International Journal of Mathematics and Statics Studies

Vol.2, No.1, pp.45-54, March 2014

Published by European Centre for Research Training and Development UK (www.ea-journals.org)

EXPONENTIAL MODELS OF SIGNAL STRENGTH OF A TELEVISION STATION IN NIGERIA

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ABSTRACT: *The signals received by television viewers vary from one location to another. This now makes the measurement of signal strength of television stations to be a very important area of research to scientists and engineers. In this paper, the line of sight and signal strength of an Ultra High Frequency (UHF) television signals in a state in Nigeria were investigated. Propagation curves for the signal along different routes were plotted and regression analysis was now used to determine the exponential models which can be used to calculate signal strength for a given line of sight at the designated routes in the state.*

KEYWORDS: Signal Strength, Line of Sight, Regression Analysis, Exponential Models, Coverage Areas, Propagation Curves.

INTRODUCTION

Television broadcasting is an important aspect of human development. The yearnings of people to information via television have continued to be on the increase for information, entertainment and education. To this extent, both the federal and state governments in Nigeria had continued to establish television stations all over the country to meet the yearnings and aspirations of the people. The first television station in Nigeria is the Western Nigeria Broadcasting Service (WNBS) wish was established in 1959 by the then premier of Western Nigeria. Since then, the business of television broadcasting had been the exclusive rights of both state and federal governments in Nigeria. However, the federal government had in the last three decades opened the business of broadcasting to private investors to complement the efforts of the state and federal government. This now brings a lot of competition into the business of television broadcasting.

All stations have their expected coverage areas and their signals should not constitute interference to others, BON (2010). As a result of this, researchers have continued to carry out a lot of work to determine the actual coverage areas of some broadcasting stations and the level of signal strength variations with distance from the transmitter base. Ajayi and Owolabi

(1981) used the radio wave attenuation technique to do the ground conductivity survey in some parts of Nigeria while Eiche (2010) measured the electric field strength to determine the coverage area of an FM radio station in Niger State, Nigeria. Oke (2012) developed a path loss prediction model for a radio station in Nigeria.

In view of the competition in the business of television broadcasting and the importance of television to the socio-economic development of the people, viewer's interest had grown from just watching anything on the screen to qualitative, clean and sharp signals on the television. This paper therefore is on exponential models of signal strength of a television station as a function of line of sight.

MATERIALS AND METHODS

The exponential models in this paper were derived from empirical results and empirical models are generally derived from and based entirely on data, Onohaebi and Odiase (2010), Dilwyn and Hamson, (1989) and Oke (2013). Therefore, to get the required data for the derivation of the models, we investigated the coverage areas of an Ultra High Frequency (UHF) television signals in Ekiti state and collated some data on the line of sight and average signal strength along different routes in state. The data collected were used to determine and classify the grades of coverage areas of the station in the state. Based on this data, propagation curves for the signal along different routes were plotted and regression analysis was now used to determine the exponential models of signal strength as a function of line of sight for the designated routes.

RESULTS

The results gotten from these investigations are as shown in table 1 below. Table 2 shows the routes along which investigations were carried out in the state and tables 3 to 6 gives the line of sight and average signal strength for the routes. Figures 1 to 4 indicates the propagation curves for different routes. This propagation curves are the variations of the electric field strength of radio signal with distance. It is an essential parameter in radio wave propagation because they are used for radio propagation planning and design.

Table 1: Line of Sight and Average Signal Strength of UHF Channel 41 for Ekiti State.

S/N	Location	Line of Sight (km)	Average Signal Strength (dBuV)
1.	Ado	0.00	80.67
2.	Iyin	9.96	48.73
3.	Igede	13.57	36.17
4.	Aramoko	22.83	21.63
5.	Erio	26.85	18.50
6.	Itawure	33.08	16.73
7.	Efon	36.21	14.23
8.	Iworoko	6.36	59.03
9.	Ifaki	13.31	41.10
10.	Ido	19.93	23.67
11.	Usi	24.01	18.39
12.	Ayetoro	30.00	16.23
13.	Otun	37.40	15.20
14.	Ikere	21.35	25.78
15.	Ise	32.15	19.20
16.	Emure	35.20	18.80
17.	Oye	17.11	35.05
18.	Ikole	32.50	20.30

Table 2: Routes along which investigations were carried out

Routes	**Towns along the Routes**
A	Ado → Iyin → Igede → Aramoko → Erio → Itawure → Efon.
B	Ado → Iworoko → Ifaki → Ido → Usi → Ayetoro → Otun.
C	Ado → Ikere → Ise → Emure
D	Ado → Iworoko → Ifaki → Oye → Ikole

