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Seasonal Variations in GSM Path Loss at L-Band Frequency in Different Microcellular Environments of Southwestern Nigeria

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Abstract

Quality of service is one of the major factors demanded by customers in any communication network services. It is therefore essential to put into consideration seasonal propagation parameters before designing and establishing any wireless network systems in order to meet demands of customers. In this research, investigation of RF channel behaviour based on extensive measurements of signal strength and other propagation parameters up to 1200 meters from the base stations adopting single sector verification technique in wet and dry seasons are presented. The measurements were carried out at 900 MHz and 1800 MHz bands in urban, suburban and rural environments of Ondo and Ekiti States of Southwestern Nigeria using Sony Ericson TEMS phones and global positioning system connected to a laptop equipped with TEMS software and cell references of the base stations in the studied areas. The measured data were analysed and propagation parameters deduced. A log-normal shadowing path loss model was formulated using the deduced propagation parameters. The results obtained showed that GSM signals suffer more losses during the wet season due to increased foliage and ground conductivity. Path loss difference between wet and dry seasons was estimated using the developed log-normal shadowing model to be around 0 to 2.4 dB, 0 to 5.5 dB and 0 to 7.0 dB for urban, suburban and rural environments respectively. These estimated losses, though not significant in urban environment, were quite significant in the suburban and rural environments. This study has provided valuable data of additional losses GSM signals are likely to suffer during the wet season for more proper planning and precise design of coverage link of GSM channels to ensure all year round quality of service.

1. Introduction

The rapidly growing wireless network channels, especially the Global System of Mobile communication (GSM) at 900 and 1800 MHz frequency bands, has made it possible for rural, suburban and urban dwellers to access many wireless technical equipment as well as mobile cell phones services [1]. However, this developmental growth came with several inherent challenges, among which are poor signal reception in different climatic conditions, network congestion, power outage and signal outages. GSM network operators in Nigeria have been trying over the years to proffer solutions to these inherent problems. Some of these challenges are peculiar to any specific environment and region in a particular climatic condition, where as some others are general to all the environments and region in all climatic conditions. For instance, the vegetation cover in the environment where these wireless networks are deployed could pose specific challenge to the signal propagation. Therefore, solutions peculiar to the environment need to be sought for each particular climatic environment.

When a radio frequency signal transmitted from a transmitter at a base station travels to a mobile receiver in wireless communication channels, it passes through the earth dynamic environment and this can impose losses [2].The transmission at L-band frequencies is usually challenged by surrounding conditions, environmental factors as a result of seasonal variations such as rain, vapour, dust and dew [1].

Nigeria has a varied vegetation ranging from thick vegetation in the southern parts to the semi-desert regions in the north and extreme northern parts. The Southwestern part of Nigeria experiences wet season every year between April and October (four to seven months) and dry season between November and March (about five months).These variations in season impose obvious changes in the environment. The increase in earth moisture content during the period of wet season gives rise to increased ground conductivity and foliage. GSM signal strength is likely to be affected by this condition among other factors. Therefore, for more proper planning and precise design of coverage link of any wireless channels, strength of signals should be properly taken into account and the effects of ground conductivity and increase foliage on cellular network received signal strength (RSS) has to be established, particularly in the region where such networks are being deployed.

In this study, two states in the Southwestern region of Nigeria are selected as a case study with three different environments investigated in each of the states. The difference in seasonal path loss of GSM propagation signal are investigated using extensive drive test measurement values from the studied environments in different seasons.

