Nigerian Journal of Engineering, Vol. 28, No. 1, April 2021 ISSN (print): 0794 - 4756, ISSN (online): 2705-3954.

Nigerian Journal of Engineering,
Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria
journal homepage: www.njeabu.com.ng

Evaluation on the Coverage Area of Digital Terrestrail Television Broadcast Network in Jos, Nigeria and its Environs

E. E. C. Igbonoba[1] and I. A. Obayuwana[2]

[1]Computer Engineering Department, Faculty of Engineering, University of Benin, Benin City, Edo State.
[2]Computer Engineering Department, Faculty of Engineering, University of Benin, Benin City, Edo State.`
igbonoba2000@live.com[1], augustine.obayuwana@uniben.edu[2]

Research Article

Abstract

This study presents the investigation of the coverage area (CA) of the digital terrestrial television broadcasting (DTTB) in Jos, Plateau State over the two major seasons of the year (wet and dry season). The campaign was carried out using the Nigerian Television Authority Company signal called Integrated Television Services limited (ITS). The aim of this research is to evaluate the coverage area of the digital video broadcasting terrestrial-second generation (DVB-T2) signal in Jos and its environs. The key measured parameter was received signal strength (RSS). The field measurement drive test was the adopted methodology for the campaign to establish the actual coverage of the DTTB in Jos. The mean data value were obtained and used to define the coverage area of the examined locations. The result obtained revealed that digital terrestrial television (DTT) signal was available only in eight (8) Local Government Area of Plateau State. The empirical analysis from the result recorded an improvement between A1- A2 and B1- B2 routes. The primary coverage of route A (A1-A2) presented an improvement of 4.2%, secondary: 25% and 29.2% in the fringe zone while in route B (B1-B2), the following improvements were recorded, primary: 24.96%, secondary: 16.64% and 8.34% in the fringe zone). The coverage area was grossly affected in the wet season. However, there was improvement in the coverage area during the dry season compared to the wet season. Furthermore, radiated map showing coverage area, curve and their grades vital for planning purposes were developed. Summarily, the result obtained will assist the broadcast operators to identify the suitable locations to install repeater or booster stations for the purpose of quality coverage to the entire State. This will guarantee optimal coverage and quality service delivery for the DTT signal (free-to-air) in Plateau State.

Keywords

Radio Propagation (RP), Digital Terrestrial Television Broadcasting (DTTB), Coverage Area (CA), Received Signal Strength (RSS).

Article History

Received: – August, 2020 **Accepted: –** March, 2021
Reviewed: – December, 2020 **Published: –** April, 2021

1. Introduction

The radio propagation (RP) is significant in everyday transmission of signals (television, radio, mobile telephone signals, Wi-Fi signals, and computer data) through electromagnetic waves. The radio propagation refers to as radio waves that travel from one place to another, usually from a transmitter (TX) to a receiver (Rx) over some distance through the atmosphere. This is affected by various occurrences such as reflection, refraction, diffraction, absorption, scattering, and polarization (Kasampalis, 2018).