Table 3: Line of Sight and Average Signal Strength for Route A

S/N	Location	Line of Sight (km)	Average Signal Strength (dBuV)
1.	Ado	0.00	80.67
2.	Iyin	9.96	48.73
3.	Igede	13.57	36.17
4.	Aramoko	22.83	21.63
5.	Erio	26.85	18.50
6.	Itawure	33.08	16.73
7.	Efon	36.21	14.23

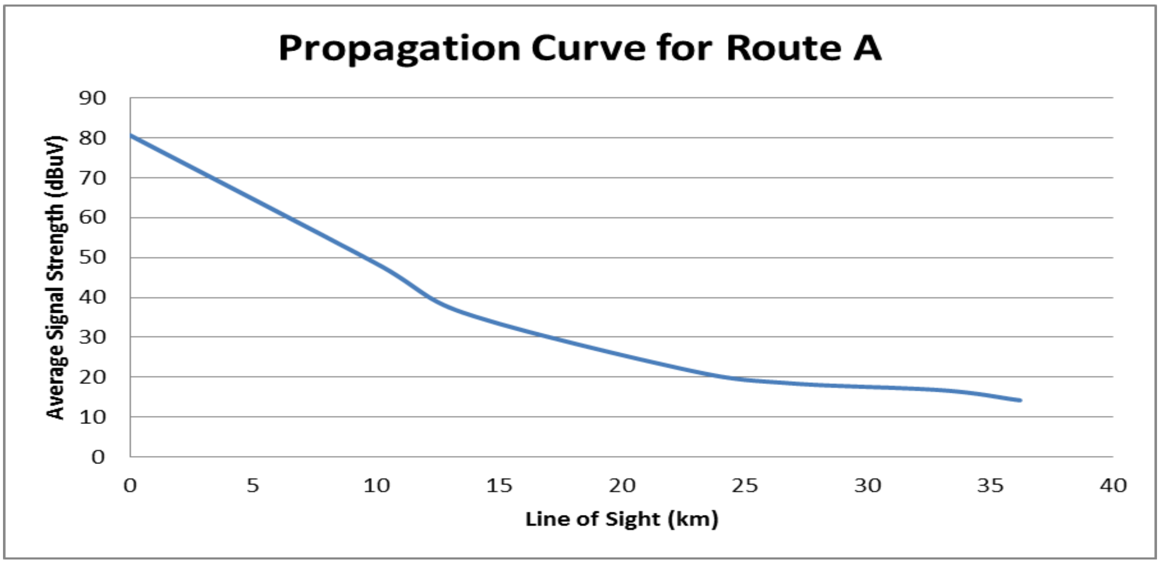

Figure 1: Propagation Curve for Route A

Table 4: Line of Sight and Average Signal Strength for Route B

S/N	Location	Line of Sight (km)	Average Signal Strength(dBuV)
1.	Ado	0.00	80.67
2.	Iworoko	6.36	59.03
3.	Ifaki	13.31	41.10
4.	Ido	19.93	23.67
5.	Usi	24.01	18.39
6.	Ayetoro	30.00	16.23
7.	Otun	37.40	15.20

