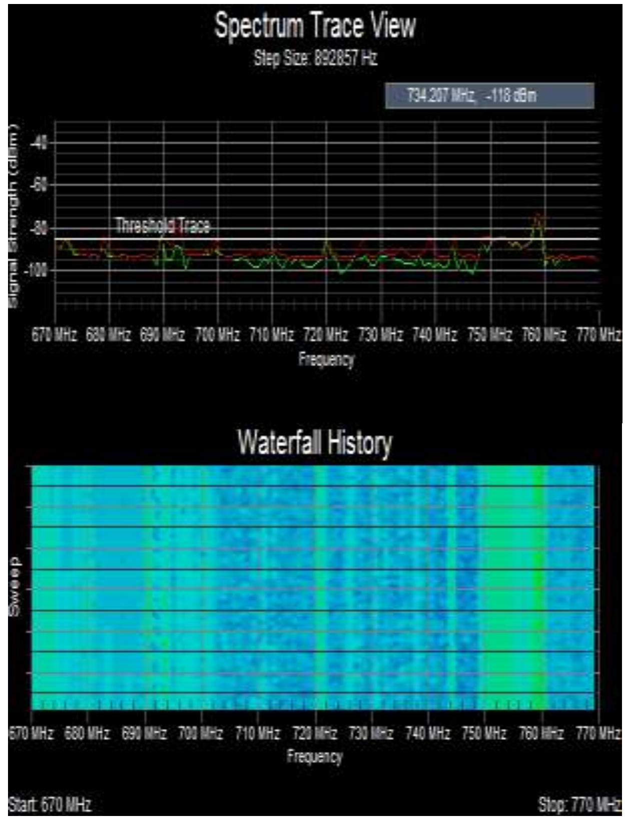

Figure 4: spectral analysis plot for frequency span (670-770MHz)

TABLE V: 670-770MHz Spectrum Occupancy Description

Frequency span	Channel no	Description	Usage
670-678	46	TV Broadcasting Station	Occupied
678-686	47	TV Broadcasting Station	Occupied
686-694	48	TV Broadcasting Station	Occupied
694-702	49	Unoccupied	Free
702-710	50	Unoccupied	Free
710-718	51	Unoccupied	Free
718-726	52	Unoccupied	Free
726-734	53	TV Broadcasting Station	Occupied
734-742	54	Unoccupied	Free
742-750	55	Unoccupied	Free
750-758	56	TV	Occupied

		Broadcasting Station	
758-766	57	TV Broadcasting Station	Occupied

Table 5 shows that the total number of channels investigated in the range was 12; total number of occupied channels = 6; Total number of unoccupied (whitespace) channels = 6; This shows that in this area 50% are occupied while 50% are free to be used by white space.

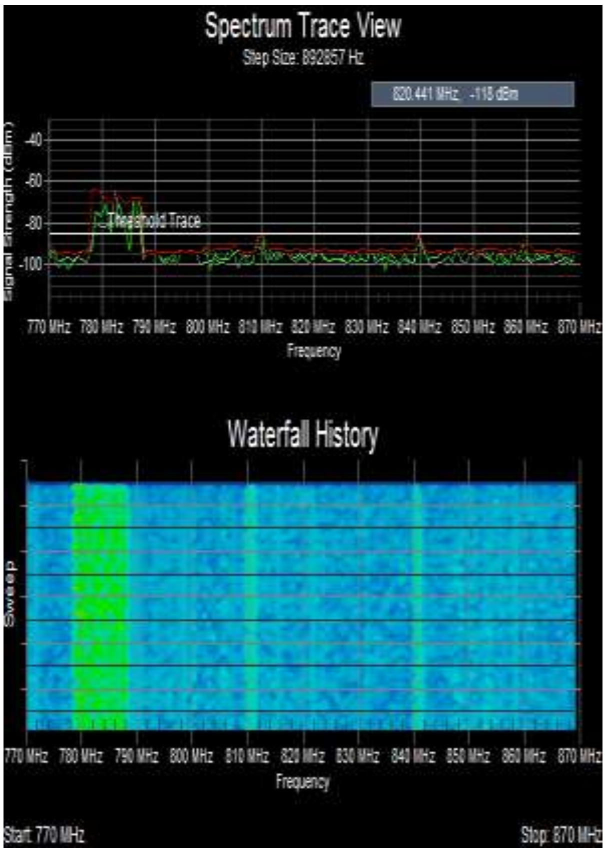

Figure 5: Spectral analysis plot for frequency span (770-870MHz)

TABLE VI: 770-870MHz Spectrum Occupancy Description

Frequency span	Channel no	Description	Usage
766-774	58	Unoccupied	Free
774-782	59	Unoccupied	Free
782-790	60	TV Broadcasting Station	Occupied
790-798	61	Unoccupied	Free
798-806	62	Unoccupied	Free
806-814	63	Unoccupied	Free
814-822	64	Unoccupied	Free
822-830	65	Unoccupied	Free
830-838	66	Unoccupied	Free
838-846	67	Unoccupied	Free
846-854	68	Unoccupied	Free
854-862	69	Unoccupied	Free
862-870	70	Unoccupied	Free

Table 6 shows that the total number of channels investigated in the range of 770-870MHz was 13; total number of occupied channels = 1; Total number of unoccupied (whitespace) channels = 12; This shows that in this area 8% are occupied while 92% are free to be used by white space. Majority of the free spectral space are in this range.

