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Research

Investigative Assessment of the Impact of Perturbations on the Digital Terrestrial Television Broadcasting Signal

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Digital Terrestrial Television Broadcasting *(DTTB)*, Digital video broadcasting-Terrestrial - Second Generation *(DVB-T2)*, Field Strength, Received Signal Strength *(RSS)*.

Abstract

This study examines the effects of perturbations on the digital terrestrial television broadcasting (DTTB) signal in Jos, Plateau State, Nigeria, using measurement-based performance analysis. In order to examine the effects of environmental perturbations on DTTB signal, measurement campaign used the Nigerian Television Authority, Integrated Television Services (ITS) digital video broadcasting -second generation (DVB-T2) signal. The aim of the research was to identify the environmental and atmospheric perturbations with highest impact on DTTB signal. Field measurement was accurately obtained throughout the measurement campaign using the E8000 series spectrum analyzer, a DVB-T2 receiver, and other facilities in order to actualize the two important measurement characteristics, such as field strength and received signal strength (RSS). The outcome showed a significant amount of dips in route A, depriving towns surrounding rocky hills of a DVB-T2 signal, as demonstrated in the Du community with RSS values of -87.1 dBm, 85.2 dBm, and -27.8 dBμV/m, -23.9 dBμV/m for field strength. Additionally, the results show that signal performance was better in the dry season compared to the rainy season (more primary coverage in the dry season compared to the rainy season), with the RSS value being -41.6 dBm versus -36.4 dBm and the field strength value being 34 dB/m versus 38.6 dB/m for route A, or the same on route B. Solving signal propagation issues requires understanding the fundamental metrics driving an increase in perturbations in any broadcast environment. Creating a model to address these issues will help with system evaluation, network planning, and broadcast service operation, ensuring quality of service (QoS).

Nomenclature and units

DTTB	Digital Terrestrial Television Broadcasting
DVB-2	Digital Video Broadcasting Terrestrial – Second Generation
E_i	Electric Field
ITS	Integrated Television Services Latitude
RSS	Received Signal Strength
dBμV/m,	Decibel microvolts per meter
dBm	Decibel-milliwatts
QoS	Quality of Service

1.0 Introduction

The term "perturbations" refers to a physical phenomenon, such as rain, snow, fog, haze, etc., that has a negative impact on the transmission channel and degrades a signal's quality and performance parameters. (Boyd, 2001) Alternately, it may be a phenomenon, such as jitter, attenuation, Doppler effect, absorption, multipath characteristics, fading, shadowing, etc., that alters the waveform of a signal and causes it to perform poorly. Additionally, perturbations are defined as an uncommon variation in a signal's motion, quality, shape, or behaviour along the transmission line (Igbonoba, 2022). Disturbances in the telecommunications sector could be caused by the environment, the atmosphere, or other elements.

The traditional analogue approach to broadcasting has been modified and revolutionized by the use of technology. A broadcast method known as digital broadcasting relies on bit streams to transmit audiovisual media information (Punchihewa, 2010). All parties involved, including broadcasters, viewers, and regulators, will greatly benefit from the introduction of DVB-T2 technological services because of the improved spectrum and power efficiency, resistance to channel distortions, additional data services, flexibility in programme quality, increased channel choice thanks to compression technology, and ability to implement Single Frequency Networks *(SFN)* of DTTB over Analogue Television ATV (Idigo and Bakare, 2021).

The characterization of wireless channels has received a lot of attention in order to facilitate the successful implementation of communication systems (Luo at al., 2018). This spans from Gudmundson's landmark paper (1991), who proposed a straightforward decreasing correlation model for shadow-fading outdoor radio channels, to more recent contributions like (wyne et al., 2009) that took correlation in indoor channels due to both multipath reflections and shadowing, as well as the processing of phase noise using pulse Doppler processing algorithms and sidelobe blanker techniques, into consideration (Aubry et al., 2016).

