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PROPAGATION CURVES AND PATHLOSS EVALUATION FOR UHF WAVE (CHANNEL 22, 479.25MHz) WITHIN KATSINA METROPOLIS

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Abstract
Propagation curve is the variation of the electric field strength of a radio signal with distance whereas signal path loss is essentially the reduction in power density of an electromagnetic wave or signal as it propagates through the environment in which it is travelling. In view of the importance of television broadcasting to the socio-economic development of the populace and the competition of the business in Nigeria, researches that can enhance Quality of Service (QoS) from broadcasting stations have become necessary to radio scientists. The aim of this research is to determine the propagation curves and path loss for Katsina State Television (KTTV) Signal within Katsina metropolis. Measurement of the signal strength was done at an interval of 1km Line of Sight (LOS) using a signal level meter along three radial routes from the transmitter with each route spanning up to 15km . A GPS hand held receiver was used to record the LOS, longitude, latitude and the elevation of the data locations. The three radial routes are route A from KTTV Base station (in Katsina) towards Batsari, route B, KTTV Base station towards Daura and route C from KTTV Base station towards Dutsinma. The signal strength values were used to plot the propagation curves along the routes of measurements. In addition, the data obtained were used equally used to evaluate the path loss using the well acceptable Okumura- Hata model for macro cell prediction. The result of the study shows that signal strength reduces with distance along the three radial routes. It further shows that towns close to the base station receive high signals compared to those far away on the same routes however, there were few exemptions; some farther locations recorded higher signal strength compared to closer locations due to higher elevation values. Also from the result, the average field strength recorded for routes A, B and C are 50.47$dB\mu V$, 46.02 $dB\mu V$ and 49.12 $dB\mu V$ respectively whereas the path loss values were found to be 90.58dB, 89.96dB and 92.73dB for route A, B and C respectively. The difference in the path losses could be associated with the different terrain and terrestrial factors (attenuation factors) peculiar with each route. Furthermore, about 15% of the populace within the metropolis had access to the primary coverage areas of the station whereas about 50% have access to the secondary coverage areas and about 35% are within the fringe coverage of the station. The overall findings will enhance UHF Television Transmission and Reception within the metropolis, the State at large and in any other similar city in Nigeria.

Keywords: *Path loss Evaluation, Propagation, UHF and Katsina*

Introduction and Theorectical Backround

In view of the importance of television broadcasting to the socio-economic development of the populace and the competition of the business in Nigeria, viewer's interest has grown beyond watching just anything on the screen to qualitative clean and sharp signals on television screen. (Akinbolati et al. 2015). Based on this premise, researches need to be carried out to determine the actual coverage areas of broadcasting stations and their optimum signal level within the areas they are designed to cover. Other research in this regard include determination of propagation curves and path loss prediction modeling which is useful for wireless communications planning and design by radio Physicists and Engineers in Nigeria. This is because of the various factors responsible for attenuation of UHF Television signal and other radio waves transmitted in space, such as terrains, weather, output power of the transmitter, height of antenna and transmitter-receiver distance. Propagation curves and path loss estimation are key factors for predicting the power received or lost at a given distance from the transmitter. Many published work had shown that path loss evaluation and modeling play a key role in coverage estimation (Ayeni, et al., 2015). The coverage areas of broadcast stations have a significant influence on the socio-economic life of the populace in this part of the World (Akinbolati, 2015, and Ajewole, et al., 2015) thus making this study a good feedback mechanism between the communities in the study areas and the government

Electromagnetic Spectrum

The electromagnetic (EM) spectrum is the range of all possible frequencies of electromagnetic radiation, which subsumes visible light as well as invisible radiations such as radio waves, infrared light and X-rays. Table 1 presents the different frequencies of electromagnetic spectrum and their applications.

Table 1: Electromagnetic Spectrum and their Applications

Frequency (Hz)	Band	Application
3-30K	Very Low Frequency (VLF)	Audio Telephone, Navigation Employs and Ground wave propagation.
30-300K	Low Frequency (LF)	Navigation aids, Radio beachers telephone.
300-3M	Medium Frequency (MF)	AM broadcast, civil defense.
3-300M	Medium Frequency (HF)	Amateur radio, Mobile radio and Military communication.
30-300M	High Frequency (HF)	VVHF, TV, FM, air traffic police/navy communications.
300M-3G	Ultra High Frequency (UHF)	UHF, TV, Radio space telemetry.

