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Analytical evaluation of path loss models for low band very high frequency

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ABSTRACT

This work exhibits the performance of path loss models for low band very high frequency (VHF) in urban and rural environment by juxtaposing path loss models such as: Egli, free space, Hata Okumura, CCIR and Cost 231 Hata models using MATLAB. The path loss value changes while varying the frequency, antenna height over path distance. Reviewing the simulation, Hata Okumura and CCIR models outperforms in the urban environment while CCIR and Free Space models surpasses in the rural environment. Making CCIR model suitable for both environments. This study examines the viability of forecasting signal losses for low band very high frequency (VHF).

Keywords: Path loss, Very High Frequency (VHF), Transmission antenna height (TAH), Reception antenna height (RAH)

1. INTRODUCTION

Electromagnetic spectrum is made up of radio waves, infra-red, visible light, ultraviolet, Gamma rays, x-rays and cosmic rays, where the frequency band for radio waves fall within 3KHz to 3GHz. Radio waves constitutes; Very Low Frequency (VLF) (3KHz to 30KHz), Low Frequency (LF) (30KHz to 300KHz), Medium Frequency (MF) (300KHz to 3MHz), High frequency (HF) (3MHz to 30MHz), Very High Frequency (VHF) (30MHz to 300MHz) and Ultra High Frequency (UHF) (300MHz to 3GHz) (Okorogu et al., 2016).

All radio system operates on a certain frequency in order to transmit and receive signal (J & K Communuications, 2020). In Nigeria, FM radio broadcasting operates on a frequency range of 87.5MHz to 108MHz (NCC, 2019), which is categorized as a low-band VHF (J & K Communuications, 2020). Progressing, an evaluation of existing path loss models will be executed for low band VHF in different environment (Ukatu and Meneya, 2022). The remaining part of the work is categorized as follows: Section 2 describes various Propagation models. Section 3, provides the results and discussions. In Section 4, conclusion followed by references in section 5.

2. PROPAGATION MODELS

Egli Path Loss Model

With a path distance range of 0.1 km to 60 km, this model is intended for frequency ranges of 40 MHz to 900 MHz. Egli JJ created the Egli path loss model using measurements of UHF/VHF TV transmission in large cities which is ideal for an erratic topography (Garah et al., 2017). The mathematical expression is given as:

EGLIPL = 20 log10 (f) + 40 Log (d) – 20 Log (TAH) + CRAH (1)

Where;

CRAH = 76.3 – 10 Log(RAH) for RAH ≤ 10m (1.1)

CRAH = 85.9 – 20 Log(RAH) for RAH ≥ 10m (1.2)

Free Space Path loss

Free space loss is the term used to describe the decline in signal quality on a line-of-sight path in the absence of obstacle (Nafaa, 2014). Thus, presented as;

FSPL= 20Log10(d) + 20Log10(f) + 32.45 (2)

With the following values: Path loss in dB, distance (d) in km and frequency (f) in MHz.

HATA Okumura Path Loss Model

This model, which was developed in 1980, was based on measurement and extrapolation from Yoshihisa Okumura's curves. With a frequency range of 150 MHz to 1500 MHz, a transmitter antenna height of 30 to 200 meters, a reception antenna height of 1 to 10 meters and a separation distance of 1 to 20 kilometers (Pathania et al., 2014).

Urban Terrain

HOPLurban = 69.55 + 26.16 Log10(f) – 13.82 Log10(TAH) – CRAH + [44.9 – 6.55Log10(TAH)] *Log10(d) (3)

Where;

CRAH = 8.29[log10(1.54* RAH)]^2 – 1.1 for f ≤ 300MHz (3.1)

CRAH = 3.2 [log10 (11.75 * RAH)]^2 - 4.97 for f ≥ 300MHz (3.2)

Suburban Terrain

HOPLsuburban = HOPLurban – 2[$\log_{10}(\frac{f}{28})$]^2 – 5.4 (3.3)

Open Rural Terrain

HOPLrural = HOPLurban – 4.78[$\log_{10}$(f)]^2 – 18.33 * $\log_{10}$(f) – 40.98 . (3.4)

CCIR OR ITU-R Path Loss Model

The International Telecommunication Union for Radio communication (ITU-R), formerly known as the Comité Consultatif International des Radio-Communication (CCIR) formed this model, which is stated as (Debus, 2006):

CCIRPL = 69.55 + 26.16 Log10(f) – 13.82 Log10 (TAH) – CRAH + [44.9 – 6.55 Log10(TAH)] Log10(d) – B (4)

Where;

CRAH = [1.1 Log10(f) – 0.7] RAH – [1.56 Log10(f) – 0.8] (4.1)

B = 30 – 25 Log10(% of area covered by buildings) (4.2)

In this equation, CRAH for the correction factor of the reception antenna height, TAH stands for the height of the transmitting antenna in meters and RAH for the height of the reception antenna in meters.