1.2 Related Work

[3], adopted a propagation model for a suburban environment of Oman, he achieved this by modifying Okumura Hata propagation model using the results of investigation of variation of path loss values in the months of summer and winter at frequency of 900 MHz. Mean error between the observed values and predicted path loss values based on Okumura-Hata model was deduced to be 6 dB. He further analysed and compared the experimental data using different cells from the month of January, the low rainy season and in August which represents a high rainy season and a difference of approximately 9 dB between the two seasons was observed. Whereas [4], also reported a comprehensive set of propagation measurement of received signal strength conducted in Cambridge, United Kingdom at 3.5 GHz. The set of measurement were used to validate the applicability of the propagation models of Cost-231 Hata models, standard university interim (SUI) and ECC-33 for urban, rural and suburban environments. Generally, it was reported that, the SUI and cost-231Hata model over predicted the path loss in the environments investigated with ECC-33 model showing the better results in urban environments than other models. [5], which focused on the prediction of seasonal trends in mobile cellular dropped calls probability in the United States of America, the study emphasized on the effects of atmospheric refraction and diffraction on GSM signal, he concluded that the effect of foliage path loss would be more during the wet season.

2. Methodology

Measurements were performed during dry season: November to December 2016 and January to March, 2017 also during wet season months between April and September, 2017 these periods were chosen in order to cover the two major seasons in Nigeria. The measurement campaign consisted of three different environments. The environments are urban, suburban and rural, the urban base stations monitored consist of Maryhill base station in Ado-Ekiti, the capital of Ekiti State and Isolo base station in Akure, the capital of Ondo State. For the suburban environments, the base stations monitored are: Oye-Ekiti base station in Ekiti State and Mobil base station in Ondo State while in rural environment, the base stations investigated are: llupeju base station in Ekiti State and Odigbo base station in Ondo State. Table 1 shows the details of the base stations and characteristics of each of the sites.

A site verification exercise was done using testing tools. The measurement tools include; Sony Eriksson test phone handset in the Net monitor mode, it is a specialized equipment used by many network providers in Nigeria for monitoring wireless signals. It is able to measure RSS in decibel miliwatts (dBm), has a sensitivity of -110 dBm, a digital GPS (MAP766CSX) and a laptop. The base station (BTS) antenna is a tri sector vertical dipole directional antenna mounted at some heights above the ground and transmitting at frequencies of 900 and 1800 MHz. The transmitted power is +40 dBm for the 900 MHz and +44 dBm for 1800 MHz bands. Figure 1.0 and 2.0 show one of the experimental sites and the measurement setup while Figure 3.0 to 4.0 present the TEMS investigation software user's interface and cell reference interface.

Table 1: Details of the base stations and characteristics of each of the sites environments

BS name	Cell id Code	Coordinate (Lat°N/Lon°E)	Elevation (m)	Antenna height (m)	Frequency (MHz)	Tx gain (dB)
Maryhill	EK2225	7.629275/5.231178	547	36	1800	17
Isolo	OD2543	7.254400/5.197166	352	36	1800	17
Oye-Ekiti	EK4406	7.784006/5.329048	543	34	1800	17
Oke-Ibukun	OD4747	6.751561/4.874220	87	34	1800	17
Ilupeju	EK3471	7.810266/5.329048	632	32	900	14
Odigbo	OD3835	6.788646/4.874220	129	32	900	14

