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A Survey on the Availability of TV White Spaces in Eastern Nigeria (FUT Owerri, As Case Study)

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Abstract— Effective utilization of future wireless communication systems such as the TV White spaces depend largely on the availability of free unused spectrum within the 470 – 860MHz UHF band. The paper, analyses the effectiveness of TV White space for last mile delivery of broadband based on spectral availability. The survey was carried out on a spectral range of 470 – 870MHz within the study area, using a RF spectrum analyser and the readings were presented using graph plots through the aid of Touchstone PC spectrum analyser. Fixed measurement was adopted and two (2) sites were chosen to take measurement. The results revealed that, 64% of the 50 channels surveyed were dormant. The degree of occupancy was found to be very low, thus providing for unused spectra spaces within the UHF frequency band which can be used to provide broadband services in sparsely populated rural areas; where data rate could be compromised for range at zero or low cost for acquiring operating spectral license.

Index Terms— broadband , frequency, internet, rural area, spectrum, tv white space, wireless communication,

1 Introduction

Broadband internet access has become an essential element of modern life and a critical enabling agent for the global information age economy. In order to tap into the evolving means of lifestyle and source new means of livelihood in a global village, ubiquitous and affordable access to broadband internet service is critical. In Nigeria, there is an appreciable number of submarine cable landings on the shores of the country providing over 9Tbits/s of combined capacity [1]. However, there are concerns about the fact that all the landings are cited Lagos and as such access to other parts of the country is choked due to the limitations of distribution infrastructure to the rest of the country. Some of the challenges to the roll-out of effective broadband to the coastal and hinterland regions of Nigeria include the geographical topology and economic implications. As a result, most operators usually shy away from providing broadband in rural areas, leading to underserved and unserved regions. Thus there is the need to invest in alternative technologies which could complement coverage range with adequate downlink capacity. Among the promising solutions for extending broadband reach into unserved and/or underserved areas is an emerging networking approach known as TV White Space (TVWS), which uses unlicensed, VHF/UHF TV channels to enable the transmission of internet traffic wirelessly over long distances.

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TV White space refers to low-power, unlicensed operation of communications services in unused portion of RF spectrum that fall within frequencies allocated by regulators to television broadcasters [2]. These White Spaces vary in number of unused channels as a function of location, due to usage by licensed and unlicensed uses such as terrestrial analogue television broadcasting, digital television broadcasting and program making and special events (PMSE) uses. The spectrum range which includes (European range is 470-790MHz) are notable for their propagation qualities. TV White Space spectrum has the ability to broadcast signals over long distances. It permits more expansive reach than conventional Wi-Fi networks, which utilize higher frequencies that limit their range at a fixed power level. A typical outdoor Wi-Fi signal travels about 100metres versus TV White Space signals that may extend to 400metres at the same power level, or up to as far as 10km at higher power. This impressive reach has spawned the nickname "Super Wi-Fi" for TV White Space networks.

In addition to their impressive range, VHF and UHF frequencies are able to convey energy through physical obstacles. This is because radio signals traversing these frequencies has longer wavelength which has an ability to penetrate walls and buildings with lesser attenuation. These propagation characteristics allow TV White Space enabled broadband access networks to connect over long distances without line-of-sight restrictions, and/or to enable very fast internet connectivity over short distances and through physical obstacles.

As a result of these core basic characteristics – superior range and physical penetration coupled with unlicensed access to spectrum – the economics of TV White Space networks become attractive. There is no direct cost required to use or acquire unlicensed White Space spectrum, the cost associated with TV White Space as an internet delivery medium is instead mainly tied to developing technologies such as antenna and radios that make use of TV White Space. This, just like Wi-Fi can lead to rapid technological innovations tied to the

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use of TV White Space which can result to cheaper microchips and even technological cost. As the writer and economist Richard Thanki [3] has commented "TV White Space spectrum has the potential to be the world's first globally available, broadband – capable licensed exempt band in the optimal sub – 1GHz spectrum. In unconnected urban and rural areas, entrepreneurs could use inexpensive, but reliable, Wi-Fi and other types of radio equipment capable of operating on TV band white spaces spectrum to deliver cost-effective broadband services".