In this research, the signal strength is the most pivotal parameter that determines the signal coverage (SC). During signal propagation, the signal strength becomes weaker, less stable, its shape may be distorted, and even its frequency may change due to perturbations arising from the environment and the atmosphere. When the radio wave is transmitted over a long distance, the strength signal weakens because the power density decreases and so the field strength decreases significantly. In free space propagation, radio waves travel within the line-of-sight (LOS) propagation medium. The Changes due to moisture and temperature in the troposphere, local temperature, air pressure, and moisture can occasionally increase the distance of radio waves propagation by bending their path over the horizon. It can also cause a very significant rise in signal strength levels at great distances for a short period (Ducting) (Kasampalis, 2018). The DTT signal transmission on the ultra- high frequency (UHF) broadcast band is by space wave which propagates on LOS from the TX to the Rx through the troposphere (Ajewole *et al*., 2014). The DTT signals are transmitted by multiplex transmitter formats using single frequency network (SFN) or multiple frequency network (MFN) and its signals are radiated from the transmitting antenna while analog signals are transmitted through a single frequency channel. The digital terrestrial system involves numerous digital terrestrial transmitters with a particular coverage area (Akinbolati *et al*, 2020). The coverage area of digital terrestrial television is subjective to the following factors; the output power of the TX, the height of the base station / antenna, height of receiving antennas, topography between the transmitter and receiver, effect of the meteorological parameters and vegetation (Akinbolati *et al*, 2016). The Partial implementation of digital switch over (DSO) has covered seven (7) States of the federation as at the time of this research work (Plateau State, Federal Capital Territory, Kaduna, Kwara, Osun, Enugu and Akwa Ibom State). This transition commenced in Nigeria on 30th April, 2016 in Jos (nbc.gov.ng).

The purpose of ensuring good coverage is aimed at improving quality of service (QoS). The attenuation and degradation of signal in analog transmission might not cause complete loss of signal because of its tolerant level. However, the same situation in DTT leads to complete signal failure, i.e. attenuation of signal below the threshold value of -116dBm leads to total loss of signal in DTT system (Faruk *et al*., 2013; IEEE 802.22 Standard, 2011).

The DVB-T2 guarantees more signal robustness, flexibility and at minimum 50% additional efficiency than DVB-T (Lusekelo and Anael, 2014). The DVB-T and DVB-T2 were designed solely to transmit digital terrestrial television. The main goals of DVB-T2 is to increase bandwidth compared to DVB-T, targeting HDTV services, increase the efficiency of the single frequency networks (SFN), providing extra services targeting robustness, and services for fixed and portable receivers with 50% capacity throughput enhancement compared to DVB-T (Kondrad *et al.*, 2009).
The concept "access to anyone, anywhere, at any time" is currently the major goal of the mobile and broadcast entrepreneurs. This is very important for the feature market that brought the technological innovation that gave rise to DVB-T2 Lite (Polak *et al*., 2015). The DVB-T2-Lite is designed to realize portable mobile TV multimedia services (Diego *et al*., 2015).

2. Literature Review

2.1 Coverage area

The coverage area of a broadcasting station is defined as the region where the desired field strength is equivalent to or surpasses the operational field strength specified for a precise reception condition (ITU-R, 2016). All broadcast networks have their anticipated coverage area and their signals are not expected to cause distortion to each other (www.nbc.gov.ng). The signal coverage area of a broadcast network is advantageous in the evaluation of the quality of service (QoS) delivered by a broadcasting station in order to minimize signal failure and optimize efficiency (Akinbolati *et al*., 2020). The coverage area of digital terrestrial television broadcasting is classified as follows:-

1. Primary coverage area: This is defined as the area covered by the transmitting station in which the signal strength is sufficient to overcome familiar distortions at any given period. In this scenario, the signal strength is reliable and can be established openly at any given period. The ITU-R recommendation stipulates that, the primary coverage area of a DTT is when the received signal strength (RSS) is ≥ -53dBm (ITU-R BT. 2035, 2003).
2. Secondary coverage area: This is defined as the area covered by the transmitting station in which the signal strength is accepted to be suitable but not adequate to overcome familiar distortions at any given period. The deployment of a reliable receiving antenna could be mandatory in order to guarantee quality reception. The ITU-R recommendation stipulates that, the secondary coverage area of a DTT is when the received signal strength (RSS) is -54 ≤ RSS ≤ -68dBm (ITU-R BT. 2035, 2003).
3. Fringe (tertiary) coverage area: This is defined as the area covered by the transmitting station in which the signal strength is very fragile and not reliable. Its service can neither be assured nor be safe against any available noise. The deployment of any strong receiving antenna might not guarantee quality reception (Ajewole *et al.*, 2014; Akinbolati *et al.*, 2015). The ITU-R recommendation stipulates that, the fringe zone coverage area of a DTT is when the received signal strength (RSS) is -68 ≤ RSS ≤ -116dBm (ITU-R BT. 2035, 2003).

