SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348 – 8549 /doi:10.14445/23488549/IJECE-V7I1P102

Volume 7 Issue 1, 5-14, January 2020

The Impact of Propagation Models on TV White Space Estimation in Southern Nigeria

Kebiru Abu[1], Stephen U. Ufoaroh[2]and Obomeghie Mariam A.[3]

Department of Electronics and Computer Engineering, Nnamdi Azikiwe University Awka, Nigeria[1,2]
Department of Electrical/Electronic Engineering, Federal Polytechnic, Auchi, Edo State, Nigeria[3].

Received Date: 18 December 2019
Revised Date: 28 January 2020
Accepted Date: 01 February 2020

Abstract: *Geo-location databases are ideal for detecting TV white spaces by white space devices (WSD) in the United States (US). The approach protects spectrum incumbent (primary users) and secondary users from interference adequately by keeping a record of the TV transmitters' information and relying on propagation models to determine the TV transmitters' protection area. This paper presents statistical path loss models derived from experimental data collected in Benin city, Edo State in Southern Nigeria from Edo Broadcasting Service (EBS), operating at 745.25MHz. The measurements' results were used to develop a path loss model for the urban areas of Edo state. The measurement results showed that the Path loss increases by 23.1dB per decade in the urban areas. Variations in path loss between the measured and the predicted values from the Okumura-Hata model were calculated by finding the mean square errors (MSE) to be 1.31dB for the urban terrain. These variations (errors) were used to modify the Okumura-Hata models for the terrain. Comparing the modified Hata model with the measured values showed a better result. The developed statistical Path loss models or the modified Hata models can be used in the urban areas of Southern Nigeria.*

Keywords — *Interference, TV whitespace, Radio Spectrum, Radio Propagation, Southern Nigeria.*

I. INTRODUCTION

Interference by white space devices (WSDs) to licensed incumbents operations in the television white spaces (TVWSs)could hinder the propagation of future wireless networks in the TV band, which has a greater transmission range and better penetration property as compared to the higher frequency bands [1].

At present, widespread research is ongoing in various research centers and institutions to discover possible ways of avoiding interference as much as possible. White space devices could avoid causing interference by accurately detecting the white spaces and transmitting only when the licensed incumbents are not transmitting.

One of the possible approaches proposed in the literature for white space detection is the use of geo-location databases. In this approach, the WSDs are required to consult a centralized (or regional mirror) geo-location database to determine if there are any TVWS (free channels) they can use without causing interference to other services. ECC requires that the WSDs have to recognize and indicate their current location before sending the query. There are few essential parameters yet to be decided in the future: the location precision, how often the devices should contact the database, and the quality of the database itself. [2]

Too precise location requirement imposes unnecessary complexity to the WSDs while contacting the server at short time intervals consumes the battery life of the devices. With this scheme, WSDs are not allowed to transmit before they receive notifications from the database about the available white spaces, if any, in their location.

This requires that the WSDs make initial connectivity to the database in some other way than the white space frequencies. Presently, the master-slave communication architecture is proposed to assuage this problem [2]; a master device, most likely an access point or a base station, having access to the location information will connect to the database via the internet. Then it, in turn, serves the inquiries of the slave WSDsat its vicinity.

At present, this method is the preferred method for detecting TV white spaces by white space devices because it guarantees a high protection of the spectrum incumbents from interference [4]. How accurate geo-location databases are in determining the protection area of the TV transmitters is largely dependent on how accurate the propagation models predict the TV signal attenuation (path loss) over distance.