2 Literature review

Cognitive radio has been an active field of academic research for a number of years. Television white space (TVWS) promises to be the first widespread commercial application born from this research. In 2002, the Defense Advanced Research Projects Agency (DARPA) embarked on the Next Generation Communications Program (XG) [4]. Developed for the U.S. military, the XG program goal was to equip troops with radios, which could exploit idle spectrum by providing dynamic ad hoc utilization of vacant frequency channels using cognitive radio techniques. XG radios can dynamically and stealthily identify idle channels and communicate on them while being able to immediately vacate the channel to yield to any primary user transmission. The Federal Communications Commission (FCC) took note and took action to draft the TVWS rules. This ability to use unused spectrum on a non-interfering basis, respecting the rights and privileges of the primary spectrum licensee, is a cornerstone of the white spaces revolution. New TVWS products and services are the first civilian and commercial applications of the XG radio model, and TVWS is likely to be the first of a number of white space initiatives [5].

The Federal Communication Commission (FCC) approved the first device in 2011 and the world's first commercial white spaces network came online at North Carolina in the year 2012 [6]. In July 2013, West Virginna University became the first university in the United States to use vacant broadcast TV channels to provide the campus and nearby areas with wireless broadband internet service [7].

Several trials have been carried out to study the effectiveness of TVWS in achieving broadband in U.S.A , Malaysia , Kenya, U.K , South Africa, Malawi e.t.c., in this paper the pilot deployment of Cambridge , U.K., and Malawi will be considered.

2.1 Cambridge U.K., Deployment

The Cambridge White Spaces Trial was designed to help Ofcom translate its proposals for licence-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 [8].

CRFS used a network of its RFeye® spectrum monitoring nodes, together with its Data Analysis System (DAS) software tools, to survey and analyse 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 Cambridge 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 [8].

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 geolocation 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.

2.2 Malawi Trial

In the Malawi trial, TVWS was used to provide internet connectivity from a base station at ZA TVWS Base station to users at Malawi Defence Force Air Wing, St. Mary Girl's Sec School, Pirimiti and Thondwe hospital and GPS (Seismology dept). The deployment was carried out by the University of Malawi in conjunction with the Malawi Communications Regulatory Authority (MACRA) and the International Centre for Theoretical Physics (ICTP). The technical partner was Carlson Wireless. A mobile monitoring of the spectrum was carried out using Spectrum analyser at Pirimiti and Thondwe hospital to confirm the possibility of TVWS pilot deployment at the hospital.

3 Methodology

Signals received at two fixed locations in the study area were taken. This was achieved by taking an overview of the entire area under scrutiny using Google Earth. The location closest the area's center was used as one of the study cites.

3.1 Study Area

The area under scrutiny for the collection of feasibility-oriented parameters lies between Latitude E7° 00′36′′ and Latitude E6° 58′18′′ and sectored in on either side by Longitude N5° 24′30″ and N5° 22′12″ covering an estimated landmass of about 18.86km2. This area encompasses the entire campus of the Federal University of Technology Owerri and its immediate environs.

The estimated coverage area of the analysis network was obtained and calculated from the map of FUTO downloaded

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using Google Earth.

3.2 Spectral Analysis

The spectral analysis was carried out utilising a RF spectrum analyser (WSUBIG). A handheld real time spectrum analyser that graphically represents the magnitude of an input signal versus frequency within the full frequency range of the instrument. Fixed site monitoring was chosen for the analysis; two suitable sites were selected for the measurement. This was to ensure that the plots gotten from the analysis would be uniform and similar to the power level to be experience by the TV White space network equipment. Towards this end the sites centrally located on the study area with a good enough height was chosen to carry out measurement. Readings were taken for a frequency span of 100 MHz for 470 – 860 MHz for over 60 sweeps.

4 Results

The results obtained reveal the various TV stations signal that can be received within the study area. The table 1 shows the licensed TV station, their channels and frequency of operation. States mentioned in the below table all share boundaries with Owerri, where Federal University of Technology is located.

