Path Loss in Nigerian Rural Vegetation Area: A Case Study in Igbaraoke, Ondo State.

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ABSTRACT

Various research studies have been carried out by different researchers on the behavior of radio wave propagation within different environment s under different environmental and geographic conditions. The models derived are specific for most environments. This study presents a measurement-based model for path loss prediction in two GSM service areas at 900MHz. This area includes the vegetation areas of Molete environs and Oke Ita environs at Ifedore local government Igbaraoke ondo state. Downlink signal strength level data were collected by using drive test exercise consisting of test mobile phones, TEMS investigation software, and MapInfo and Google Earth. The data obtained was analyzed to obtain the path loss exponent. The path loss obtained for the vegetation is computed as 5.4, which shows a poor GSM signal level. An empirical model was proposed for the received power signal in a mangrove environment. The empirical model developed was validated by comparing with the measured values, which yield a mean percentage error to be 30.24 and 25% for site A and B respectively. The result from the comparison shows high quantity of dispersion on both site A and site B and hence the developed model is not suitable for the environment.

(Keywords: pathloss, TEMS, model, vegetation, environment, radio signals)

INTRODUCTION

A signal could be defined as a quantity that changes with time, space, frequency or any other independent variable. It is also defined as an electrical impulse or radio wave transmitted or received.

Mobile radio such as the GSM has various limitations on channels used to transmit and it performance generally in wireless communication system, by propagation we mean the behavior of radio frequency when propagating from geographic location to another. Like light waves, radio waves are hugely affected by the phenomena of reflection, refraction, diffraction, absorption, polarization, scattering and free space loss. All these phenomena solely depend on geographic environs (such as the terrain, buildings, vegetation) which could either be rural or suburban areas.

Knowledge of the phenomena that yield path loss propagation in dense vegetation area such as in rural areas is an important factor in wireless communication. However, the electromagnetic models of the radio frequency in such environment have been found to be challenging due to its complexity. Reasons for its complexity include too many parameters such as the terrains, thick forest, positioning of the transmitting and receiving station. However one can never predict to a reasonable accuracy the amount of attenuation loss that could be encountered in rural environs. However, when we consider suburban areas where it majorly comprise of buildings with less vegetation and undulating features, presents a unique influence on radio wave propagation, because buildings in suburban region are evenly spaced and operators are open to different option on areas to situate there mast.

One may therefore say that radio wave propagation in suburban or open areas (defined by Okumura as one that is clear for a radius range of 300-400m) is almost completely understood and losses are quite simple enough to calculate and accurate enough to describe propagation characteristics. The problem that may arise in urban area is the impossibility of knowing exact factors influencing the transmission of radio wave to include size, shape, spacing and composition of all buildings in the transmission path.

However, all these factors have motivated researchers to develop path loss propagation models capable of including essential characteristics of suburban and rural environments. The propagation medium infrastructure and system specification like frequency, transmitted power and antenna height are critical components of mobile communication system which requires a care full and accurate modeling of its elements in order to accomplish projects to satisfy the demands of different coverage.

Researchers in the past also demonstrated radio frequency signal propagates in an obstacle environment with high attenuation. However, it is not practical to move such an obstacle in the interest of improved radio service (Schwartz, 2004). Thus one can investigate what happens to the radio signal when its incidence on such obstacle, with a view to know signal characteristics [1].

This study therefore reveals an approximation of site attenuation approach, which has been used for obtaining propagation loss at 900MHz. Vegetation effects on radio propagation, penetration loss capabilities and attenuation curves are also discussed and analyzed.

METHODOLOGY

A careful study was carried out on the nature of the Mangrove areas in terms of sizes of trees, heights, shapes, and quantity of leaves as well as the intending location of the Base stations.

Received signal strength levels (power received) were measured from a distance of at least 100m from the base station for the environment investigated. The data was analyzed to determine the actual mean received signals for each sector of a macro-cell station. The environment was visited many times for at most five days and the power received were taken in active mode during down link transmission.

DEVELOPMENT OF EMPIRICAL MODEL

$$Pr = Pt\ K\ (do / d)^{b} \quad \textbf{(1)}$$

The expression above is given as [3] for the received power at a distance from the transmitter. Where;

P_r = the received power
P_t = the power transmitted where do is the reference distance for antenna far field
b = path loss index
K = wave constant

DATA COLLECTION AND ANALYSIS

In this study, data was obtained from two different sites, namely Molete and Oke which are respectively called site A and site B. The collection of down link signals commenced at an approximate distance of less than 100meters from the base station. The vehicle then moves along the direction of the main sectors of each directional antenna away from the site until it gets to the coverage boarder.