Source: *(ITU-R, 2012)*

Propagation curves

Propagation curve is an essential parameter in radio wave propagation theory and equipment design. It is the variation of the electric field strength of a radio signal with distance (Ajayi, and Owolabi, 1979). It helps to predict the received signal strength (RSS) (Zeinab, et al., 2013) from locations away from the transmitter. It depends on transmitter power, the nature of signal path (rural or urban) and the terrain of the locations involved (Bothias., 1987; Kenedy, and Bernard, 1986). It is used for radio propagation planning and designing (Bothias, 1987).

Path Loss

The signal path loss is essentially the reduction in power density of an electromagnetic wave or signal as it propagates through the environment in which it is travelling. There are many reasons for the radio path loss that may occur (Isobona et al., 2013) .This is the behavior of radio waves when they are transmitted, or propagated from one point on the Earth to another or into various parts of the atmosphere. As a form of electromagnetic radiation, like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, scattering, polarization. Fig. 2 shows the different behaviors of radio wave when they are transmitted in space.

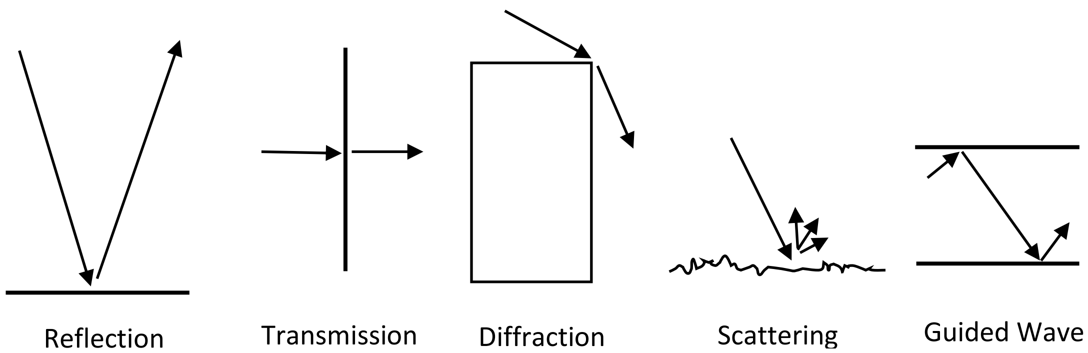

Fig. 2: Different behavior of radio wave when they are transmitted in space

Path loss Prediction Models

There are various propagation prediction models for mobile radio communications systems such as ITU models, Long-Rice model, Okumura-Hata's model, Lee's model, Durin's model, Walfisch and Bertoni's model, Friis transmission equation etc. In this work, attention will be given to prediction model by Okumura-Hata equation. This is because this model has wide acceptability and has been adopted by International Telecommunications Union –Radio (ITU-R) as a model to benchmark new approaches for both **micro** and **macro cells** propagation. (Armoogun et al., 2010)

i. **Okumura-Hata Model for Urban Areas**

The Hata Model for Urban Areas, also known as the Okumura-Hata model is a developed version of the Okumura

Model, and it is the most widely used radio frequency propagation model for predicting the behavior of cellular transmissions in built up areas. This model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection and scattering caused by city structures. This model also has two more varieties for transmission in Suburban Areas and Open Areas. Hata Model predicts the total path loss along a link of terrestrial microwave or other type of communications. This particular version of the Hata model is applicable to the radio propagation within urban areas. This model is suited for both point-to-point and broadcast transmissions and it is based on extensive empirical measurements taken (Akingbade and Olorunnibi, 2013). This model is suited for both point-to-point and broadcast transmissions and it is based on extensive empirical measurements taken in Tokyo Japan, in the year 1968.

Hata Model for Urban Areas is formulated as:

$$Lu = 69.55 + 26.16 \log f - 13.82 \log h_b - \alpha(h_m) + [44.9 - 6.55 \log h_b] \log d \quad (1)$$

For large city with the wave frequency of transmission, $f \geq 400\, MHz$,

$$\alpha(h_m) = 3.2[\log(11.75\, h_m)]2 - 4.97 \quad (2)$$

From equations (1) and (2)

Lu is the path loss in Urban Areas in dB,

h_b, is the height of base station antenna in meters,

h_m, is the height of mobile station antenna in meters,

f, is the frequency of transmission in MHz,

$\alpha(h_m)$ is the antenna height correction factor and

d, is the line of sight distance between the base and mobile stations in kilometer.

