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Exploration of TV White Spaces Using an RTL-SDR Spectrum Sensing Cognitive Radio Simulink Technique

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Abstract

The aim of this work is to use a spectrum sensing cognitive radio developed in Simulink to explore the TV band spectrum between the frequency range of 470 MHz to 870 MHz in order to establish its capability for usage for unlicensed communications. The methodology chosen for this work was to explore, view and analyse TV spectrum between the 470 MHz to 870 MHz in the Urban region of Benin City using a Software defined radio interfaced with a real time model of a spectrum explorer in MATLAB-Simulink. This is to ascertain the spectrum activities of the primary users of the Spectrum. An Energy detector modelled in Simulink interfaced with a software defined radio was used to perform real time spectrum sensing, signal prediction and spectrum management decision. The energy detector in MATLAB-Simulink interfaced with the software defined radio forms the Spectrum sensing cognitive radio. It was implemented and it performed spectrum sensing in the 470 MHz to 870 MHz TV spectrum in real time. It was observed that the frequencies between 770 MHz to 800 MHz and 800 MHz to 831 MHz were 90% and 70% unoccupied by the Primary users respectively. Hence, these frequencies can be used alternatively for unlicenced communications as the secondary users during the deployment of the spectrum sensing cognitive radio in other to avoid interference with the primary users. The other frequencies aside the two ranges mentioned between the 470 MHz to 870 MHz had 70% to 100% occupancy by the primary users.

1.0. Introduction

The bodies that govern communications in a particular region assign various bandwidths to different communication infrastructure that utilize the spectrum as primary users. The Nigerian Communications Commission (NCC) is responsible for radio spectrum regulation in Nigeria. The RF spectrum spans between 3kHz to 300GHz. Communication infrastructures such as the TV band, the GSM band, the ISM band and the satellite communication band etc. have been assigned a fixed bandwidth for their usage. However, most of these services do not utilize the spectrum assigned to them all the time, so this has led to the phenomenon of spectrum holes or spaces at certain period whereas new applications are contending for available free spectrum for usage. The one-time allocation of the radio spectrum that has provided exclusive right of using the spectrum to only the licensed users is now a major cause of both spectrum underutilization and spectrum artificial scarcity [1-6].

When a cognitive radio is deployed for spectrum sensing, a particular frequency band that is not occupied by its primary user at a particular location and at a particular time can be spotted out to be used as a communication channel for another services pending when that frequency band is again reoccupied by its primary user. The temporary user is termed the secondary user.

One portion of the RF frequency band that has the potential of accommodating the operations of cognitive radios acting as primary users is the Television white spaces. TV white spaces refer to portions of spectrum in the television bands that are not used by any licensed services at a specific location and at a specific time. TV white space technology is a promising one, when it comes to using such vacant spaces for alternative communications such as deploying it for emergency communication to provide broadband connectivity to areas where the traditional GSM communications and internet service is being hampered by network congestion or interoperability barriers.

TV frequency band can penetrate terrains and buildings with good signal strength. The Ultra high frequency band (UHF) band spectrum has very good characteristics of wireless radio propagation. These frequencies can be employed for unlicensed use by secondary users at a particular location and at a particular time where the spectrum is not being occupied by licensed users [8]. By this, the existing spectrum is put into more efficient use. Nevertheless, the original user must be protected from any interference from unauthorized users. The secondary user must exit the band immediately after the primary user arrives. The systems that operate in the TV bands are digital TV with sensitivity of -116dBm, analogue TV with sensitivity value of -94dBm and wireless microphone with -107dBm [4]. As regards to this, the Federal Communications Commission (FCC) in the United States of America (USA) made known an information that a threshold of -114dBm as the criteria of TV white spaces [5]. The idea behind this is to make use of the underutilized spectrum of the original occupants for secondary access so that white space devices, in this case, cognitive radio with low power can utilize this spectrum without creating interference with the original occupying systems. The underutilized Broadcast TV channels vary sparingly in a way from one location to another. Cognitive radio will have the ability to sense the spectrum, and then perform operations if the TV white space channels are unoccupied by the secondary users. A quantitative assessment of TV white space for Urban area of Edo State in south-south region of Nigeria in the 470 -870 MHz band shows that over 50% of the 50 channels assessed in this area were underutilized [8]. In the event of public safety emergencies, the TV whitespace will be able to provide supplementary services to augment public safety communications.

The Nigerian Communications Commission (NCC) has activated the Emergency Communication Centres (ECCs) across the country in other to improve security of life and property. At the time when the country is faced with security issues and many more life-threatening incidents, including the coronavirus disease (COVID-19), the ECCs established by NCC across the states and the Federal Capital Territory (FCT) have been central to saving lives. A total of 19 ECCs have already been established in 18 states and the FCT. And the NCC has made known that the centres play a vital role during emergencies, as they facilitate response from emergency response agencies such as the police, the Federal Road Safety Commission (FRSC), the Nigerian Security and Civil Defense Corps (NSCDC), Fire and Ambulance Services, National Emergency Management Agency (NEMA) and other related bodies by dialing 112 from any network (Adepetun, 2021). The Emergency Communications Centre (ECC) Project is intended to bridge the communication gap between the distressed and emergency agencies in the country. The Nigerian Communications Commission has undertaken the task of facilitating the building and equipping of Emergency Comm [2] Centres in all 36 states of the federation and the Federal Capital Territory, Abuja. All telecom operators will be mandated to route emergency calls through the dedicated three-digit toll free number, 112, from each state to the emergency centre within that state. The operators who are resident in the ECC will then process the distress call and contact the relevant Emergency Response Agency (e.g. Fire Service, Police, FRSC, Ambulance, etc.) whose primary duty is to handle the case. Numerous centres have been built and provided with equipment across the nation in all six geopolitical zones [9].