2.2 Propagation curve

The propagation curve is a critical factor in a wireless transmission specifically in broadcasting. This is the deviation of the electric field strength of a radio signal with respect to space (distance) and environment. The propagation curve is influenced by the TX output, the classification of the signal route (urban or rural) and the environment (Akinbolati *et al*., 2016). The propagation curve is highly instrumental in the calculation of coverage area and path-loss. The precise calculation of the coverage area is very vital in the design of broadcast system (Nisirat *et al*., 2011). The propagation curve expresses the propagation form of every radio signal as it relates to the terrestrial topographies along the signal route. The ITU-R encouraged the Scientists and Engineers in the Telecommunication Industry to promote the study of the propagation curves (ITU-R, 1995).

2.3 Review of related works

Akinbolati *et al*., (2020) investigated the propagation curves and coverage areas of digital terrestrial television broadcast base stations in the tropical zone. The aim of the research was to develop the propagation curve and classify the coverage area of digital terrestrial television broadcast network in Nigeria. The drive test methodology was adopted in the investigation campaign. The result obtained revealed that digital terrestrial television signal do not decrease generally with distance as projected by the theoretical inverse square law. Rather, it undulates with respect to distance due to terrain and tropospheric components along its propagation path. Finally, the researchers could not establish the perturbation component that has higher effect on signal propagation. Furthermore, Carla *et al.*, (2019) predicted digital terrestrial television coverage using machine learning regression. The aim of the research was to evaluate the performance of the machine learning regressor algorithms. The researchers employed two methodologies: - simulation analysis based on machine learning regression algorithm and field measurements in terms of electric field strength corresponding to the DTT channels. The results obtained were compared to the three error metrics with support vector regression, lasso regression, multilayer perceptron regression and ordinary kriging technique. Satisfactorily, the results using random forest regression depict a considerable improvement in the accuracy of coverage prediction under a low computational load. The researchers concluded by not pointing out the likely impairment in a real life situation.

3. Materials and Method

This section presents the measurement and readings of DVB-T2 television signal levels in different locations around Jos and its environs, Plateau State, Nigeria. The measurement campaign was carried out in the wet and dry season (July - August and November - December, 2019) to actually ascertain if rain has serious effect on TV signals in the area investigated. The locations were divided into two major routes (route A and B) across the assumed coverage area of the DVB-T2 TV signals. The two major routes were sub-divided into route A_1, A_2, B_1 and B_2 (A_1, B_1 measured in the wet season while A_2, B_2 measured in the dry season). The signal from Integrated Television services (ITS) was used for the measurement campaign. The network (ITS) has operating frequency of 522 MHz and is the only DVB-T2 network operator (free-to-air) in Plateau State at the time of this research. The field measurement drive test was adopted to measure the ninety six (96) locations (twenty four locations per route). The results obtained in the wet season were compared to the result obtained in the dry season on same route. During the measurement exercise, eight (8) Local Government Areas were covered i.e. Jos North, Jos East, Jos South, Bassa, Riyom, Barkin Ladi, Bokkos and Mangu. The Figure 1 presents the geographical map of the evaluated area.

