

Coverage and Performance Evaluation of VHF and UHF Electric Field Strength Distribution in Urban Area of Ilorin, Nigeria

Oseni, O.F. and Ojo, F.K..

Abstract: This paper evaluated the coverage and performance of VHF and UHF signal level from two different transmission stations in the urban area of Ilorin, Kwara State, Nigeria. The performance characteristics of the two bands are of special importance regarding coverage and quality requirements. Effective communication links require direct line of sight; however, this cannot be achieved in a build-up areas where obstacles are present along the communication paths, which in turns result in signal strength degradation. In this work, the signal strength and performance of Nigeria Television Authority (NTA), Ilorin, and Kwara State Television (KWTV) were investigated along some six selected routes. The measurement was taken with a spectrum analyzer. Global positioning system (GPS) device was used to measure the coordinates between the transmitter and receiver during measurement. Microsoft Excel software was used to show the graphical variation of the field strength. Furthermore, the result obtained reveal the performance of the two transmitting stations under National Broadcasting Commission (NBC) and Federal Communication Commission (FCC) thresholds, the highest percentage coverage recorded from the two stations along route 3 are 66.48% for VHF and 6.92% for UHF. The need for repeater stations was suggested to routes with poor coverage so as to improve the signal quality based on NBC standard.

Keywords: Communication, Coverage Areas, Field Strength, Ultra High Frequency bands, Very High Frequency

I. Introduction

Television and radio station broadcast are using the Very High Frequency (VHF) and Ultra High Frequency (UHF) band in many countries of the world. The yearning of general public for wireless services is on the increase and are crucial in our day to day activities, which are deployed for entertainment, political campaign, information and education [1]. When VHF band was dominated with different systems, the need to expand into UHF band was obvious in order to

meet the increasing demand of numerous end users. The UHF band is more attractive because lower frequencies are prone to extraneous influences and also higher frequencies problems or difficulty that signals have in penetrating buildings. Also, the practical antenna size in the UHF band makes it an ideal choice for broadcast service, thus the UHF band is highly competitive [2].

The reception of VHF waves are not impaired by static noise and the band is suitable for short-distance terrestrial communication, thus, transmissions are restricted to local radio horizon less than 160 km [3]. VHF is also less affected by atmospheric noise and other extraneous influences of higher frequencies from electrical equipment, but it is blocked by land features such

Oseni, O.F. and Ojo, F.K. (Department of Electronic and Electrical Engineering, Ladoké Akintola University of Technology, Ogbomosho, Oyo State, Nigeria.)
Corresponding author: ooseni@lutech.edu.ng
Phone Number: +2348033934222.
Submitted: 12-09-2022
Accepted: 30-09-2022

as buildings, trees or hilly terrain [4]. It is less affected by buildings and can be received indoor, but in a metropolitan areas with a lot of building multipath television reception due to reflection from these buildings causes problem of good signal reception in the band [5]. The useful signal and /or the interference varies with time, thus, time- availability is employed to find the percentage of time for which the acceptance ratio is exceeded [6]. More so, the quality of signal at a given location is also a function of receiver orientation, noise figure, sensitivity, receiving antenna, transmission line loss and antenna gain, spurious Radio Frequency (RF) emission, time of the day, transmitter – receiver distance, transmitter power and terrain effect [7].

The evaluation of coverage areas depends crucially on the transmitter power, the directivity of the aerial, the ground conductivity and the frequency of propagation and also, the station location, antennal setting and temperature have a strong influence on the coverage area [8,9]. The performance of the field strengths measured was evaluated based on the Nigeria Broadcasting Commission (NBC) specified acceptable minimum electric field strength for urban area which are 60 dB μ V/m for VHF (band III) and 70dB for UHF – television (Band V) [10]. The (FCC) also specified minimum electric field strengths for an urban area to be 77 dB μ V/m for VHF band III and 80 dB μ V/m for UHF band V [11]. Thus, coverage and performance of the two bands were evaluated using these thresholds. In the recent years, signal measurements in the VHF / UHF bands within the urban clutter areas have become popular important research topic, as evidenced by a varieties of research being conducted in many areas, most of these works focused on VHF/UHF coverage, the problems of shadowing and multipath effects, without much consideration for the improvement on