By specifications, Okumura-Hata model has the following range for optimum result:

Carrier frequency: $150\, MHz \leq f \leq 1500\, MHz$

Base station height: $30\, m \leq h_b \leq 200\, m$

Mobile station height: $1\, m \leq h_m \leq 10\, m$

Distance between mobile and base station $1\, km \leq d \leq 20\, km$.

(Nizirat et al 2011, Akingbade and Olorunnibi, 2013)

For sub urban area, the path loss is given by

$$L(sub-urban)(dB) = L(urban) - 2\left(\log(f/28)\right)^2 - 5.4 \quad (3)$$

On the other hand, the path loss for open rural area, is given by,

$$L(open)(dB) = L(urban) - 4.78\left(\log(f)\right)^2 + 18.33(\log f) - 40.94 \quad (4)$$

Where $L(urban)$ is the path loss for urban area and

f, is the carrier frequency in MHz .

Materials and Methods

Instrumentation

Table 2 presents the list of instruments that were used for data collection and their purposes whereas Table 3 shows details of the transmission characteristics of the experimental station.

Table 2: Instrument and their uses during this research

Instrument	Uses
Field strength meter	To measure signal strength
GPS GARMIN MAP 78S	To measure the locations Longitude and latitude, and the elevation above sea level. And to monitor the line of sight from the base station.
Vehicle	For mobility along the routes
Coaxial cable	To connect the antenna to the field strength meter
Receiving antenna	Receiving signals from the transmitting antenna

Table 3: Transmission Characteristics of experimental station

Parameter	Characteristics
Base station geographic coordinate	Latitude N 12^0 28.370' Longitude E 7^0 29.145'
Base station elevation	528.0m
Base station carrier frequency/ channel	479.25MHz/22
Transmitter	1Kw
Base station transmitting power(W)	500W
Height of transmitting mast(m)	60.96
Transmitting Antenna gain(dB)	3
Height of receiving antenna (dB)	1.2m

Study Area

Katsina state is located at North West geopolitical zone of Nigeria with Katsina as the state capital it was carved out of Kaduna state in September 23, 1987. The state has 34 local government areas and lies within coordinates 12^0 15'N 7^0 30'E and 12.250^0

N 7.500^0 E with land mass of $24{,}192km^2$ (9,341 sq mi). It has a population of 5,792,578 (2006 Nigerian census) and a population density of $160/km^2$ (420/sq mi). Figure 3 shows the location of Katsina State on the map of Nigeria, whereas figure 4 shows the map of Katsina State indicating the routes direction for electric field strength measurement. Table 4 shows more details about the routes.

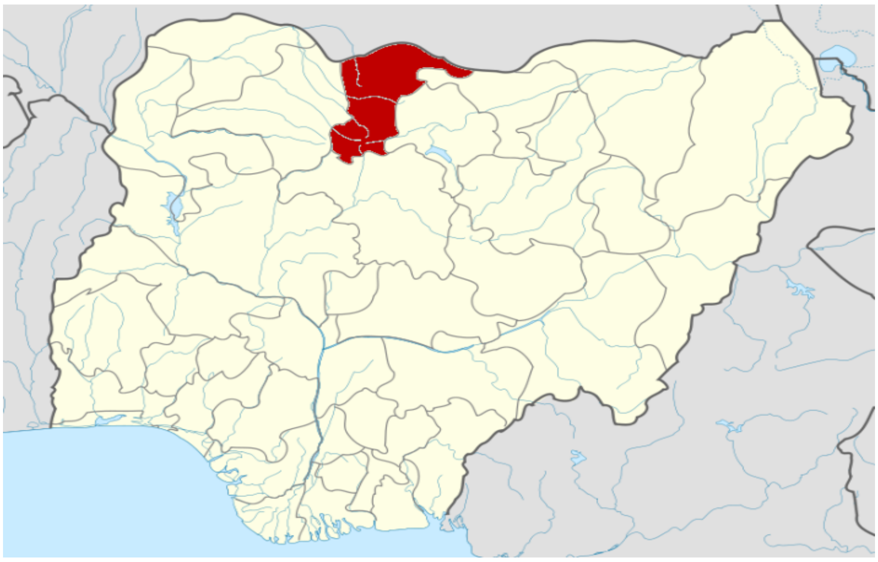

Fig 3: Map of Nigeria showing location of Katsina State

Fig. 4: Map of Katsina State showing the three routes used for data collection

Table 4: Route definition for the field work

Route	Direction/ Definition
A	KTTV Transmission Base towards Batsari (0-15 km LOS)
B	KTTV Transmission Base towards Daura (0-12 km LOS)
C	KTTV Transmission Base towards Daura (0-12 km LOS)