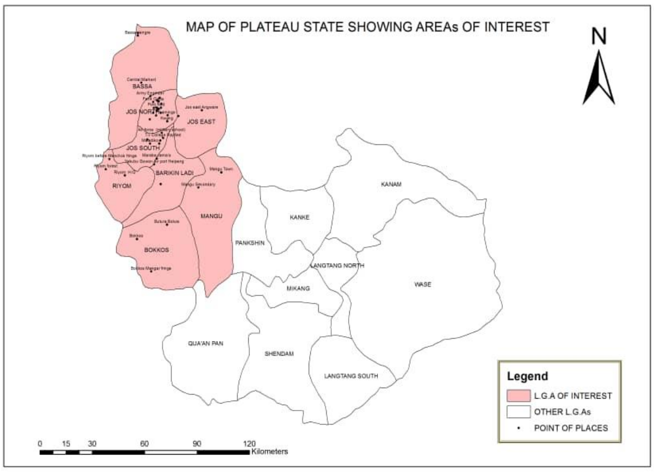

Figure 1: The Study Map (www.researchgate.net)

The map in Figure 1 presents the geographical location of the seventeen (17) Local Government Areas (LGA) of Plateau State with the signal coverage area. The map was downloaded from www.researchgate.net and modified to suite the purpose of the research using geographical information system software (ArcGIS). The Table 1 presents the ITS transmitter parameters.

Table 1: The ITS network parameters

S/N	Parameter	DVB-T2 Value
1	TX frequency	522 MHz
2	Effective isotropic radiated power (EIRP)	62.14dBm
3	Base station location and Geographical Coordinate	Latitude: 9.89°, Longitude: 8.87°
4	Base station transmitted power (Kw)	1.3 Kw
5	Base station frequency (MHz)	522 MHz
6	Transmitting antenna height (m)	107 m
7	Mobile antenna height (m)	10 m
8	Antenna Pattern	Horizontal – Omnidirectional

3.1 Equipment used

The digital spectrum analyzer Deviser E8000A series was used to measure the key parameters. To ensure high stability and relative precision using spectrum analyzer in carrying out field measurement in broadcasting, ITU recommendations on field measurement, relevant equipment and settings specified were followed (ITU-R, 2011).

The measurement tool for the field test system comprise of test equipment carried in a Van and driven to test locations within the selected areas. The test equipment used as presented in Figure 2 include:

A. A Calibrated Logarithmic Antenna
B. Dedicated decoder (Digital Terrestrial Receiver) capable of decoding (DVB-T2) signals
C. A Deviser Spectrum analyzer E8000A series
D. A Television monitor capable of displaying SDTV and HDTV (DVB-T2) signals
E. Global positioning satellite (GPS) enable smart phone for location detection
F. 75Ω, 15m RF cable and connectors

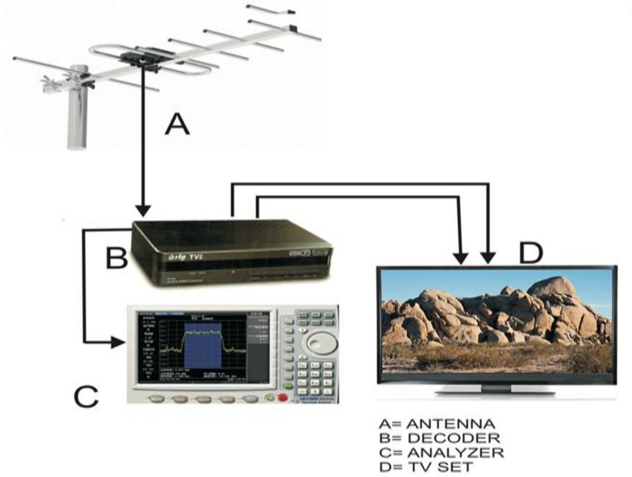

Figure 2: Equipment setup for field measurement

The set-up for field strength, received signal strength and reception quality measurement (ground and rooftop level) procedure was carried out to achieve acceptable result as laid down by ITU for frequency managers, monitoring services, and broadcasters etc.

3.2 Data collection

The measurement of the RSS, channel power and field strength using the ITS signal was carried out along the four routes (A_1, A_2, B_1 and B_2). The RSS data for the Four (4) routes were obtained with the 10m height RF receiver on each location. The geographical coordinates of the locations were logged and used as the reference points by the smart phone enable GPS receiver for the routes.