Figure 1. Photographs of one of the investigated base stations and environments

Figure 2. Measurement instrumentation setup

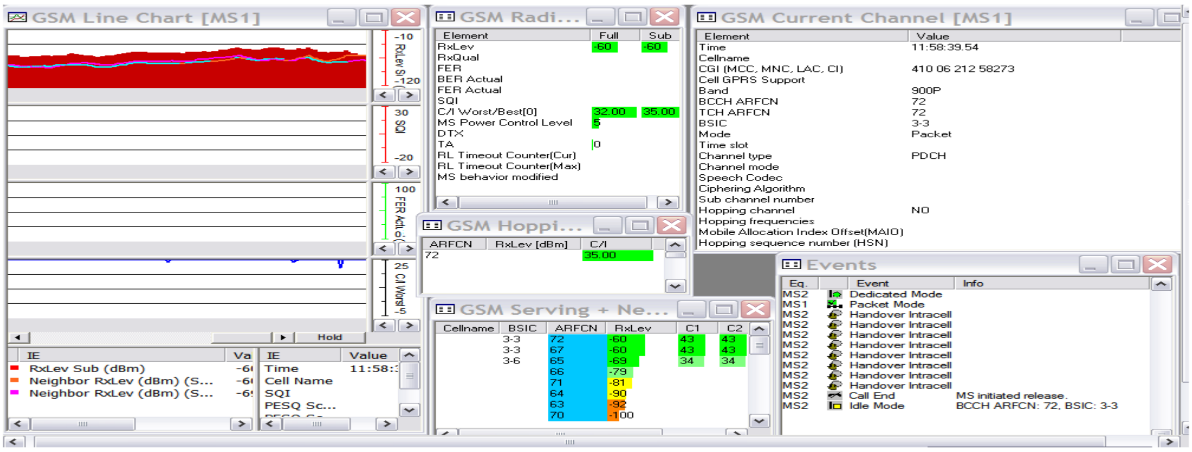

Figure 3. TEMS software user's interface

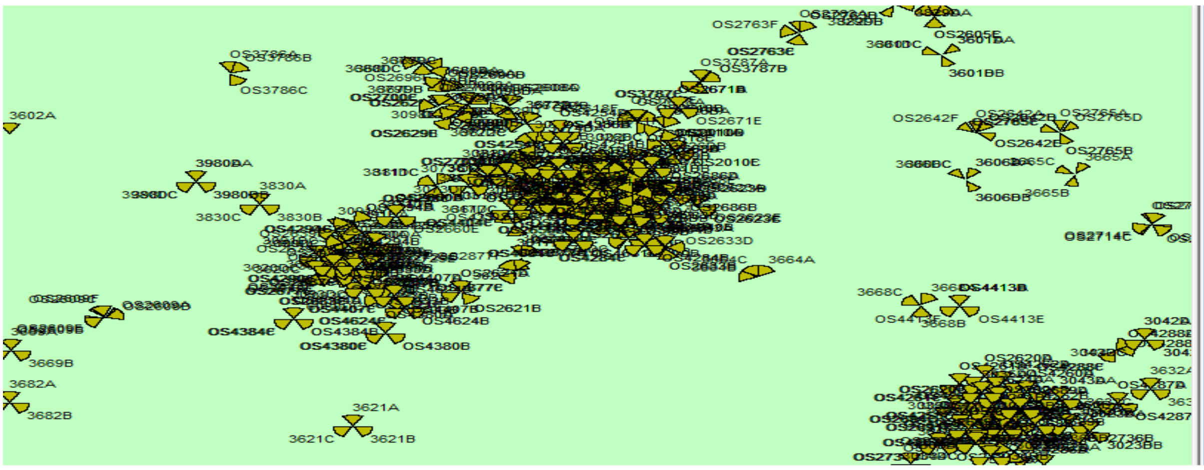

Figure 4. One of cell refs of Ekiti State.

2.1 Data Collection and Processing

Intensive drive test was carried out along all identified paths in all the proposed environments in Southwestern Nigeria. The drive test process was conducted by initiating calls at the beginning of each experiment using a data gathering investigation device called Test Mobile System (TEMS) at a height of 1.2 m. The reports of acquisition of radio signal level and several other GSM signal parameters were acquired using a high sensitive Sony Ericsson signal measurement phone linked to a laptop with an installed TEMS software and uploaded cell refs of the network provider. The positioning information, elevation and distances between the transmitter and the receiver were gathered through the GPS antenna that communicates directly with GPS satellite, the measuring system takes up to 100 points in one minute. To avoid measuring signal strength from other sectors and base stations, a single sector verification (SSV) was adopted in this work.

