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Path Loss Prediction Model for a Radio Station in Nigeria

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Abstract

The quality of signals received by radio listeners is of keen interest to stakeholders in the broadcast world. This now makes the measurement of the field strength distribution of radio channels to be of great importance to scientists and engineers. In this paper, I measured the field strength of a radio station in Ekiti State, Nigeria by using a digital field strength meter (DAGATRON TM 10) and I used a global positioning system (GPS) receiver to monitor the line of sight (LOS) from the base station. The GPS was also used to monitor the latitude, longitude and elevation above sea level of the various locations visited. Based on the data I got from all these measurement, I came up with a path loss prediction model for the 91.5 MHz radio channel in Ekiti State, Nigeria along certain routes. The results, which shows that elevation and distance from the transmitter are the predominant factors in determining field strength at a particular place, will be very useful for stakeholders in the broadcast world.

Keywords: Model, Path loss, Prediction, Measurement, Transmitter, Field strength.

1.0 Introduction

Telecommunication is the transmission of information, over significant distances, for the purpose of communication. Before the advent of civilization, telecommunications involved the use of visual signals such as beacons, smoke, signal flag and audio messages via coded drum beats, lung-blown horns, or messages sent by land whistles. In this modern age of civilization, telecommunication now involves the use of devices such as telegraphs, telephones, teletypes and the use of radio and microwave communications as well as optic fibers and their associated electronics together with the use of satellites and internet.

Path loss is the reduction in power density of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of a communication system. It may be due to many factors such as free-space loss, refraction, diffraction, reflection. Path loss is also influenced by terrain contours, environmental factors, urban or rural, propagation medium, the distance between the transmitter and the receiver and the height and location of antennas [1].

Path loss prediction model, also known as radio wave propagation model or radio frequency propagation model is an empirical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions.

A single model is often developed to predict the behavior of propagation for all similar links under similar constraints created with the goal of formalizing the way radio waves are propagated from one place to another. Such models typically predict the path loss along a link or the effective coverage area of a transmitter.

Various telecommunication links has to encounter different terrain, path, obstruction, atmospheric conditions and other phenomena, it is not possible to formulate the exact loss for all telecommunication system in a single mathematical equation. As such, different models exist for different types of radio link under different conditions. The models rely on computing the median path loss for a link under certain probability that the considered condition will occur.

Radio propagation models are empirical in nature, which means they are developed based on large collections of data collected for a specific location. For any model, the collection of data has to be sufficiently large to provide enough likeliness to all kind of situations that can happen in that location.

A lot of work has been done on the measurement of field strength to determine the coverage area of some radio stations. Ajayi and Owolabi [2] looked at the coverage area of the 702 kHz Medium Wave Transmitter at Minna while Eiche [3] considered the measurement of electric field strength to determine the coverage area of FM radio station in Niger State of Nigeria. Ajayi and Owolabi [4] did the ground conductivity survey in some parts of Nigeria using radio wave attenuation technique, to mention a few. Theoretical and

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experimental studies of path loss prediction models can be found in many literatures. However, there is no assurance that the available models can fit in perfectly to all geographical locations. In Nigerian sub region, particularly in Ekiti State, studies are still needed to provide suitable models to predict the path loss for their radio stations along different routes because of the topography of the area. Based on this, I took measurement in a lot of locations so as to come up with a path loss prediction model for the 91.5MH_Z Radio channel along certain routes in Ekiti State.

2.0 Materials and Method

The procedure employed in carrying out this work is such that requires the physical presence of the investigator in various towns and villages in Ekiti State where the signal is expected to be received. This is done to measure the longitude and latitude of the place, the elevation of the place above sea level, the line of sight distance of the place to the transmitter base and the field strength of the radio signal. The position of the transmitting antenna or transmitter base is marked as “home”. Then at distances away from the transmitter base, at specific points in the various towns, measurements were taken and recorded. The data so collected are tabulated for easy computation and analysis. The procedure is repeated in all the towns and villages with the aid of a digital field strength meter (DAGATRON TM 10) and a global positioning system (GPS) receiver. The experimental results were recorded in multiples to enhance a high degree of accuracy.