The researchers (Luo et al., 2018) used deterministic Allan Variance *(AVAR)* methods to explore the perturbation components of wireless signals in RSS modeling and measurements. The aim was to have a deeper comprehension of the RSS signal. The results show that AVAR may be used to create a flexible model of the RSS perturbations as expressed by coloured noise components, but they were unable to pinpoint any issues that might have arisen during the process. In the research article from (Idigo and Bakare 2021) used Port Harcourt and its surroundings as a case study to give a measurement-based performance analysis of startimes television broadcasts in the south-south region of Nigeria. The Received Signal Power *(P)*, Modulation Error Rate *(MER)*, Pre-Bit Error Rate *(CBER)*, and Post Bit-Error Rate *(LBER)* were measured as the important parameters utilized to determine the performance analysis between channel 17 and channel 51 using the test bed methodology approach. The outcome showed that Channel 17 had a higher MER than Channel 51. The results showed that Channel 17 has a better MER than Channel 51 because its signal extends to the north and south of the transmitter, respectively, but they were unable to identify the determining factor. (Ojo et al., 2021) investigated how atmospheric variables (atmospheric temperature, pressure, relative humidity, wind speed, and noise temperature) affected the intensity of the digital terrestrial television signal over the Karshi area of Abuja, in the north-central region of Nigeria. The goal of the study was to identify a straightforward method for reducing the impact of various meteorological conditions on DTT signal strength reception. They used a straightforward field measuring approach. The results showed that relative humidity had a strong influence on signal strength while atmospheric and noise temperature, wind speed, and wind direction had a weaker influence. However, the researchers were unable to determine which of the measured parameters had the greatest impact on DTT signal. Deep neural networks for digital communications were subjected to real-time over-the-air adversarial perturbations by (Sandler et al., 2022). The research's contribution was the definition of adversarial perturbations that are class-specific and sample-independent. The outcome demonstrated that sources other than the communications device are capable of emitting adversarial disturbances. In order to determine whether there are transmitters that broadcast signals with various types of modulation, (Kim et al., 2022) examined the channel-aware adversarial attacks against deep learning-based wireless signal classifiers. Deep neural networks were used at each receiver to categorize the modulation kinds of the over-the-air signals that were received to achieve this. The investigations certified defence, which adds noise to training data to make the modulation classifier resilient to adversarial perturbations, was offered as a conclusion. The researcher was unable to develop a proven algorithm for their experimental procedure.

Since environmental and atmospheric disturbances are the main issue affecting signal propagation in the broadcast and telecommunication industries, this research concentrated on them.

1.1 Key Performance Indicators for DTTB Signals

Communication engineers have demonstrated that the field strength and received signal strength *(RSS)* are accurate measures for assessing the effects of perturbations on the DTTB signal within the broadcast network services. To actually understand the influence of perturbations on the digital signal transmission medium, it is still essential to use the field strength and RSS parameters that were collected through the field measurement campaign methods in point-to-area digital transmission systems of DTTB. Each test offers a quantifiable and helpful indication of the system's performance that is closely correlated with its operational performance (Idigo and Bakare, 2021). These two crucial variables are frequently employed to describe digitally modulated transmissions.

(i) Field Strength

The intensity of an electric field at a specific location is expressed quantitatively as the electric field strength *(E)*. The volt per metre *(v/m or v m-1)* is the common unit. A potential difference of one volt between locations spaced apart by one meter is represented by field strength of 1 v/m.

$$E_T = \sqrt{\sum_{i=1}^{19} (E_i)^2} \quad (1)$$

where; Ei is the electric field for i^{th} band. E19 is the electric field caused by the other transmitters (Kurnaz and Engiz, 2016)

(ii) Received Signal Strength (RSS)

The strength of a signal received is measured at the antenna of the receiver and is known as the received signal strength *(RSS)*. The broadcast power, the separation between the transmitter and the receiver, and the radio environment all affect RSS (Chen and Yang, 2012). It is challenging to make up measurements arbitrarily, and the received signal strength is closely tied to the transmitter's position. Using Friis's function (Xi et al., 2016).

$$RSS = 10Log\left(\frac{P_{R_x}}{1mW}\right) \quad (2)$$

We can model RSS as

$$RSS=10Log\left(\frac{P_{T_x}}{1mW} \; T_b G_r^2 \, G_t^2 \left(\frac{\lambda}{4\pi d}\right)^4\right) \quad (3)$$

where, P_{T_x} is the transmit power, G_r is the power of the antenna, G_t is the typical gain for real dipole-like tag antenna. T_b is the backscatter transmission loss.