received signal strength. The work presented by [12] carried out the measurement in the city of Ilorin, Nigeria. And also, [13] carried out similar work on electric field strength distribution of UHF TV signal in Yenagoa with Niger Delta Television, the quality of received signal was considered. In [14], an extensive path loss propagation measurement were conducted in two different cities to develop Kriging algorithm for distance- based path loss prediction in VHF and UHF bands. Also, similar work was conducted in [15] to determine signal attenuation and propagation loss parameters also in the VHF and UHF spectrum bands. The works focused on mining exploration using Kriging Interpolation Method (KIM), a geostatistical spatial interpolation technique. The data obtained was analyzed to determine the variation pattern of electric field distribution, but could not evaluate the performance of the field strength. In this work, percentage coverage using the two thresholds were then compared and reasonable conclusion were made on quality of signal based on their performance.

II. Materials and Methods

A. Materials Selection

i. Experimental Site

Ilorin is in the North Central part of Nigeria and capital of Kwara state, with latitude 8°25' 55"N and Longitude 4°36'25"E of the Greenwich meridian as shown in Figure 1. It has an area of about 100km². Kwara state shares boundary with Kogi state, Ekiti state, Niger state, Osun state and Oyo State and also, with an international boundary with The Republic of Benin as shown in Figure.2 It is one of the largest and fast growing cities in Nigeria with a population of about 847,582 (showed by the 2006 population census figures) [10]. The

weather conditions of Ilorin annually can be classified into two, the rainy season and the dry season. The rainy season starts from the end of March and ends in October while dry season starts from November to February. Usually, Ilorin experiences harmattan from the Sahara desert region of the North between the months of December and January which is cold-dry months in the region [16]

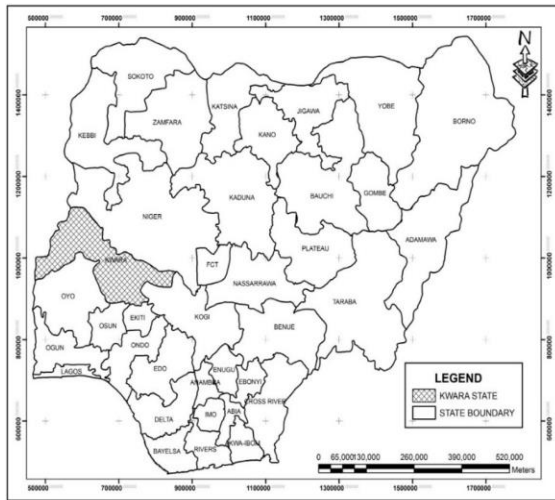


Figure 1: Nigeria showing Kwara state settlement mapping, [16]

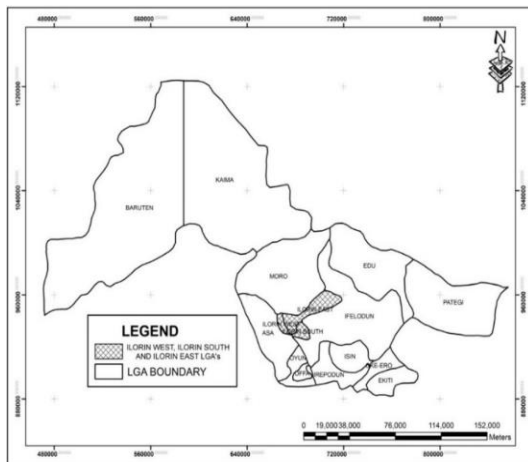


Figure 2: Kwara State showing Ilorin Local Govt. areas settlement mapping, [16]

ii Instrumentation:

Table 1 presents the configuration of the spectrum analyzer and the receiver antenna used.

The spectrum analyzer has a frequency range of 100Hz to 7GHz, while the receiver antenna is Omni-directional, with a range of 70MHz to 1GHz. Other instruments used are the field car, connectors, and coaxial cable and a laptop computer for data logging.