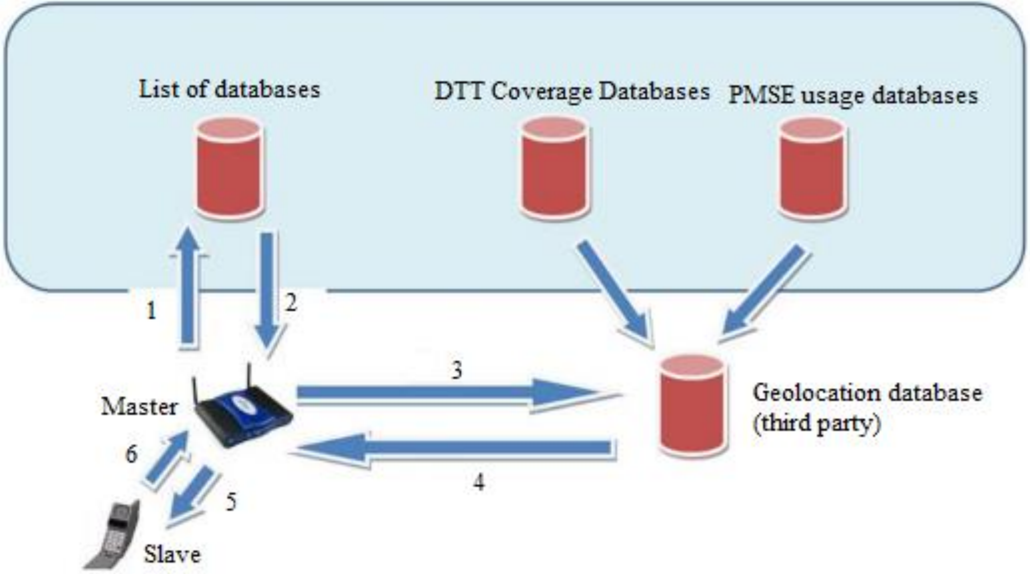

Fig.1. Possible geo-location database proposed by Ofcom.[2],[3]

Therefore, to determine the actual effect of Benin City, Edo State, and the Nigerian environment on signal propagation, field measurements have that indubitable advantage of taking into account all their effects on the propagated signal. This research aims to improve the quality of wireless services on TVWS Estimation in Edo State, Nigeria, by carrying out site-specific measurements and developing an acceptable Path loss model for the region.

This paper is structured as follows: section 2.0introduces propagation models widely in use; section 2.1looks at performance evaluation done by the authors on a public safety white space network in Benin City, Edo State, Nigeria; section 3describes the method of data collection deployed. Section 4 presents data analysis and results. Section 5 compared the measured results with results from existing models and propose possible adjustments to the Hata (urban) model for improved accuracy of its use within Edo State, Nigeria.

II. PROPAGATION MODELS

In wireless communications, when a signal propagates from the transmitter to the receiver, the signal's power is affected by distance, terrain, obstructions (such as trees, buildings, etc.), and atmospheric conditions. In this paper, three different propagation models are used to estimate the TVWS availability in Benin City, Edo State: Hata, Egliand free space. These propagation models are explained in the following subsections.

A. Hata model for urban areas

This is an enhancement of the Okumura model and is sometimes called the Okumura-Hata model. This model incorporates the effects of diffraction, reflection, and scattering caused by city structures[1], [5]. It is suited for both point-to-point and point-to multipoint transmissions. Its expression for urban areas is given in Equation 1:

$$PL_{Hata}(dB) = 69.55 + 26.16 log_{10} f_{MHz} - 13.82 log_{10} h_t - a(h_r) + (44.9 - 6.55 log_{10} h_t) log_{10} d_{km} \quad (1)$$

Where $h_t$and $h_r$are base station and mobile antenna heights in meters respectively,

$d_{km}$is the link distance

$f_{MHz}$is the frequency of transmission

The term $a(h_r)$is an antenna height-gain correction factor that depends upon the environment [1], [6].

It is equal to zero for $h_r = 0$; otherwise, it is equal to $3.2(log_{10} 11.75 h_r)^2 - 4.97$ with $f_{MHz} > 300$, which was the case in our situation.

B. Egli Model

It is a model that assumes gently rolling terrain between transmitter and receiver and does not require the terrain elevation data between them. It is normally used for point-to-point communication. It is applicable in scenarios where there is line-of-sight (LOS) transmission between one fixed antenna and one mobile antenna and where transmission has to go over irregular terrain. The model does not apply to rugged terrain areas and where there is a significant obstruction such as vegetation in the middle of the link [1], [7] its equations for the propagation loss is given as follows:

$$PL_{Egli}=\begin{cases}20log_{10} f_{MHz}+P_0\ +76.3, & h_r<10\\ 20log_{10} f_{MHz}+P_0\ +83.9, & h_r>10\end{cases}(2)$$

$$P_0= 40log_{10} d_{km} - \ 20log_{10} h_t - \ 10log_{10} h_r(3)$$

Where $f_{MHz}$is the frequency of transmission, $d_{km}$is the link distance, $h_t$is the base station antenna height in *meters* and $h_r$is the mobile station antenna height in *meters*.