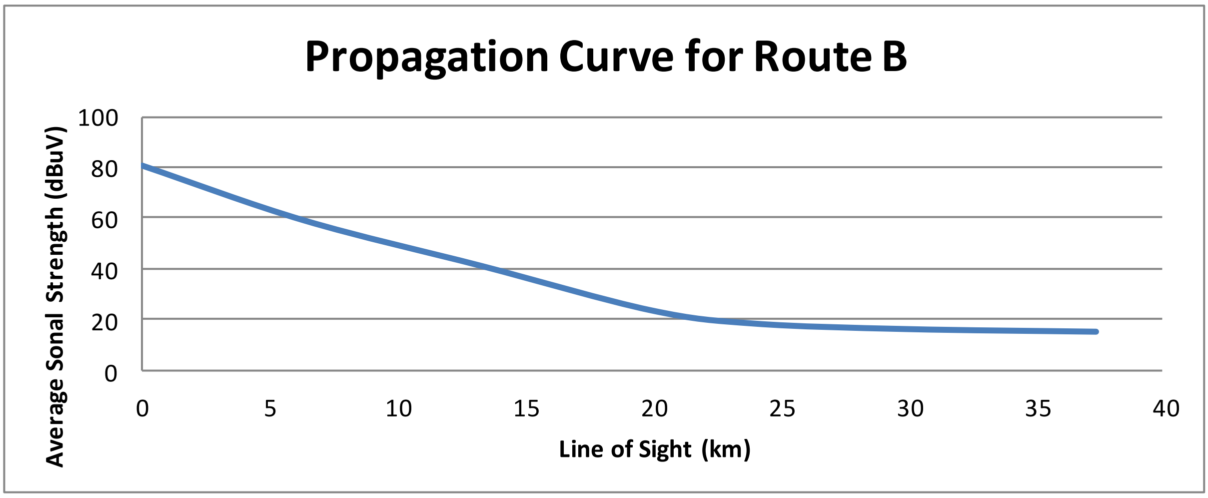

Figure 2: Propagation Curve for Route B

Table 5: Line of Sight and Average Signal Strength for Route C

S/N	Location	Line of Sight (km)	Average Signal Strength (dBuV)
1.	Ado	0.00	80.67
2.	Ikere	21.35	25.78
3.	Ise	32.15	19.20
4.	Emure	35.20	18.80

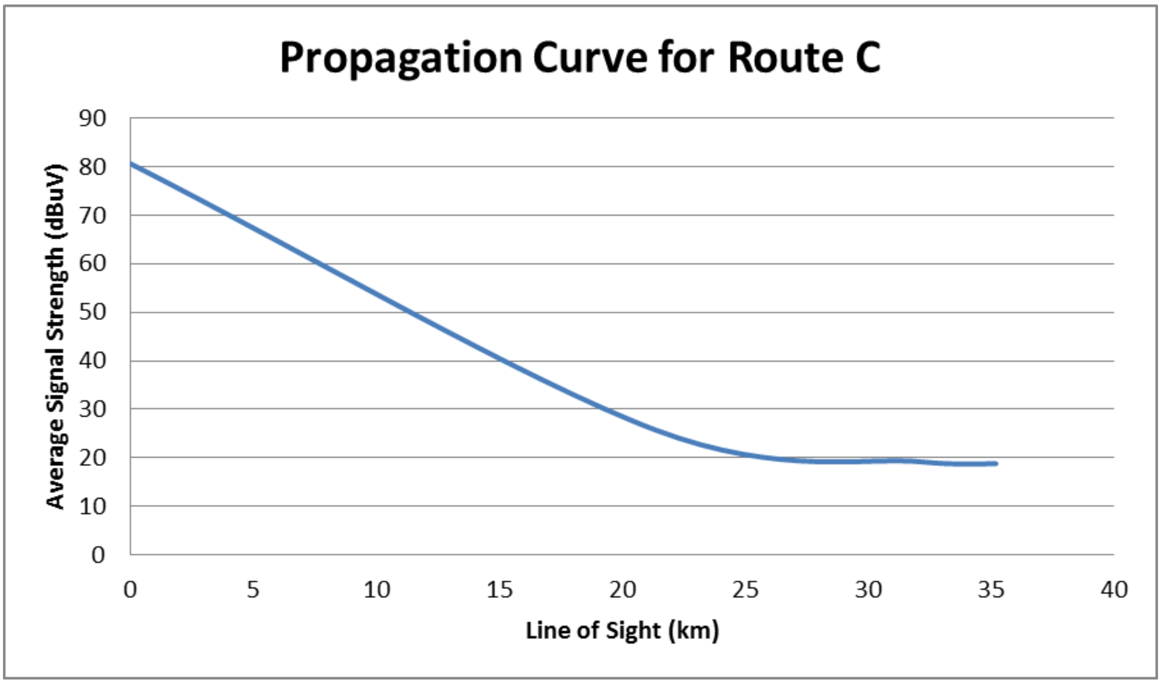

Figure 3: Propagation Curve for Route C

Table 6: Line of Sight and Average Signal Strength for Route D

S/N	Location	Line of Sight (km)	Average Signal Strength (dBuV)
1.	Ado	0.00	80.67
2.	Iworoko	6.36	59.03
3.	Ifaki	13.31	41.10
4.	Oye	17.11	35.05
5.	Ikole	32.50	20.30