Cognitive radio can also be employed in these ECCs' so as to act as alternative mode of communication to provide broadband connectivity using TV white spaces to areas where the traditional GSM communications and internet service is being hampered by network congestion or interoperability barriers.

A use case of using TVWS for emergency communications can be seen when Microsoft announced a commercial pilot which is in collaboration with Spectra Link Wireless, this would provide low cost and wireless connectivity that is affordable to students and faculties at universities in Koforidua, Ghana and an initiative that is linked joint with Facebook [7] (Microsoft 2014). Spectra Link Wireless will be deploying high speed wireless networks that will cover all Nations University, the college, and Koforidua Polytechnic. [10] The network will utilize TV white spaces (TVWS) frequency enabled radios and some other wireless technologies to connect campus buildings, this will ensure they have access to fast broadband internet access. With this, no less than ten schools have been connected to broadband internet service at internet browsing speeds of 4 Mps using dormant UHF spectrum between 480 MHz and 690 MHz meant for TV broadcast services [8]. These schools are captured among the first pilot trial in South Africa to study the impacts of connecting regions that are underserviced to the internet using TVWS, which are the vacant frequencies meant for television broadcasting. It was in like manner announced that a second trial will be used to demonstrate the utilization of TVWS to connect rural regions in Limpopo, South Africa.[10]

In this project we intend to utilize a spectrum sensing cognitive radio to perform spectrum sensing of the TV spectrum in the 470 to 870 MHz band for the Urban area of Benin city, Edo state. Edo state has about seven TV stations that utilize the frequency band from 487.25 MHz to 743.25 MHz.

1.1. TV White Spaces availability in Southern Nigeria (Case Study, Benin City)

[8] carried out a spectral analysis of the TV band in Benin City, Edo State, Nigeria. The analysis was done using an RF explorer 3G combo model, and a handheld real time spectrum analyzer that is based on an integrated frequency synthesizer. The spectrum graphically represents the magnitude of an input signal versus frequency within the full frequency range of the instrument. The monitoring style chosen for this analysis is fixed site monitoring. The monitoring was done over several hours for 24 hours. The that was taken with the aid of the spectrum analyzer was used to measure the signal strength received for all the 50 UHF channels which corresponds to the 470 MHz to 870 MHz band.

The licensed TV stations, their channels and Frequencies of operation that can be received in Benin City as obtained from the results are shown in Table 2.

Table 2: TV Stations parameters in Edo State

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

Table 3: Summary of 470 MHz – 870 MHz Spectrum Occupancy in Benin City

Frequency Span (MHz)	Channel Number	Signal Description	Usage Status
470 -478	21	TV Broadcast Station	Occupied
478 – 486	22	Unoccupied	Free
486 – 494	23	TV Broadcast Station	Occupied
494 – 502	24	TV Broadcast Station	Occupied
502 – 510	25	TV Broadcast Station	Occupied
510 -518	26	TV Broadcast 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 Broadcast Station	Occupied
558 – 566	32	Unoccupied	Free
566 – 574	33	TV Broadcast Station	Occupied
574 -582	34	Unoccupied	Free
582 – 590	35	Unoccupied	Free
590 – 598	36	Unoccupied	Free
598 – 606	37	TV Broadcast Station	Occupied
606 – 614	38	TV Broadcast Station	Occupied
614 – 622	39	Unoccupied	Free
622 – 630	40	TV Broadcast Station	Occupied
630 – 638	41	TV Broadcast Station	Occupied
638 – 646	42	Unoccupied	Free
646 – 654	43	TV Broadcast Station	Occupied
654- 662	44	TV Broadcast Station	Occupied
662 – 670	45	TV Broadcast Station	Occupied
670 -678	46	TV Broadcast Station	Occupied
678 – 686	47	TV Broadcast Station	Occupied
686 – 694	48	TV Broadcast 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 Broadcast Station	Occupied
734 – 742	54	Unoccupied	Free
742 – 750	55	Unoccupied	Free
750 – 758	56	TV Broadcast Station	Occupied
758 – 766	57	TV Broadcast Station	Occupied
766 – 774	58	Unoccupied	Free
774 – 782	59	Unoccupied	Free
782 – 790	60	TV Broadcast 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

Figure 1 shows the pictorial chart of the spectrum occupancy results obtained and Table 2 provides the summary of observation from the Spectral Analysis.