Data collection and handling

Measurement of the electric field strength of channel 22, Ultra-High Frequency (UHF) Television Station in Katsina was carried out radially from the base station along different routes in the state. Data collection was made at intervals of 1km (LOS) from the main station in Katsina along the routes. The state was divided into three (3) major routes classified A, B and C. Table presents the details for the routes used for the electric field strength measurements. The main station (Transmitting antenna) located at Katsina was marked and use as reference point using the GPS receiver for all the routes. The GPS receiver cursor was placed on the base station's location already marked as KTTV on the GPS waypoint memory. The line of sight from the base station was monitored during the drive of the field vehicle. The GPS was also used to measure the location's longitude, latitude, and the elevation above sea level of the data points. A digital field strength meter with the receiving antenna connected to it via a coaxial cable of about 1.2m length using an I-connector was powered and used to measure the electric field strength of the signal (the base station's frequency (479.25MHz) that was stored in the meters memory would be recalled during the measurement) and the multiple values of the signal strength meter were recorded. This procedure was repeated for subsequent measurements.

Chapter Four

Result and Discussions

Results

The data obtained were used to plot the propagation curves along the three routes of data collection whereas Okumura-Hata model as expressed in (1)- (3) being a model that has been adjudged as a standard to benchmark new approaches (Armoogun et al, 2010) by the ITU was used to evaluate path losses along the routes. These path loss values are as depicted in Table 5. The path loss values were plotted against distance along side with the propagation curves. Figures 4, 5 and 6 present these plots.

Table 5: Evaluated path loss values along the three routes of data collection.

Calculated path loss(dB) for Route A (KTTV towards Batsari)	Calculated path loss(dB) for Route B (KTTV towards Daura)	Calculated path loss(dB) for Route C (KTTV towards Dutsinma)
0.000	0.000	0.000
72.88	81.71	84.20
89.08	86.66	91.57
92.60	93.00	98.21
99.08	98.28	102.5
102.7	102.4	105.6
108.4	105.8	108.2
111.5	108.5	110.5
114.2	110.6	112.4
115.4	112.6	114.1

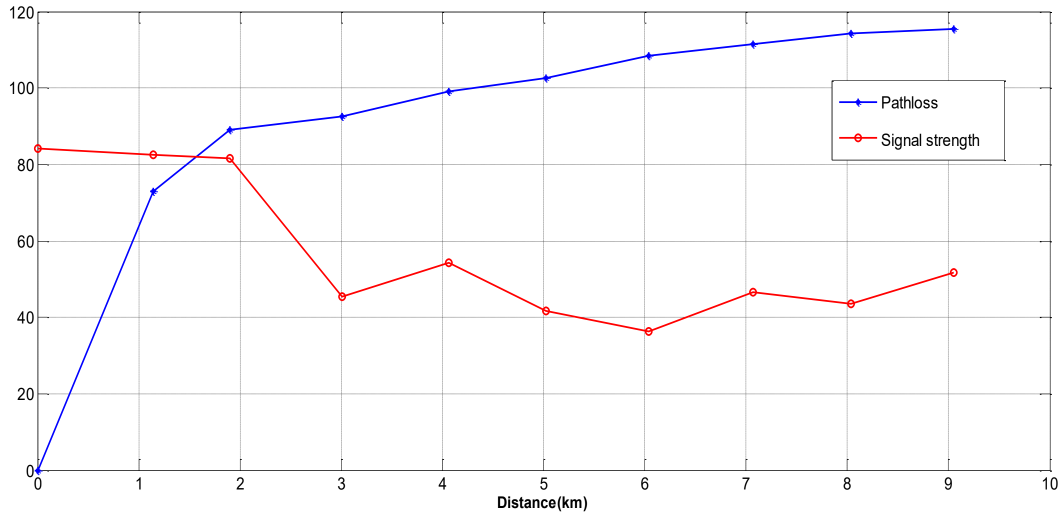

Fig.4: Propagation curve : Signal strength (dBμV) and path loss (dB) against distance(LoS) for route A (Base station-Batsari)