COST 231 Hata Model

This is an advancement of the Hata-Okumura model, which is applied in the modeling of propagation loss in the 1500MHz–2000MHz frequency range. However, because of its simplicity and the availability of a correction factor, it can be used to forecast path loss for frequency ranges greater than 2000 MHz (Nafaa, 2014). This model accommodates simultaneously the base station (transmitter) antenna heights of 1 to 10 meters, path lengths of 1 to 20 kilometers and mobile station (receiver) antenna height of 30 to 200 meters (Chhaya et al., 2012).

Mathematical expressed as:

CHPL =46.3 + 33.9 $\log_{10}$ (f) – 13.82 $\log_{10}$ (TAH) –CRAH + [44.9 –6.55 $\log_{10}$ (TAH)] $\log_{10}$ (d) + Cm (5)

For Urban

CRAH = 3.20[Log10(11.75 * RAH)]^2 – 4.79 for f > 400MHz (5.1)

For Suburban and Rural

CRAH = [1.11 Log10 (f) – 0.7] * RAH – [1.5Log10(f) – 0.8] (5.2)

The correction factor, abbreviated Cm, is 0dB for rural or suburban areas and 3dB for urban areas.

3. RESULTS AND DISCUSSIONS

MATLAB was used in analyzing data collected from Today FM and Radio Uniport both located in Obio/Akpor Local Government Area of Rivers State Nigeria. Different path loss models were juxtaposed to identify the best pick for urban and rural environment. The path loss models applied in the evaluation are: Egli, free space, Hata Okumura, CCIR and Cost 231 Hata models.

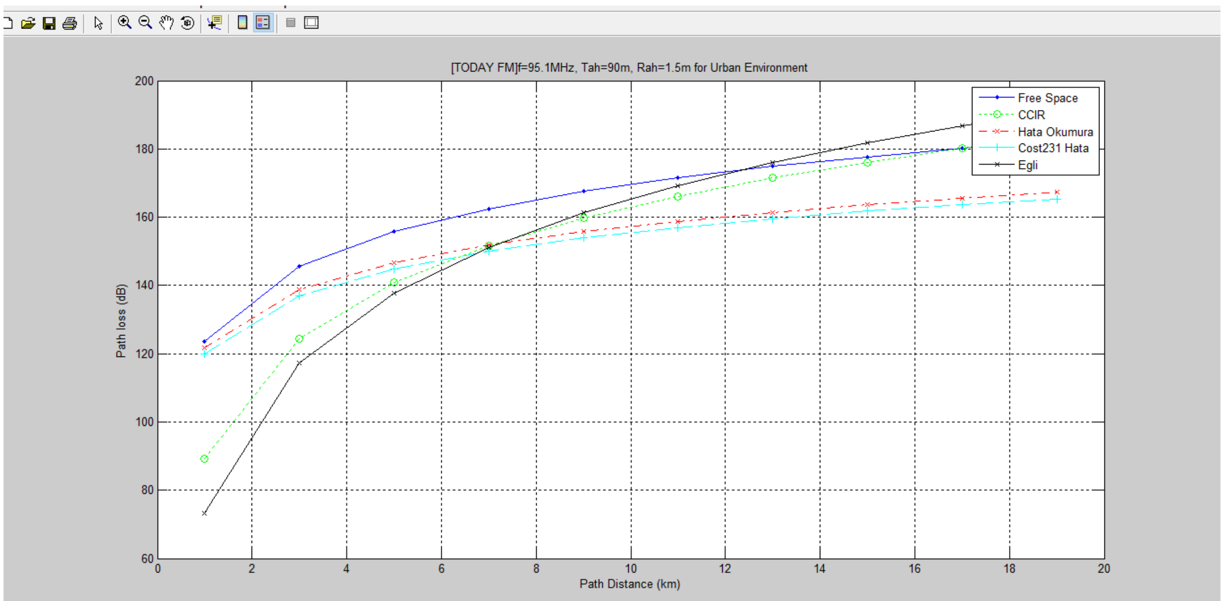

Figure 1 Showing path loss vs. distance for urban environment using Today FM's Data