Table 1: Measuring Equipment and Configuration Used

Spectrum Analyzer N9342C Agilent, 100 Hz- 7 GHz	
Displayed average noise level (DANL)	-164 dBm/Hz
Preamplifier	20 Db
Resolution bandwidth (RBW)	10 kHz
Impedance	50 ohms
Receiver Antenna: Diamond RH799 RH 795	
Frequency range	70 MHz-1 GHz
Form	Omnidirectional
Height	1.5 m
Gain	2.1 Bi

B. Methods

i Theoretical Electric Field Strength

Friis Equation can be used to show the relationship between the transmitter, receiver and Coverage area estimation. The extent to which the radio wave will travel is a function of the transmitter power, receiver power, transmitter gain and receiver gain. Thus, the Friis Equation is shown below

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2 \quad (1)$$

From the above,

P_t is the transmitter power in watts or dBwatts, P_r is the receiver power in watts or dBwatts, G_r is the receiver gain in dB, G_t is the transmitter gain in Db, λ is the efficiency and R which is the Coverage distance of the radio wave.

Table 2: Characteristics of Transmitting Station

S/N	Parameter	Nta, Ilorin	Kwara Tv, Ilorin
1.	Base station's Geographical Coordinate	Latitude 8° 25' 55"N, Longitude 4° 36' 25"E	Latitude 8° 31' 47"N, Longitude 4° 36' 49"E
2.	Base Station Carrier Frequency/ Channel	203.25 MHz/ VHF 9	583.25MHz/UHF 35
3.	Base Station Transmitting Power (KW)	2.60	10
4.	Height of Transmitting mast(m)	185.00	307.85
5.	Height of Receiving Antenna(m)	1.51	1.51
6.	Receiving Antenna Gain(dB)	2.51	2.51

The value of electric field strength of the various television station measured to determine the coverage distance, d from the antenna of each TV station according to the relation shown below:

$$E = \frac{\sqrt[2]{30P_t}}{d} \quad (2)$$

Where E = electric field strength, (V/m), P_t = effective radiated power, (Watts) and d = coverage distance in meters.

ii Field Strength Measurement and Analysis

The field strength measurements were conducted with Nigeria Television Authority (NTA) band III of the VHF-TV and Kwara State television (KWTV) band V of the UHF-TV transmitters, Ilorin. Detailed characteristics of the experimental stations chosen with their center frequency was presented in Table 2. NTA transmits at a frequency of 203.25MHz (VHF – TV) and the output of the transmitter during the period of this work was substantially constant at 2.6kw.

Kwara Television (KWTV) Ilorin transmit at a frequency of 583.25MHz (UHF – TV), the output power in this case is 10kw. The signal level of the transmitters of the station were taken along the following routes shown in Table 3 The details of area where measurements were taken including location co-ordinates for the

transmitters, antenna height and a map of the area with individual measurement locations were recorded.

Table 3. Route Covered During the Measurement

Routes	Area Covered
Route 1	Unilorin- Tanke - Fate- Basin
Route 2	Basin- Sango- KWTV
Route 3	KWTV Unilorin Teaching Hospital- Oke oyi
Route 4	University Teaching Hospital- Maraba- Ipata- Oja oba
Route 5	Oja Oba- Oja iya- Depression along Taiwo`
Route 6	Oja oba- Agaka - Gera ilorin- Asadam- NTA Gammo

From the data obtained, Microsoft excel was used to draw and compare on a single graph for each route, the received field strength, Nigeria Broadcasting commission (NBC) and Federal communication commission (FCC) specified minimum field strength and the data was used to evaluate the percentage coverage for each route and to draw the bar charts showing these percentage coverage.

iii. Evaluation of Percentage Coverage Based on NBC Specified Minimum Field Strength for an Urban Area.