This process was repeated for each sector of the site under which the experiment was performed. The average power received for each sectors of both site A and Site B are respectively shown in Table 1 and Table 2.

Recall from Equation 1:

K = wave constant

The expressions for the wave constant at a reference distance do for antenna far field is given as [6]:

$$K = \Phi^2 / (4\pi\ do)^2 = (\Phi / 4\pi\ do)^2 \quad \textbf{(2)}$$

Where;
Φ = wave length, π = constant = 3.143
Recall $\Phi = C / f$, where C = the speed of light, f = frequency of the signal under consideration.
Taking log of Equation (1):

$$P_r\ (dBm) = P_t\ (dBm) + K\ (dB) – 10\ b \log (d/do) \quad \textbf{(3)}$$

Table 1: Test Station at MOLETE (SITE A).

TX/RX DISTANCE (m)	SECTOR1	SECTOR2	SECTOR3
500	-38	-46	-44
1000	-52	-46	-48
1500	-54	-52	-53
2000	-58	-59	-58
2500	-62	-64	-64
3000	-68	-67	-67
3500	-70	-72	-74
4000	-72	-76	-82
4500	-74	-75	-70
5000	-79	-73	-75
5500	-83	-80	-81
6000	-86	-88	-83
6500	-90	-90	-88
7000	-94	-94	-92
7500	-97	-96	-90
8000	-97	-99	-97
8500	-98	-100	-99
9000	-102	-102	-104
9500	-106	-102	-109
10000	-108	-110	-111

Table 2: Test Station at OKE ITA (Site B).

TX/RX DISTANCE (m)	SECTOR1	SECTOR2	SECTOR3
500	-46	-46	-60
1000	-38	-48	-63
1500	-53	-60	-72
2000	-58	-52	-75
2500	-63	-60	-79
3000	-65	-70	-80
3500	-65	-80	-84
4000	-69	-92	-88
4500	-77	-78	-88
5000	-79	-79	-89
5500	-88	-83	-94
6000	-85	-89	-98
6500	-90	-91	-102
7000	-97	-105	-99
7500	-105	-92	-120
8000	-112	-108	-100
8500	-109	-118	-122
9000	-100	-102	-98
9500	-99	-109	-114
10000	-101	-122	-118

Also taking log of Equation (2):

$$K\ (dB) = 20 \log (\Phi / 4\pi\ do) \qquad \textbf{(4)}$$

Since the frequency of operation is 900MHz, Φ = 0.3333

For outdoor propagation do is recommended to be chosen between (10- 100). [2]

Substituting the value of Φ and other parameter into Equation (4) and taking do = 100m
K = -71.53 dB, substitute K into equation (4) yields

$$P_r\ (dBm) = P_t\ (dBm) - 71.53\ dB - 10\ b \log (d/do) \qquad \textbf{(5)}$$

Recall P_t = power transmitted = 45dB, since b = path loss index which is obtained from the curves shown in the figures below.

A proposed path loss exponent for vegetation area is obtained by finding the average of path loss exponent derived from the two Sites; it is computed as shown below

$$b = (5.5+5.3+5.3+5.8+5.9+4.6)/6 = 5.4$$

Therefore equation (5) becomes:

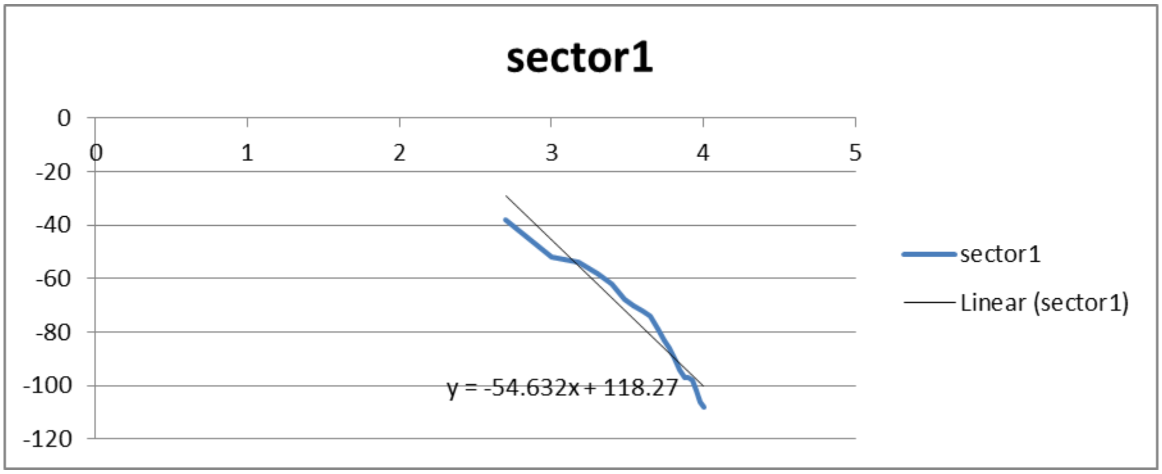
$$P_r\ (dBm) = -26.53 - 54 \log (d/do) \qquad \textbf{(6)}$$