The following are the steps followed in during the data gathering:-

1. The equipment is connected as shown in figure 2
2. The antenna was raised 10-meters above ground level
3. The antenna was oriented for maximum signal level considering the DVB-T2 transmitter clear line-of-sight and other obstacles on the transmitter path
4. The key parameters were measured and recorded i.e. field strength, channel power and RSS
6. The reception quality of the decoded signal was assessed.
7. The coordinates of the location was taken with Google earth map and recorded
8. The above steps were repeated three times at each location.

The spectrum analyzer used could not measure RSS. The RSS was calculated using channel power parameter measured in milli-volts decibel (dBmV). The dBm was converted to RSS in milli-decibel (dBm). The conversion was done using A.H systems Inc. or Cantwell Engineering - useful formulas for radio frequency (RF) related conversions.

$$\text{dBmV} - 10\log10\,(z) - 30 = \text{dBm} \qquad (1)$$

4. Results and Discussions

The service grade classification of the DVB-T2 signal in Jos and its environs as investigated using Integrated Television Services limited signal were classified into primary, secondary and tertiary (fringe) zone as outlined in the literature review. The study equally produced signal strength propagation curve needed by broadcast Engineers for adequate DTT planning. The graphs in Figure 3, 4, 5 and 6 are presented using 3- dimensional Pie chart graph.

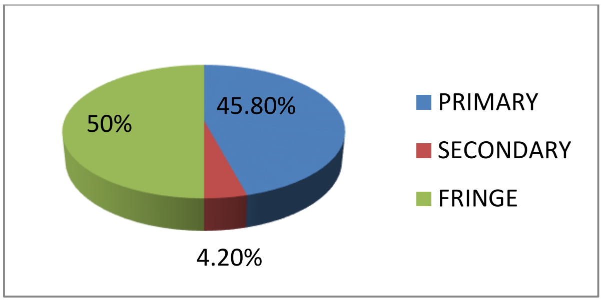

Figure 3: Coverage Analysis for Route A_1.

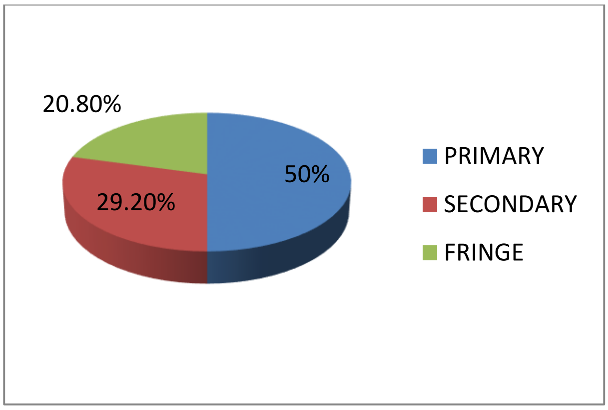

Figure 4: Coverage Analysis for Route A_2

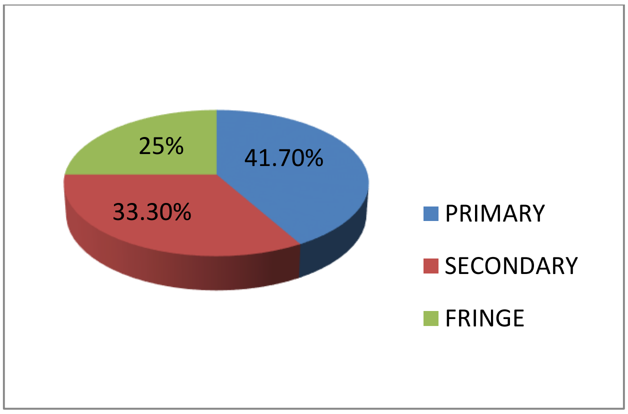

Figure 5: Coverage Analysis for Route B_1.