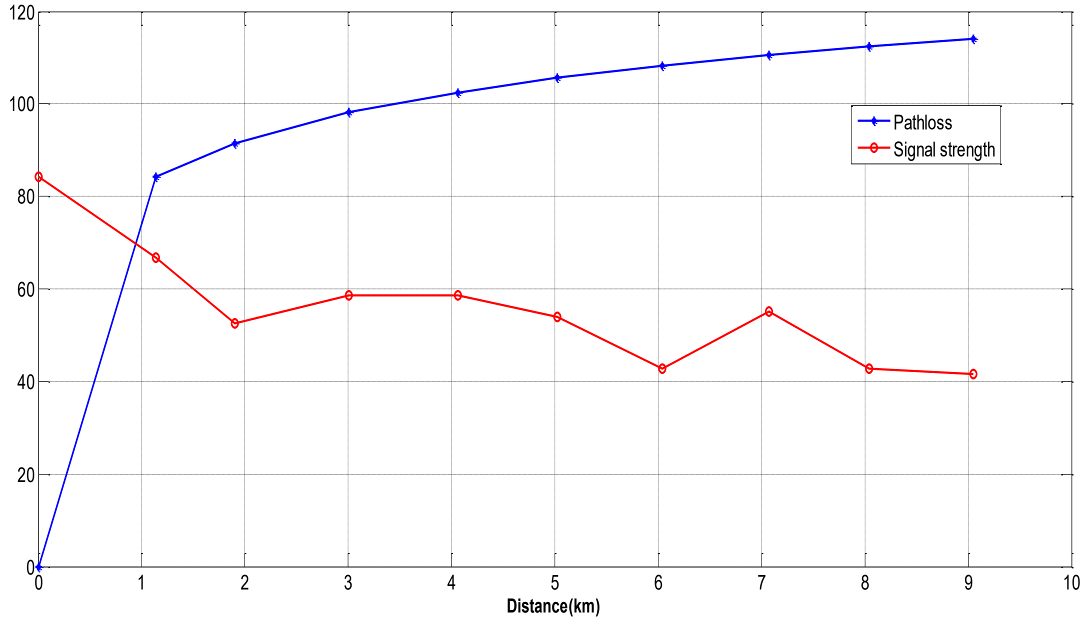

Fig. 5: Propagation curve: Signal strength (dBµV) and path loss (dB) against distance (LoS) for route B (Base station-Daura)

