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Path-Loss Determination of 91.5 MHZ FM Radio Channel of Ekiti State

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Abstract: *The measurement of the field strength distribution of Ekiti State broadcasting service radio channel propagating at 91.5MHz was conducted round the stretch of the State, with physical presence of the investigator in all the local government areas. The elevation of area visited including its longitude and latitude, and the field strength were measured, as well as the line of sight distance to the transmitter base with the use of the Dagatron Tm 10 Level (field strength) Meter, and Global Positioning System (GPS) receiver GARMIN MAP 76 Personal Navigator. For path loss prediction model calculations, investigation was carried out along four (4) major different routes away from Broadcasting Services of Ekiti State, (BSES) 91.5MHZ base station.The path loss prediction for Ekiti State was developed, and a comparison between the path loss prediction models by Friis and Okumura-Hata was made, to determine the most suitable for the terrain existing in Ekiti State, Nigeria. The corresponding error statistic in terms of the mean prediction error calculated using a statistical term-standard error of estimation to find the prediction error as the difference between the measured and predicted values. It was established that the path losses along the four routes considered of the radio signal being propagated increases with increase in distance moved away from the base station. Friis transmission equation underestimated, with a mean error of 1.76dB along routes A,B,C and D while Okumura-Hata model gave a mean error of 2.68dB along routes A,B,C and D. Thus, Okumura-Hata model gave a closer prediction to the measurements in all the routes and so, is more suitable for path loss prediction for Very High Frequency VHF waves in Ekiti State and that addition of a loss factor of 2.68dB be added to correction factor for any route in Ekiti State, Nigeria.*

Keywords: *Comparison, estimated data, frequency band, path loss, signal strength, transmitter.*

I. Introduction

The measurement of field strength distribution over a vast area of that across Ekiti State is highly complex task. Ekiti State is situated entirely within the tropics. It is located b tween longitude 40^o 5' and 50^o 45' East of the green-wich meridian and latitudes 70 ^{o} 15'and 80^o 45' North of the Equator. In 1996 when it was created, the population was put at 1,750,000, and mainly in upland zone rising over 250meters above sea level. Ekiti has a rhythmically undulating surface, and the landscape consists of ancient plains broken by steep-sided outcropping dome rocks. In radio frequency telecommunications, field strength is the magnitude of the received electromagnetic field which will excite-a receiving antenna and thereby induce a voltage at a specific frequency in order to provide an input signal to a radio receiver for such applications as cellular broadcasting, radio telephony and a wide variety of other radio-related applications[1,2]. A radio frequency, RF electromagnetic wave has both an electric and a magnetic component (electric field and magnetic field) and it is often convenient to express the intensity of radio frequency, RF environment at a given location in terms of units specific to each component. The unit "volt, per meter" (V/m) for electric field and the unit "Amperes per meter" (A/m) for magnetic field. A unit for characterizing the total electromagnetic field is "power density". Power density is most appropriately used when the point measurement is far enough away from the antenna of the transmitter. Radio frequency (RF) propagation is the behaviour of power density of Radio waves when they are transmitted, or propagated from one point of the earth to another or into various parts of the atmosphere. Like light waves, radio waves are affected by the phenomenon of reflection, diffraction, absorption, polarization and scattering. Radio propagation (power density) is also affected by the daily changes of water vapour in the troposphere and ionization in the upper atmosphere due to the sun [2,3]. Radio propagation (power density) is affected by several other factors determined by its path from point of propagation to the point of reception. Hence the need to measure the field strength at points away from the transmitter base.Free space or the earth's atmosphere is often used as a transmission medium for wave propagation [4,5,6]. To propagate transverse electromagnetic waves through the earth's atmosphere, it is necessary that the energy be radiated from the source (Base station) and then the energy captured at the receiving end which are functions of antennas, with radiating energy antenna called the transmitter and the capturing energy antenna called the receiver [6,7]. Space wave propagation includes radiated energy that travels in the lower few miles of the earth atmosphere, and include both direct and ground – reflected waves. Direct waves travel essentially in a straight line between the transmit and receive antennas commonly called line - of - sight (LOS) transmission, while ground reflected waves are those waves that are reflected by the earths surface as they propagate between the transmit and receiver antennas. Field intensity at the receive antenna depends on the distance between the two antenna (attenuation and absorption) and whether the direct and ground reflected waves are in phase (interference) [7,8]. The curvature of the earth presents a horizon to space wave propagation called the radio horizon, and due to atmospheric refraction, the radio horizon extends beyond the optical horizon for the common standard atmosphere[6,8]. The radio horizon is approximately four – thirds that of the optical horizon. Refraction is caused by the troposphere due to changes in its density, temprature, water vapour content, and relative conductivity, and radio horizon can be lengthened simply by elevating the transmit or receive antennas above the earth's surface with towers or by placing them on top of mountains or high buildings [8,9,10]. The strength of the electric field E (in volts/meter) at a distance r from a point source is given by E = $30P_t$ /r ; where P_t is the original transmitted power in watts, and one of the maxwell's equations [6,7,10]. Effective isotropic radiated power (EIRP) is defined as an equivalent transmit power and is expressed mathematically as