The Nigeria broadcasting commission according to its broadcasting code of conduct 2010, specified a minimum field strength for an urban

area which are 60dB μ V/m for VHF (Band III) and 70dB μ V/m for UHF- Television (Band V). This was used as the minimum threshold in evaluating the percentage coverage along each route. Thus, percentage coverage of each route was calculated through the formulae as shown:

$$\text{Percentage coverage of VHF} = \frac{\text{Total number of field strength points measured within or above threshold of 60dB}\mu\text{V/m}}{\text{the total number of field strength points measured}} \times 100 \quad (3)$$

$$\text{Percentage coverage of UHF} = \frac{\text{Total number of field strength points measured within or above threshold of 70dB}\mu\text{V/m}}{\text{the total number of field strength points measured}} \times 100 \quad (4)$$

iv. Evaluation of Percentage Coverage Based on FCC Specified Minimum Field Strength for an Urban Area.

The Federal communication commission according to its code of federal regulations of 2007, specified a minimum field strength for an urban area which are 77dB μ V/m for VHF (Band III) and 80dB μ V/m for UHF- Television (Band V). This was used as the minimum threshold in evaluating the percentage coverage along each route. Thus, percentage coverage of each route was calculated through the formulae shown below:

$$\text{Percentage coverage of VHF (Band III)} = \frac{\text{Total number of field strength points measured within or above threshold of 77dB}\mu\text{V/m}}{\text{the total number of field strength points measured}} \times 100 \quad (5)$$

$$\text{Percentage coverage of UHF (Band V)} = \frac{\text{Total number of field strength points measured within or above threshold of 80dB}\mu\text{V/m}}{\text{the total number of field strength points measured}} \times 100 \quad (6)$$

III. Results and Discussion

In this work, performance evaluations were carried out for both UHF and VHF, also, the percentage coverage were enumerated. Figures 3, 4, 5, 6, 8, 9 and 10 show the electric field strength

against distance produced for channel 9 NTA, Ilorin and channel 35, KWTv, Ilorin, for some selected routes under survey while Figures 7 and 11 present the percentage coverage bar chart representing all the route being surveyed. Table 4 presents the total percentage coverage of the entire urban area of Ilorin which are the 6 routes surveyed during the measurement campaign. It accounts for NBC and FCC thresholds, these are bodies that set guidelines or protection margins as minimum or maximum exposure or radiation limits for electric field strength. The implication of the values obtained to the credibility of the received signal strength is coverage area reduction. For NTA Ilorin, the total coverage areas of the state are 32% and 0.02 % of land mass of the state under NBC and FCC respectively. Also, for Kwara TV, the total coverage areas of the state are 1% and 0 % of land mass of the state under NBC and FCC respectively.

Table 4. Total Percentage Coverage of the entire urban area of Ilorin

Transmitting Station	Total Percentage Coverage based on NBC threshold	Total Percentage Coverage based on FCC threshold
NTA, Ilorin	32%	0.02%
KWTv, Ilorin	1%	0%

It could be seen from the result obtained that the theoretical or calculated electric field strength is always above the NBC and FCC specified minimum electric field strength for an urban area, but reduces as the distance increases. This shows that the higher the distance the greater the attenuation. It was also found that the measured field strength gotten during the measurement campaign is usually lower than the theoretical field strength. This is as a result of the high building and complex terrain that causes

attenuation and obstruct the signal being transmitted in Ilorin. It was however found that the VHF and UHF electric field strength points measured for the two transmitters, performed poorly when the NBC threshold was used and its performance depreciated more when the FCC threshold was used.

Figure 3,4,5 and 6 depict the path profile for the measurement of NTA (VHF III) routes; considered in this work; the electric Field Strength is plotted against distance from the

transmitter in km. The figures show the comparison between the calculated field strength and actual measured field strength, NBC and FCC thresholds along routes 1,3 and 5. On route 3 the losses are predominately large compared with route 1 and 2, this is due to refraction and diffraction of signal from buildings along the route. This route is within University Teaching Hospital with many concrete structures, the area consists of retail, commercial, high rise residential and low rise industrial, categorized as urban area.