TABLE 1

NBC licensed stations in Imo, Rivers, Abia and Anambra state

STATE	STATION	CHANNEL	FREQUENCY
ABIA	Broadcasting Corporation of Abia state (BCA)	47	679.45MHz
ABIA	NTA Umuahia	21	471.25MHz
ABIA	NTA Umuahia	6	187.25MHz
ANAMBRA	NTA Onitsha	35	583.25MHz
ANAMBRA	Anambra Broadcasting Service (ASBC)	27	519.25MHz
ANAMBRA	MBI	41	631.10MHz
ANAMBRA	Silverbird TV	30	543.25MHz
IMO	NTA Owerri	12	224.25MHz
IMO	Imo Broadcasting Corporation (IBC)	59	775.25MHz
RIVERS	NTA Port-Harcourt	10	210.25MHz
RIVERS	River state Television (RSTV)	22	479.25MHz
RIVERS	Silverbird TV Port-Harcourt	23	487.25MHz
RIVERS	AIT television Port-Harcourt	21	471.25MHz

(Source: ccm.com.ng/pdf/radio_station.docx)

The results from the spectral analysis carried out for 470MHz to 570MHz is as shown in the fig. 1. below.

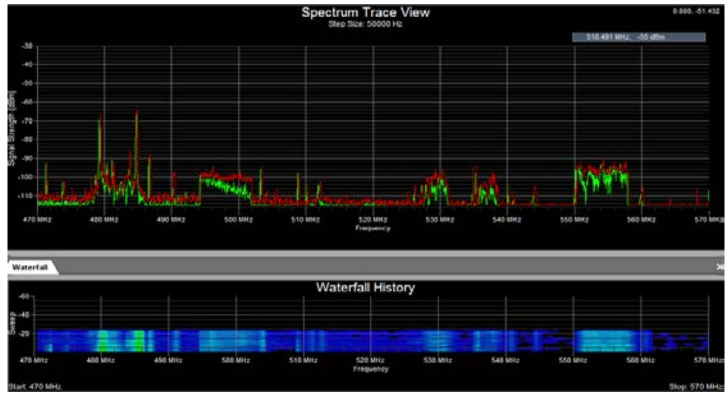

Fig. 1. Spectral analysis plot for frequency span (470 – 570MHz).

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TABLE 2

SUMMARY OF 470 – 570MHZ SPECTRUM OCCUPANCY

Frequency span	Channel no	Description	Usage
470 – 478MHz	21	TV Broadcasting station	AIT Television Port-Harcourt
478 – 486MHz	22	TV Broadcasting station	River state Tele-vision(RSTV)
486 – 494MHz	23	TV Broadcasting station	Silverbird TV
494 – 502MHz	24	Digital Video Broadcasting	Unknown
502 – 510MHz	25	TV Broadcasting station	Unknown
510 – 518MHz	26	Unoccupied	Free
518 – 526MHz	27	Unoccupied	Free
526 – 534MHz	28	4MHz bandwidth occupancy	Unknown
534 – 542MHz	29	4MHz bandwidth occupancy	Unknown
542 – 550MHz	30	Unoccupied	Unknown
550 – 558MHz	31	Digital Video Broadcasting	Unknown
558 – 566MHz	32	Unoccupied	Free

Total number of channels withi 470 – 570MHz range is 12; Total number of occupied channels = 9; Total number of unoccupied (white space) channels = 3; The table 2 above reveals that some of the licensed channels are occupied by their owners, others are occupied by unknown owners and few (25%) are unoccupied or free.

Results for spectral coverage carried out for 570 to 670MHz is shown in fig. 2 below.

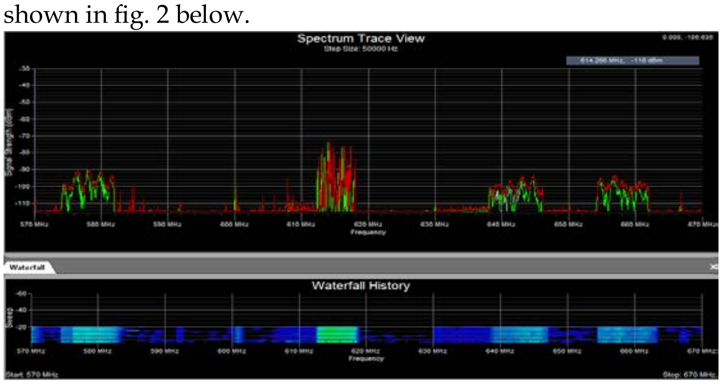

Fig. 2. Spectral analysis plot for frequency range 570 – 670MHz.