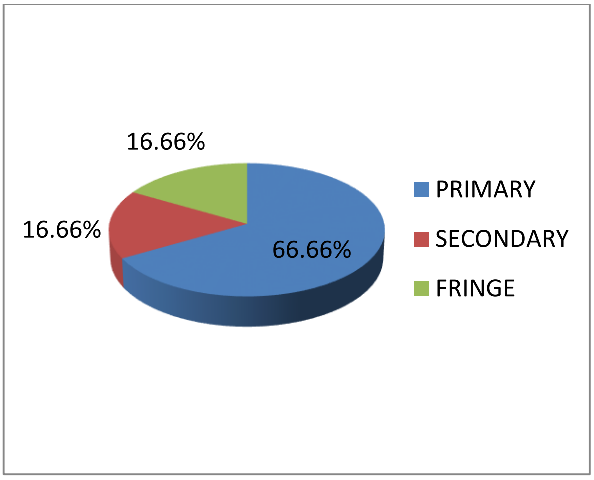

Figure 6: Coverage Analysis for Route B2.

The coverage analysis of both routes A (A1, A2) and B (B1, B2) presented a great improvement in signal coverage area. The Table 2 presents the different results obtained from the graphical analysis?

Table.2: Coverage Analysis ITS Signal

Route	Primary Coverage	Secondary Coverage	Fringe Coverage
A1	45.8%	4.2%	50%
A2	50%	29.2%	20.8%
B1	41.7%	33.3%	25%
B2	66.66%	16.66%	16.66%

The coverage analysis in Table 2 presented the following results, route A_1, primary coverage: eleven locations presented values in the bracket of (-41.6 to -53dBm) representing 45.8% of the coverage area, secondary: only a location presented (-55dBm) representing 4.2% and fringe coverage: 12 locations (-68.4 to -87.1dBm) representing 50%. Route A2, primary coverage: 12 locations (-36.4 to -47.6dBm) representing 50%, secondary: 7 locations (-62 to -67.7dBm) representing 29.2% and fringe: 5 locations (-69.1 to -85.2dBm) representing 20.8%. Route B1, primary: 10 locations (-42.2 to -52.8dBm) representing 41.7%, secondary: 8 locations (-53.2 to -65.1dBm) representing 33.3% and fringe: 6 locations (-68.8 to -72.4dBm) representing 25% of the coverage area. While Route B2, primary coverage: 16 locations (-36.5 to -55.2dBm) representing 66.66%, secondary: 4 locations (-54.1 to -66.1dBm) representing 16.66% and fringe coverage: 4 locations (-69.1 to -69.7dBm) representing 16.66% of the coverage area.

Furthermore, the result in Table 2 recorded an improvement between A_1- A_2 and B_1- B_2. The primary coverage of route A presented an improvement of 4.2%, secondary: 25% and 29.2% in the fringe zone while in route B, the following improvements were recorded, primary: 24.96%, secondary: 16.64% and 8.34% in the fringe zone).

The difference in A_1, A_2 and B_1, B_2 implies that rain and its properties have great influence on signal transmission and propagation. The measurement done in the dry season recorded higher signal output.

The Figure 7 presents the coverage map of the investigated area. The signal coverage map was developed using the

Geographical information system software (ArcGIS). The map shows the different locations in route A and B in the coverage area of Jos and its environs.