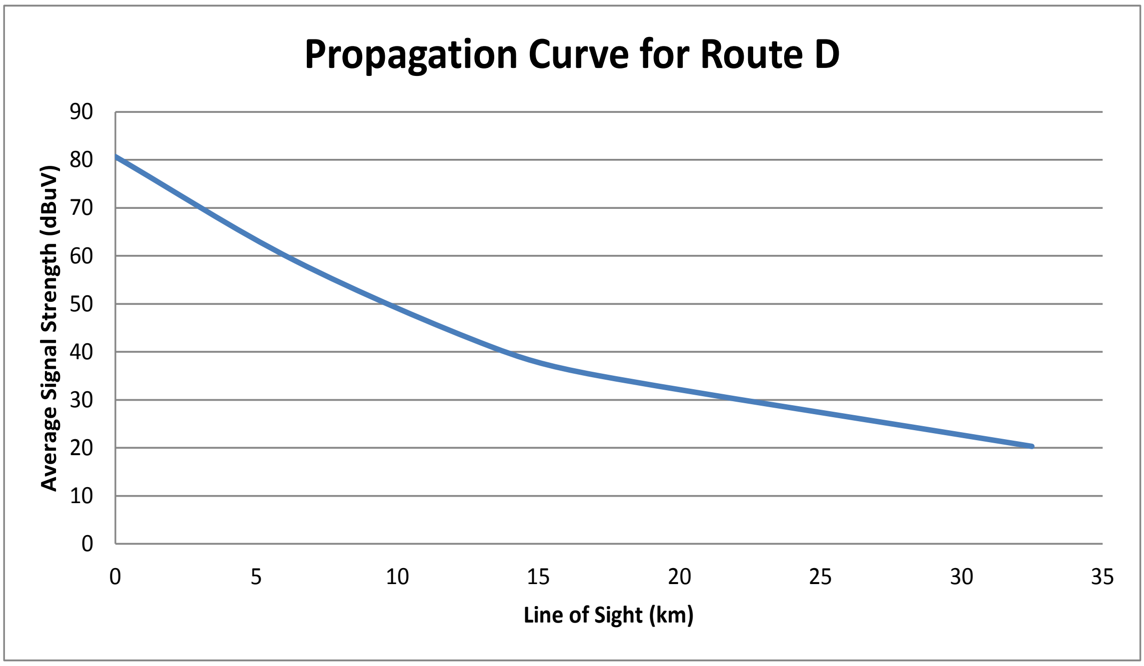

Figure 4: Propagation Curve for Route D

From the graphs in figures 1 to 4, we can easily see that the functions cannot be perfectly represented (approximated) by straight lines. We now take the logarithms of the data for average signal strength and perform the regression analysis on the values for the line of sight and the logarithmic values of the average signal strength so as to get an exponential regression model.

The estimated regression equation for the curve will therefore be given by

$$logY = a + bX \quad (1)$$

where

$$a = \frac{\sum_{i=1}^{n}(logY_i)\sum_{i=1}^{n}(X_i)^2 - \sum_{i=1}^{n}(X_i)\sum_{i=1}^{n}(X_i)(logY_i)}{n\sum_{i=1}^{n}(X_i)^2 - (\sum_{i=1}^{n}(X_i))^2} \quad (2)$$

and

$$b = \frac{n\sum_{i=1}^{n}(X_i)(logY_i) - \sum_{i=1}^{n}(X_i)\sum_{i=1}^{n}(logY_i)}{n\sum_{i=1}^{n}(X_i)^2 - (\sum_{i=1}^{n}(X_i))^2} \quad (3)$$

Tables 7 to 10 gives all the summations for the determination of the values of a and b for the four routes considered.

Table 7 : Summations for Route A

Line of Sight (X_i)	Average Signal Strength (Y_i)	$logY_i$	${X_i}^2$	$X_i logY_i$
0.00	80.67	4.3904	0.0000	0.0000
9.96	48.73	3.8863	99.2016	38.7076
13.57	36.17	3.5882	184.1449	48.6919
22.83	21.63	3.0741	521.2089	70.1817
26.85	18.50	2.9178	720.9225	78.3429
33.08	16.73	2.8172	1094.2864	93.1930
36.21	14.23	2.6554	1311.1641	96.1520
$\sum_{i=1}^{n} X_i = 142.5$	$\sum_{i=1}^{n} Y_i = 236.66$	$\sum_{i=1}^{n} logY_i = 23.3294$	$\sum_{i=1}^{n} {X_i}^2 = 3930.9284$	$\sum_{i=1}^{n} X_i logY_i = 425.2691$