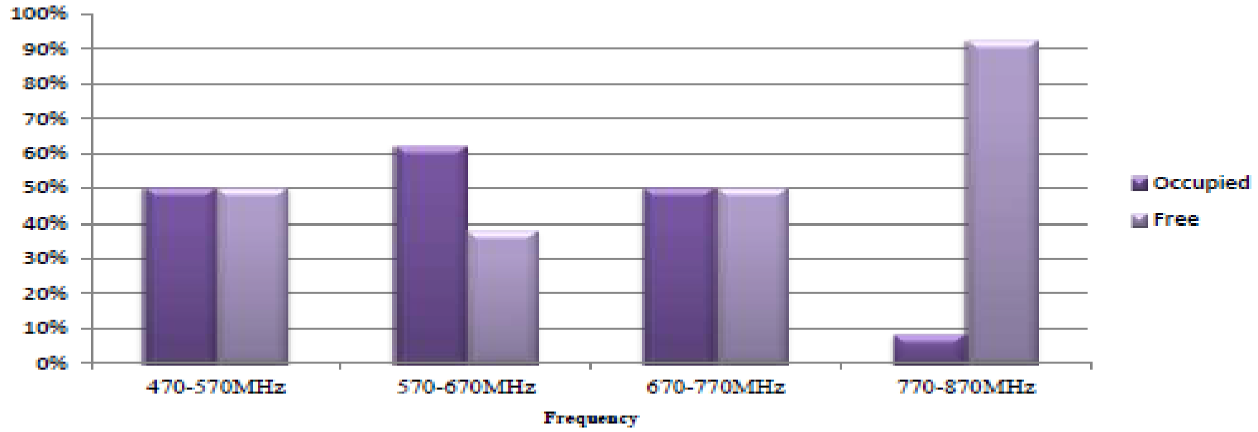

Figure 1: Spectrum occupancy from Ugbowo area, Benin City, Edo State

An RF explorer was used for the measurements and its results showed that the ambient noise level of any transmission channel when the primary user is absent is 90 to -144dbm. However, putting into consideration low power transmission, -100dBm was chosen as the noise threshold for the measurement.

Results from the above analysis from Table 2.3 show that there is much of free spectrum in this area, which can be used for broadband connectivity. It is seen from the results that the available TV white space is 58% even though the measurement was taken from dense area of Benin City. Since each TV channel uses 6 MHz of bandwidth; the TV white space of 232 MHz which is available can be utilized by cognitive radios.

1.2. RTL-SDR interfaced with Simulink as a Low-cost spectrum analyzer

Low-cost spectrum analyzers, particularly those utilizing Software-Defined Radio (SDR) technology, have transformed the field of radio frequency (RF) engineering by providing affordable and flexible tools for signal measurement and analysis. low-cost solutions like the RTL-SDR (a USB dongle based on the RTL2832U chipset) have emerged as viable alternatives, allowing a wider audience, including hobbyists, educators, and researchers, to engage in RF analysis without the prohibitive financial barriers [12]. SDR based spectrum analyzers offer several advantages such as Affordability, Flexibility such that they can be easily reconfigured through software to accommodate various frequencies and modulation type, Wide frequency sensing range, and Real Time Processing such that users can visualize and interpret RF signals immediately. However, the SDR based spectrum analyzer has the following limitations- Accuracy; that is the instrument may not achieve the same level of accuracy as traditional, high-end instruments, and Dynamic range and sensitivity; because high end spectrum analyzers generally provide superior dynamic range and sensitivity, enabling them to detect weaker signals amidst noise and interference. Low-cost options may struggle in such environments, which can affect measurement reliability [12].

2.0. Methodology

The RTL-SDR used in this work is an RTL-SDR interfaced with Simulink.

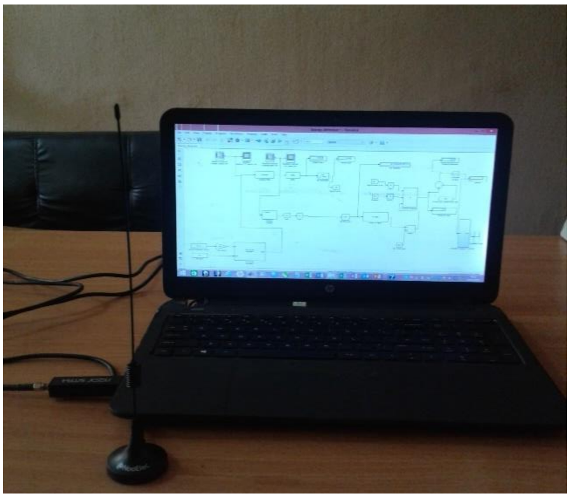

Figure 2: Spectrum Sensing Cognitive Radio Setup

2.1. Spectrum Sensing Results of the 470 MHz To 870 MHz Using The RTL-SDR Spectrum Sensing Cognitive Radio Simulink Technique

The RTL-SDR was tuned to the TV spectrum band to sense primary users signals between the frequency range of 470 MHz to 870 MHz. A sampling rate of 3 MHz was used for the spectrum analyser in Simulink.
Measurements using the Spectrum sensing cognitive radio in the TV spectrum showed that the ambient noise level in the absence of any transmission channel occupied by a primary user is -90 to -114dbm [8]. Putting sufficient cushion in place for low power transmission, -100dBm was chosen as the noise threshold for comparing against the threshold value for a primary user signal that is present.

The results are presented in Table 5 and Figure 3.