Table 3 presents the mean received value of both sites and values obtained for the empirical model with respect to Equation (6).

The Empirical model [3] obtained when compared to the measured received signal of site A and site B, observe a large amount of variance in the values obtained for each site.

The relative errors of the predicted (Empirical) model to the measurement of site A and Site B are computed to be 30.24 and 25%, respectively.

Figure 1: Simulations of Table 1 Sectors, 'Molete site' (site A)



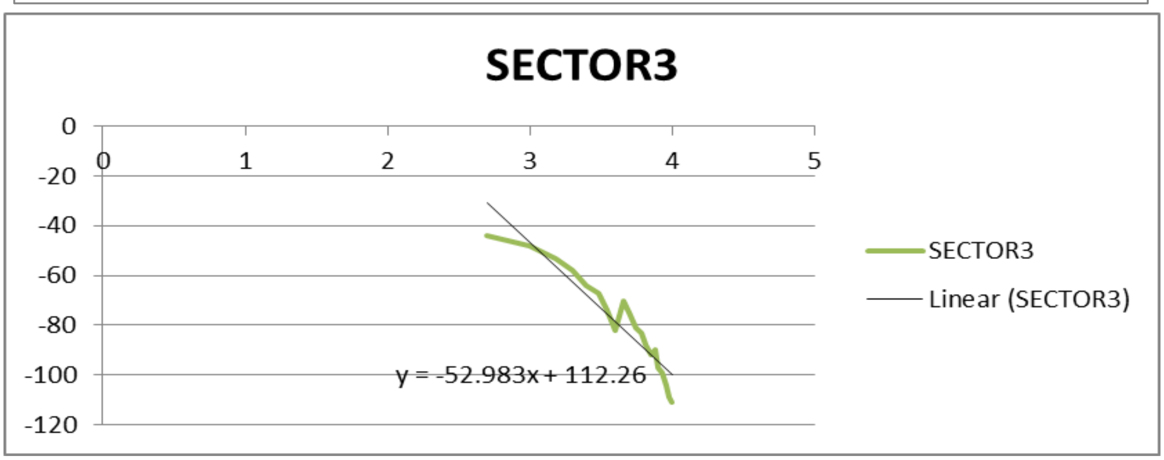
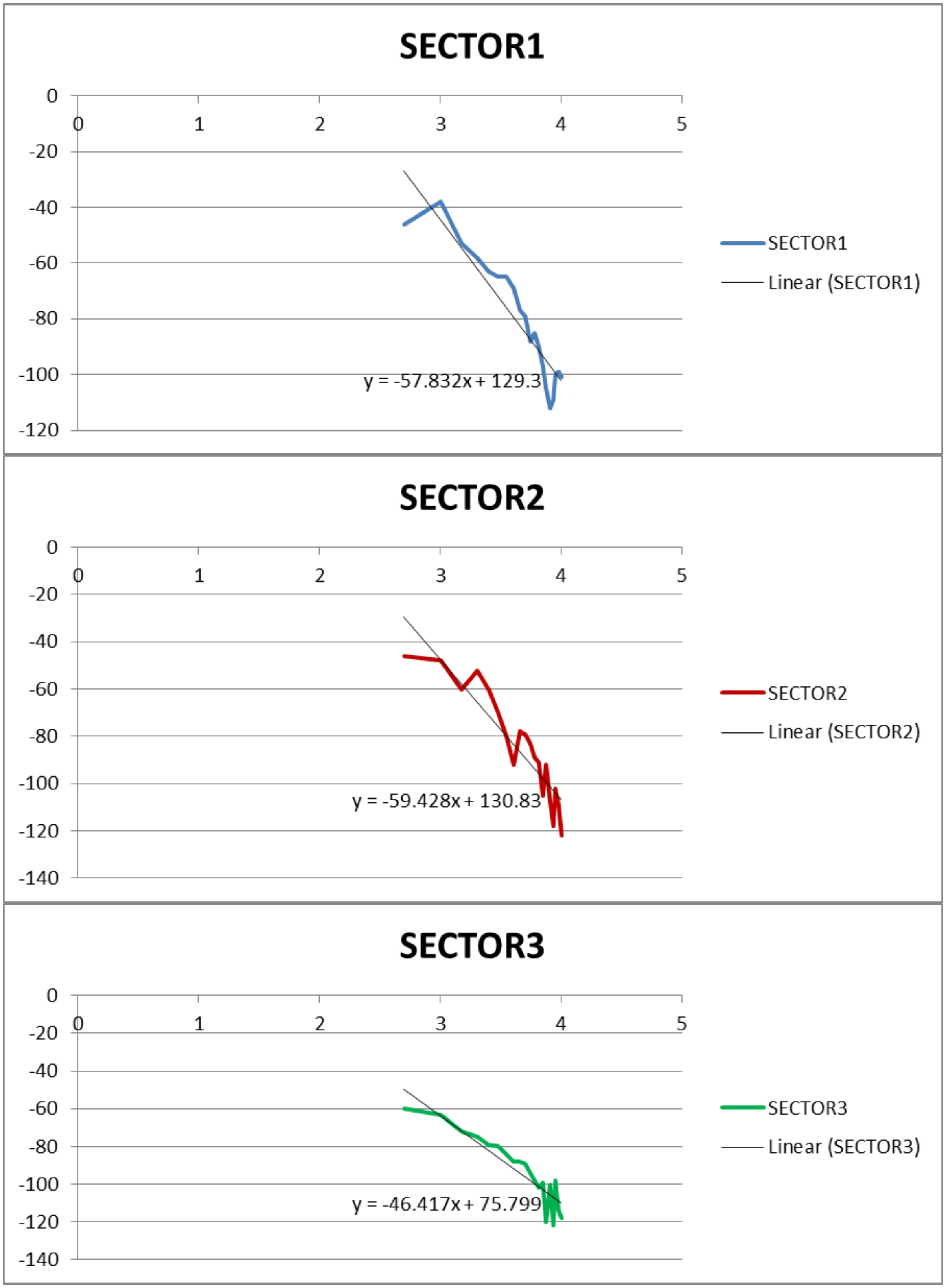