The measured RSS values for each microcell was recorded in log files. These log files were transferred for more extraction process of the required data to a processing/analytical software known as ACTIX. ACTIX is a drive test software used for further processing of drive test results. It supports troubleshooting and optimization of GSM networks. This tool can automatically troubleshoot for problems in GSM and WCDMA RF system. This tool was applied to convert the acquired log files into excel worksheet format for further analysis.

2.2 Path Loss Calculation

The path loss (dB) is determined from the measured RSS values by the expression [6, 7]:

$$P_L = EIRP - RSS_m \quad (1)$$

where EIRP is the total power density from the transmitter and it is expressed as [6]:

$$EIRP = P_T + G_T + G_R - L_T - L_R \quad (2)$$

Using equation (3.2) in equation (3.1) gives the expression for the propagation path loss in decibel [8]:

$$P_L = P_T + G_T + G_R - L_T - L_R - RSS_m \quad (3)$$

where P_T is base station transmitted power; G_R and G_T are gain of mobile receiver and base station transmitter respectively; L_R and L_T are mobile receiver and transmitter cable loses in (dB) and RSS is the received signal strength.

2.3 Path Loss Modelling

A log normal shadowing model which includes path loss exponent and shadow fading factor has been selected for predicting the distance of dependable wireless network link between the transmitter and the mobile station. The basic equation for this model is:

$$P_{Loss}(dB) = P_{Loss}(d_0) + 10n\log_{10}(\frac{d}{d_0}) \quad (4)$$

where *n* is the path loss exponent which denotes the rate of increase of path loss with receiver distance from the transmitter. The value of *n* depends on a particular environment. $P_{Loss}(d_0)$ is the path loss at the reference distance d_0 usually taken as 100 m and d is the distance between Tx and Rx.

Measurement results have shown that at any distance (d), the path loss (dB) at a particular location is random and distributed log-normally about the mean distance as [9];

$$P_{Loss}(dB) = P_{Loss}(d_0) + 10n\log_{10}(\frac{d}{d_0}) + X_\sigma \quad (5)$$

X_σ is a zero mean Gaussian distributed random variable with standard deviation σ in decibel (dB). In each season, field parameters such as path loss exponent and shadow fading values of the environments considered were calculated. The path loss exponent *n* was estimated by using the relation shown in [8].

$$n = \frac{\sum_{i=1}^{b}\{P_L(d_i) - P_L(d_0)\}}{\sum_{i=1}^{b} 10Log_{10}(\frac{d_i}{d_0})} \quad (6)$$

The shadow fading (standard deviation) σ in (dB) was estimated by Gaussian distribution of the measured path loss [11].

3. Results and Discussion

Fittings of the log-normal shadowing model with the measured path loss values for all the base stations monitored during the dry and wet seasons in urban, suburban and rural environments are presented. At all distances, the practical shadowing model exhibited a better agreement with the measured path loss values in both wet and dry seasons as depicted in Figures 5 to 16.

The differences in the path loss between both sets of data measured in both seasons are presented and analyzed using practical propagation parameters of shadowing model. This is in accordance with the work of [3]. Figures 17 to 22 show the plots of wet and dry season path loss differences for urban, suburban and rural environments of the investigated environments. These differences represent additional propagation path losses due to seasonal changes. Figures 17 and 18 are the plots of path loss difference between wet and dry seasons for urban environments of Maryhill and Isolo base stations, in the urban environments. At all distances from the transmitter, an approximate differences of 0 to 2.4 dB was observed. Also Figures 19 and 20 show the path loss difference in both seasons for suburban environments of Oye-Ekiti and Oke-Ibukun base stations. In all the suburban environments monitored, similar trends were observed, at distances up to around 420 m, a path loss difference of 2.5 dB between both seasons was observed and this difference increased to an approximate value of about 5.5 dB from 420 m onwards. Figure 21 and 22 are also the plots for rural environments of Ilupeju, and Odigbo base stations, in Figure 21, at distances close to the base station up to 550 m, path loss differences of about 0 to 2.3 dB were observed and 7.0 dB from 550 m onwards. In Figure 22, at distances near the base station up to 500 m, path loss differences of about 0 to 5 dB were observed and around 7.0 dB at higher distances.