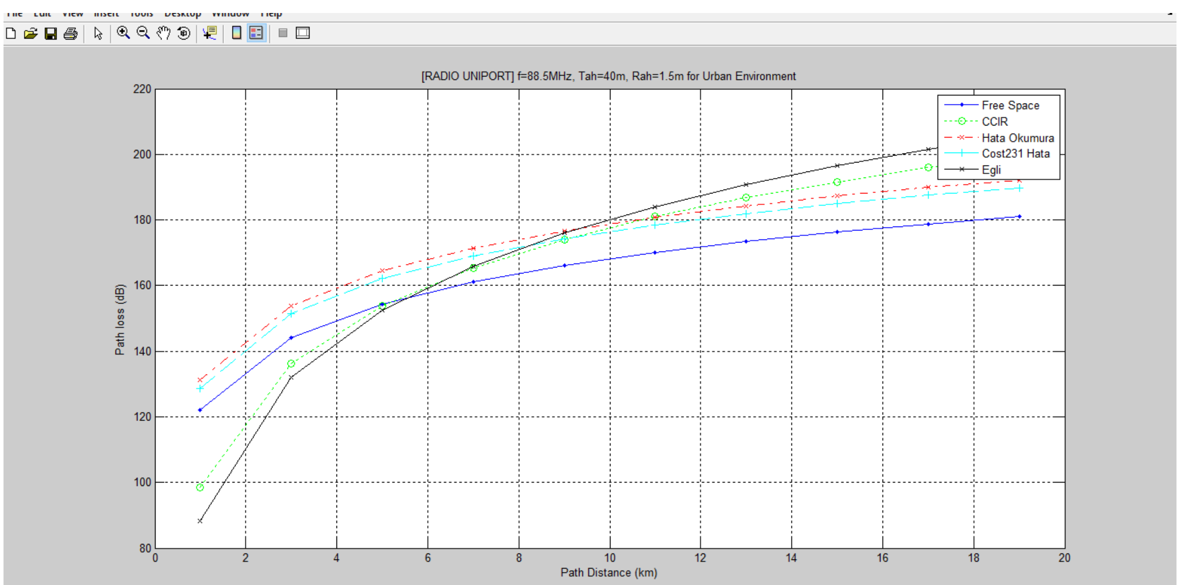

Figure 2 Showing path loss vs. distance for urban environment using Radio Uniport's Data

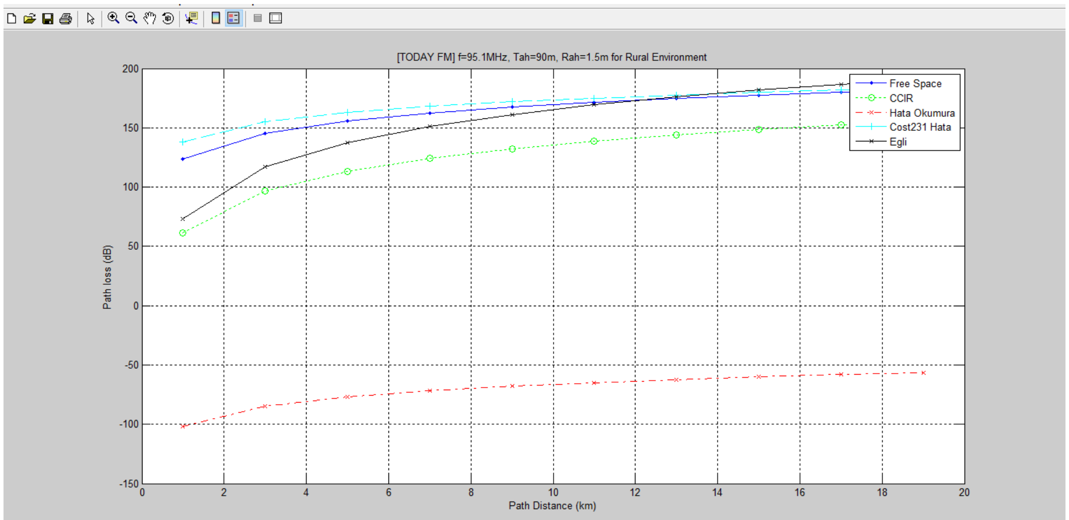

Figure 3 Showing path loss vs. distance for rural environment using Today FM's Data