Figure 2: Simulation of Table 2 OKE ITA site (site B).



The table below shows the mean distribution of Molete (site A), Ita Oke (site B) and the empirical model value.

Table 3: Data for the Comparison of Measurement for site A, site B and the Empirical Model for Distance between 500m and 10000m.

TX/RX DISTANCE (m)	Molete (site A)	Ita Oke (site B)	Empirical	Site A variation	Site B variation
500	-42.67	-50.67	64.27	21.67	13.6
1000	-48.67	-49.67	80.53	31.68	30.86
1500	-53	-61.67	90.04	37.04	28.37
2000	-58.33	-61.67	96.79	38.46	35.12
2500	-63.33	-67.33	102.02	38.69	34.69
3000	-67.33	-71.67	106.29	38.96	34.62
3500	-72	-76.33	109.91	37.91	33.58
4000	-76.67	-83	113.04	36.37	30.04
4500	-73	-81	115.80	42.8	34.8
5000	-75.67	-82.33	118.27	42.6	35.94
5500	-81.33	-88.33	120.51	39.18	32.18
6000	-85.67	-90.67	122.55	36.88	31.88
6500	-89.33	-94.33	124.43	35.1	30.1
7000	-93.33	-100.33	126.17	32.84	25.84
7500	-94.33	-105.67	127.78	33.45	22.11
8000	-97.67	-106.67	129.30	31.63	22.63
8500	-99	-116.33	130.72	31.72	14.39
9000	-102.67	-100	132.06	29.39	32.06
9500	-105.67	-107.33	133.33	27.66	26
10000	-109.67	-113.67	134.53	24.86	20.86

Figure 3: Mean Received Level for Site A Sector.