It is thus apparent that wireless mobile networks experience higher losses during wet season than dry season, this is due to increased foliage, increased ground conductivity and higher humidity during wet season [1,3], with rural area having a higher path loss difference, followed by suburban and urban environments having the least difference. Various reasons can be responsible for the higher difference in rural environment: Firstly, in urban environment, there are fewer trees and less vegetation when compared to rural and suburban environment. Thus, there would be less foliage in urban areas. Secondly, there are more paved surfaces, asphalt roads and concrete floors surfaces in urban environment than in rural and suburban environments. Moisture is hardly retained on these surfaces and this gives rise to an almost constant value of ground conductivity all year round in urban environments. Similar seasonal differences had been observed by [3] in Oman and [10] in Zaria, Nigeria.

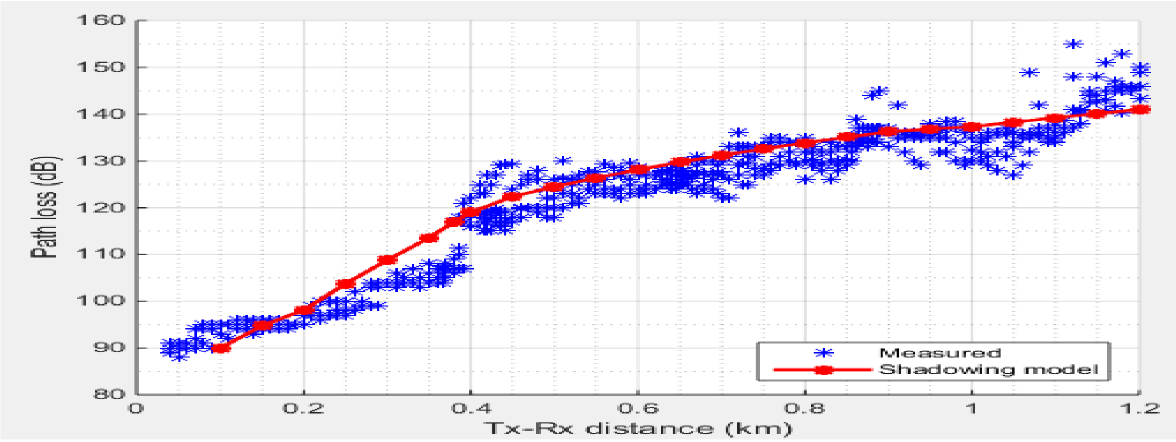

Figure 5. Comparison of Shadowing model with wet season measured path loss values for Maryhil base station