For the calculation of path losses of the radio station in Ekiti state, investigations were carried out along four different routes away from Broadcasting Service of the State, (BSES 91.5MH_Z).

The routes along which investigations were carried out were tagged routes A, B, C and D. These routes are shown in Table 1.

The measured data were used to formulate the path loss prediction model for the 91.5 MHz FM station in Ekiti State.

Free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line of sight path through free space. In free space, all electromagnetic waves obey the inverse square law which states that the power density of electromagnetic waves is proportional to the inverse of the square of the distance from a point source [5, 6].

FSPL is proportional to the square of the distance between the transmitter and the receiver, and it is also proportional to the square of the frequency of the radio signal.

According to some authors [7, 8], the equation for FSPL is

$$FSPL = (\frac{4\pi d}{\lambda})^2 = (\frac{4\pi df}{c})^2 \qquad (1)$$

This equation is only accurate in the far field where spherical spreading can be assumed; it does not hold close to the transmitter.

Another way of expressing the FSPL is in form of decibel given as

$$FSPL = 10log_{10}\left(\left(\frac{4\pi df}{c}\right)^2\right) \qquad (2)$$

$$= 20log_{10}\left(\frac{4\pi df}{c}\right)$$

$$= 20log_{10}(d) + 20log_{10}(f) + 20log_{10}(\frac{4\pi}{c})$$

For typical radio applications, it is common to find f measured in units of GHz and d in km, in which case the FSPL equation becomes

$$FSPL_1 = 20log_{10}(d) + 20log_{10}(f) + 32.45 \qquad (3)$$

Equation (3) is also known as Friis Transmission Equation [7].

Okumura-Hata Model is the most widely used radio frequency propagation model for predicting the behavior of cellular transmissions. This model incorporates the graphical information from Okumura Model and develops it further to realize the effects of diffractions, reflection and scattering caused by city structures.

The Okumura-Hata Model predicts the total path loss along a link of terrestrial microwave or other type of cellular communication [8]. It is applicable to the radio propagation within urban areas. This model is suitable for both point-to-point and broadcast transmissions and it is based on extensive empirical measurements taken.

The Okumura-Hata model for a large area is given by

$$FSPL_2 = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(H_b) - C_h + [44.9 - 6.55log_{10}(H_b)]log_{10}(d) \qquad (4)$$

$$C_h = 8.29[log_{10}(1.54H_m)]^2 - 1.1 \quad \text{for frequency} \leq 200MH_Z.$$

3.0 Results

Measurement is the process of observing and recording the observations collected as part of a research effort. It is the process of determining the magnitude of a quantity, such as mass, length, field strength, etc. to a unit of measurement.

Table 6 shows the line-of-sight in kilometers, the latitude and longitude in degrees, the elevation in meters above sea level, the radio signal strength, the location where the readings were taken and the local government area corresponding to the location. These measurements of field strength at different locations were taken in multiples and I calculated the average to ensure a high level of accuracy of the figures. Table 7 shows the parameters used for the experiment.

Using equations (3) and (4) to compute the path losses, I arrived at the values in Tables 8 to 11 for the routes under study. (i.e. routes A, B, C and D respectively).

When least square regression analysis was carried out on the data in Tables 8 to 11, I was able to derive equations (5) to (12).

$$L_{FA} = 86.10 + 0.49x \quad (5)$$
$$L_{FB} = 82.03 + 0.17x \quad (6)$$
$$L_{FC} = 86.20 + 0.49x \quad (7)$$
$$L_{FD} = 85.11 + 0.57x \quad (8)$$
$$L_{OA} = 108.60 + 0.74x \quad (9)$$
$$L_{OB} = 102.9 + 1.06x \quad (10)$$
$$L_{OC} = 109.10 + 0.74x \quad (11)$$
$$L_{OD} = 107.58 + 0.85x \quad (12)$$

Path losses along the four routes were now computed using the empirical models above and I got the values in Tables 12 to 15.