In a practical wireless system, the following elements, such as:

- Path loss on a large scale caused by the distance between transmitter and receiver.
- The effect of large objects in the channel between the transmitter and receiver is known as medium scale fading or shadowing.
- Small-scale fading is the result of the addition of multipath waves at the receiver, either constructively or destructively, as it moves on the order of a wavelength.
- Temporal fading brought on by the movement of people and things around us.
- Interference brought on by other signals being transmitted in the same band.
- Thermal clamour fluctuations in transmit power brought on by battery life, climate, or other hardware changes in the transmitter.
- Changes in the receiver's RSS measurement circuit brought on, once more, by battery, temperature, or other hardware changes.

Any uncertainty can be modeled using a random term in this way, which may contain more effects than just thermal noise. These guidelines provide a straightforward approach to explain RSS and manage its mathematical expression. However, they are only possible if the PSD of the noise is roughly distributed evenly across the unbounded bandwidth. The perturbations can no longer be regarded as being uncorrelated if significant fluctuations are observed or exist in the PSD, hence this issue needs to be taken into consideration (Luo et al., 2018).

(iii) Propagation of DTTB Signal

System evaluation, network planning, and broadcast service operation all need careful consideration of the effects that electromagnetic wave interactions with the propagating medium have on the radio signal propagation in a television (TV) broadcasting system. Depending on the occurrence of particular propagation effects, changes in velocity, phase, dispersion, signal degradation, etc. can be modeled (Aragón-Zavala et al., 2021). The DTTB may experience coverage gaps as a result of the frequency bands' propagation characteristics, geographical obstacles, and man-made clutter. Digital TV requires precise forecasts, but analogue TV does not (Saunders and Aragón-Zavala, 2007). Changes in signal characteristics for terrestrial fixed links and NLOS are summarized in Figure 1.

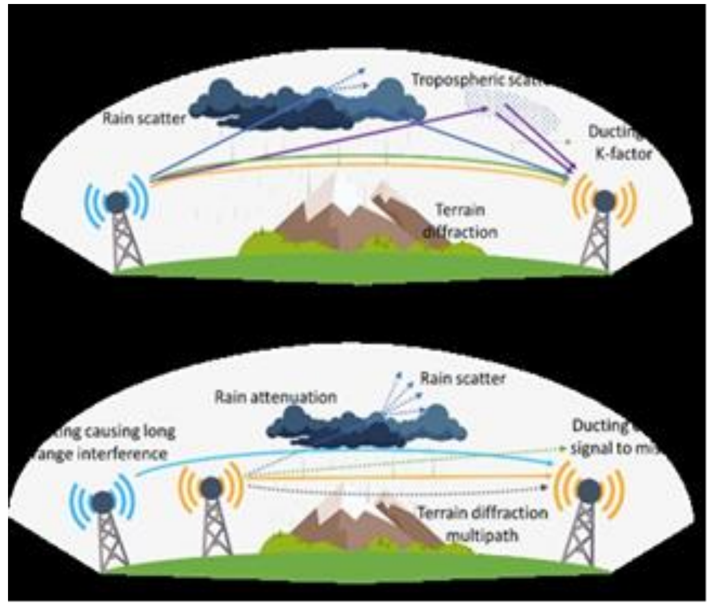

Figure 1 Propagation mechanisms affecting DTTB systems (Aragón-Zavala et al., 2021).

(iv) Digital Terrestrial Television Broadcasting (DTTB) Coverage Areas

All digital terrestrial television stations have their expected coverage areas and their signals should not constitute interference to others. The determination of coverage areas of broadcast channel is useful in the assessment of quality of service (QoS) rendered by broadcasting stations so as to minimize coverage failures and maintenance of the areas the station was originally designed to service (Akinbolati et al., 2020). The coverage areas for digital terrestrial broadcast channels are classified into three as stated below.

(a) Primary Coverage Area for DTTB

This is referred to as a zone near the transmitting station when the signal strength is sufficient to always overcome common interference. The signal strength can be reliably received. The signal strength is consistent and can always be plainly heard. ITU-R BT. 2035 (2003) states that the signal level corresponding to the DTTV principal coverage region is Received Signal Strength (RSS) ≥- 53dBm (Igbonoba and Obayuwana, 2021).

(b) Secondary Coverage Area for DTTB

The signal strength in this area close to the transmitting station is frequently good enough to be useful but is not always strong enough to cancel out regular interference. For a clear reception, an active receiving antenna can be required. The signal level equal to DTTV secondary coverage region can be categorized as: -54 ≥RSS ≥ -68dB, under ITU-R standard, ITU-R BT. 2035 (2003). (Igbonoba and Obayuwana, 2021).

