DEVELOPMENT OF A MULTI-BAND PATH LOSS PREDICTION MODEL FOR CELLULAR NETWORK IN LAGOS ISLAND, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ENGINEERING (M.ENG) DEGREE IN INFORMATION AND COMMUNICATION ENGINEERING IN THE DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING. COLLEGE OF ENGINEERING, COVENANT UNIVERSITY.

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ACCEPTANCE

This is to attest that this dissertation is accepted in partial fulfilment of the requirements for the award of the degree of Master of Engineering in Information and Communication Engineering in the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Nigeria.

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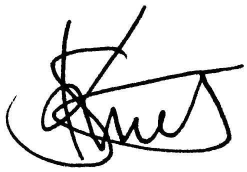
DECLARATION

I, **HINGA, SIMON KARANJA (19PCK01989)** declares that this research was carried out by me under the supervision of Prof. AAA. ATAYERO of the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Nigeria. I attest that the dissertation has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data and scholarly information used in this dissertation are duly acknowledged.



HINGA, SIMON KARANJA

18th Oct 2021
Signature and Date

CERTIFICATION

We certify that this dissertation titled "**DEVELOPMENT OF A MULTI-BAND PATH LOSS PREDICTION SYSTEM FOR LAGOS ISLAND, NIGERIA** is an original research work carried out by **HINGA, SIMON KARANJA** (**19PCK01989)** in the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria under the supervision of Prof. Aderemi A. Atayero. We have examined and found this work acceptable as part of the requirements for the award of Master of Engineering in Information and Communication Engineering.

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DEDICATION

This research work is dedicated to Gianna and Jane.

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LIST OF ABBREVIATIONS

2D	Two Dimension
3D	Three Dimension
3GPP	3rd Generation Partnership Project
4G	Fourth Generation
5G NR	5G New Radio
5G	Fifth Generation
5GCM	5G channel model
ABG	Alpha-Beta-Gamma
ANN	Artificial Neural Network
CI	Close-In
CNN	Convolutional Neural Network
DDTV	Digital Terrestrial Television
EDGE	Enhanced Data for GSM Evolution
EML	Extreme Machine Learning
FFNN	Feed-forward neural network
FI	Floating Intercept
GHz	Giga Hertz
GSM	Global System of Mobile Communication
HSPA	High Speed Packet Access
ITU	International Telecommunication Union
LoS	Line of Sight
LTE	Long Term Evolution
MAE	Mean Absolute Error
MATLAB	MATrix LABolatory
METIS	Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society-II
MHz	Mega Hertz
MiWEBA	The Millimeter-Wave Evolution for Backhaul and Access
ML	Machine Learning
MLP	Multi-layer Perceptron
mmWave	Millimetre Wave

MSE	Mean Square Error
NLoS	Non LoS
NN	Neural Networks
NPCA	Non-linear PCA
PCA	Principal Component Analysis
PL	Path Loss
PLE	Path Loss Exponent
QoS	Quality of Service
RMSE	Root Mean Square Error
SDGs	Sustainable Development Goals
SVM	Support Vector Machine
TX1	Transmitter point one
TX2	Transmitter point two
TX3	Transmitter point three
TX4	Transmitter point four
TX-RX	Transmitter-Receiver
Wi-Fi	Wireless Fidelity
WINNER	Wireless World Initiative New Radio

ABSTRACT

Mobile cellular communication offers an efficient means to connect the world as a global village. Despite mobile and personal communication advancements, the existing wireless infrastructures suffer from signal attenuation in both uplink and downlink communication. 5G millimeter-wave application in mobile connectivity to realize high-speed and reliable communication is attributed with high path loss and absorption losses than existing cellular network operating in the 2G, 3G, and 4G technology infrastructure. This research project presents a detailed 3D ray-tracing technique at 28 GHz and 700 MHz for Lagos Island, Nigeria to investigate five unique path loss scenarios: path loss, free space path loss with antenna pattern, free space path loss without antenna pattern, excess path loss with antenna pattern, and the excess path loss without antenna pattern for an urban environment. To achieve an accurate path loss model the Close-In (CI) model, Floating Intercept (FI) path loss model, Hata model, ECC-33, COST-231, Okumura-Hata path loss models were developed. Root mean square error (RMSE) analysis was used to evaluate the prediction performances of the developed optimal path loss model for Lagos Island. For the case of 28 GHz, the average achieved FI (α, $\boldsymbol{\beta}$, σ) parameters were 189.92352, 0.1654 dB, and 0.66948 dB, While the average CI (η, $X\sigma$) parameters were 2.309355 dB and 56.236425. From all the scenarios evaluated, the lowest path loss exponent achieved was 0.45 dB, while the highest path loss exponent was 3.8. We have established that the FI path loss model accurately characterizes path loss for the Lagos Island environment with the lowest RMSE of 0.0359 dB and the highest RSME of 0.0997 dB. In contrast, the CI model over-predict the path loss at 28 GHz with the lowest RMSE of 0.0495 dB and the highest RMSE of 2.2547 dB. For the 4G LTE at 700 MHz, The CI model had a better prediction accuracy for transmitter point two. The ECC-33 path loss model had an optimal path loss prediction with the least RMSE of 0.6743 dB. The EGLI path loss prediction model showed a pessimistic performance with the highest RMSE of 2.2496 dB, followed by HATA-Okumura with 1.9606 dB and COST-231 extension-to-Hata path loss model with 1.9399 dB. This work opens a new area of research on mm-Wave at 28 GHz in Lagos Island, and the results obtained from this work can be used to benchmark future studies on mmWave in a similar environment.

Keywords: Millimeter Wave, Path Loss modelling, Close-In model, Floating Intercept model

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The exponential growth in data demand, communication infrastructure, mobile subscription, and high mobile and IoT devices penetration has significantly stretched the cellular bandwidth requirements. Future communication technology needs to improve spectral efficiency, increase bandwidth, and improve spectrum reuse technology to overcome the current limitations of cellular technologies. Machine learning application has a vast potential to solve socio-economic challenges and transform business models towards realizing the 17 Sustainable Development Goals (SDGs) and the associated 169 targets (Asadikia, Rajabifard, & Kalantari, 2021). Governments and public administrators can exploit the sizeable coherent 5G mm-Wave communication infrastructure and mobile connectivity ubiquity to realize IoT-enabled Smart Cities and Connected Communities (Andreev et al., 2015; Djahel, Doolan, Muntean, & Murphy, 2015). In this way, city managers can effectively handle economic, social, and environmental challenges for citizens' well-being (Atzori, Iera, & Morabito, 2010; Francisco, 2020). Electronic and mobile health applications can bridge the social and economic gaps between developing and developed countries for better health care delivery in marginalized areas (Barjis, Kolfschoten, & Maritz, 2013; Gurstein, 2005). Access to high-definition video content has significantly contributed to the rapid growth of mobile data traffic. The resulting unprecedented mobile data traffic add some stress to the current telecommunication infrastructure in both rural, suburban, and urban areas.

Meanwhile, network operators are faced with the challenges of improving the network coverage and capacity to meet up with the upsurge in mobile data traffic demand, particularly in high-density traffic areas. Therefore, mobile network operators are expected to optimize their network capacity to meet user Quality of Service (QoS) requirements. Deployment of additional base stations is the most feasible approach to address this