C. Free space path loss

This is a basic propagation model, which describes the propagation path loss between transmitter and receiver in free space, with no obstacles that could cause reflection or diffraction. It simply describes reducing the signal power density as proportional to the distance's square from the transmitter and square of the frequency. [1]

Calculating free space transmission loss requires a faithful representation of the transmitter and receiver characteristics. Assuming we have a transmitter with power P_tCoupled to an antenna that radiates Omni-directionally. At a distance *d* from the transmitter, the radiated power is distributed over an area of $4\pi d^2$, so that the power flux density is given as:

$P_d = \frac{P_t}{4\pi d^2}(4)$

Transmission loss for such a system depends on how much of this power is captured by the receiving antenna. If the effective aperture of the antenna isA_e, the wavelength of the received signal λ, and the power density P_d can be determined [8]. The effective area $A_e$of the receiving isotropic antenna is given as follows:

$A_e = \frac{\lambda^2}{4\pi}(5)$

While power received is

$P_r = P_d \times A_r = \frac{P_t \times \lambda^2}{(4\pi d)}(6)$

Any loss can be calculated from the transmitted and received power as:

$L_p = P_t - P_r\ \ (7)$

Substituting (6) in (7) yields equation (9)

$L_p(dB) = \ 20Log_{10}(4\pi) + 20Log(d) -$
$20LogLog_{10}\ (\lambda)(8)$

Then substituting (λ (in km) = 0.3 / f (in MHz)) and rationalizing the equation produces the generic free-space path loss formula, which is given as:

$$P_L(dB) = \ 32.44 + 20LogF_{MHz} + 20Logd_i(9)$$

Where *f* = frequency in MHz and *d* = distance in km. Equation 9 is the Harald T. Friss free space path loss.

a) Performance Evaluation

To have an understandable picture of how propagation models can perform in the TV frequency band, ground truth evaluation of the approaches were performed by conducting a real-time spectrum measurement campaign and comparing values of the path losses obtained from the measurements against those predicted by the propagation models discussed in the previous section in Benin-city, Edo State, Nigeria. This section gives a detailed discussion of how the whole process was carried out.

III. MEASUREMENT SETUP

A. Experimental Measurement Environment

The field measurements were carried out in the urban city of Benin. Benin is a city located in Edo State. An Analog Terrestrial Television (ATT) transmitter of one of the public TV broadcasters in Southern Nigeria, the Edo Broadcasting Service (EBS) TV situated along Aduwawa road on channel 55 UHF Band that transmit on 743.25MHz frequency with mast height 228.6m and transmitter rating of 30KW located on coordinates 6° 21´ 7.686 "N and 5° 40´ 25.95 "E with Effective Radiated Power (ERP) of 44.77dB, was used as a reference for the measurements. Readings were taken at intervals of 100m from the base transceiver station at a near-constant mobile station height of 1.5meters. Fig. 2 depicts the Google map location of the reference measurement site. Table 1 shows the measurement parameters.

Table 1: Measurement Parameters.

Frequency	743.25MHz
Base station Antenna height	228.6m
Transmitted power	44.77dB
Transmitter rating	30KW
Channel	55 UHF
Coordinates	6° 21´ 7.686"N, 5° 40´ 25.95"E
Spectrum analyzer antenna height	1.5 meters

Fig.2. Google map of Aduwawa, Benin City. (Courtesy: Google earth)

B. Measuring Instruments/Equipment

1. Spectrum Analyzer **(**RF explorer 3G combo model)
2. A laptop equipped with touchstone RF spectrum Analyzer software.
3. Mini USB cable.
4. A global positioning system (GPS) receiver set.
5. Compass

C. NBC Licensed Stations in Edo State

Table 2 shows the licensed TV station signal, their channels, and frequency of operation that can be received within the study area.

The measured received signal strength (in dBm) from the base station transmitter was carried out during December 2017 and repeated in January and February 2018 along three different routes, designated as radio path a, b, and c as depicted in Fig. 3. Due to variations in the received signal strength measurements, the mean values are used for the model development.