(c) DTTB Tertiary Coverage Area Fringe

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The signal strength around the transmitting station is frequently low and unreliable; neither its service nor its immunity to interference can be guaranteed. It's possible that using an active receiving antenna won't always result in a clear reception. ITU-R BT. 2035 (2003) states that the signal level equal to the DTTB fringe coverage region is: -68 ≥RSS ≥ -116dBm (Igbonoba and Obayuwana, 2021).

2.0 Materials and Methods

(a) Study Area

The city of Jos is located in Plateau State, Nigeria. Geographically, the city has an elevation of 1,220 meters above the sea level with coordinates of 09° 55' 00''N and 08° 53' 25''E. The city of Jos is situated in the Guinea Savanna agro-ecological Zones of the middle belt region of Nigeria with rocky hilly features. The Figure 2 presents the Google map of Jos and its environs.

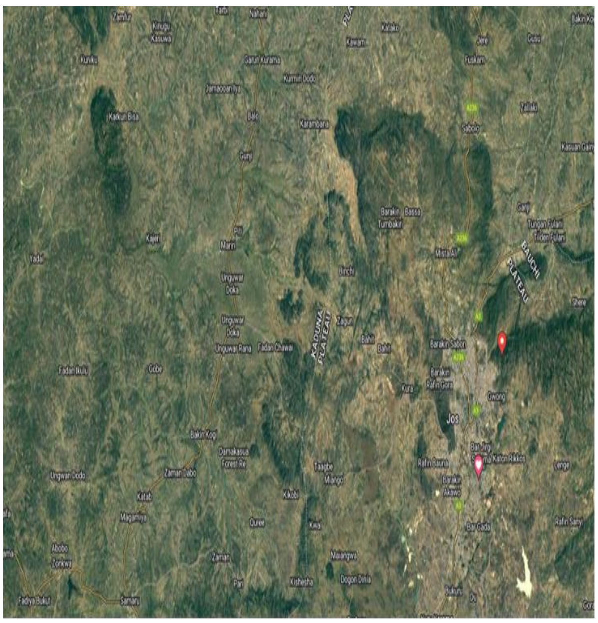

Figure 2 Google Map of Jos City

(b) Materials and Measuring Procedure

An E8000A series spectrum analyzer, a DTT receiver *(set-up-box)*, a receiving antenna, smart phone-enabled Google Earth map software, a personal computer *(PC)* system, a television, a power producing set, and other auxiliary facilities are among the tools utilized to collect data for this campaign.

Using a straightforward field measurement approach methodology, the test facilities were set up in the measurement campaign setting. This was created to produce the necessary research data for use in additional analysis and study. The measurement campaign was conducted in the Nigerian Plateau State metropolis of Jos and its surroundings. Two major routes, A and B, and a total of 96 measuring locations were established, spanning both the wet and dry seasons. Twenty-four measuring points were allowed on each route per season (i.e. route A subdivided into A1, A2 and route B into B1, B2; A1, B1 represent wet reason in different routes while A2, B2 represent dry season). The Deviser E8000A spectrum analyzer assessed received signal strength and field strength (dBμV/m, or decibel microvolts per metre) (dBm – decibel milliwatts). ITU recommendations on field measurement, pertinent equipment, and settings specified in (Igbonoba and Omoifo, 2021) were followed to adopt specified ITU regulations. This was done to ensure high stability and relative precision when using a spectrum analyzer to conduct field measurements in broadcasting. The test equipment for the field test system is carried in a van and driven to the test sites within the chosen areas as the measuring tool.

For the measuring campaign, the Integrated Television Services *(ITS)* signal was utilized. At the time of this research, the network *(ITS)*, which operates on a frequency of 522 MHz as assigned by the National Broadcasting Commission *(NBC)*, is the only DVB-T2 network operator in Plateau State. The working network characteristics for the ITS transmitter are shown in Table 1.

