Abstract — Implementations of Radio frequency wave propagation models are necessary to determine propagation characteristics through a medium. Its study provides an estimation of signal characteristics and the effect of environment and the medium over which it travels. This paper performs some analysis on few empirical Propagation models the mechanisms, their path loss behavior suitable for path loss prediction techniques in broadcast communication. Experimental measurements of received signal strength indication for the 92.9 MHz Radio broadcasting Station were made in urban areas of Federal Capital Territory Abuja, Nigeria. Measured data were compared with those obtained by three prediction models: COST-231, ECC-33 and OKUMURA-HATA models, the results show that in general the ECC-33 Model over-predicted the path loss in all environments with Root Means Square error (RMSE) of 166.46, while the COST-231 model has 18.33 having the best results. Okumura-Hata predicted well in the near field with 16.50 and deviated from measured data at the far field. The prediction analysis also accessed the Received Signal Strength Indication of Kapital FM in twenty (20) locations in Abuja; hence, it identifies Route A to be less susceptible to signal attenuation as compared to Route B.

Key words — Path Loss; Radio Broadcast Station; Signal.

I. INTRODUCTION

Radio signal path loss is essentially the reduction in power density of an electromagnetic wave as it propagates through the environment at which it is travelling [1]. Path loss prediction models are used as survey tools to determine the signal strength at various locations. They help to determine the signal strength of a location before the installation of equipment. For Broadcast Station operators, a coverage survey is important because huge investment is expended. The path loss prediction model enables the problem to be solved before installation, hence the cost is considerably reduced” [1].

The effect of obstacles such as mountains, ridges, vegetation, soil structures and environmental conditions on VHF Radio propagation is an important factor for system planners involved in broadcasting [2]. These obstacles constitute path loss in the propagation of radio signals and thus need to be investigated.

The design of the communication system, therefore, involves a range of values for various parameters, one of which is the transmit power.

Higher transmit power ensures large allowable separation distance between the transmitter (Tx) and Receiver (Rx) hence, the losses in signal path per unit distance depends on the property of the medium and the transmitting power.

In a terrestrial communication system, electromagnetic wave propagation is affected by reflection, diffraction, absorption, and scattering, which lead to dynamic variation of signal strength as a function of time, frequency, distance, Antenna height, Antenna configuration, local scattering, environmental condition and Soil structure [3].

The successful design and deployment of a wireless system require a good knowledge of the characteristics of the propagation channel. To this end, therefore, channel modelling for many scenarios have been the topic of path loss modelling for many years. To analyze the wireless medium, path loss prediction is considered to be one of the most important characteristics.

Path loss psychoanalysis provides information on the power density reduction of the EM waves as they propagate in a specific environment which is essential for analyzing the medium’s capability and Radio coverage of the wireless scheme [4].

Reflection occurs when the propagating electromagnetic wave in a medium impinges upon an object with dissimilar electromagnetic properties. The amplitude and phase of the reflected wave are robustly related to the medium’s inherent impedance incident angle and electric field polarization [3].

Diffraction is the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture caused by sharp irregularities in the radio waves. It leads to the development of secondary wavefronts, bending of waves. It is caused by objects which are in order of the wavelength, hence it depends on the geometry of the objects, Amplitude, Phase and Polarization of the incident wave. In other words, it is due to an object appearing in the path of the wave; hence signal can bend around the object. In most cases there is signal loss, the losses increase the more rounded the object is. Radio signals diffract better around sharp edges. That is edges that are sharp to the wavelengths [1], [3].

Rough surfaces and finite surfaces scatter the incident energy in all directions with a radiation diagram which depends on the roughness and size of the surface or volume. The dispersion of energy through scattering means a decrease of the energy reflected in the specular direction. This simple view leads to account for the scattering process only by

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decreasing the reflection coefficient and thus, only by multiplying the reflection coefficient with a factor smaller than one which depends exponentially on the standard deviation of the surface roughness according to the Raleigh theory. This description does not take into account the true dispersion of radio energy in various directions but accounts for the reduction of energy in the specular direction due to the diffuse components scattered in all other directions [8].