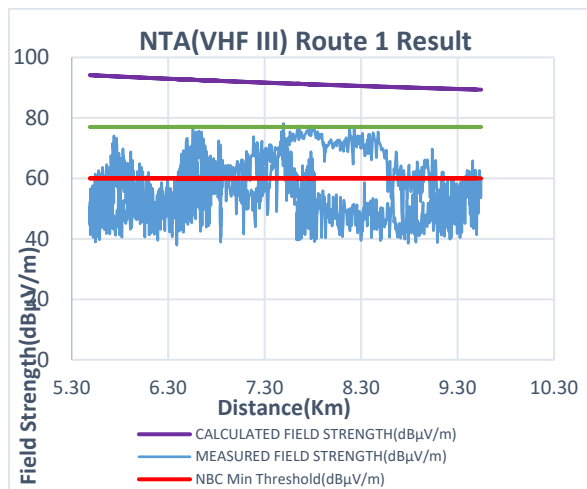


Figure 3: Electric Field Strength measured against distance for NTA (VHF III), route 1

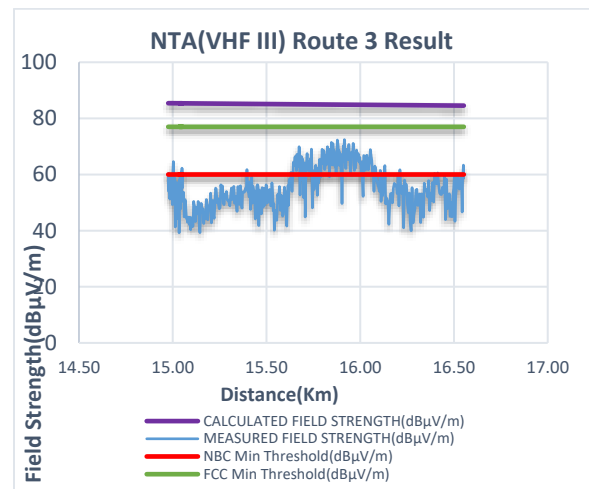


Figure 4: Electric Field Strength measured against distance for NTA (VHF III), route 3

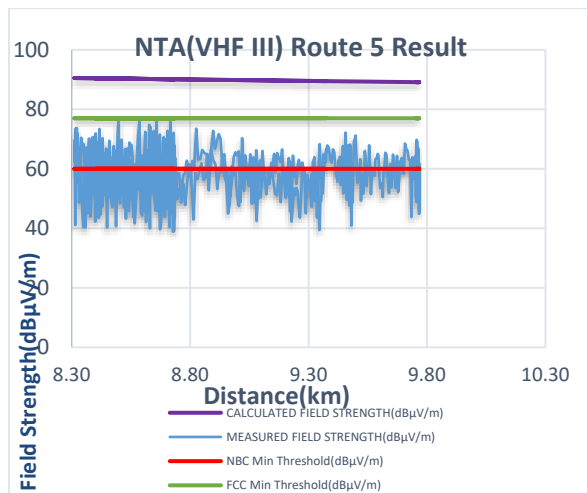


Figure 5: Electric Field Strength measured against distance for NTA (VHF III), route 5

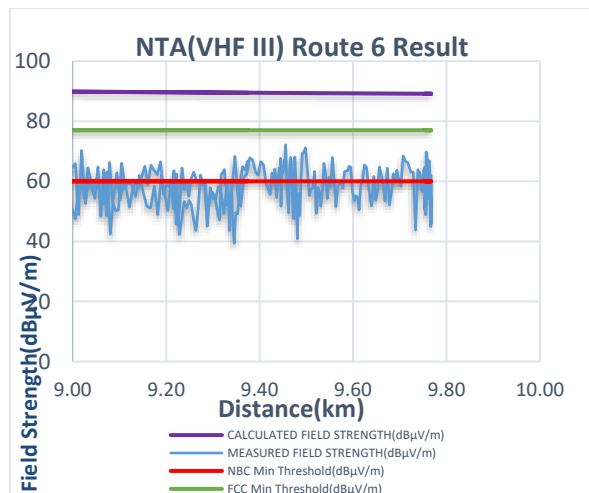


Figure 6: Electric Field Strength measured against distance for NTA (VHF III), route 6