Table 5: Spectrum sensing between 470 MHz to 500 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
471.5	25.17	79.21	0
474.5	36.92	122.4	1
477.5	36.98	122.8	1

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
480.5	39.55	135.5	1
483.5	38.08	123.5	1
486.5	30.83	112	1
489.5	25.96	85.74	0
492.5	28.89	94.64	0
495.5	41.23	136.5	1
498.5	38.39	128.9	1

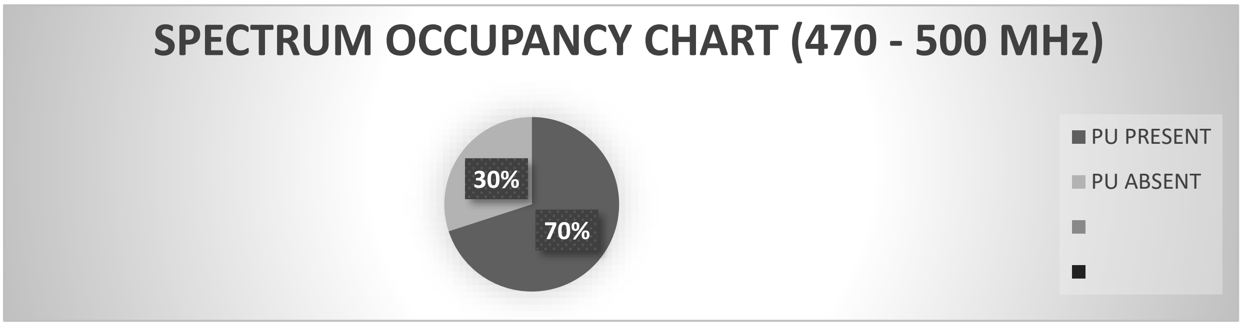

Figure 3: Spectrum Occupancy Chart (470 – 500 MHz)

Table 6: Spectrum sensing between 500 MHz to 530 MHz.

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
501.5	41.89	137.6	1
504.5	32.93	114	1
507.5	30.58	106.6	1
510.5	42.56	138.1	1
513.5	41.79	136.9	1
516.5	42.88	137.9	1
519.5	42.32	137.6	1
522.5	42.53	138.8	1
525.5	41.99	136.7	1
528.5	42.49	138.4	1

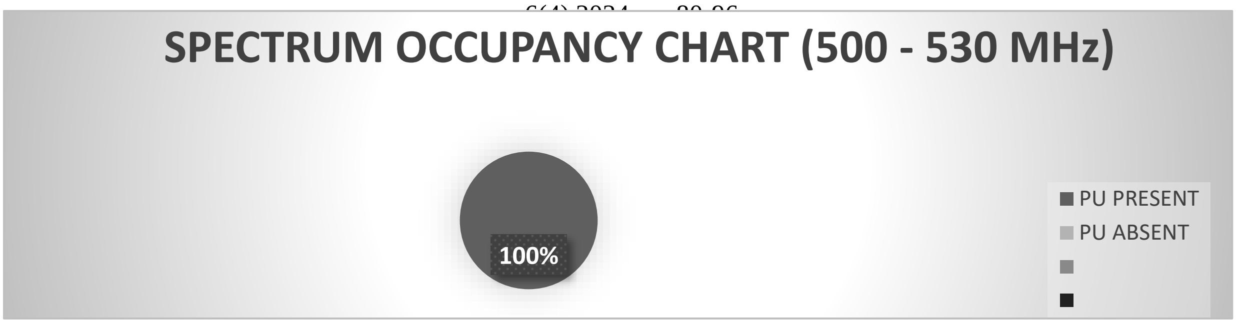

Figure 4: Spectrum Occupancy Chart (500 – 530 MHz)

Table 7: Spectrum sensing between 530 MHz to 560 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
531.5	41.41	136.4	1
534.5	41.3	136.3	1
537.3	42.55	138.7	1
540.5	42.4	138.6	1
543.5	42.87	139	1
546.5	43	140	1
549.5	42.87	139.6	1
552.5	42.84	139.5	1
555.5	42.94	139.8	1
558.5	43.15	140.9	1

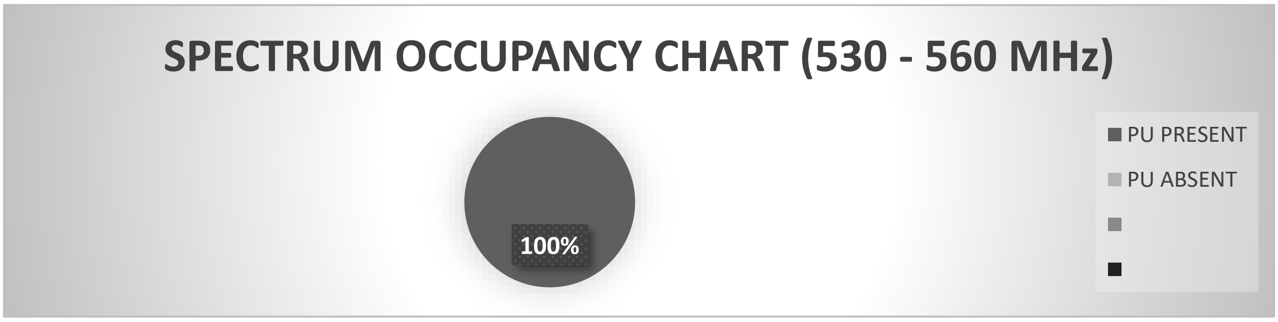

Figure 5: Spectrum Occupancy Chart (530 – 560 MHz)

Table 8: Spectrum Sensing between 560 MHz to 590 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_0/H_1)
561.5	42.98	139.9	1
564.5	42.7	139.4	1
567.5	43.04	140.1	1
571.5	30.38	106.9	1
573.5	35.56	116.6	1
576.5	43.05	139.8	1
579.5	37.22	121.6	1
582.5	43.06	140.9	1
585.5	43.21	140.6	1
588.5	20.07	61.29	0