$$EIRP = P_r A_t \text{ watts} \quad (1)$$

Where P_r= total radiated power, A_t = transmit antenna directive gain or

$$EIRP\ (dBm) = 10 \log \frac{P_r}{0.01} + 10 \log A_t \quad (2)$$

EIRP or simply ERP (effective radiated power) is the equivalent power that an isotropic antenna would have to radiate to achieve the same power density in the chosen direction at a given point as another antenna. The power density ata given point, when expanded to include the transmit antenna gain is

$$\Im = \frac{P_r.A_t}{4\pi R^2} \quad (3)$$

Antennas are reciprocal devices; an antenna has the same power gain and directivity when it is used to receive electromagnetic waves as it has for transmitting electromagnetic waves. Consequently, the power received or captured by an antenna is the product of the power density in the space immediately surrounding the antenna and the antenna directive gain. Therefore,

$$\text{captured power} = c = \Im A_r = \frac{P_r.A_t A_r}{4\pi R^2} \quad (4)$$

Where A_r is the receiver antenna power gain. The captured power is not all useful; some of it is dissipated in the receive antenna [7,10]. The actual useful received power is the product of the received power density, the receive antenna's direct gain, and the receive antenna's efficiency or the receive power density times the receive antenna's power gain. If an antenna is lossless, it radiates 100%of the input power and the power gain is equal to the directive gain [8,11,13]. An antenna does not actually amplify the input power, but concentrates its radiated power in a particular direction. If gain is realized in one direction, a corresponding reduction in power density (a loss) must be realized in another direction [11,13]. The direction in which an antenna is pointing is always the direction of maximum radiation, and for maximum radiation, and maximum captured power, a receiver antenna must be pointing in the direction from which the reception is desired.Table 1 shows the radio frequency spectrum with frequency band of 300 to 3000kHz used for medium frequency AM radio broadcasting, 3 to 30MHz and 30-300MHz for high frequency (HF) and very high frequency (VHF) broadcasting channels.

Table 1: Radio Frequency Spectrum and Uses [2]

Frequency Band	Descriptive Designation	Uses
3-30kHz	Very Low Frequency (VLF)	In radio navigation system
30-300kHz	Low Frequency (LF)	In submarine link
300-3000kHz	Medium Frequency	AM Radio Broadcast, Links for ships
3-30MHz	High Frequency (HF)	Broadcasting; radio link satellite communication
30-300MHz	Very High Frequency (VHF)	TV Broadcasting, point to point communication
300-3000MHz	Ultra High Frequency (UHF)	TV Broadcasting, RADAR, Radio Navigation
3-30GHz	Super High Frequency (SHF)	Satellite communications, RADAR, Radio Navigation
30-300GHz	Extremely High Frequency (EHF)	For Research

II. Materials And Methods

2.1 Materials used:

The following instruments and materials were used in the course of carrying out this research;

i. The Dagatron Tm 10 Level (field strength) Meter, with frequency range (5MHz-862MHz), measurement range (15-120dBμV), resolution (0.1dB), and accuracy (+/-3dB), and Unit of measurement in dB-μV.

ii. The Global Positioning System (GPS) receiver; GARMIN MAP 76 Personal Navigator
iii. FM receiver
iv. Ekiti State Administrative map.

Based on the models used and the nature of this experiment the following parameters as in table 2 were used.

Table 2: Experimental parameters

Parameter	Route A	Route B	Route C	Route D
Frequency	91.5MHz	91.5MHz	91.5MHz	91.5MHz
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

Using equation 4.1 and equation 4.2 to compute path losses, I arrived at the values in the tables 4.3, 4.4, 4.5, 4.6 for the routes under study. (Route A, B, C, and D respectively).