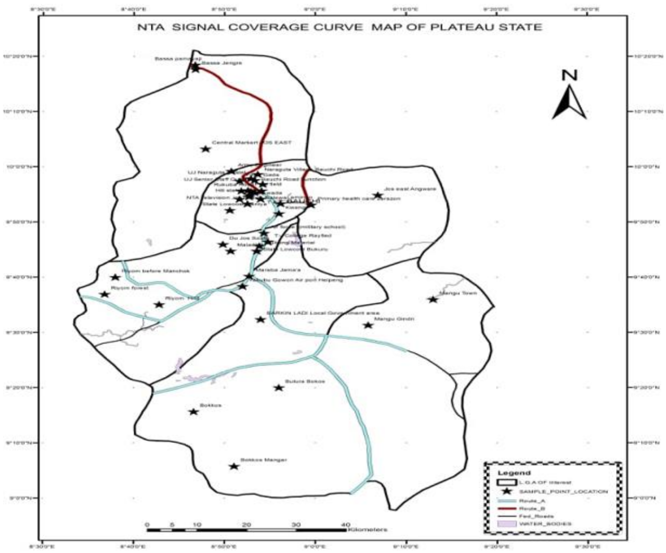

Figure 7: Map of Jos and its Environs showing the Signal Coverage Area

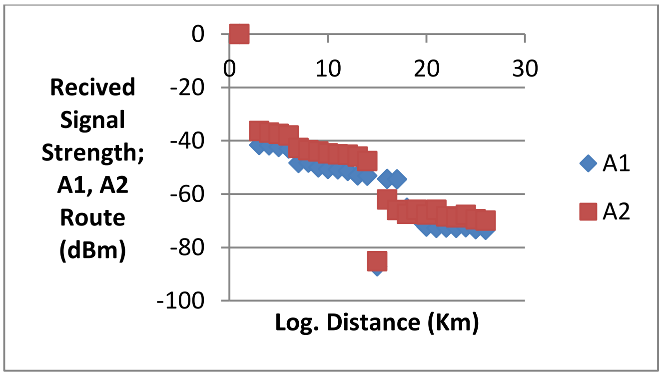

Figure 8: Plot of RSS of Route A1, A2 vs. Log. Distance

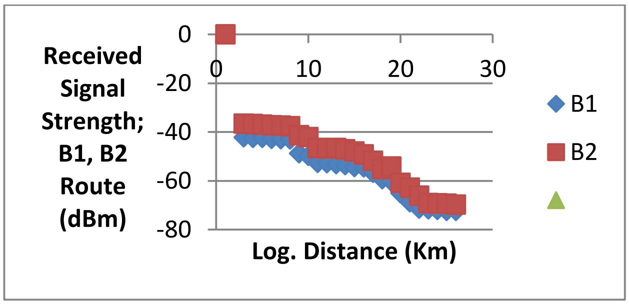

Figure 9: Plot of RSS on Route B1, B2 vs. Log. Distance

The graphs in Figure 8 and 9 present the received signal strength (RSS) levels between route A_1 - A_2 and B_1 - B_2 and their difference along same route in different seasons. However, apart from the attenuation arising from the terrain, the results shows that the measurements obtained in the dry season recorded higher RSS due to less raining activities compared to the results obtained in the wet season. This is because DTT signals surfers the effect of surface refractivity in the wet season compared to dry season (Akinbolati *et al*., 2017).This validates the fact that rain has tremendous effect on the signal propagation.

4.1 Propagation curve

This section presents the result on the impact of LOS separation distance on RSS over each of the routes in the wet and dry season. The Figure 10 and 11 present the propagation curve of route A and B in wet and dry season. The RSS undulates with distance between the wet and dry season. However, it does not vary inversely as anticipated hypothetically by the inverse square law. This is due to the terrain and atmospheric condition peculiar to the routes. As the distance between the transmitting stations to the receiver station increases, the path-loss increases. The common observation on the impact of LOS distance on RSS in route A1, A2 (wet and dry season), RSS drops to about -87.1 dBm and -85.2 dBm of its average initial base station value (-41.6 dBm and -36.4 dBm) at about 12.38 Km from the base station as presented in Figure 10.