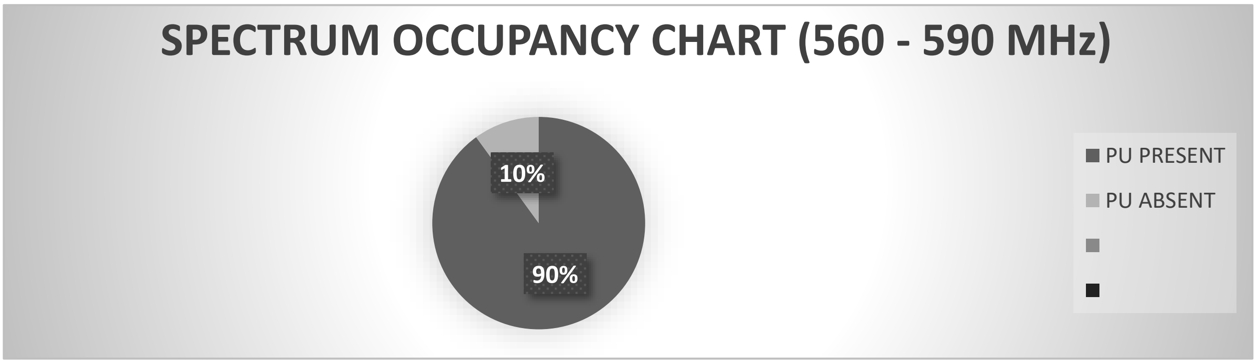

Figure 6: Spectrum Occupancy Chart (560 – 590 MHz)

Table 9: Spectrum Sensing between 590 MHz to 620 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
591.5	18.26	64.41	0
594.5	39.46	130.7	1
597.5	42.39	139.6	1
601.5	42.43	139.7	1
603.5	32.8	103.1	1
606.5	41.91	138	1
609.5	42.33	138.2	1
612.5	42.06	138.1	1
615.5	41.5	136.9	1
618.5	41.85	137.1	1

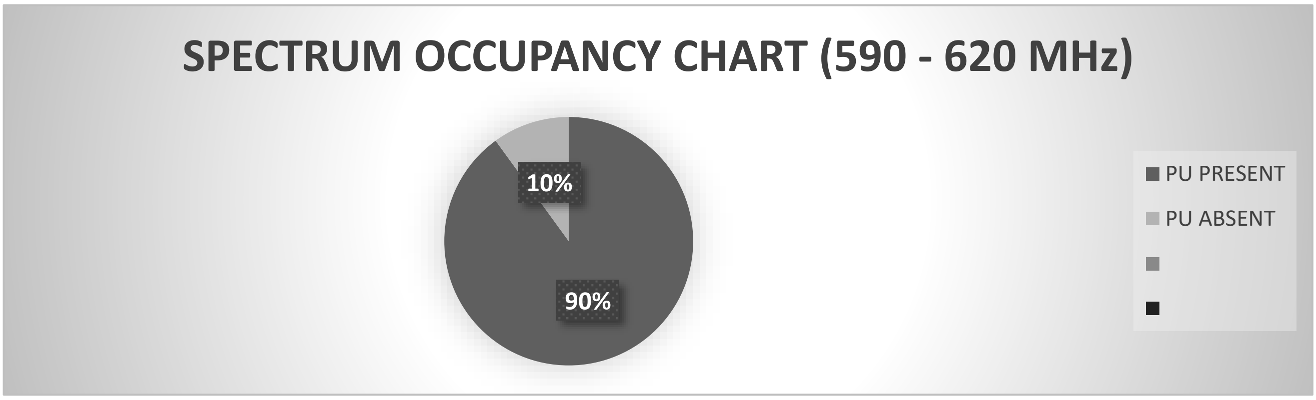

Figure 7: Spectrum Occupancy Chart (490 – 620 MHz)

Table 10: Spectrum sensing between 620 MHz to 650 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
621.5	42.59	138.9	1
624.5	42.47	140.2	1
627.5	42.01	138	1
630.5	42.34	138.1	1
633.5	42.36	138.6	1
636.5	42.01	138	1
639.5	42.27	138.2	1
642.5	42.38	139.2	1
645.5	42.52	140.2	1
648.5	33.85	110	1

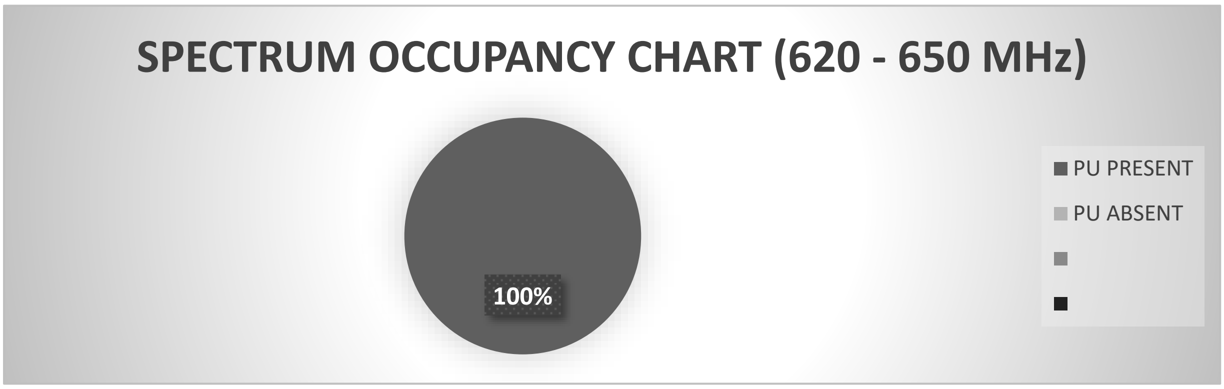

Figure 8: Spectrum Occupancy Chart (620 – 650 MHz)