I now computed the standard error of estimate between the values in Tables 8 to 11 and the values in Tables 12 to 15 by using the formulae [9]

$$S_{er} = \sqrt{\frac{\sum(Y - Y_{est})^2}{N}} \quad (13)$$

Equation (13) was now applied to get the results in Tables 17 to 24.

Table 25 gives the path loss mean error between estimated empirical values and measured values.

Table 1: Routes along which investigations were carried out

Routes	**Towns along the Routes**
A	Ado → Iworoko → Ifaki → Orin → Ido → Usi → Ayetoro → Otun → Ekan.
B	Ado →Ikere → Iju → Itaogbolu.
C	Ado → Iyin → Igede → Aramoko → Itaore → Efon.
D	Ado → Iworoko → Ifaki → Ayegbaju → Oye.

Table 2: Interpretation of notations in equation (1)

Notations	**Interpretation**
λ	Signal wavelength (in meters)
f	Signal frequency (in hertz)
d	Distance from the transmitter (in meters)
c	Speed of light in a vacuum which is 2.99792458×10^8 meters per second

Table 3: Interpretation of notations in equation (4)

Notations	**Interpretation**
H_m	Height of mobile station antenna unit (in meters)
H_b	Height of base station antenna unit (in meters)
f	Signal frequency (in hertz)
C_h	Antenna height correction factor
d	Distance base and mobile station (in km)

Table 4: Interpretation of notations in equations (5) to (12)

Notations	**Interpretation**
L_{FA}	Predicted path loss using Friis transmission equation for Route A
L_{FB}	Predicted path loss using Friis transmission equation for Route B
L_{FC}	Predicted path loss using Friis transmission equation for Route C
L_{FD}	Predicted path loss using Friis transmission equation for Route D
L_{OA}	Predicted path loss using Okumura-Hata Model for Route A
L_{OB}	Predicted path loss using Okumura-Hata Model for Route B
L_{OC}	Predicted path loss using Okumura-Hata Model for Route C
L_{OD}	Predicted path loss using Okumura-Hata Model for Route D
x	the line of sight (the distance away from the transmitter)

Table 5: Interpretation of notations in equation (13)

Notations	Interpretation
S_{er}	Standard error of estimate
Y	Original value
Y_{est}	Estimated value of Y
N	Total number of variables

Table 6: Measurement of the Field Strength Distribution of FM Radio (91.5 MHz) Channel across Ekiti State.