2.2. Research Methodology

The method adopted in carrying out this investigation is such that requires the physical presence of the investigator in the various locations (all the towns and villages) where the signal is expected to be received. This is done to measure the longitude and latitude of the place, the elevation 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 / transmitter base is marked as "home" on the position page of the GARMIN GPS map and stored in the memory. Then at distances away from the transmitter base, at specific points in the various towns measurements were taken and recorded for the line of sight distance from the transmitter base, longitude and latitude, elevation above sea level, and field strength of the radio signal are carried out. The electric field strength of the transmitted television signal for different locations with their corresponding distances (LOS) from the base station were recorded. Also, determined and recorded were the latitude, longitude and the altitude of the various locations where data were collected. Arrangements were made with the station to ensure continuous operation of the transmitter during the data collation period. The data so collected are tabulated for easy computation / analysis. The procedure is repeated in all the town and villages with the aid of the following high precision instrument:

- The Dagatron Tm-10CATV/TV Field Strength Analyzer (5MHz to 862MHz)
- The Global Positioning System, (GPS) receiver
- The Ekiti State administrative map for easy navigation of the state

It also provides a sure guide along the selected routes were path-loss prediction model calculation was carried out. The experimental result readings were in multiples to enhance a high degree of accuracy.For path loss prediction model calculations, investigation was carried out along four (4) different routes away from Broadcasting Services of Ekiti State, (BSES) 91.5MHZ base station. The routes along which investigation was carried out are tagged routes A,B,C,D:

- Route A: Ado – Iworoko – Ifaki – Orin Ekiti – Ido – Usi – Ayetoro – Otun – Ekan (Kwara State)
- Route B: Ado – Ikere – Iju – Itaogbolu, (Ondo State)
- Route C: Ado – Iyin – Igede – Aramoko – Itaore – Efon
- Route D: Ado – Iworoko – Ifaki – Ayegbaju – Oye

The measured data were used to validate propagation model proposed by Friss and Okumura-Hata in order to determine the necessary adjustments to those models for use in the design of communication system in Ekiti State.

III. Results

These measurements of field strength at different locations were taken in multiples, then the average is calculated so as to ensure a high level of accuracy of the figures. The line-of-sight distance in kilometre (km), the latitude in degree, the longitude in degree, the elevation in meters above sea level, the average value of the field strength (Radio signal), the location where the readings were taken and the local government area corresponding to the location were displayed in a tabular form as the result of the field experimentation.

3.1 Measurement of filed strength distribution of FM radio on (91.5) channel across Ekiti State.

Fris Transmission equation is given by $L = 20\log_{10}\left(\frac{4\pi df}{c}\right)$

Where d, is the line-of-sight, LOS distance away from the transmitter in kilometres, f is the frequency of the wave in MHz, and c is the speed of light in free space. L is the path loss in decibel, dB.
Then FSPL (dB) = $20\log^{d}+20\log^{f}+32.45$ ----------------------5

Okumura Hata model for a large number is formulated as

$L=69.55+26.16\log^{f}-13.8\log h_B-CH+[44.9-6.55\log h_B]\log^{d}$
$CH=8.29[\log(1.54hm)]^2-1.1$ for frequency ≤ 200MHz -------------------6

Where L=path loss unit: decibel, dB
h_M= Height (m) of mobile station antenna; h_B=Height (m) of base station antenna; f=frequency(MHz) of transmission. C_H= Antenna height correction factor; d= Distance base (km) and mobile station.
When least square regression analysis was carried out on the data in table 3, equation 7 was derived.

$$LFa = 86.10 + 0.49 \times \text{LOS Distance} \quad LFb = 82.03 + 0.17 \times \text{LOS Distance}$$
$$LFc = 86.20 + 0.49 \times \text{LOS Distance}$$

$LFd = 85.11 + 0.57 \times \text{LOS Distance}$
$LOa = 108.60 + 0.74 \times \text{LOS Distance}$
$LOb = 108.60 + 0.74 \times \text{LOS Distance}$
$LOc = 109.1 + 0.74 \times \text{LOS Distance}$
$LOd = 107.58 + 0.85 \times \text{LOS Distance}$ ……………7

Where,
LFa, b, c, d = Estimated / Predicted path loss using Fris transmission equation for Route A,B,C,D
LOa, b, c, d = Estimated / predicted path loss using Okumura-Hata Model for Route A,B,C,D
LOSDistance is the distance away from the transmitter.

When equation3 is applied, it gave the approximate values of the predicted path loss data in table 4,5,6,7.

Table 3. Measured electric field signals for different locations within the State.