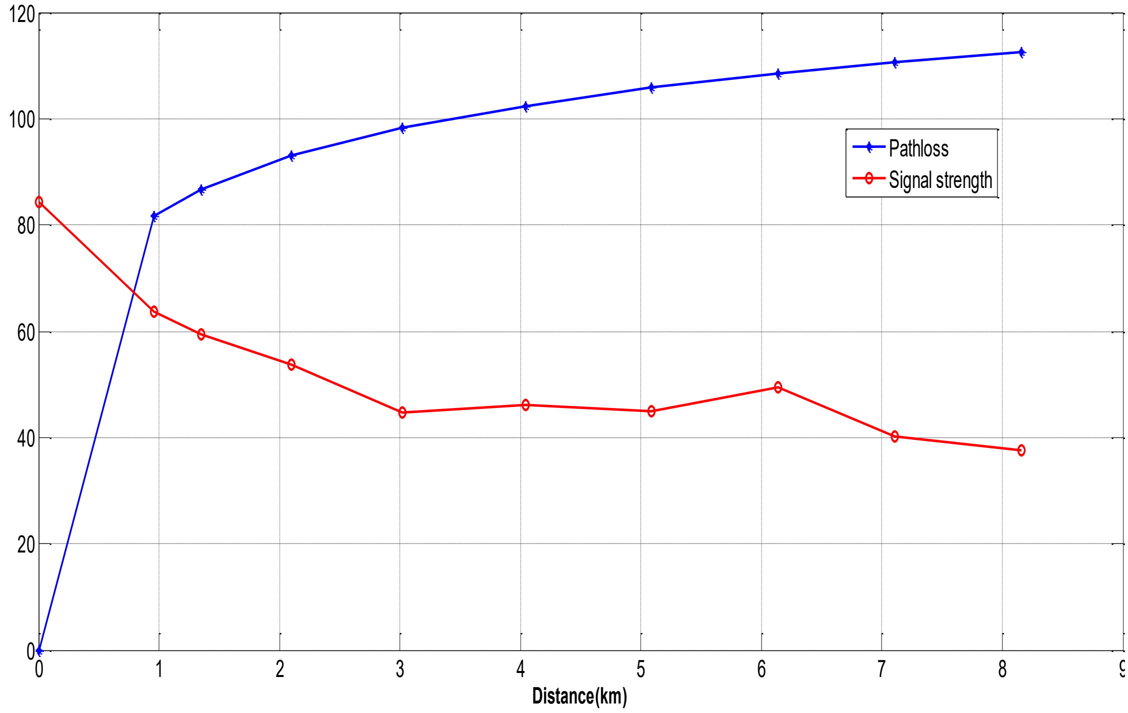

Fig. 6: Propagation curve: Signal strength (dBµV) and path loss (dB) against distance (LoS) for C (Base station towards Dusinma)

Discussion of Results and graphs

Fig. 4 is the graph of signal strength and path loss against distance along route A. From this graph it is observed that signal strength varies inversely with distance. The signal decay was not rapid obviously due to the high stable elevation values of the metropolis. The signal reduces to half of its value within the metropolis (around 6-8km). Path loss along this route is directly proportional to distance especially at the far field of the station, which means the higher the distance, the lower the signal strength and the higher the path loss as the wave travels from the transmitter due to space loss and other related factors. Also there is increase in field strength at some points for example point 4 on the graph 3m away from base station (after Radio companion) with field strength values from 45.30dB to 54.25dB, with distance increase of 1km interval which is contrary to conventional decrease in field strength with increase in distance. This is as a result of increase in elevation level from 519m to 521m above sea level on same route.

From figures 5 and 6 it was also observed that signal strength reduces as the distance increases from the transmitter which brings about increase in path loss as it goes farther away from the station which is basically free space loses with little effect of vegetations, terrains, and other wave properties such as refraction, reflection and interference. The effects of high elevation values on the Received Signal Strength (RSS) were also observed. This leads to increase in field strength at distances of 4km, 5km and 7km as against the inverse square law of wave propagation as observed in figure 5. From figure 6 along route C, the same trend was observed.

Conclusion

In this research work, the Signal Strength of Katsina State Television (KTTV) Channel 22, 479.25MHz was measured along three (3) radial routes within (0-15km) line of sight from the transmitter's base station in Katsina State. Also, Elevation (AGL), Line of Sight (LOS) from base station and Geographic Coordinates readings of data locations were taken at 1km intervals on the three radial routes. These parameters were used to calculate the path loss using Okumura Hata Model. The result of the study shows that signal strength reduces with distance along the three radial routes. It further shows that towns close to the base station receive high signals compared to those far away on the same routes however, there were few exemptions; some farther locations recorded higher signal strength compared to closer locations due to higher elevation values neglecting the effect of distance contrary to the inverse square law. These results are in agreement with the results obtained in the works of Akinbolati, et al. (2016) and Akingbade and Olorunnibi, (2010). The implication of this is that high elevation at reception ends enhances Quality of Reception (QoR) and minimizes path losses in the study area. The residents of the state are encouraged to use higher antennas to ensure Quality of Service (QoS) from the broadcasting station. This is consistent with similar works (Akinbolati, et al. 2016) since the use of high antennas on the UHF band minimizes losses due to multi paths effect. Also from the result, the average field strength recorded for routes A, B and C are 49.02 $dB\mu V$, 50.47$dB\mu V$, and 46.02 $dB\mu V$ respectively, whereas the path loss values were found to be 90.58dB, 89.96dB and 92.73dB for route A, B and C respectively. The difference in the path losses could be associated with the different terrain and terrestrial factors (attenuation factors) peculiar with each route. Furthermore, about 15% of the populace within the metropolis had access to the primary coverage areas of the station whereas about 50% have access to the secondary coverage areas and about 35% are within the fringe coverage of the station as deduced from the propagation curves. The overall findings of this work will enhance UHF Television Transmission and Reception within Katsina metropolis, the State at large and in any other similar city in Nigeria.

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