S/N	LOS Distance (in km)	Latitude (in degrees)	Longitude (in degrees)	Elevation (in meters)	/E/ Radio Signal	/E/ Radio signal (average)	Location	Local Government Area
1.	4.48	7.71536	5.248821	416.5	71.5/69.9	70.7	UNAD gate	Ado Ekiti
2.	6.36	7.73045	5.2614	431.5	60.60/61.4	61.0	Iworoko	Irepodun/Ifelodun
3.	10.04	7.76520	5.25211	562.6	44.4/45.9	45.15	Near Ifaki	Irepodun/Ifelodun
4.	12.61	7.78841	5.24291	571.8	49.7/50.1	49.9	Ifaki 1	Ido-Osi
5.	14.00	7.80055	5.23759	577.9	34.7/35.0	34.85	Ifaki 2	Ido-Osi
6.	17.55	7.83243	5.23466	560.5	28.4/31.2	39.8	Orin Ekiti	Ido-Osi
7.	20.00	7.84561	5.18964	561.4	27.8/31.7	29.75	Ido 1	Ido-Osi
8.	17.8	7.84281	5.18711	587.4	40.9/42.1	41.5	FMC Ido	Ido-Osi
9.	22.0	7.86018	5.17669	564.2	36.7/35.2	35.95	Usi 1	Ido- Osi
10	23.32	7.87160	5.17353	595.8	36.7/35.2	35.95	Usi 1	Ido – Osi
11	24.70	7.88387	5.17095	555.3	16.1/15.9	16.0	Usi 2	Ido-Osi
12	30.0	7.92513	5.14532	567.5	26.2/24.6	25.4	Ayetoro Ekiti	Ido – Osi
13	36.40	7.98166	5.13265	600.1	32.0/31.7	31.85	Moba grams. Otun Ekiti	Moba
14	37.40	7.98748	5.12238	548.7	17.7/17.2	17.45	7th Day Church Otun Ekiti	Moba
15	40.04	8.00922	5.11231	558.8	28.1/29.6	28.85	Otun Ekiti	Moba
16	42.64	8.02944	5.0991	548.5	15.6/15.3	15.45	Obaji community High School Ekan	Kwara State
17	35.57	7.98176	5.15615	558.4	24.0/23.4	23.7	Igogo 1	Moba
18	25.48	7.98354	5.16557	559.1	22.5/21.5	22.0	Igogo 2	Moba
19	36.27	7.99342	5.17689	545.5	15.6/15.4	15.5	Ikosu	Moba
20	35.92	7.99445	5.20028	528.8	19.7/21.7	20.7	Ikun Ekiti	Moba
21	31.65	7.95809	5.21895	559.2	27.9/27.7	27.8	Ijesamodu	Ilejemeje
22	31.23	7.95519	5.23006	558.2	18.4/17.0	17.7	Iye Ekiti	Ilejemeje
23	30.64	7.95027	5.23832	550.5	22.9/20.6	21.1	Iye LGA Sec.	Ilejemeje
24	28.37	7.952051	5.31650	572.7	18.9/20.6	19.75	Isan Ekiti	Oye
25	26.46	7.89705	5.33297	601.2	20.4/24.1	22.25	Ayede	Oye
26	24.81	7878550	5.33906	595.5	24.7/24.4	24.55	Itaji Ekiti	Oye
27	17.42	7.80117	5.34036	568.5	42.4/41.9	42.15	Oye Town 1	Oye
28	16.80	7.79886	5.33410	554.9	38.0/37.2	37.6	Oye Town 2	Oye
29	16.82	7.79324	5.29316	552.8	46.8/44.4	45.6	Ayegbaju Ekiti	Oye
30	31.76	7.38986	5.26986	391.4	33.2/30.7	31.95	Iju Itagbolu	Ondo State
31	23.03	7.49424	5.22702	361.5	34.7/35.3	35.0	Amoye School Ikere	Ikere
32	20.08	7.49487	5.25425	367.5	32.3/31.4	31.85	General Hospital Ikere	Ikere
33	20.75	7.49080	5.21912	368.5	36.9/34.5	35.7	Idi-isin ikere	Ikere
34	21.54	7.49678	5.17143	390.5	30.5/29.9	35.2	COE Ikere	Ikere
35	27.33	7.50277	5.07054	378.2	22.5/26.7	24.6	Igbara Odo St. Raphael Cath. Church	Ekiti South West
36	27.78	7.50546	5.06233	379.1	35.2/35.6	35.4	Igbara odo 2	Ekiti South West
37	29.70	7.59019	4.99198	476.5	31.3/29.8	30.55	Ikogosi	Ekiti West
38	27.49	7.61127	5.00617	454.9	32.2/29.6	30.9	Erinjiyan Ang. Church	Ekiti West
39	27.39	7.61301	5.00670	465.3	23.4/24.0	23.7	Olohan's Palace Erinjiyan	Ekiti West
40	22.83	7.69280	5.04066	50.66	44.4/44.0	44.2	Oke Iro Aramoko Ekiti	Ekiti West