TABLE 3

570 – 670MHZ SPECTRUM OCCUPANCY DESCRIPTION

Frequency span	Channel no	Description	Usage
566 – 574MHz	33	Unoccupied	Free
574 – 582MHz	34	Digital Video Broadcasting	Unknown
582 – 590MHz	35	Unoccupied	Free
590 – 598MHz	36	Unoccupied	Free
598 – 606MHz	37	Unoccupied	Free
606 – 614MHz	38	Unoccupied	Free
614 – 622MHz	39	6MHz channel use	Unknown
622 – 630MHz	40	Unoccupied	Free
630 – 638MHz	41	Unoccupied	Free
638 – 646MHz	42	Digital Video Broadcasting	Unknown
646 – 654MHz	43	Unoccupied	Free
654 – 662MHz	44	Digital Video Broadcasting	Unknown
662 – 670MHz	45	Unoccupied	Free

Table 3 shows that the total number of channels investigated in this range was 13; Total number of occupied channel was 4; The frequency occupancy for 670 to 770MHz range is as shown in fig 3 below:

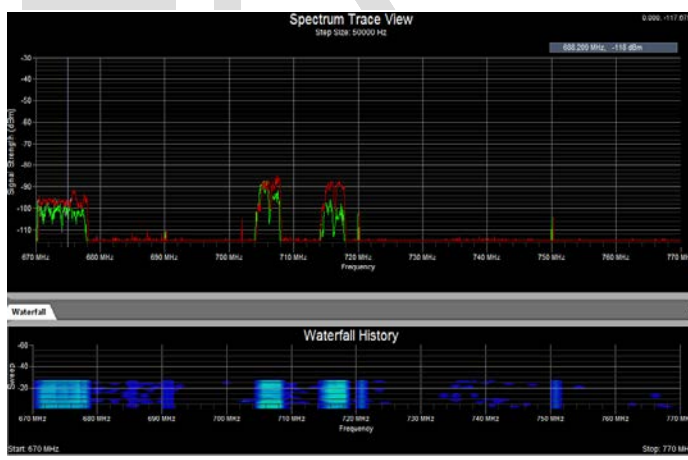

Fig. 3.: 1st Spectral analysis plot for frequency span (670 – 770MHz)

TABLE 4
670 – 770MHZ SPECTRUM OCCUPANCY DESCRIPTION

Frequency span	Channel no	Description	Usage
670 – 678MHz	46	Digital Video Broadcasting	Unknown
678 – 686MHz	47	Unoccupied	Free
686 – 694MHz	48	Unoccupied	Free
694 – 702MHz	49	Unoccupied	Free
702 – 710MHz	50	4MHz channel use	Unknown
710 – 718MHz	51	4MHz channel use	Unknown
718 – 726MHz	52	Unoccupied	Free
726 – 734MHz	53	Unoccupied	Free
734 – 742MHz	54	Unoccupied	Free
742 – 750MHz	55	Unoccupied	Free
750 – 758MHz	56	Unoccupied	Free
758 – 766MHz	57	Unoccupied	Free

Total number of channels = 12; Total number of occupied channel = 3; Total number of unoccupied (white space) channel = 9; In table 4, 25% of the frequency range channels are occupied by unknown stations while 3 in every 4 channels are free.