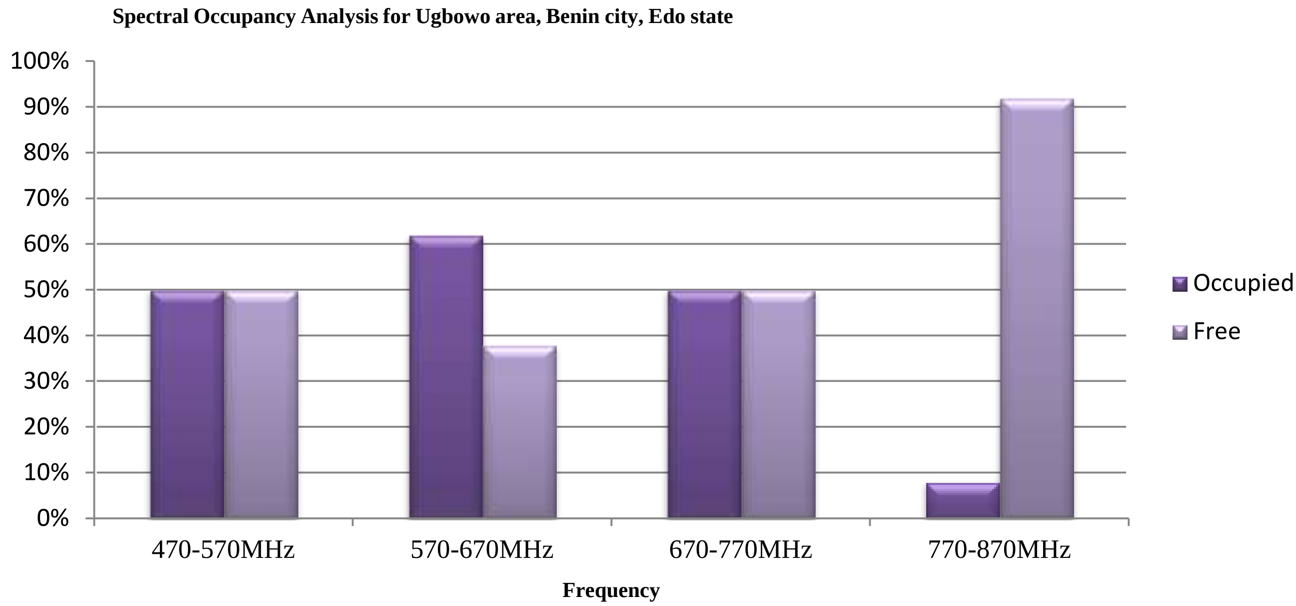

Figure 6: Spectrum occupancy in Ugbowo area, Benin City, Edo State.

V. DISCUSSION

Measurements using RF explorer revealed that the ambient noise level in the absence of any transmission channel occupied by a primary user is -90 to -114dbm. This was confirmed through repeated measurements in a known vacant channel at 24:00hrs when the station normally ends transmission. i.e Edo Broadcasting Service (EBS) that transmit on 743.25MHz . Keeping sufficient cushion for low power transmission -100dBm was chosen as the noise threshold for the measurement. The following is a summary of the analysis of the plots obtained from the readings. The summary is shown in table 7.

TABLE VII: Summary of Observation from Spectral Analysis

Description	Number
Total number of channel analyzed	50
Total number of occupied channel	21
Number of unoccupied (white space) channel	29
Percentage of occupied channel	42%
Percentage of unoccupied (white space) channel	58%
Total free spectrum(whitespaces)	232MHz

The analysis shows that an abundance of free spectrum is available which can be utilized for broadband connectivity at Ugbowo area of Edo State, Nigeria.

VI. CONCLUSION

There is no denying the fact that TVWS is one of the best candidate to curb the spectrum crunch that is been faced by the global communication scene. It not only offers better spectrum management but due to the inherent propagation characteristics of the UHF band is an economically viable solution. Not only developed nations are cashing on the advantages of TVWS technology but

countries with minimal communication infrastructure are going for it because of its ease of deployment, being mainly in the license exempt and serving large coverage areas. This paper was able to analyze the availability of
TVWS in Ugbowo area of Edo State Nigeria, as an alternative way to meet the growing demands of wireless
devices. It is seen from the results that available TV white space is 58% even in the dense area of Benin City center. Considering each TV channel uses 6MHz of bandwidth; the available TV white space of 120 MHz which was determined for the densest case could be reused by cognitive radios.

In the course of our findings, it was discovered, reasonable percentage of the TV band is unused, even without digitization. The digitization of TV transmissions is underway and may free up even more TV spectrum. A study on the design and implementation of a geo-location database for TV white space in south-south region of Nigeria that will help in the protection of terrestrial TV broadcast receivers and the coexistence of secondary devices will be the major topic for our future work.

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