41	23.23	7.70662	5.03866	475.3	40.8/39.5	40.15	Aramoko 2 Iwaro St.	Ekiti West
42	26.85	7.73086	5.01015	519.5	37.8/39.3	38.66	Erio Ekiti	Ekiti West
43	33.08	7.72658	4.95151	452.5	21.6/19.3	20.45	Itawure Efon	Efon
44	34.91	7.69198	4.93091	481.2	47.9/53.2	50.55	Efon LGA Secretariat	Efon
45	25.96	7.66760	7.92105	521.8	23.6/24.3	23.95	Efon 2	Efon
46	36.21	7.66194	4.91891	533.9	15.4/15.2	15.3	Government college Efon	Efon
47	24.49	7.80021	5.06432	450.7	39.0/39.5	39.25	Ijero roundabout	Ijero
48	25.36	7.81658	5.06658	505.0	44.3/42.9	43.6	Owa's palace Ijero Ekiti	Ijero
49	13.57	7.67077	5.12396	575.6	55.6/54.7	55.15	Igede Ekiti	Irepodun/Ifelodun
50	9.96	7.39517	5.09517	578.5	55.7/56.8	56.25	Iyin Ekiti	Irepodun/Ifelodun

Table 7: Experimental Parameters

Parameter	Route A	Route B	Route C	Route D
Frequency	$91.5MH_Z$	$91.5MH_Z$	$91.5MH_Z$	$91.5MH_Z$
Power transmitted	9.45KW	9.45KW	9.45KW	9.45KW
Height of base station	200m	200m	200m	200m
Height of mobile station	1.85m	1.85m	1.85m	1.85m

Table 8: Path Loss Prediction along Route A

LOS (in km)	4.48	6.36	10.10	14.00	17.55	22.0	24.70	30.0	35.0	42.64
Friis Model (X)	84.17	87.7	91.8	94.6	96.6	98.5	99.5	101.2	102.6	104.3
Okumura – Hata Model (Y)	106	111.4	117.39	121.62	124.55	127.47	128.97	131.49	133.49	136.05

Table 9: Path Loss Prediction along Route B

LOS (in km)	3.01	4.00	10.08	15.03	20.08	23.03	31.76
Friis Model (X)	81.2	83.7	91.7	95.2	97.7	98.9	101.7
Okumura – Hata Model (Y)	101.71	105.39	117.36	122.54	126.29	128.07	132.23

Table 10: Path Loss Prediction along Route C

LOS (in km)	5.00	9.96	11.00	13.59	28.87	23.23	26.85	33.08	34.91	35.96
Friis Model (X)	85.7	92.5	92.5	94.3	100.9	99.0	100.3	102.1	102.5	102.8
Okumura – Hata Model (Y)	108.28	117.21	118.49	121.21	130.99	128.18	130.05	132.76	133.45	133.84

Table 11: Path Loss Prediction along Route D

LOS (in km)	4.00	6.36	10.04	12.61	16.80	16.82	17.42	20.25	30.00	34.04
Friis Model (X)	83.7	87.7	91.7	93.4	96.18	96.2	96.5	97.8	101.2	102.3
Okumura – Hata Model(Y)	105.39	111.39	117.31	120.26	123.96	124.00	124.45	126.40	131.49	133.12

Table 12: Empirical Path Loss Prediction along Route A

LOS (in km)	4.48	6.36	10.10	14.00	17.55	22.0	24.70	30.0	35.0	42.64
Friis Model (X_{est})	86.1	89.22	91.05	92.96	94.70	96.88	98.20	100.8	103.25	106.99
Okumura – Hata Model (Y_{est})	111.92	113.31	116.07	118.96	121.59	124.88	126.88	130.80	134.50	140.15

Table 13: Empirical Path Loss Prediction along Route B

LOS (in km)	3.01	4.00	10.08	15.03	20.08	23.03	31.76
Friis Model (X_{est})	84.17	84.87	89.19	92.70	96.28	98.38	104.58
Okumura – Hata Model (Y_{est})	106.09	107.14	113.58	118.83	124.18	127.18	136.57

Table 14: Empirical Path Loss Prediction along Route C

LOS (in km)	5.00	9.96	11.00	13.59	28.87	23.23	26.85	33.08	34.91	35.96
Friis Model (X_{est})	88.65	91.1	91.59	92.57	105.35	97.58	99.36	102.41	103.31	103.82
Okumura – Hata Model(Y_{est})	112.80	116.47	117.24	119.14	130.46	126.29	128.97	133.58	134.93	135.71