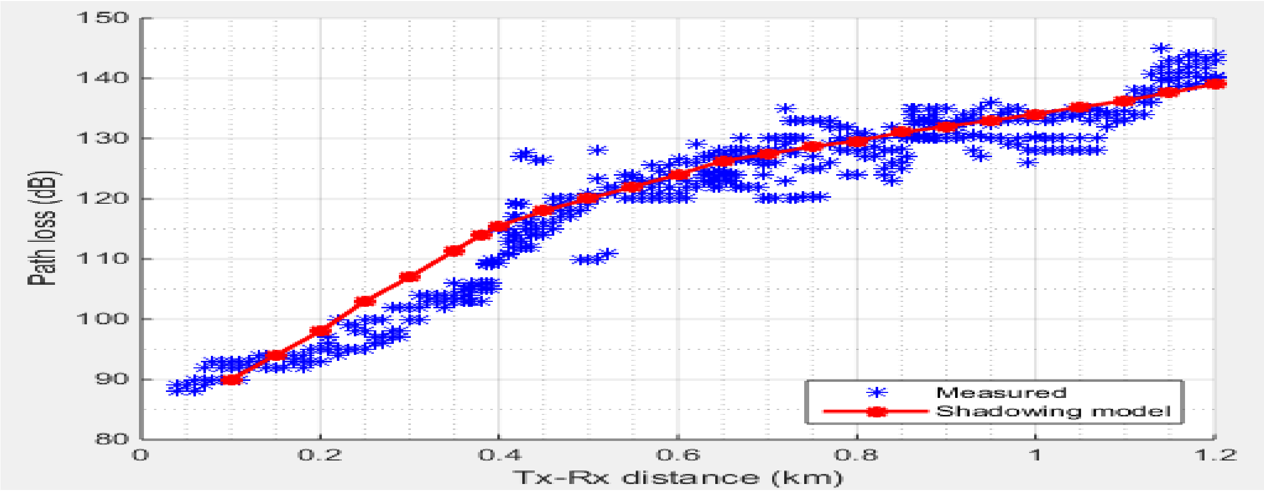

Figure 6. Comparison of Shadowing model with dry season measured path loss values for Maryhil base station.

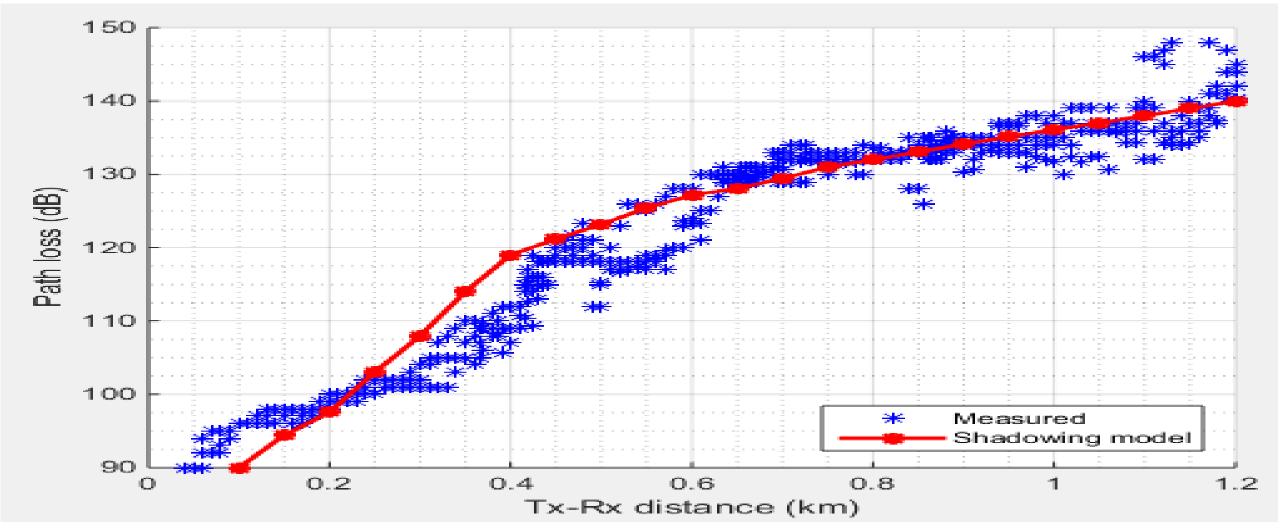

Figure 7. Comparison of Shadowing model with wet season measured path loss values for Isolo base station.