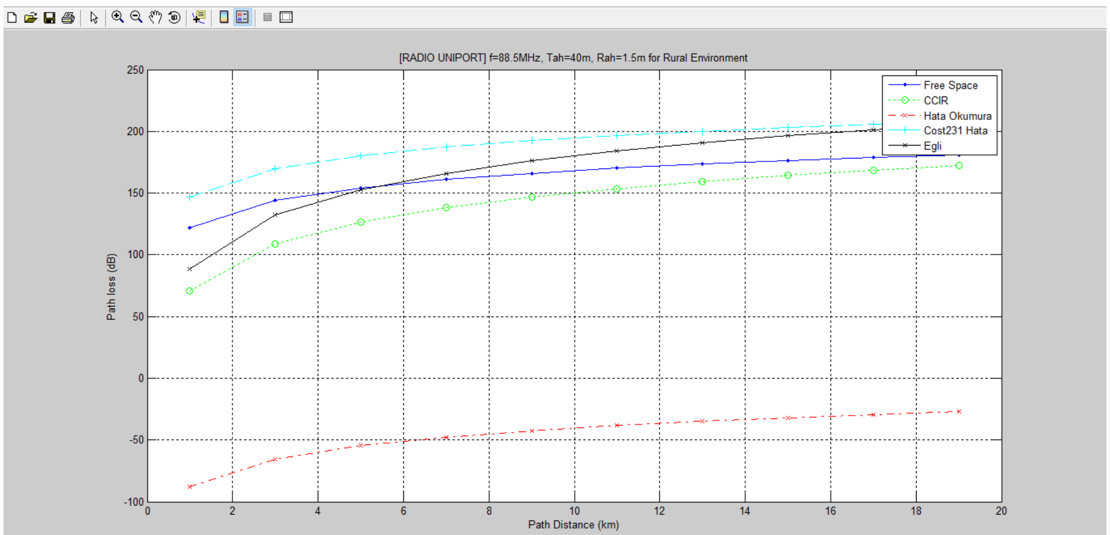

Figure 4 Showing path loss vs. distance for rural environment using Radio Uniport's Data

Referring to Figure 1, Hata Okumura, CCIR and Free Space models outperformed in urban environment using data from Today Fm just as Cost 231Hata, Hata Okumura and CCIR tops in urban environment using Radio Uniport's data as indicated (Figure 2). Making Hata Okumura and CCIR a suitable pick for urban environment.

For rural environment, CCIR, Free Space and Cost231 Hata models surpassed using data from Today FM as shown (Figure 3). Meanwhile from Figure 4, CCIR, Free Space and Egli models showed better performance using data from Radio Uniport. Therefore, CCIR and Free Space models tops in the rural environment. Based on commonality, the CCIR model can be suitably applied to both urban and rural environment for low band VHF.

4. CONCLUSION

In this paper, evaluation of path loss models for low band VHF in Urban and rural environment were simulated based on the influence of transmitter antenna height and transmitter frequency from two radio Stations over varying distance. The simulation portrait Hata Okumura and CCIR as a suitable pick for urban environment as well as CCIR and Free Space models for rural environment. Making CCIR model suitable for path loss modelling in both environment when using low band VHF.

Ethical issues

Not applicable.

Informed consent

Not applicable.

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This study has not received any external funding.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Chhaya D, Prasad M, Dalela P. Tuning of Cost-231 Hata Model for Radio Wave Propagation Predictions. Comput Sci Inform Technol 2012; 255-267. doi: 10.5121/csit.2012.2227
2. Debus W. RF Path Loss & Transmission Distance Calculations. AXONN 2006.
3. Garah M, Oudira H, Djouane L, Hamdiken N. Particle Swarm Optimization for the Path Loss Reduction in Suburban and Rural Area. Int J Electr Comput Eng 2017; 21 25-2131.
4. J & K Communications, Inc. UHF, VHF and 800MHz. The Frequency Differences and Application 2020.
5. Nafaa MA. Simulation and Analysis of Path Loss Models for Wimax Communication System. SDIWC 2014; 692-703.
6. NCC. National Frequency Management Council of the Federal Republic of Nigeria. National Frequency Allocation Table. Nigeria 2019. https://ncc.gov.ng/technical-regulation/spectrum/frequency-allocations#segment-2-30-30 0mhz
7. Okorogu V, Alumona T, Onwuka P. Technical Overview of Frequency Assignment for Radio Broadcasting in Nigeria. IOSR J Electr Electron Eng 2016; 11(5):1-5.
8. Pathania P, Kumar P, Rana SB. A Modified Formulation of Path Loss Models for Broadcasting Applications. Int J Recent Technol Eng 2014; 3(3):44-54.
9. Ukatu I, Meneya N. Performance analysis of path loss models for digital terrestrial transmission in urban and rural environment. Indian J Eng 2022; 19(52):410-414.
10. Ukatu IE, Meneya N. Path Loss Mitigation for Digital Terrestrial Transmission in Onne, Rivers State, Nigeria. Indian J Eng 2022; 55-71.