Fig. 4 below shows the spectral occupancy detected in the 770

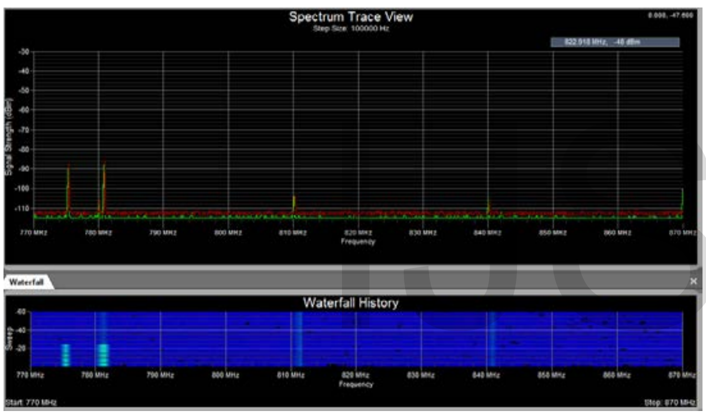

Figure 4: 2nd Spectral analysis plot for frequency span (770 – 870)

TABLE 5
770 – 870MHZ SPECTRUM OCCUPANCY DESCRIPTION

Frequency span	Channel no	Description	Usage
766 – 774MHz	58	Unoccupied	Free
774 – 782MHz	59	TV Broadcasting station	Orient Television Owerri
782 – 790MHz	60	Unoccupied	Free
790 – 798MHz	61	Unoccupied	Free
798 – 806MHz	62	Unoccupied	Free
806 – 814MHz	62	Unoccupied	Free
814 – 822MHz	64	Unoccupied	Free
822 – 830MHz	65	Unoccupied	Free
830 – 838MHz	66	Unoccupied	Free
838 – 846MHz	67	Unoccupied	Free
846 – 854MHz	68	Unoccupied	Free
854 – 862MHz	69	Unoccupied	Free
862 – 870MHz	70	Unoccupied	Free

Total number of channel in table 5 range was 13; Total number of occupied channel = 1;Total number of unoccupied (white space) channel = 12. The 766 to 870MHz frequency span has 92% of the 13 channels as free. Majority of the free spectral space are in this range.

5 DISCUSSION

The readings taken from the two different location, channel activity were detected at a noise level of (-100dBm) with a flat average noise level of (-114dBm). Digital and analogue TV signals were detected, including low power signals from distant transmitters. The following is a summary of the analysis of the plots obtained from the readings. The summary is as shown in table 6.

TABLE 6
SUMMARY OF OBSERVATIONS FROM SPECTRAL ANALYSIS

Description	Number
Total number of channels analysed	50
Number of occupied channel	16
Number of unoccupied (white space) channel	34
Number of Analog terrestrial TV broadcasting stations	4
Number of digital video broadcasting channels	6
Number of unknown signal channel	6
Percentage of occupied channel	32%
Percentage of unoccupied channel	68%

Therefore the total free spectrum (white space)

$$= 34 \times 8 = 272\text{MHz}$$

From the plots it could be noticed that, of the over 34 unused channel, about 15 channels are adjacent to already used channels and hence according to Federal Communications Commission (FCC) specification, these channels can only be utilised by TV White Space equipment, broadcasting at a lower power (16dBm) (4dBm lower than on non-adjacent channels) [9]. The analysis shows an abundance of free spectrum predominantly in the 570 to 870MHz range which can be utilized for rural broadband connectivity.

6 CONCLUSION

The spectral analysis measurements shows that the spectral usage of the UHF frequency band within the study region is relatively fair (32%). The availability of spectrum for broadband delivery, within the 570 to 870MHz range is large with 60 – 90% of channels free of occupancy. The spectrum between the digital multiplexes were relatively clear, with most of the narrowband signals accounted for by analogue TV transmissions, which are in the process of being phased out. This will in turn open more bandwidth within the UHF band. The UHF spectrum is particularly attractive because it is located between 200MHz and 1GHz offering an optimal balance between transmission capacity and distance coverage. Since spectrum availability varies with location, it is bound to be more abundance in the rural areas.

The provision of wireless broadband internet to unconnected or poorly connected rural areas is foreseen to be one of the key applications that will use TV White spaces. The high cost of installing optical fibre and BTS in remote locations, makes it imperative to find a cost effective wireless solutions as TV White space technology to ensure higher internet penetration especially to remote locations in Nigeria such as the arid northern, mountainous, riverine and densely vegetated areas.

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