Table 1 ITS Network Parameters

S/N	Parameter	DVB-T2 Value
1	Carrier frequency	522MHz
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)	1.3Kw
5	Base station frequency (MHz)	522MHz
6	Transmitting antenna height (m)	107m
7	Mobile antenna height (m)	10m
8	Antenna Pattern	Horizontal – Omnidirectional

(c). Experimental Set-Up

The DVB-T2 receiver with the cable system and the E8000 series spectrum analyzer were attached to the signal receiving antenna as shown in figure 3 (a and b). The E8000series spectrum analyzer was then used to measure and record the field strength and received signal strength (RSS) at the appropriate measuring locations in the months of July/August and November/December of 2021.

(a)


(b)

Figure 3 Connection of E8000A series analysis to the receiving antenna.

2.1 Data Presentation

The tables 2 and 3 present the data obtained from the field measurement with respect to different distances from the transmitter and the location coordinates presenting the measured variables' value such as the field strength and received signal strength cutting across the ninety six (96) locations in both wet and dry season were presented.

3.0 Results

The data analysis of the result obtained from the field arising from the two key parameters implied how terrain and atmospheric condition impacted negatively on DTTB signal in Jos and its environs. The figure 4 -5 and Figure 6 – 7 present the graph of RSS vs Log. Distance and field strength *(FS)* vs Log. Distance of routes A_1, A_2 and B_1, B_2 respectively