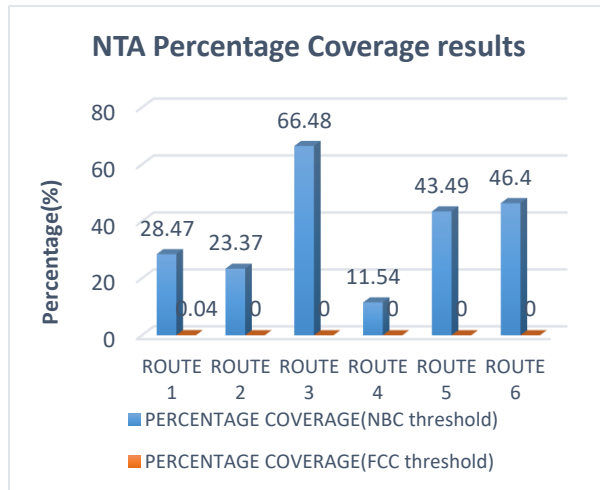


Figure 7: Bar chart of NTA percentage coverage for each route

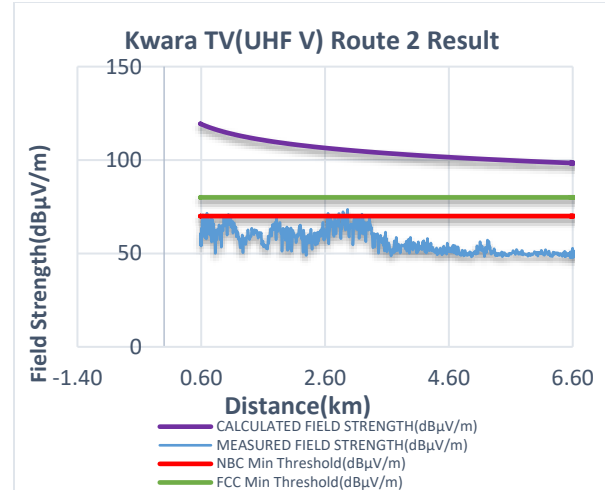


Figure 8: Electric Field Strength measured against distance for route 2 of Kwara TV (UHF V).

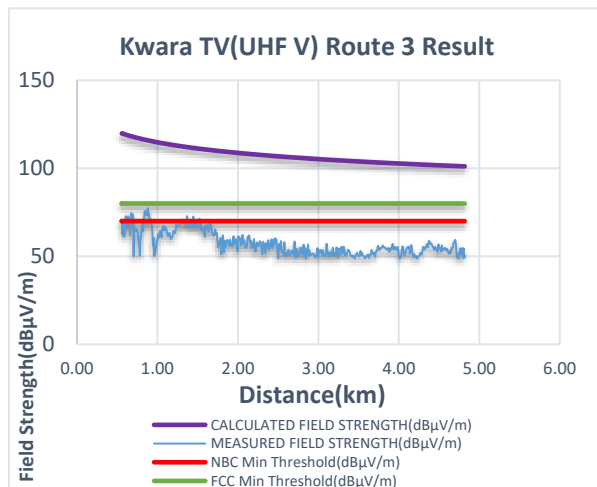


Figure 9: Electric Field Strength measured against distance for route 3 of Kwara TV (UHF V)

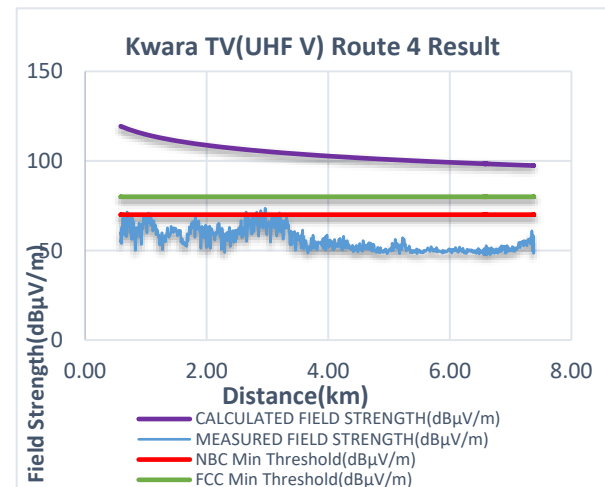


Figure 10: Electric Field Strength measured against distance for route 4 of Kwara TV (UHF V)