Table 15: Empirical Path Loss Prediction along Route D

LOS (in km)	4.00	6.36	10.04	12.61	16.80	16.82	17.42	20.25	30.00	34.04
Friis Model (X_{est})	87.39	88.74	90.83	92.30	94.69	94.50	95.04	96.65	102.21	104.51
Okumura – Hata Model (Y_{est})	110.98	112.99	116.11	118.30	121.86	121.88	122.39	124.80	133.08	136.51

Table 16: Interpretation of notations in tables 12 to 15

Notations	Interpretation
X_{est}	the estimated value of the Friss transmission model
Y_{est}	the estimated value of the Okumura – Hata Model

Table 17: Standard Error of Estimate along Route A Using Friss Transmission Model

LOS (in km)	4.48	6.36	10.10	14.0	17.55	22.0	24.7	30.0	35.0	42.64
X	84.17	87.7	91.8	94.6	96.6	98.5	99.5	101.2	102.6	104.3
X_{est}	86.1	89.22	91.05	92.96	94.70	96.88	98.20	100.8	103.25	106.99
$(X - X_{est})^2$	3.73	2.31	0.56	2.69	3.61	2.62	1.69	0.16	0.42	7.24
S_{er}	1.58									

Table 18: Standard Error of Estimate along Route A Using Okumura-Hata Model

LOS (in km)	4.48	6.36	10.10	14.0	17.55	22.0	24.7	30.0	35.0	42.64
Y	106.00	111.40	117.39	121.62	124.55	127.47	128.97	131.49	133.49	136.05
Y_{est}	111.92	113.31	116.07	118.96	121.59	124.88	126.88	130.80	134.50	140.15
$(Y - Y_{est})^2$	35.04	3.65	1.74	7.08	8.76	6.71	4.37	0.48	1.02	16.81
S_{er}	2.93									

Table 19: Standard Error of Estimate along Route B Using Friss Transmission Model

LOS (in km)	3.01	4.00	10.08	15.03	20.08	23.03	31.76
X	81.2	83.7	91.7	95.2	97.7	98.9	101.7
X_{est}	84.17	84.87	89.19	92.70	96.28	98.38	104.58
$(X - X_{est})^2$	8.82	1.36	6.30	6.25	2.02	0.27	8.29
S_{er}	2.18						

Table 20: Standard Error of Estimate along Route B Using Okumura-Hata Model

LOS (in km)	3.01	4.00	10.08	15.03	20.08	23.03	31.76
Y	101.71	105.39	117.36	122.54	126.29	128.07	132.23
Y_{est}	106.09	107.14	113.58	118.83	124.18	127.18	136.57
$(Y - Y_{est})^2$	19.18	3.06	14.29	13.76	4.45	0.79	18.84
S_{er}	3.26						

Table 21: Standard Error of Estimate along Route C Using Friss Transmission Model

LOS (in km)	5.00	9.96	11.00	13.59	28.87	23.23	26.85	33.08	34.91	35.96
X	85.7	92.5	92.5	94.3	100.9	99.0	100.3	102.1	102.5	102.8
X_{est}	88.65	91.1	91.59	92.57	105.35	97.58	99.36	102.41	103.31	103.82
$(X - X_{est})^2$	8.7	1.96	0.83	2.99	19.80	2.02	0.88	0.096	0.66	1.04
S_{er}	1.97									

Table 22: Standard Error of Estimate along Route C Using Okumura-Hata Model

LOS (in km)	5.00	9.96	11.00	13.59	28.87	23.23	26.85	33.08	34.91	35.96
Y	108.28	117.21	118.49	121.21	130.99	128.18	130.05	132.76	133.45	133.84
Y_{est}	112.80	116.47	117.24	119.14	130.46	126.29	128.97	133.58	134.93	135.71
$(Y - Y_{est})^2$	20.43	0.55	1.56	4.29	0.28	3.57	1.17	0.67	2.19	3.50
S_{er}	1.95									