Table 11: Spectrum sensing between 650 MHz to 680 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
651.5	28.8	98.54	0
654.5	42.69	139.8	1
657.5	42.98	140.9	1
660.5	42.76	139.6	1
663.5	42.45	139.2	1
666.5	39.54	138.6	1
669.5	42.71	139.6	1
672.5	41.97	139.7	1
675.5	33.71	107	1
678.5	40.08	131.5	1

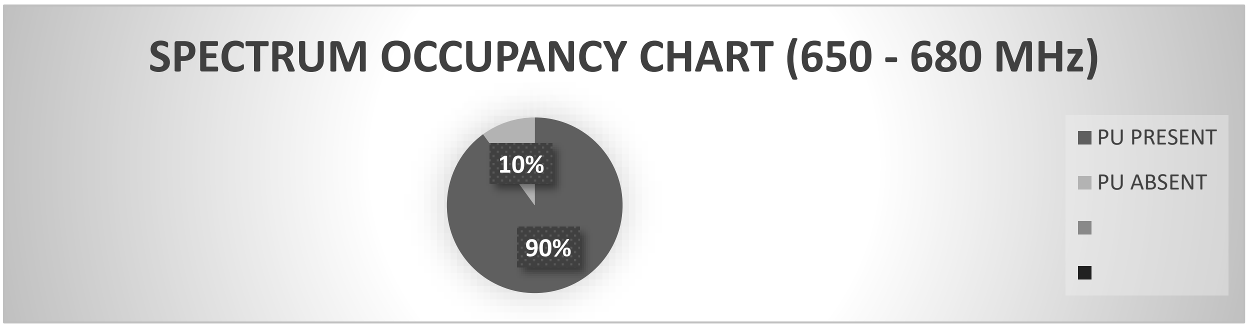

Figure 9: Spectrum Occupancy Chart (650 – 680 MHz)

Table 12: Spectrum sensing between 680 MHz to 710 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
681.5	42.23	138.1	1
684.5	41.62	136.8	1
687.5	42.15	137.9	1
690.5	41.33	136.4	1
693.5	41.84	137.1	1
696.5	40.02	134.2	1
699.5	42.84	139.4	1
702.5	42.99	140.6	1
705.5	43	141.8	1
708.5	42.96	140.2	1

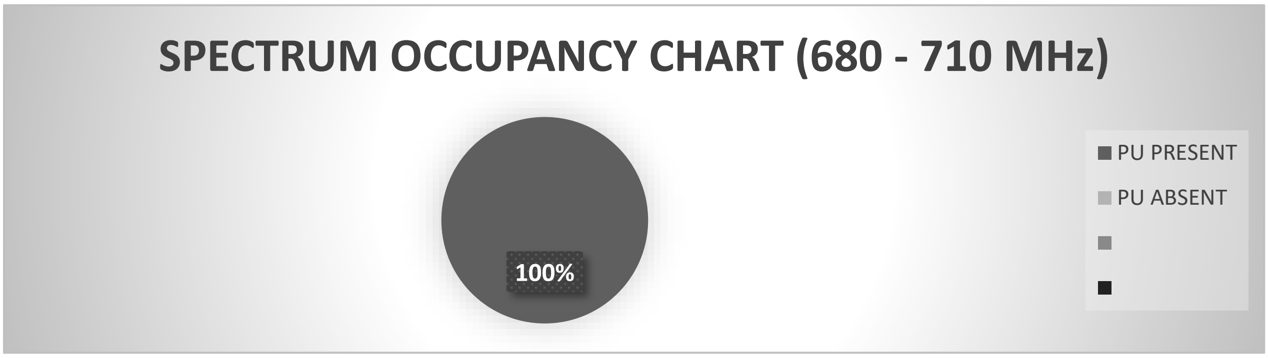

Figure 10: Spectrum Occupancy Chart (680 – 710 MHz)

Table 13: Spectrum sensing between 710 MHz to 740 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
711.5	43.16	141.8	1
714.5	43.06	141.2	1
717.5	43.07	141.4	1
720.5	43.66	143.2	1
723.5	43.15	141.4	1
726.5	42.67	140.7	1
729.5	43.08	141.4	1
732.5	43.09	141.5	1
735.5	43.09	141.5	1
738.5	43.44	142.4	1

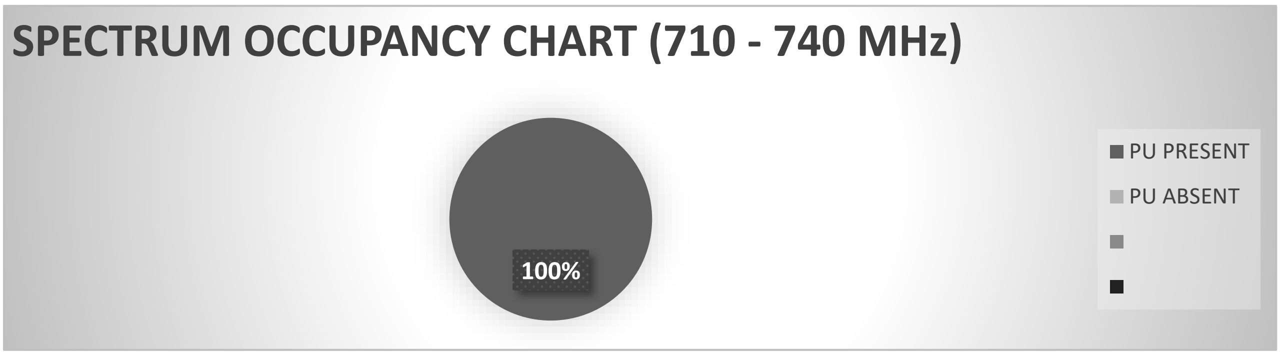

Figure 11: Spectrum Occupancy Chart (710 – 740 MHz)