Table 2: TV Stations parameters in Edo State

S/No	STATION	CHANNEL	FREQUENCY
1.	Edo Broadcasting Station	55	743.25MHz
2.	Independent Television	22	479.25MHz
3.	Silverbird Television	30	543.25MHz
4.	NTAIruekpen	45	663.25MHz
5.	NTA Benin	7	189.25 MHz
6.	NTAUzairue	41	631.25MHz

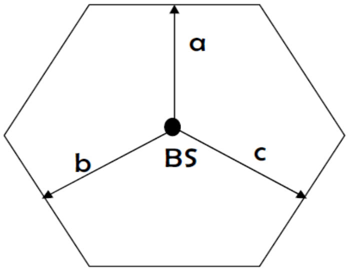

Fig.3. Diagram showing the base station (BS) transmitter and the three different radio routes.

IV. RESULTS AND ANALYSIS

For Path Loss determination, experimental field data (RSS) were gathered to optimize the model derived, whose validity must be tested since the model is bound to be ineffective and should not be deployed if its validity cannot be tested. Table 3 shows the mean values of the measured RSS value and Subsequent values of Path Losses for specified distances, 0.1km≤ di ≤ 2.0km; obtained using equation 10. [9].

$$P_L(dB) = 10Log\left(\frac{p_t}{p_r}\right)(dB) \quad (10)$$

Recall, Path Loss Exponent indicates the rate at which Path Loss increases with distance. Path Loss can, therefore, be Estimated or Predicted using data obtained from field measurements, which are substituted into Equation 11

$$P_L(dB) = P_L(d_0) + 10nLog(\frac{d}{d_0}), \quad (11)$$

A simple power-law path loss model [10] was chosen for predicting the distance of reliable communication between two mobiles. A modified power-law path loss model is given as:

$L_p(d_i) = L_p(d_o) + 10nLog(\frac{d}{d_0}) + X\sigma$ (12)

Where

$$n = \frac{[L_p(d_i) - L_p(d_o)]}{[10 \log_{10}(\frac{d_i}{d_o})]} \quad (13)$$

where $X\sigma$ is a Zero-Mean Gaussian distributed random variable (in dB) with standard deviation σ(in dB). Using linear regression analysis, the path loss exponent, n, can be determined by minimizing (in a mean square error, sense) the difference between measured and predicted values of equation (13) to yield:

$$n = \frac{\sum_{i=1}^{m}[L_p(d_i) - L_p(d_o)]}{\sum_{i=1}^{m}[10 \log_{10}(\frac{d_i}{d_o})]} (14)$$

Where the term $L_p(d_i)$ represents Measured Path Loss or (Pm), and $L_p(d_0)$Represents Predicted PathLoss or (Pr), and k is the number of measured data or sample points.

The expression, $L_p(d_i) - L_p(d_o)$, that is, $(P_m - P_r)$ is an error term concerning n, and the sum of the mean squared error, e(n), is expressed as:

$$e(n) = \sum_{i=1}^{m}[L_p(d_i) - L_p(d_o)]^2 \quad (15)$$

The value of n, which minimizes the Mean Square Error (MSE), is obtained by equating the derivative of equation (15) to zero and solving for n:

$$\frac{\delta e(\eta)}{\delta n} = 0 \quad (16)$$

From Equation (10), at a close in the distance, d_o of 100m, the Average Received Power is:

$power(R_{Xav}) = P_r = dBm = -62dBm.$

That is, $-62 = 10logP_r orlogP_r = -6.2$

$P_r = log^{-1} - 6.2$

$P_r = 6.309 \times 10^{-7} dB$andHence $P_t = 30kw = 44.77dB$

Working with decibel (dB) unit, the measured Path Loss value becomes:

$$P_L(d_i) = 10Log\left(\frac{44.77}{6.309 \times 10^{-7}}\right) = 79dB$$

Subsequent values of Path Losses for specified distances, 0.1km ≤ di ≤ 2.0km; are evaluated using the same procedure and presented in Table 3

The path loss can be estimated or predicted using data obtained from field measurements, which are substituted into equation (11)

$$P_L(dB) = P_L(d_0) + 10nLog(\frac{d}{d_0})$$

From field measurement, at the close in the distance (d_0) of 0.1 km, $L_p\ (d_0)$ = 79dB.