Table 8 : Summations for Route B

Line of Sight (X_i)	Average Signal Strength (Y_i)	$logY_i$	${X_i}^2$	$X_i logY_i$
0.00	80.67	4.3904	0.0000	0.0000
6.36	59.03	4.0781	40.4496	25.9367
13.31	41.10	3.7160	177.1561	49.4600
19.93	23.67	3.1642	397.2049	63.0625
24.01	18.39	2.9118	576.4801	69.9123
30.00	16.23	2.7869	900.0000	83.6070
37.40	15.20	2.7213	1398.7600	101.7766
$\sum_{i=1}^{n} X_i = 131.01$	$\sum_{i=1}^{n} Y_i = 254.29$	$\sum_{i=1}^{n} logY_i = 23.7687$	$\sum_{i=1}^{n} {X_i}^2 = 3490.0507$	$\sum_{i=1}^{n} X_i logY_i = 393.7551$

Table 9 : Summations for Route C

Line of Sight (X_i)	Average Signal Strength (Y_i)	$logY_i$	${X_i}^2$	$X_i logY_i$
0.00	80.67	4.3904	0.0000	0.0000
21.35	25.78	3.2496	455.8225	69.3790
32.15	19.20	2.9549	1033.6225	95.0000
35.20	18.80	2.9339	1239.04	103.2733
$\sum_{i=1}^{n} X_i = 88.7$	$\sum_{i=1}^{n} Y_i = 144.45$	$\sum_{i=1}^{n} logY_i = 13.5288$	$\sum_{i=1}^{n} {X_i}^2 = 2728.485$	$\sum_{i=1}^{n} X_i logY_i = 267.6523$

Table 10 : Summations for Route D

Line of Sight (X_i)	Average Signal Strength (Y_i)	$logY_i$	X_i^2	$X_i logY_i$
0.00	80.67	4.3904	0.0000	0.0000
6.36	59.03	4.0781	40.4496	25.9367
13.31	41.10	3.7160	177.1561	49.4600
17.11	35.05	3.5568	292.7521	60.8568
32.50	20.30	3.0106	1056.25	97.8445
$\sum_{i=1}^{n} X_i = 69.28$	$\sum_{i=1}^{n} Y_i =$ 236.15	$\sum_{i=1}^{n} logY_i =$ 18.7519	$\sum_{i=1}^{n} X_i^2 =$ 1566.6078	$\sum_{i=1}^{n} X_i logY_i =$ 234.098

To get the model for the signal strength as a function of line of sight along route A, we substitute the summations from table 7 in equations (2) and (3) above to have

$$a = \frac{(23.3294)(3930.9284) - (142.5)(425.2691)}{7(3930.9284) - (142.5)^2}$$

$$= \frac{91706.2010 - 60600.8468}{27516.4988 - 20306.25} = \frac{31105.3542}{7210.2488} = 4.3141$$

$$b = \frac{7(425.2691) - (142.5)(23.3294)}{7(3930.9284) - (142.5)^2}$$

$$= \frac{2976.8837 - 3324.4395}{27516.4988 - 20306.25} = \frac{-347.5558}{7210.2488} = -0.0482$$

The estimated regression equation is therefore given by

$$logY = 4.3141 - 0.0482X$$

This now gives

$$Y = 74.7463e^{-0.0482X} \qquad (4)$$

Equation (4) is the required exponential model of signal strength as a function of line of sight along Ado – Efon route.

Substituting the summations from table 8 in equations (2) and (3) and simplifying as above, we have the required exponential model of signal strength as a function of line of sight along route B (Ado – Otun route) as

$$Y = 74.9409e^{-0.0492X} \qquad (5)$$

Similarly, the required exponential models of signal strength as functions of line of sight along routes C (Ado – Emure route) and D (Ado – Ikole route) are given by equation (6) and (7) respectively

$$Y = 75.4975e^{-0.0425X} \quad (6)$$

$$Y = 76.5543e^{-0.0424X} \quad (7)$$

DISCUSSION OF RESULTS

The derived exponential models can be used to predict signal strength for a given line of sight at the designated routes in the state. The models show that the signal strength of the station is inversely proportional to the line of sight. This is indicated in the decay of the field strength with distance in all the routes. This clearly justifies the inverse square law. We also noticed from our results that signal strength of this station was good enough between 0 and 15km radial from the transmitter base. The station covers about 75% of the entire landmass of the state with 18% of the land mass having optimum coverage (primary coverage). About 27% of the state was averagely serviced by the station (secondary coverage), 30% of the state was fairly serviced and about 25% of the state was not serviced by the station because of their topographical features.

CONCLUSION AND RECOMMENDATIONS

The management of the station needs to establish booster stations in areas where weak signal strengths are recorded. This will improve the socio-economic development of the people and also ensure that government policies and programmes are well disseminated to them. The transmitter to be installed in any of these routes should be of 1.0kW or 1.5kW output capacity. This will increase the optimum coverage of the station and not necessarily cause interference to any neighbouring television stations.

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