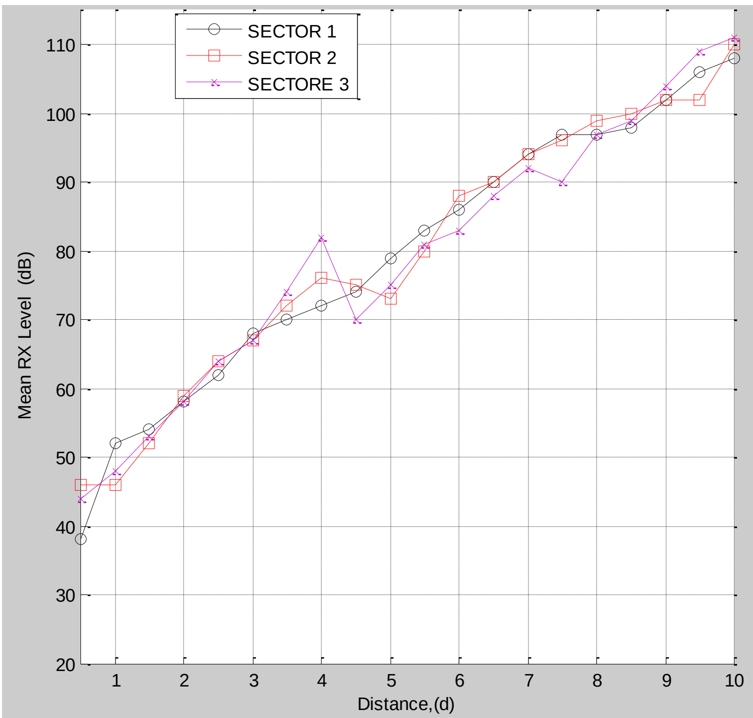
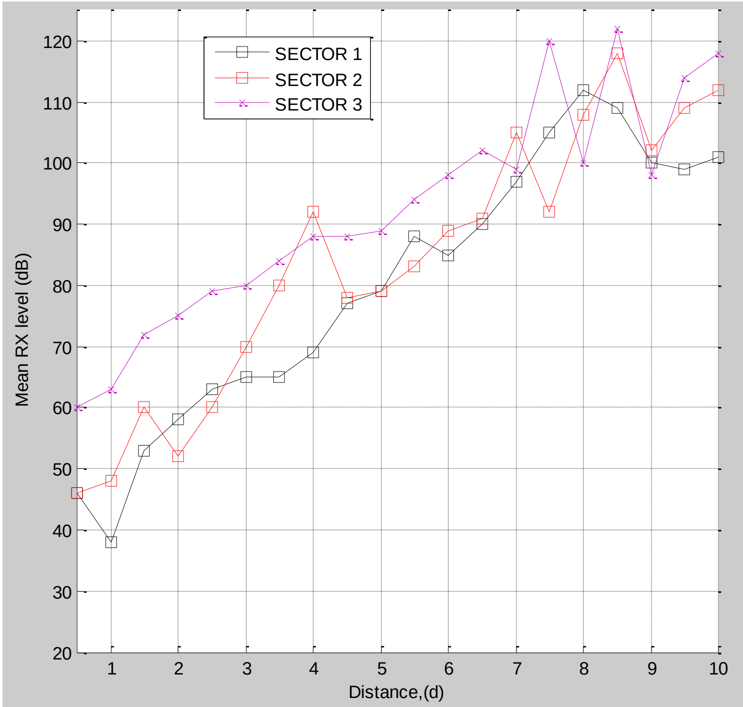


Figure 4: Mean Received Level for Site B Sector.



CONCLUSION

This study reveals the quality of received power at 900MHz in south-west Nigeria. The quality of signal in the region is poor due to the opaque nature of obstacles such as hills [4], plantations, and rocks found between the transmitting base station and the mobile receiver. The effect experience includes the properties of light wave such reflection, refraction, diffraction, multipath.

This effect is evident in the path loss exponent obtained. The purpose of mobile planning is to predict the received signal strength in the region. Also recall that models are derived depending on the environment used to determine the quality of signal strength [5]. The received signals obtained from two sites in Igbaraoke, Ondo State south-west Nigeria was use as case study. From the mean received power of each site, an empirical model was developed for the received power and compared. However obtained values for the model of each site was found not satisfying.

The mean percentage error of the predicted (empirical) compared to the measurement of site A and B is respectively 30.24 and 25%. Hence, the model developed to predict the receive power is inefficient.

Note: rural environments especially areas dominated with vegetation are heavily affected with poor mobile signal because of the opaque nature of vegetation.

This concludes that most rural areas are unlikely ever to be effectively covered since the cost of erecting a cell tower is too high for a few subscribers.

However, it is important to carry out field measurement so as to ascertain beyond reasonable doubt the level of losses experienced.

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