Estimated or Predicted values of Path Loss at specified distances are calculated as follows:

At d_i = 0.1km =d_0, $d_i = 0.1km = d_0$

$$P_L(di) = 79 + 10nlog\frac{0.1}{0.1} = 79$$

$Atd_0 \ = 0.1kmandd_1 \ = 0.2km$

$$P_L(di) = 79 + 10nlog\frac{0.2}{0.1} = 79 + 3.01n$$

Subsequent evaluations were carried out in the same manner.

Table 3: Measured and predicted Path Loss for Benin Urban

Distance (km)	RSSI (dBm) Average	Measured path loss $[L_p(d_0)]$	Predicted path loss $[L_p(d_i)]$
0.10	-62.0	79	79
0.20	-68.0	85	79 + 3.01n
0.30	-72.3	89	79 + 4.77n
0.40	-76.0	93	79 + 6.02n
0.50	-79.3	96	79+ 6.98n
0.60	-81.0	98	79 + 7.78n
0.70	-73.0	90	79 + 8.45n
0.80	-78.6	95	79 + 9.03n
0.90	-79.0	96	79 + 9.54n
1.00	-89.0	106	79 + 10n
1.10	-92.0	109	79 + 10.4n
1.20	-88.3	105	79+10.79n
1.30	-85.3	102	79 +11.13n
1.40	-89.0	106	79 + 11.46n
1.50	-95.0	112	79 + 11.76n
1.60	-88.3	105	79 +12.04n
1.70	-94.0	111	79 + 12.30n
1.80	-96.6	113	79 + 12.55n
1.90	-91.6	108	79 + 12.78n
2.00	-86.0	103	79 + 13.01n

From the result of the evaluation, we have that equation (16) becomes;

$$e(n) = \sum_{i=1}^{m}[L_p(d_i) - L_p(d_o)]^2$$

$$e(n) = 10573 - 8896.72n + 1925.64n^2$$

$$\frac{\delta e(n)}{\delta n} = 2[1925.64n] - 8896.72 = 0$$

$$\frac{\delta e(n)}{\delta n} = 3851.28n - 8896.72$$

$$n = \frac{8896.72}{3851.28}$$

$$n = 2.31$$

To determine the standard deviation, $\sigma\ (dB)$ about the mean values:

$$\sigma = \sqrt{\sum \frac{[P_L(d_i) - P_L(d_0)]^2}{N}}$$

$$= \sqrt{\sum \frac{[10573 - 8896.72n + \quad 1925.65]^2}{20}}$$

$$= \sqrt{\sum \frac{[10573 - 8896.72(2.31) + \quad 1925.65(2.31)^2}{20}}$$

$$\sigma = \sqrt{\frac{297.037765}{20}}$$

$$\sigma = \sqrt{14.85}$$

$$\sigma = 3.85 \quad = 4dB$$

The standard deviation, $\sigma$of the log-normal shadowing about its mean value is 4dB

Hence,$L_p(dB) = 79 + 10(2.31)Log\left(\frac{d}{d_0}\right) + 4$

Therefore, the resultant Path Loss Model for shadowed Benin Urban Environment is:

$$L_p(dB) = 83 + 23.1Log\left(\frac{d}{d_0}\right)$$

The empirical path loss model for Benin urban area is given as:

$$L_p(dB) = 83 + 23.1Log\left(\frac{d}{d_0}\right)$$

$$L_p(dB) = 83 + 23.1Log(D)dBm \qquad (17)$$

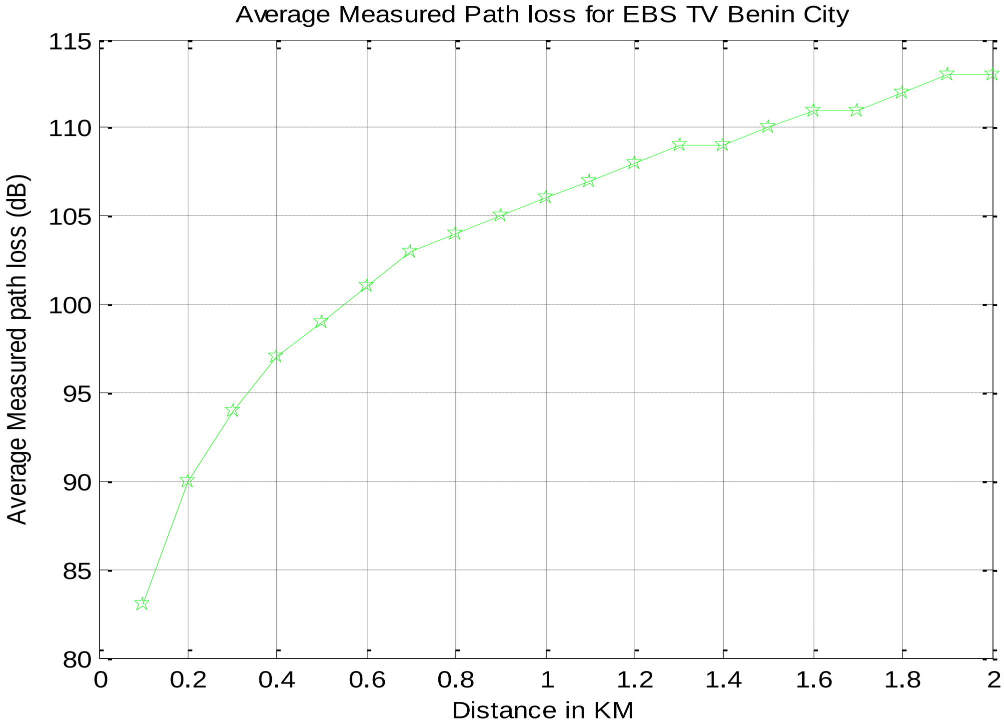

Fig.4.Simulation of Average measured Path loss distance for Benin Urban

V. A *Comparison of the measured model with existing models*

To lend integrity to our derived Proposed Path Loss model, this work compared the statistically predicted result of Received Signal Strength and that of other existing (traditional) models with the measured results. THEREFORE, the RSS (Pr) is calculated under the same set of transmission conditions using the same simulation parameters. Recalling equation (1) for the Urban path loss determination of the Hata model, equation (2) for the EgliModel, and equation (9) for the free space model and substituting the test parameters (*f=743.25MHz,hm=1.5m, and hb=228.6m*) into the equations, produced plots shown in Fig. 5.