Soil structure: Physical properties of the soil have some effects on signal propagation. This is because the soil is a dielectric material characterized by a dielectric constant. The propagation of electromagnetic waves is directly linked to the dielectric constant of the material. More distinctively, a smaller value of the dielectric constant principally implies a better setting for the propagation of EM waves. The soil medium behaves as a dielectric material composed of air, bound water, free water, and bulk soil. If the soil presents a small density and high porosity, the performance of the propagation of EM waves is better due to the high quality of air. However, the presence of water in the soil has a contrary effect on communication.

The quality of water in the soil, which is usually measured as the volumetric water content (VWC) of the soil is the main factor that contributes to the EM wave attenuation otherwise known as Path loss. Electromagnetic waves encounter much higher attenuation in soil compared to air and this fact severely hampers the quality of service (QoS) [9].

Free Space Path Loss (FSPL) is the loss in signal strength of electromagnetic wave that would result from a line-of-sight path through space usually air with no obstacle nearby to cause reflection or diffraction.

It does not include factors such as the gain of the antenna used at the transmitter and receiver, nor any loss associated with hardware imperfections. This parameter is a very essential component of this proposed Dissertation.

There are already established formulas associated with it for path loss prediction.

Free space path loss is proportional to the square of the distance between the transmitter and receiver and also proportional to the square of the frequency of the radio signal. For any type of wireless communication, the signal disperses with distance. Therefore, an antenna with a fixed area will receive less signal power; the further it is from the transmitting antenna [10].

For the same Antenna dimension and separation, the longer the carrier wavelength the lower the frequency and the higher the free space loss. The equation indicates as the frequency increases; the free space loss also increases. This equation also showed that it can be compensated by the Antenna gain [10].

*Multipath:* In broadcasting is related to signals that travel by more than one route from the transmitter and arrive at the receiver at slightly different times, causing ghost images or audio distortion [11].

*Atmospheric Losses:* In signal propagation, certain phenomena affect the strength of the signal from the transmitter in reaching the desired location of the receiver at the far-field. One of these is the effect of atmospheric properties such as Raindrops, atmospheric gasses, and fogs.

When this happens the radio frequency signal may be absorbed or scattered thereby reducing its strength from smooth propagation hence the received signal may be less than the transmitted signal. This effect that causes signal attenuation is called atmospheric losses, somewhat losses as a result of properties of the atmosphere that interfere with the signal.

This is of great importance in modelling of path loss; however, this effect is more pronounced at Millimeters wavelength, hence it may not be of major significance to this study which I am undertaking under VHF (92.9MHz) signals.

The anxiety of communication Engineers is to develop an effective communication system in which the information is delivered to its destination with unhindered signal strength.

He, therefore, needs to take into account factors that may affect the effective propagation of radio signals from the source to destination.

In trying to realize these objectives many Scholars in telecommunication has performed a lot of analysis and predictions for its achievement. This analysis and predictions are called propagation Models. Communication Engineers, as well as researchers, therefore, deploy different propagation models to predict and determine the path loss by comparing the precise data and designed data. The precise data is the measured data while the designed data is the calculated data. The designed data is done using mathematical equations based on free-space loss.

Therefore, the establishment and improvement of communication systems rely on propagation models that take into consideration the environment in which the location of the station is to be established [12]. So many Models has been considered and worked out in empirical, deterministic, and stochastic.

Empirical models are based on observations and measurements, the deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal strength at a particular location and it requires a 3-D map of the propagation environment.

Stochastic model on the other hand model the environment as a series of random variables [13].

This work will be comparing some of these Models bases on the urban Nature of Abuja and the frequency band over which this work is carried out to predict the best model for the Abuja environment as no serious work is carried out yet, even though the proliferation of radio broadcasting in Abuja as a result of liberalization of broadcasting in Nigeria with Radio Stations get congested in Abuja.

II. RESULTS

Table I is the Received signal Strength Indication (RSSI) in milli decibel (dBm) as a function of distance in Kilometre (KM) between the transmitter and receiving Antenna taken at intervals of five (5) Kilometers. Empirical Measurements were taken along Route (A) and Route (B).