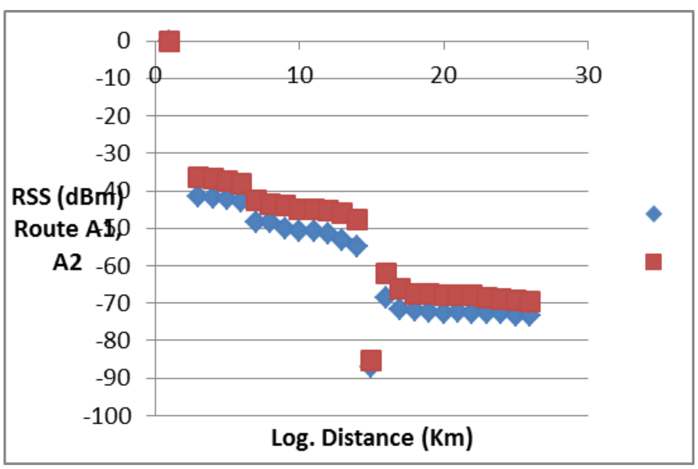

Figure 4 Plot of RSS vs. Log. Distance in Route A_1, A_2

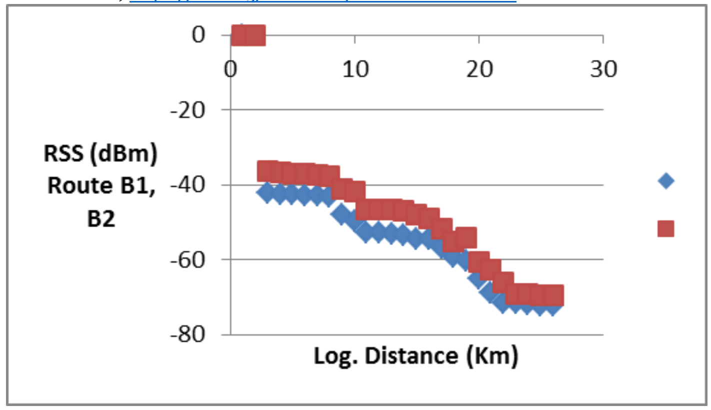

Figure 5 Plot of RSS vs. Log. Distance in Route B_1, B_2

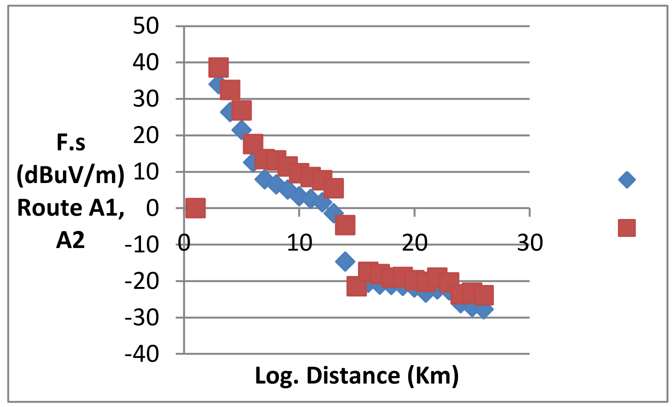

Figure 6 Plot of FS vs. Log. Distance in Route A_1,A_2

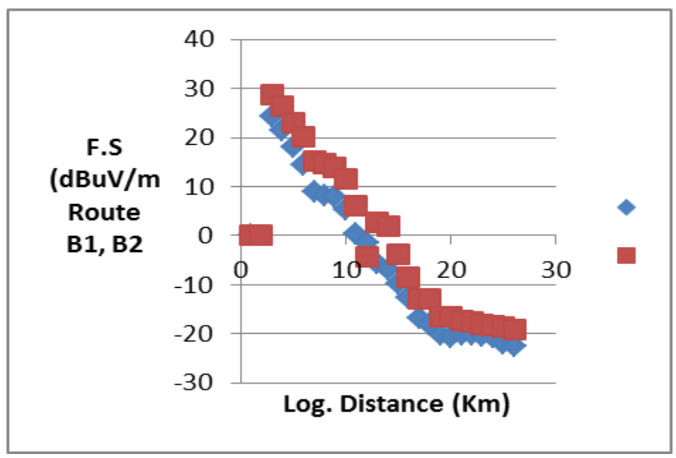

Figure 7 Plot of FS vs. Log. Distance in Route B_1, B_2

4.0 Discussions

4.1 Coverage Area Analysis of the Different Routes Investigated

The service grade classification of the DVB-T2 signal in Jos as investigated using Integrated Television Services limited signal was represented using 3- dimensional Pie chart graph and the charts are presented in Figure 8 -9

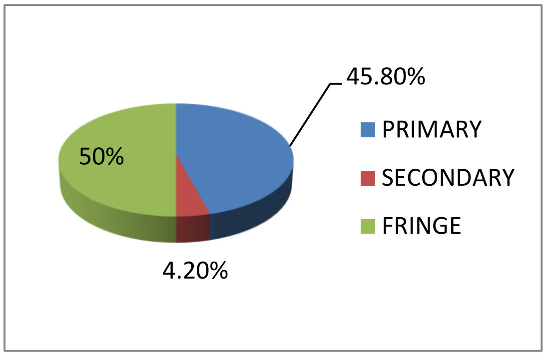

Figure 8a Coverage Analysis for Route A1

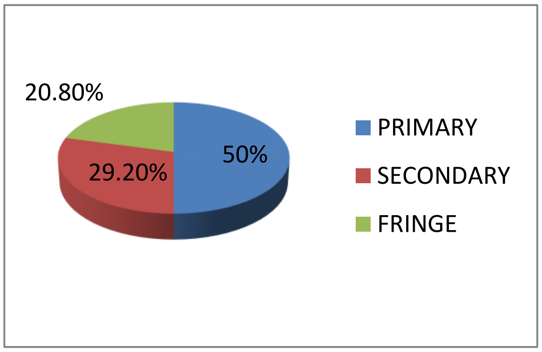

Figure 8b Coverage Analysis for Route A2

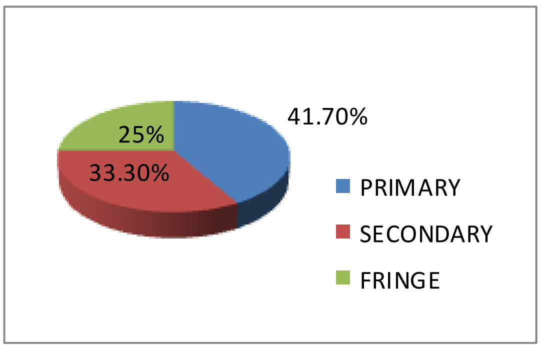

Figure 9a Coverage Analysis for Route B1

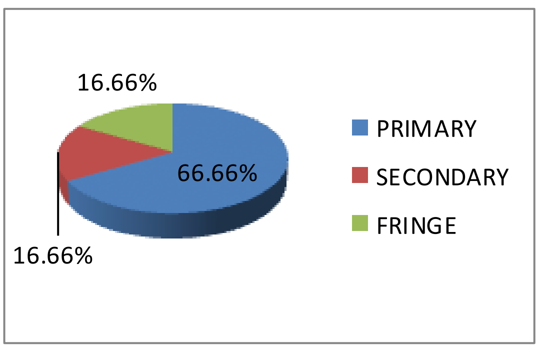

Figure 9b Coverage Analysis for Route B_2

The coverage analysis of both routes A (A_1, A_2) and B (B_1, B_2) presented a great improvement in the signal coverage area. The different signal coverage analysis results as obtained from the field as presented in Figure 8 and 9 recorded an improvement between route A_1, A_2 and B_1, B_2 due to the variation in the atmospheric conditions associated with rain. The primary coverage of route A presented an improvement of 4.2%, secondary: 25% and a reduction of 29.2% in the fringe zone while in route B, (primary: 24.96%, secondary: 16.64% and a reduction of 8.34% in the fringe zone).