S/N	LOS (km)	Latitude (Degree)	Longitude	Elevation	/E/ Radio Signal	/E/ (Average)	Location	LGA
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	Ifaki2	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 Moba
14.	37.40	7.98748	5.12238	548.7	17.7/17.2	17.45	7th Day Church	Otun 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 com High School	Ekan
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	Ilesamodun	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	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
32.	20.08	7.49487	5.25425	367.5	32.3/31.4	31.85	General Hospital	Ikere
33.	20.75	7.49080	5.21912	368.5	36.9/43.5	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 Cat
36.	27.78	7.50546	5.06233	379.1	35.2/35.6	35.4	Igbara Odo 2	Ekiti South
37.	29.70	7.59019	5.99198	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
39.	27.39	7.61301	5.00670	465.3	23.4/24.0	23.7	Olohan's Palace	Erinjiyan
40.	22.83	7.69280	5.04066	50.66	44.4/44.0	44.2	Oke Iro Aramoko	Ekiti
41.	23.23	7.70662	5.03866	475.3	40.8/39.5	40.15	Aramoko 2	Iwaro St.

Table 4: Path loss prediction along route A

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
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 colledge	Efon
47.	24.49	7.80021	5.06432	450.7	39.0/39.5	39.25	Ijero roundabout	
48.	25.36	7.81658	5.06658	505.0	44.3/42.9	43.6	Owa's Palace	Ijero Ekiti
49.	13.57	7.67077	5.12396	575.6	55.6/54.7	55.15	Igede Ekiti	Irepodun/Ife
50.	9.96	7.39517	5.09517	578.5	55.7/56.8	56.25	Iyin Ekiti	Irepodun/Ife

Table 5: Path loss prediction along route B

Los (km)	3.01	4.00	10.08	15.03	20.08	23.03	31.76
Fris Model (dB)	81.28	3.79	1.79	5.29	7.79	8.91	01.70
Kumura –Hata Model (dB)	101.71	105.39	117.36	122.54	126.29	128.07	132.23

Table 6: Path loss prediction along route C

Los (km)	5.00	9.96	11.00	13.59	28.87	23.23	26.85	33.08	34.91	35.96
Fris Model (dB)	85.7	92.5	92.5	94.3	100.9	99.01	100.3	102.1	102.5	102.8
Okumura-Hata	108.28	117.21	118.49	121.21	130.99	128.18	130.05	132.76	133.45	133.84

Table 7: Path loss prediction along route D

Los (km)	4.00	6.36	10.04	12.61	16.80	16.82	17.42	20.25	30.00	34.04
Fris Model (dB)	83.7	87.7	91.7	93.4	96.18	96.20	96.5	97.8	101.2	102.3
Okumura-Hata	105.39	111.39	117.31	120.26	123.96	124.00	124.45	126.40	131.49	133.12

Table 8: Comparison of path loss empirical model with measurement along route A.

MODEL	FRIIS (dB)	OKUMURA-HATA (dB)
STANDARD ERROR OF ESTIMATE	1.51	2.89

Table 9: Comparison of path loss empirical model with measurement along route B.

MODEL	FRIIS (dB)	OKUMURA-HATA (dB)
STANDARD ERROR OF ESTIMATE	2.16	3.25

Table 10: Comparison of path loss empirical model with measurement along route C.

MODEL	FRIIS (dB)	OKUMURA-HATA (dB)
STANDARD ERROR OF ESTIMATE	2.16	3.25

Table 11: Comparison of path loss empirical model with measurement along route D.

MODEL	FRIIS (dB)	OKUMURA-HATA (dB)
STANDARD ERROR OF ESTIMATE	1.76	2.65

Table 12: Path loss mean error between estimate empirical model with measured value

MODEL	FRIIS (dB)	OKUMURA-HATA (dB)
STANDARD ERROR OF ESTIMATE	1.74	2.68

3.2 Comparison between estimated data with measured data.

The measurements in Tables 4,5,6,7 were compared with the estimated / predicted values in equation 7 by the use of standard error of estimate and tables 8,9,10,11 were developed with a path loss mean error in table 12

$S = \sqrt{\sum \frac{(y - yest)^2}{n}}$ Where yest = estimated value of y

∑ = summation; S= standard error of estimated; Y=original variable; N= total number of variables

This clearly shows that both Friis and Okumura-Hata's model give a relatively accurate result with the measured data with Friis giving a fairly underestimation of the path result.