Table 23: Standard Error of Estimate along Route D Using Friss Transmission Model

LOS (in km)	4.00	6.36	10.04	12.61	16.80	16.82	17.42	20.25	30.00	34.04
X	83.7	87.7	91.7	93.4	96.18	96.2	96.5	97.8	101.20	102.3
X_{est}	87.39	88.74	90.83	92.30	94.69	94.50	95.04	96.65	102.21	104.51
$(X - X_{est})^2$	13.62	1.08	0.76	1.21	2.22	2.89	2.13	1.32	1.02	4.88
S_{er}	1.76									

Table 24: Standard Error of Estimate along Route D Using Okumura-Hata Model

LOS (in km)	4.00	6.36	10.04	12.61	16.80	16.82	17.42	20.25	30.00	34.04
Y	105.39	111.39	117.31	120.26	123.96	124.0	124.45	126.40	131.49	133.12
Y_{est}	110.98	112.99	116.11	118.30	121.86	121.88	122.39	124.80	133.08	136.51
$(Y - Y_{est})^2$	31.25	2.56	1.44	3.84	4.41	4.49	4.24	2.56	2.53	11.49
S_{er}	2.62									

Table 25: Path Loss Mean Error between Estimated Empirical Values and Measured Values

MODEL	FRIIS	OKUMURA-HATA
Path loss mean error	1.87	2.69

From Tables 8 to 15 and 17 to 25, we can see that Okumura-Hata model gave a closer prediction to the measurements in all the routes and so, it is more suitable for path loss prediction in Ekiti State. Friis transmission equation under-estimated the path loss prediction in Ekiti State with a mean error of 1.87dB along the routes while Okumura-Hata model gave a mean error of 2.69dB along the routes. Equation (14) gives a modified Okumura-Hata model for the prediction of path losses for the 91.5 FM radio station along any route in Ekiti State. This equation was derived by adding the mean deviation error to the original Okumura-Hata model to generate a suitable path loss prediction model for the radio station in the state.

From equation (4), the original Okumura-Hata model is given by

$$FSPL_2 = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(H_b) - C_h + [44.9 - 6.55log_{10}(H_b)]log_{10}(d)$$

The modified Okumura Hata model developed for path loss prediction in Ekiti State is therefore given by

$$\begin{aligned} FSPL_2 = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(H_b) \\ -C_h + [44.9 - 6.55log_{10}(H_b)]log_{10}(d) + 2.69 \end{aligned} \qquad (14)$$

4.0 Discussion of Results

Friis transmission equation and Okumura-Hata model were used to predict the path losses along four routes in Ekiti State and the results were shown in Tables 8 to 11. It was established that path loss of propagated radio signals increases with distance moved away from the base station. Least square regression analysis was carried out on the data in Tables 8 to 11 and empirical models were derived.

Tables 12 to 15 gives the empirical path loss predictions along the four routes considered. We have the standard error of estimate along all the routes, using the Friss and Okumura-Hata models, in Tables 17 to 24. Table 25 gives the path loss mean error between estimated empirical values and measured values.

From all the analysis, we can see that Okumura-Hata model gave a closer prediction to the measurements in all the routes and is more suitable for path loss prediction in Ekiti State. Friis transmission equation under-estimated the measured value. Therefore, Okumura-Hata model was modified and adopted for path loss prediction of electromagnetic signal in Ekiti State 91.5 FM MHz station.

5.0 Conclusion

Two empirical propagation models, the Friis transmission equation and the Okumura-Hata model were used to predict the path loss at locations along four routes in Ekiti State. The results obtained established the fact that attenuation of electromagnetic waves increases as the wave fronts move farther away from the transmitter. Measurements taken were compared with predictions made by the two propagation models used. Friis transmission equation under-estimated the path loss while Okumura-Hata model shows a closer agreement with the measured results. Therefore, a modified Okumura-Hata path loss prediction model, for Ekiti State 91.5 FM MHz station, was developed. This result will be very useful for Government and stakeholders in the broadcasting world.

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