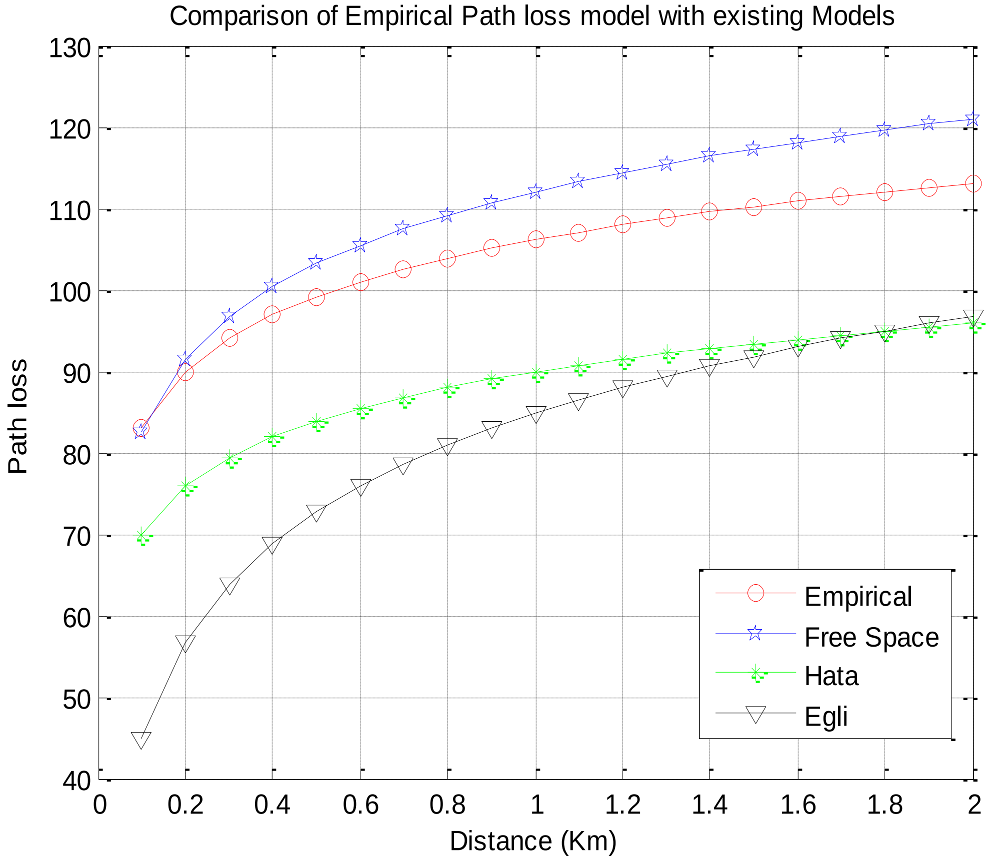

Fig.5.Graph plot showing the comparison of various Path Loss Models

B. Modified Hata Model

The Hata model value was lower than the measured values in the urban terrain tested from the comparison result. This is certainly due to the differences in Tokyo's physical development compared to the Edo State, Nigeria. To improve on the accuracy of the Hata model in the region, the mean square error (MSE) between the measured and the Hata models were calculated using equation 18: [11],[12] is given by:

$$MSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_m - P_r)^2} \qquad (18)$$

Where: Pm is the measured path loss (dB), Pr is the predicted path loss (dB), N is the number of measured data points.

$$MSE = \sqrt{\sum_{i=1}^{N}(P_m - P_r)^2} / \text{(N)} \qquad (19)$$

The MSE was found to be 1.31dB for urban areas and was used to modify the Hata models, and the results were compared to the measured values as shown in Fig.6. The modified Hata models for Benin urban area is as follows:

$$PL_{Hata}(dB)= 68.64 + 26.16log_{10}f_{MHz} - 13.82log_{10}h_t - a(h_r) + (44.9 - 6.55log_{10}h_t)log_{10}d_{km} (20)$$