Table 14: Spectrum sensing between 740 MHz to 770 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
741.5	42.86	140.7	1
744.5	43.08	141.4	1
747.5	42.81	140.3	1
750.5	37.08	125	1
753.5	38.49	127.7	1
756.5	40.62	138.8	1
759.5	42.72	140.2	1
762.5	42.5	139.8	1
765.5	39.29	130.6	1
768.5	22.14	75.11	0

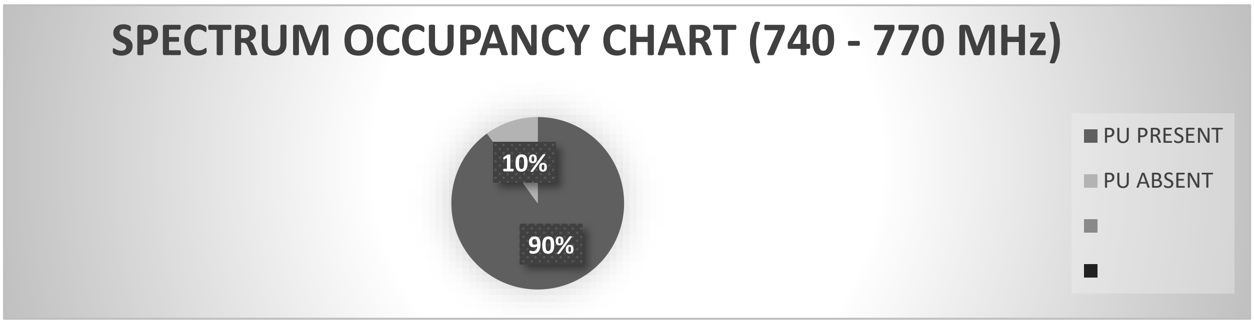

Figure 12. Spectrum Occupancy Chart (740 – 770 MHz)

Table 15: Spectrum sensing between 770 MHz to 800 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
771.5	24.44	83.27	0
774.5	26.57	85.33	0
777.5	28.18	93.2	0
780.5	22.16	72.16	0
783.5	24.32	78.56	0
786.5	22.48	75.14	0
789.5	38.29	130.1	1
792.5	21.72	70.51	0
795.5	23.59	78.71	0
798.5	24.22	79.2	0

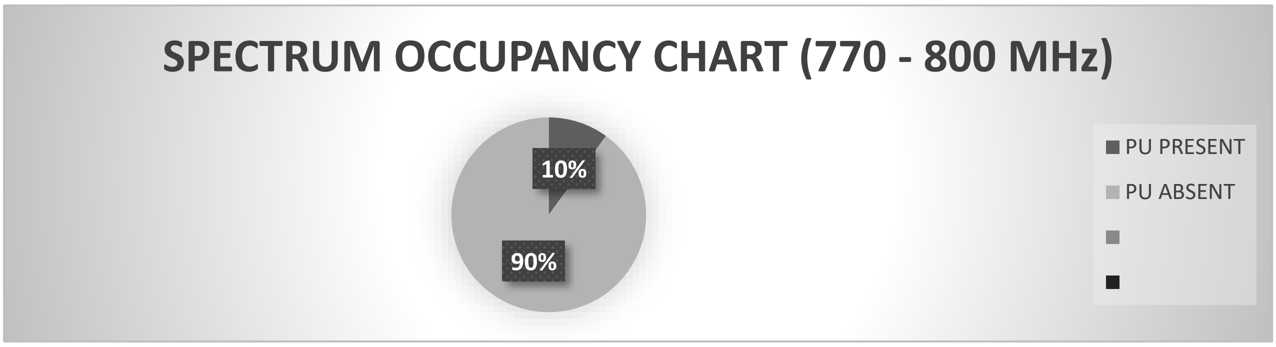

Figure 13: Spectrum Occupancy Chart (770 – 800 MHz)

Table 16: Spectrum sensing between 800 MHz to 831 MHz

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
801.5	24.6	80.3	0
804.5	23.14	76.67	0
808.5	22.46	73.46	0
811.5	34.06	111.6	1
814.5	26.2	79.95	0
817.5	26.44	85.66	0
820.5	27.54	88.42	0
823.5	43.03	141.8	1
826.5	42.9	140.7	0
829.5	43.09	141.5	1