Figure 7 show the clear distinction of percentage coverage of all the routes in contention for both NBC and FCC thresholds with NTA. It was observed from the television signal strength measured across six routes, that, there are direct line of sight along route 3, 5 and 6, between transmitter and receiver. Also, there is a significant variation of the electric field strength of a minimum of 11.54% along route 4 and a maximum value of 66.48% coverage along route 3. The University Teaching Hospital, Maraba-Ipata-ojo oba, route 4 has area with tertiary

coverage; which implies that the residents in those area need a special antenna or signal booster to enjoy NTA services.

Figures 8, 9 and 10 shows the measured field strength of Kwara TV (UHF V) against the distance in meter, the measured field strength shows the true variation of the transmitted signal as influenced by terrain, physical structures and clutter characteristics of the city, Ilorin. It was observed that the measured values are below the optimum values. These figures showed specific performance on the selected routes, where the

measured fields were below the benchmark of both NBC and FCC.

Figure 11 show the clear distinction of percentage coverage of all the routes in contention for both NBC and FCC thresholds with KWTv. KWTv has areas of weak electric field strength distribution and some of those area are as a result geographical structures such as trees, mountains, the degree of irregularity of terrain is greater at UHF than at VHF.

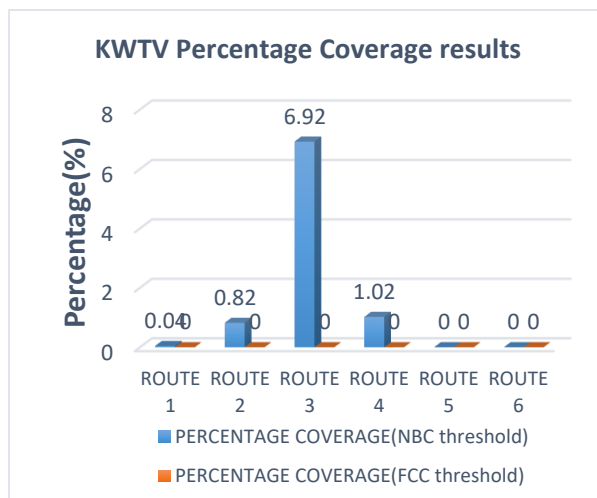


Figure 11: Bar chart of NTA percentage coverage for each route

IV. Conclusion

The work presents the coverage and performance evaluation of VHF and UHF electric field strength in the urban area of Ilorin and two transmitting stations belonging to this bands were used to carry out the measurements. However, the NBC and FCC thresholds have been used to compute the percentage coverage for each transmitter along six routes in the urban area of Ilorin, this coverage is needed to evaluate the performance of the various electric field strength radiated by these transmitters and from the findings, the highest percentage coverage recorded from the two stations along route 3 are 66.48% for VHF and 6.92% for UHF. There is

need for the transmitting station in the VHF band to increase their present transmitting power and antenna to a higher value so that the coverage areas can increase, and at the same time provide quality services and good signal reception in the urban area of Ilorin. More so, the transmitting station in the UHF band should upgrade their facilities in order to enhance the signal strength across the urban area of the state and install at least two or more booster stations, because of the economic importance of television news and programs.

It could however be concluded that the NBC code of conduct pertaining to VHF and UHF bands' minimum field strength be reviewed and the FCC code of conduct be adopted, so future transmitting stations will follow this standard and if it can't be met, the transmitting station field strength may fall back on the NBC threshold. This will allow the transmitting stations to optimize their coverage and provide quality signal strength to the various subscribers in the urban area of Ilorin.