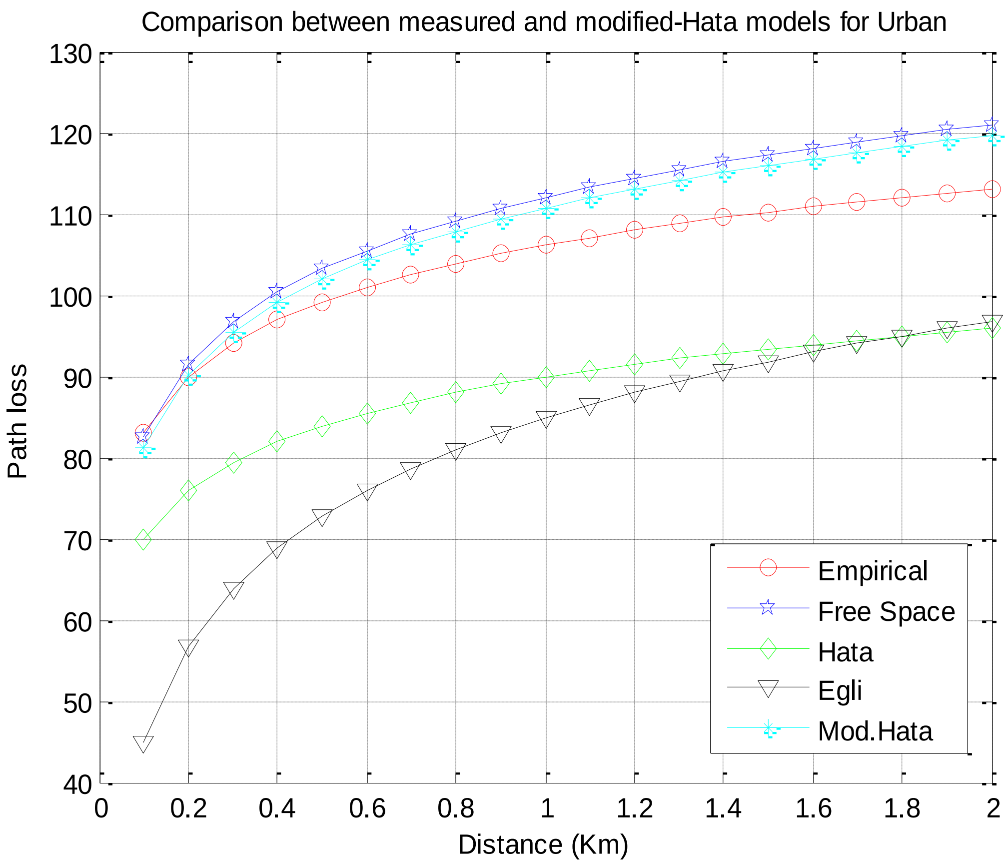

Fig.6. Comparison between the measured and the modified-Hata Models for Urban

VI. CONCLUSION

This paper presents the statistically derived path loss model for TVWS network for wireless communication systems for the Benin urban area of Edo State, Nigeria. The comparison between the measured model and the Hata model showed a difference used to modify the Hata model for effective use in Edo State, Nigeria. A study on the design and implementation of a geo-location database for TV white space identification in the Southern region of Nigeria will help protect terrestrial TV broadcast receivers, and the coexistence of secondary devices the major topic for our future work.

REFERENCES

[1] Hope M, Antoine B, Marco Z., Guy .L. Z (2015). “On the Impact of Propagation Models on TV White Space Measurements in Africa”.International Conference on Emerging Trends in Networks and Computer Communications (ETNCC)pp. 148–154. DOI: 10.1109/etncc.2015.7184825

[2] Alemu, T. B., (2012), “Spectrum Availability Assessment Tool for TV White Space”, MSc. Thesis Master of Science in Technology, School of Electrical Engineering, Aalto University available online: http://lib.tkk.fi/Dipl/2012/urn100704.pdf Accessed June 5, 2013.

[3] Ofcom, (November 2009). “Implementing geo-location", http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/summary/geolocation.pdf retrieved April 2, 2018.

[4] Saeed A., Ibrahim M., Youssef M., and HarrasK.A., (2013) “Towards dynamic real-time geo-location databases for TV white spaces.”arXiv preprintarXiv:1303.3962.

[5] Oluwole, F. J., and Olajide, O. Y. (2013). “Radiofrequency propagation mechanisms and empirical models for hilly areas.” International. Journal of Elect. Comput. Eng. (3): pp. 372–376.

[6] Wang, H., Noh, G., Kim, D., Kim, S., and Hong, D. (2010). “Advanced sensing techniques of energy detection in cognitive radios.” Communications and networks, Journal of 12, no. 1. pp. 19-29.

[7] Chebil J, Lawas A.K, and Islam M. D, (2013)."Comparison between measured and predicted path loss for mobile communication in Malaysia.” World Applied Sciences Journal 21: pp. 123-128.

[8] Ubom, E.A., Idigo, V. E., Azubogu, A.C.O., Ohaneme, C.O., and Alumona, T. L. (June, 2015). “Path loss Characterization of Wireless Propagation for South-South Region of Nigeria”. International Journal of Computer Theory and Engineering, Vol. 3, No. 3, pp 360-364.

[9] Nwalozie G. C, Ufoaroh S. U, Ezeagwu C. O, Ejiofor A. C, (February 2014), “Path loss prediction for GSM mobile networks for the urban region of Aba, South-East

Nigeria" International Journal of Computer Science and Mobile Computing, Vol.3 Issue.2, pp. 267-281.

[10] Smith, M.S. et al.,(April 2000) "A new methodology for deriving path loss models from cellular drive test data, Proc. AP 2000, conference, Davos, Sivitzerlend.

[11] Obot A, Simeon .O and Afolayan (2011). "Comparative analysis of pathloss prediction models for the urban macrocellular environment" Nigerian Journal of Technology. Vol. 30, No.3. pp. 50-59.

[12] Katulski, R. J. and Kiedrowski, A. (2005). Empirical Formulas for determination of the Propagation Loss in urban radio access links, Proceedings of IEEE 62nd Vehicular Technology Conference, Dallas, USA, pp. 1742-1746.

[13] Saurav Jain , M.V. Raghunadh. "Spectrum Sensing Based on Cyclostationary Detector using USRP", International Journal of Engineering Trends and Technology (IJETT), V11(4),188-191 May 2014. ISSN:2231-5381.