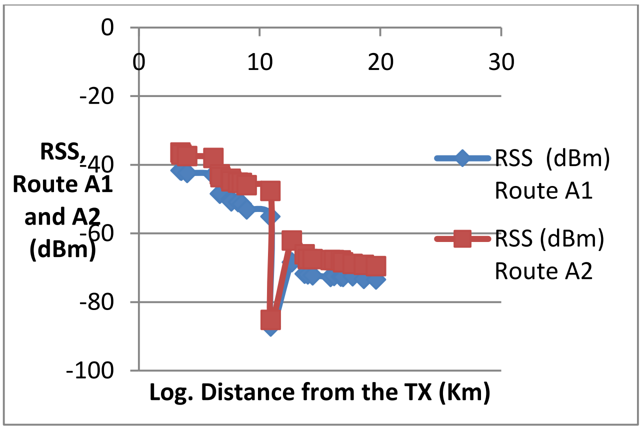

Figure 10: Propagation Curve Showing the Signal Strength with Log. of Distance of Route A

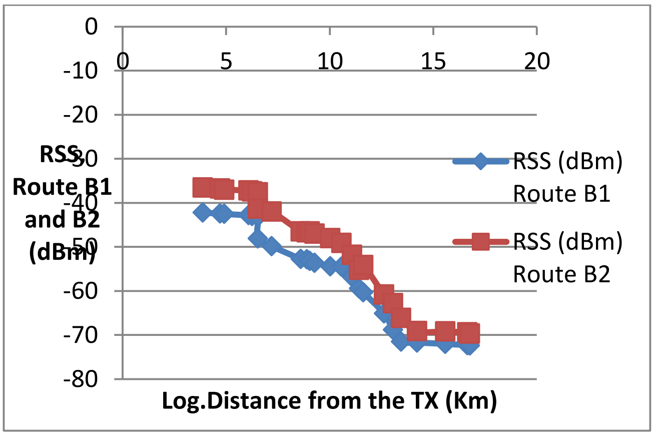

Figure 11: Propagation Curve Showing the Signal Strength with Log. of Distance of Route B.

The Figure 11 presented a similar variation at about 10.07 Km from the base station, the RSS drips from the -42.2 dBm and -36.5 dBm to -54.4 dBm and -48dBm respectfully. From the analysis in Figure 10, the signal strength decreases to a little about half of its initial value while in Figure 11, the decrease was not up to half of its initial value. Furthermore in a situation where the decrease is up to half of its initial value then, the distance is called the Average Half Decay (AHD).

5. Key Contributions

The following milestones were achieved towards the advancement of knowledge by this research study.

1. Signal strength propagation curve needed by broadcast Engineers for adequate DTT planning has been developed for Jos and its environs, Plateau State.
2. The digital television signal coverage for Jos and its environs was classified into primary, secondary and Fringe zone.
3. This research work has provided a set of data that will lead to the understanding and planning of DVB-T2 broadcast network in Plateau State, Nigeria.

6. Conclusion

The evaluation of DVB-T2 transmission network in Jos and its environs established that digital transmitter has good signal coverage area between the TX and the Rx. The DVB-T2 system functions on the basis of less transmitting power with lower reception signal levels. However, most areas within the primary and secondary coverage had quality, robust and reliable service apart from the fringe zones.

The empirical analysis from the result recorded an improvement between A1- A2 and B1- B2. The primary coverage of route A (A_1-A_2) presented an improvement of 4.2%, secondary: 25% and 29.2% in the fringe zone while in route B (B_1-B_2), the following improvements were recorded, primary: 24.96%, secondary: 16.64% and 8.34% in the fringe zonea.

The analysis from the result and discussion clearly classified the digital terrestrial television signal in Jos and its environs into primary, secondary and tertiary (fringe) zone based on the ITU-R recommendation. Furthermore, the signal coverage curved was equally developed which will aid broadcast network planning in Jos, Plateau State. The future research will focus on the following:-

1. Prediction of digital terrestrial television coverage using machine learning regression analysis
2. Attenuation a factor of terrain (vegetation, soil moisture, trees heights) on DTT signals
3. Path-loss due to tropospheric scatter and their comparison to simulation results calculated with various propagation models.

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