3.3 The developed Model

From all the table above, Hata model gave a closer prediction to the measurements in all the routes and so, is more suitable for path loss prediction in Ekiti State. Friis transmission equation underestimated, with a mean error of 1.76dB along routes A,B,C and D while Okumura-Hata model gave a mean error of 2.68dB along routes A,B,C and D. The mean deviation error for prediction along any route in Ekiti State. The original Okumura-Hata model is given by:

$L = 69.55 + 16\log^F - 13.82\log h_B - C_H + [44.9 - 6.55\log h_B] \log^d$

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

$L = 69.55 + 26.16\log^F - 13.82\log h_B - C_H + [44.9 - 6.55\log h_B] \log d + 2.68\text{dB}$

3.4 Discussion and Interpretation of result.

Friis transmission equation and Okumura-Hata were used to predict the path losses along four routes in Ekiti State and the result are shown in table 4,5,6,7. It was established that path loss of radio signal being propagated increases with increase in distance moved away from the base station. Least square regression analysis was carried out on the data in table 4,5,6,7 then equation7, was derived. When equation7 was applied it gave approximate value of the predicted path loss data in tables 4,5,6,7.

The corresponding error statistic in terms of the mean prediction error was calculation using a statistical term-standard error of estimation to find the prediction error as the difference between the measurement and the predicted values. This is shown on tables 8,9,10,11. This shows that Okumura-Hata model gave a closer prediction to the measurement in all the routes and is more suitable for path loss prediction in Ekiti State. Friis transmission equation underestimated the value measured. Therefore, Okumura-Hata model was modified and adopted for path loss prediction for electromagnetic signal in Ekiti State.

IV. 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 model used. Friis transmission equation under estimated the path loss. Okumura model show a closer agreement with the measurement result. Hata's model shows that it is more suitable for use in path loss prediction in Ekiti State. With the mean error value gotten, modified Okumura-Hata path loss prediction model for Ekiti was developed. From the observed result, it is therefore established that, of the two model used, Hata's model is suitable for use in path loss prediction for Very High Frequency VHF waves in Ekiti State and that addition loss factor of 2.68dB be added to correction factor for any route in Ekiti State.

References

[1]. http/www.nbc.gov.com; visited on 12-01-2013

[2]. Broadcasting Organization of Nigeria (BON) Directory. 2010, 10-70

[3]. G.O. Ajayi, and I.E. Owolabi, "Medium Wave Propagation Curves (for use in medium Wave transmission planning and design)" Technical Report of the Radio Wave Propagation Research Group, Department of Electronic and Electrical Engineering, University of Ife, Nigeria. 1975

[4]. G.O. Ajayi, and I.E. Owolabi, Coverage Area of the 10kW, 702 kHz Medium Wave Transmitter at Minna and Feasibility Studies for full Radio Coverage Area of Niger State, Technical Report of the Electrical Communication Consultancy Unit (ECCU), Department of Electrical and Electronic Engineering, University of Ife, Nigeria. 1979

[5]. L. Bothias, Radio Wave Propagation, McGraw-Hill Inc. New York St. Louis San Francisca Montreal Toronto 1987, 144-175.

[6]. Beasley and Miller: Modern Electronic Communication, 8th edition, Prentice Hall of India pvt. Ltd. 2010

[7]. G. Kennedy, and D. Bernand, Electronic Communication Systems, McGraw Hill/Macmillan, Singapore, 1992, 80-150

[8]. G.O. Ajayi, and I.E. Owolabi, Ground Conductivity Survey in some parts of Nigeria using Radio Wave Attenuation Technique, NJECT, 6(4), 1981, 20-40.
[9]. O.O. Fagbohun: Studies of Electric field distribution of uhf television signal in Ekiti State, Nigeria. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834, p-ISSN 2278-8735, Volume 9, Issue 2 Ver. V (Mar-Apr), 2014) pp 111-121; American National Engineering Database ANED-DDL 14.2834/iosr-jece-S0925111121;DOI(Digital Object Identifier)10.9790/2834- 0925111121
[10]. CCIR Report 239-6, Propagation Statistics required for Broadcasting Service using the frequency Range 30 to 1000MHz", Recommendations and Reports of the CCIR, Vol 5, ITU, Geneva, In Hall M. (Ed); Ibid, 1986, 256.
[11]. R.E Collin, Antennas and Radiowave propagation, McGraw Hill Inc. New Delhi, 1985, 40-409
[12]. M. Eiche, Measurement of the electric field strength to determine the Coverage Area of FM Radio Stations in Niger State, Nigeria. 2010
[13]. O.O Fagbohun : " Dealing with Noise and Interference in Electronic instrumentation circuits" Compendium of Engineering Monographs (CEM) Journal, Vol. 2, No. 3 , 2005, Pp 28-35
[14]. ITU-R, Document 3/11 I-E,, Working Party 3J, Draft Handbook on Radio meterology, 1995, 25-60
[15]. http/www.en.wikipedia org.
[16]. http/www/gps.go/systems/gps/indexhtml.