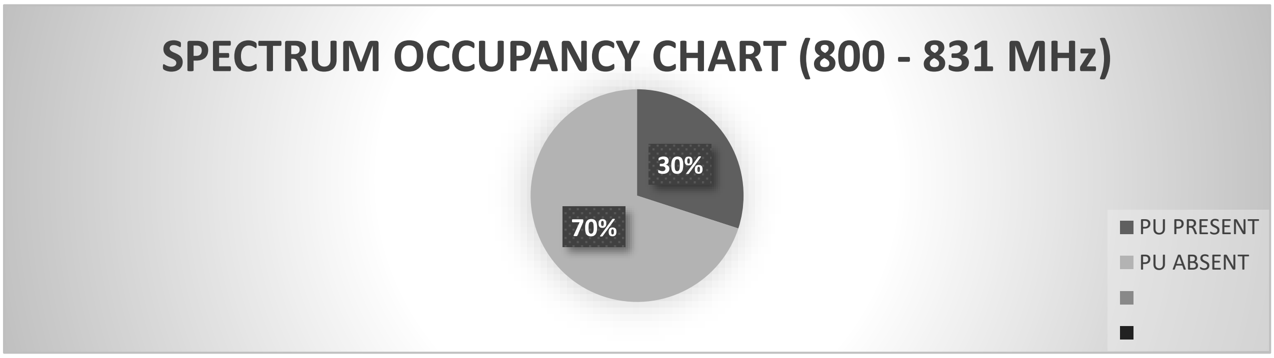

Figure 14: Spectrum Occupancy Chart (800 – 831 MHz)

Table 17: Spectrum sensing between 831 MHz to 870 MH

Centre Frequency (MHz)	Measured Signal Power (-dB)	Calculated Signal threshold value from captured Primary user signal (|dB|)	Cognitive Radio Spectrum Decision (H_o/H_1)
832.5	39.84	129.3	1
835.5	43.06	141.08	1
838.5	43.1	141.4	1
841.5	43.16	142	1
844.5	42.68	140.9	1
847.5	43.09	141.7	1
850.5	42.87	140.7	1
853.5	42.91	139.3	1
856.6	42.82	140.5	1
859.5	42.91	141.15	1
862.5	42.91	141.15	1
865.5	43.02	141.9	1
868.5	42.95	141.2	1

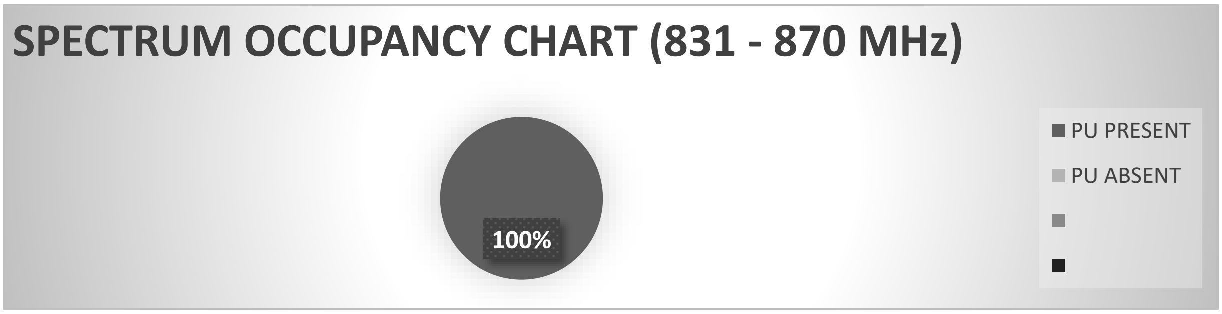

Figure 15: Spectrum Occupancy Chart (831 – 870 MHz)

3.0. Discussion of Results

The signals were captured in real time by the RTL-SDR interfaced with the energy detector model in Simulink. Spectrum sensing was done successfully using centre frequencies from 471.5 MHz to 868.5 MHz in frequency intervals of 3 MHz. It can be observed that the frequencies between 770 MHz to 800 MHz and 800 MHz to 831 MHz were 90% and 70% unoccupied by the Primary users respectively. Hence, these frequencies can be used alternatively for unlicenced communications by secondary users during the deployment of the spectrum sensing cognitive radio in other to avoid interference with the primary users. The other frequencies aside the two ranges mentioned between the 470 MHz to 870 MHz had 70% to 100% occupancy by the primary users. The frequency channels that recorded less than 40% can be termed unoccupied.

3.1. Comparison with similar study in other region, Nigeria

[1] presented a similar study that evaluated the availability of Television White Space (TVWS) in Ondo State radio vision-television station in Akure, southwestern Nigeria. The spectrum

measurement was done outdoor in the frequency bands of the licensed networks ranging from 470 MHz – 960 MHz using a tiny spectrum Analyzer. The results obtained showed that 71.05% of the 38 channels in that region were unused. The summary of percentage occupancy compared with Benin city; Edo state (this work) is presented in Table 18.

Table 18: Percentage spectrum occupancy of TV and white spaces in the 470 - 870 MHz frequency band per location

Description	**Location1**	**Location2**
	Akure, Ondo State	Benin city, Edo state (this work)
Percentage of occupied spectrum	28.95%	85%
Percentage of unoccupied spectrum	71.05%	15%

This shows that the rate of occupancy in Benin city is higher, this may be due to the number of TV stations in the state as Edo state has at least six active TV stations while Ondo state has about two active TV stations. However, about 15% of the TV spectrum can still be available for unlicensed communications in Edo State.

4. Conclusion

The cognitive radio was able to provide intelligent response of the absence or presence of primary user signal in the TV spectrum which proves the evidence of TV white spaces. Hence, a secondary user could these vacant spaces for unlicensed communications or emergency communications in the absence of a primary user or vacate the band when a primary user is detected.

Nomenclature
Ho = Signal of primary user absent
Hi = Signal of primary user present

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