4.2 Findings

1. It was found that rocky hills and rain were the key perturbations degrading the DVB-T2 signal quality in Jos and its environs as investigated.
2. It was equally found that the rocky hills created a lot of dips along the measured paths

5.0 Conclusions

This work has verified the DVB-T2 signal's extensive coverage, which was determined from the findings of a field measurement campaign that was conducted in Jos and its surroundings in Plateau State. The values of field strength and received signal strength *(RSS)* collected from the field were used to determine the impact of perturbations on DTTB reception or signal quality. It suggests that the two main factors affecting signal quality in the environment studied were rain and rocky hills. The field strength and RSS values in Tables 2 and 3 show a significant amount of dips in route A, preventing DVB-T2 signal from reaching villages near rocky slopes, as demonstrated in the Du community with RSS values of -87.1dBm, 85.2dBm, and -23.9dBmμV/m and -27.8dBmμV/m in terms of field strength. Additionally, the results suggest that signals are better in the dry season than the rainy season (more primary coverage in the dry season than the rainy season), with the RSS value being -41.6 dBm versus -36.4 dBm and the field strength value being 34 dBμV/m versus 38.6 dBμV/m for route A and alternatively the same on route B at its peak.

In order to ensure quality of service *(QoS)* delivery, system evaluation, network planning, and broadcast service operation will all benefit from pinpointing the main disturbances in any broadcast environment under consideration and developing a model to overcome them.

Contribution to Knowledge

The research work has provided a set of data in appreciating the key perturbations impacting on DVB-T2 signal thereby giving room to better understanding and planning of DVB-T2 broadcast network in Nigeria.

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Declaration of conflict of interest

No conflict of interest

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Table 2: Field Strength and RSS Data of DVB T2 Signal along Route A_1, A_2.

S/N	Location	Coordinate (Latitude/Logitude)	Distance (Km)	RSS_1 (dBm)	RSS_2 (dBm)	FS_1 (dB$\mu V/m$)	FS_2(dB$\mu V/m$)
1	Tudun Wada Urban	Lat:9.90,Log:8.88	2.22	-41.6	-36.4	34	38.6
2	Tudun Wad Rural	Lat:9.87,Log:8.88	2.25	-41.7	-36.9	26.4	32.4
3	Airforce Military Sch.	Lat:9.87,Log:8.89	2.51	-42.3	-37.4	21.4	26.8
4	State Lowcost, Rantya	Lat:9.86,Log:8.86	4.14	-42.9	-38	12.6	17.6
5	NTA TVC, Rayfield	Lat:9.50,Log:8.53	4.71	-48.4	-42.7	7.9	13.4
6	NTA TVC, Rayfield	Lat:9.52,Log:8.54	4.74	-48.2	-43.6	6.5	13.1
7	Maiadiko	Lat:9.83,Log:8.89	5.75	-50	-44	5.1	11.4
8	Building Material	Lat:9.84,Log:8.86	5.85	-50.6	-44.8	3.2	9.6
9	Lamingo	Lat:9.90,Log:8.93	6.66	-50.8	-45.1	2.5	8.5
10	Kwang	Lat:9.85,Log:8.82	7.15	-51.4	-45.2	1.6	7.6
11	State Lowcost, Bukuru	Lat:9.83,Log:8.86	7.85	-53	-45.9	-1.4	5.4
12	DU	Lat:9.52,Log:8.55	12.34	-55	-47.6	-14.7	-4.7
13	DU	Lat:9.50,Log:8.54	12.38	-87.1	-85.2	-21.5	-21.5
14	Mararaba Jumai	Lat:9.72,Log:8.86	18.49	-68.4	-62	-20.5	-17.5
15	Riyom Hq	Lat:9.66,Log:8.87	23.6	-71.7	-66	-21	-18.1
16	Riyom Market	Lat:9.62,Log:8.74	25.2	-71.9	-67.4	-21.1	-19.1
17	Heipeng Airport	Lat:9.66,Log:8.89	27.52	-72.2	-67.4	-21.4	-18.9
18	Barkin Ladi Urban	Lat:9.68,Log:8.88	38.64	-72.7	-67.7	-21.8	-19.8
19	Forest	Lat:9.68,Log:8.79	41.3	-72.4	-67.7	-23.2	-20.2
20	Mangu Town	Lat:9.69,Log:8.80	47.22	-72.6	-67.8	-22.3	-19.1
21	Mangu Gindri	Lat:9.67,Log:8.82	49.14	-72.7	-68.4	-22.6	-20.4
22	Butura Bokkos	Lat:9.42,Log:8.95	61.67	-72.5	-68.8	-26.1	-23.7
23	Bokkos Town	Lat:9.43,Log:8.89	70.18	-73.2	-69.1	-27.2	-23.2
24	Bokkos Mangar	Lat:9.38,Log:8.86	92.17	-73.4	-69.5	-27.8	-23.9