References

- [1] Ajewole, M.O., Akinbolati, A., Adediji, A.T. and Ojo, J.S. "Precipitation Effect on the coverage Areas of Terrestrial UHF Television Stations in Ondo State, Nigeria", *International Journal of Engineering and Technology*, vol. 4, no. 9, 2014, pp. 1 – 12.
- [2] Biryukov, S.V., Tyukin, A.V., Tyukin, L.V. Kolmogorova, S.S. "Improved Method of Measuring Electric Field Strength by the Mean Value of Double Sensors and Devices for Its Application", www.iopscience.iop.org, Accessed on November 9, 2021.
- [3] Chhavi, R.B., Stuart, H., Chris, B. and Geza, B. "Instrument to Measure Environmental and Personal Radiofrequency Electromagnetic field", *Physics and Engineering Sciences in Medicine*, vol.45, no. 11, 2022, pp. 687-704.

- [4] Cetin, K., Begum, K.E. and Murat, C.B. "Measurement and Evaluation of Electric Field Strength Levels in Primary and Secondary Schools in a Pilot Region", Published at <https://www.researchgate.net/publication>, Accessed on December 2018.
- [5] Ajewole, M.O., Onyedi, O.D., Adediji, A.T. and Eiche, J.F. "Spatial Variability of VHF/UHF Electric Field Strength in Niger State, Nigeria", *International Journal of Digital Information and Wireless Communications*, vol. 3, no. 3, 2013, pp. 26 – 34.
- [6] Famoriji, J.O. and Olosoji, Y.O. "Effects of Hilly Terrain on UHF Band Radio Frequency Propagation", *International Journal of Science and Research*, vol. 2, no. 4, 2013, pp. 1- 3.
- [7] Jimoh, A.A., Surajudeen-Bakinde, N. and Bello, O. "Assessment of Multipath and Shadowing Effect on Band UHF in Build-up Environments", *ATBU Journal of environmental Technology*, vol. 10, no. 1, 2017 pp. 1-11.
- [8] Faruk, N., Bello, O.W., Oloyede, A.A., Surajudeen-Bakinde, N.T., Obiyemi, O., Olawoyin, L.A., Ali, M. and Jimoh A. "Clutter and Terrain Effects on Path Loss in the VHF/UHF Bands", *Journal of The Institute of Engineering and Technology*, vol. 12, no. 1, 2018 pp. 69-76.
- [9] Prince Chigozie, I. and Onuabuchi, V.C. "Investigation of Diurnal Variation of Signal Strength Generated by FM Transmitter", *European Scientific Journal*, vol. 14, no. 18, pp. 235-246.
- [10] Nigeria Broadcasting Code, (2010), "A Publication of National Broadcasting Commission", resourcedat.com/wpcontent/uploads/2011/09/Nigeriabroadcastingcode.pdf. Accessed on, September 22, 2014.
- [11] Code of Federal Regulations, (2007). "A Publication of Federal Communications Commission", www.gpo.gov/fdsys/pkg/CFR-2007-title47-vol4-chapI.xml, Accessed on December 10, 2014.
- [12] Faruk, N., Ayeni, A.A. and Adediran, Y.A. "Characterization of Propagation Path Loss at UHF/VHF Bands for Ilorin City, Nigeria", *Nigerian Journal of Technology (NIJOTECH)*, vol. 32, no. 2, 2013, pp. 235-265.
- [13] Emeruwa, C. and Dieokuma, T. "Electric Field Strength Distribution of UHF Television Signal: Case Study of Niger Delta Television Yenagoa, Bayelsa State, Nigeria", *Journal of Electronics and communication Engineering*, vol. 16, no. 3, 2021 pp. 52-59.
- [14] Faruk, N., Abdulrasheed, I.Y., Surajudeen-Bakinde, N.T., Adetiba, E., Oloyede, A.A., Abdulkari, A., Sowande, O., Ifijeh, A.H. and Atayero, A.A. "Large-scale Radio Propagation Path Loss Measurements and Predictions in VHF and UHF Bands", www.cell.com/heliyon. Accessed on February 23, 2021.
- [15] Yang, Z., Tran, L.C. and Safaei, F. "Step Length Measurement of Using the Received Signal Strength Indicator", *Sensors*, vol. 21, no. 2, 2021, pp. 1-16.
- [16] Adesanya "Clutter Effect on Path Loss Models at VHF/VHF Bands in Urban Area", Unpublished B.Sc. thesis, University of Ilorin, Ilorin Nigeria, 2014.