While Route A is along Nyanya Axis of the Federal Capital city of Abuja to the right of Radio House where Kapital FM 92.9MHz is located on Latitude 9° 2’ 30.192” N, Longitude 7° 29’ 30.246” E, Route B is to the left of Radio House along Gwagwalada Axis. The table compares the empirical values of Route A and B with that of the deterministic values.

| Route | Distance (KM) | RSSI (dBm) | Deterministic | Empirical A | Empirical B |
|-------|--------------|-----------|--------------|-------------|-------------|
| A     | 0            | 0         | -            | -           | -           |
| A     | 5            | 0         | -            | -           | -           |
| A     | 10           | 0         | -            | -           | -           |
| A     | 15           | 0         | -            | -           | -           |
| B     | 0            | 0         | -            | -           | -           |
| B     | 5            | 0         | -            | -           | -           |
| B     | 10           | 0         | -            | -           | -           |
| B     | 15           | 0         | -            | -           | -           |

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The Highest signal strength on Route A is -45.0 dBm and its lowest value is -66.2 dBm. Route B has its highest Received signal Strength indication (RSSI) at -47.0 dBm while its lowest value is at -67.8 dBm, the table also show the deterministic strongest RSSI at -10.97 dBm and the lowest at -39.17 dBm. While the strongest RSSI was received at the Base of the transmitting Antenna, the lowest was at a distance of forty-five (45) Kilometers (KM) away from the transmitting Station. Critical look at the table also shows the calculated Relative Errors which was used as a measure of precision due to equipment and other errors that would have set in as a result of inconsistencies relative to measurement actions.

The table 2 summarizes the performance predictions analysis related to route A and B measured and predicted Values as mentioned above. The scenarios are, Predicted, measured value for Route A and Route B.

![Graph of Received Signal Strength against the Distance](image-url)

![Graph of Measured Values Along Route 1 and Route 2](image-url)

The comparison between the predicted value and the measured values in terms of Route A at its strongest point and that of the predicted has a variation of -24.21 dBm at 0 km while, its weakest point has a variation of -27.04 dBm, synonymously, that of the Empirical Route B and the predicted in its strongest form has a variation of -26.21 dBm and the weakest form varies with -27.63 dBm, once again there exist a signal diminution which has validated one of the reasons for carrying out this performance analysis of Path Loss Prediction models. For further discussion find below Fig.1 showing the graph of Received Signal Strength as a function of distance.
This is a known fact since frequency Modulated signals travel on straight line and online-of-sight propagation, hence, can be interfered by objects standing in the direction of propagation [1]. Since Abuja is a high-density region, such obstruction is highly available.

Table IV is a comparison results between predicted values and measured values for the path loss against the variable distances, which shows that the path loss increases with distance due to the corresponding decrease in received signal strength (RSS). Its plot is shown in Fig. 2, which shows that, Radio signal path loss is essentially the reduction in power density of an electromagnetic wave as it propagates through the environment at which it is traveling [1].

![Graph of Path Loss against the Distance](image)

The measured data and signal strength values of selected empirical path loss models in urban environments of Abuja were analysed and compared at the frequency of 92.9 MHz.

Path loss model is the most important parameter for path loss using three models: Okumura-Hata Model, ECC-33 Model, and COST-231 Model based on using the same parameters. The results of comparison conclude that the Okumura-Hatta and COST-231 Model are better predictive of the Abuja environments, even though the Okumura-Hata shows its best performance on short distance.

### III. CONCLUSION

Choosing a model for the implementation of a link budget should be a very thoughtfully provoking process as Models can vary significantly even in the case that an appropriate environment is chosen there could be difference between the strongest and weakest signal. In the case of our performance Analysis, there was a difference between them at 45 km in all the routes. The choice also depends on whether you need a large margin in compensating for a large Path Loss. However, doing so will increase the cost of design as the component have to handle more losses and noise strata.

However, the purpose of this analysis is to verify the best Path Loss Prediction Model that will be the best for Broadcast Engineers for the implementation of their link budget.

It is also to provide a practical measurement on the deployment of path loss prediction Model from the performance evaluation of different models hence, providing necessary information for assessment in cogent decision when establishing a Radio Station.

These models allow network planners to achieve an acceptable quality of service performance evaluation of different models hence, providing necessary information for assessment in cogent decision when establishing a Radio Station.

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