Table 3: Field Strength and RSS Data of DVB-T2 Signal along Route B1, B2.

S/N	LOCATION	Coordinate	Distance (Km)	RSS_1 (dBm)	RSS_2 (dBm)	FS_1 (dB$\mu V/m$)	FS_2(dB$\mu V/m$)
1	Hill Station	Lat:9.54,Log:8.52	2.44	-42.2	-36.5	24.3	28.6
2	Police HQ, Gomwalk RD.	Lat:9.91,Log:8.88	2.95	-42.4	-36.7	21.4	26.3
3	T $ T Junction	Lat:9.90,Log:8.90	3.09	-42.5	-37	18.1	23.1
4	Tafawa Belewa RD.	Lat:9.92,Log:8.89	4.05	-42.8	-37.2	14.3	20.2
5	Tafawa Belewa RD.	Lat:9.92,Log:8.88	4.21	-43	-37.4	8.9	15.2
6	Polio Field	Lat:9.93,Log:8.87	4.5	-43.1	-37.6	8.3	14.7
7	Rukuba Road	Lat:9.95,Log:8.86	4.5	-48.1	-41.3	8	14
8	Agwan Rukuba	Lat:9.93,Log:8.91	5.24	-49.8	-42	5.4	11.6
9	UJ Senior Staff QTR.	Lat:9.95,Log:8.90	7.25	-52.7	-46.5	0.4	6.1
10	Faringada	Lat:9.58,Log:8.89	7.75	-52.8	-46.7	-1.4	-4.2
11	Bauchi RD. Junction	Lat:9.95,Log:8.90	8	-53.2	-46.5	-5.6	2.6
12	UJ Naraguta Hostel	Lat:9.96,Log:8.89	8.44	-53.6	-47	-6.9	1.9
13	Naraguta Village, Bauchi RD.	Lat:9.99,Log:8.90	10.07	-54.4	-48	-9.9	-3.9
14	Army Engineers, Zaira RD.	Lat:9.97,Log:8.85	11.37	-54.5	-49.1	-12.6	-8.6
15	Zarazon Health Care	Lat:9.98,Log:8.87	12.83	-56.8	-51.8	-16.9	-12.9
16	Central Market	Lat:9.99,Log:8.85	13.6	-59.4	-55.2	-18	-13
17	LEA School	Lat:9.96,Log:8.88	14.5	-60.3	-54.1	-20.1	-16.6
18	Rukuba Barrack	Lat:9.96,Log:8.85	18.3	-65.1	-60.8	-20.6	-16.6
19	Bassa Hq	Lat:9.95,Log:8.87	20.2	-68.8	-62.8	-20.3	-17.3
20	NNPC Depot	Lat:9.92,Log:8.88	22.1	-71.5	-66.1	-20.1	-17.7
21	Angware	Lat:9.93,Log:8.85	26.41	-71.7	-69.1	-20.4	-18.1
22	Riyom Manchok Axis	Lat:9.94,Log:8.86	36.13	-72	-69.2	-20.7	-18.4
23	Jengre	Lat:9.95,Log:8.87	46.13	-72.3	-69.4	-22.1	-18.7
24	Pamayaji	Lat:9.94,Log:8.86	47.56	-72.4	-69.7	-22.4	-19.1