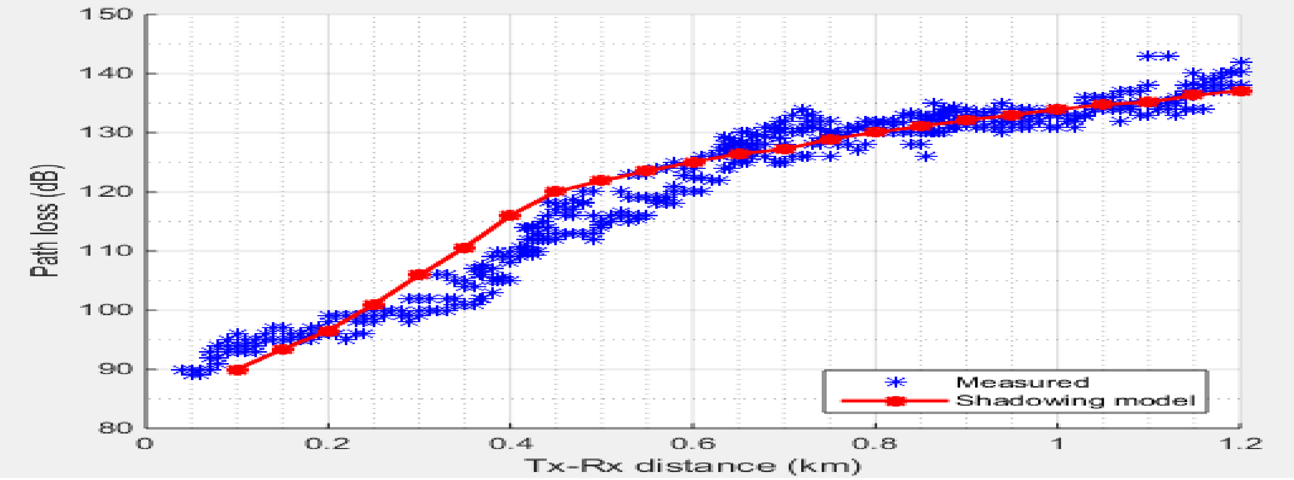

Figure 8. Comparison of Shadowing model with dry season measured path loss values for Isolo base station

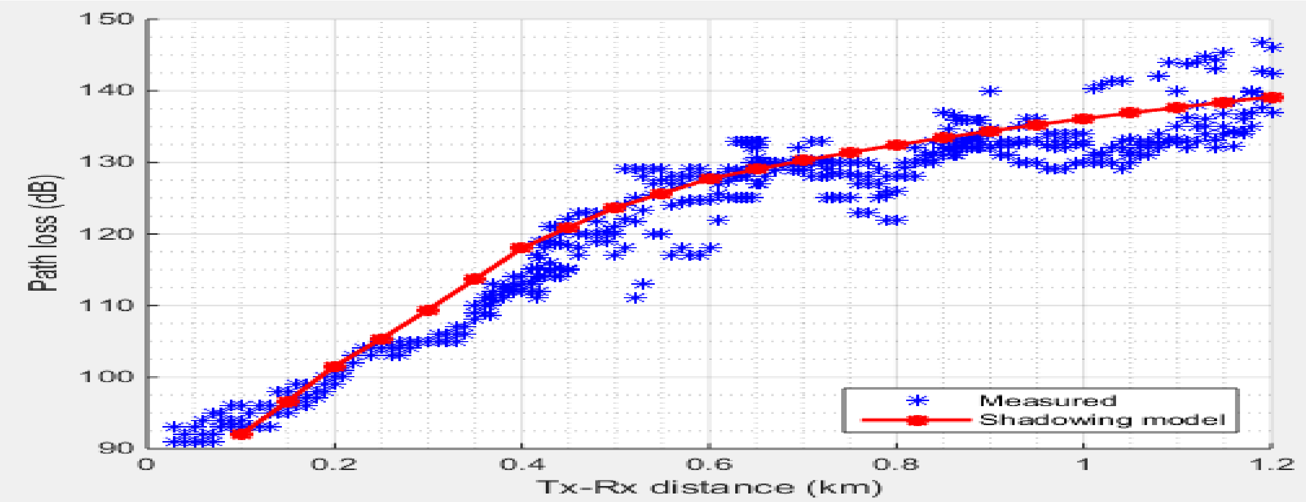

Figure 9. Comparison of Shadowing model with wet season measured path loss values for Oye-Ekiti base station.

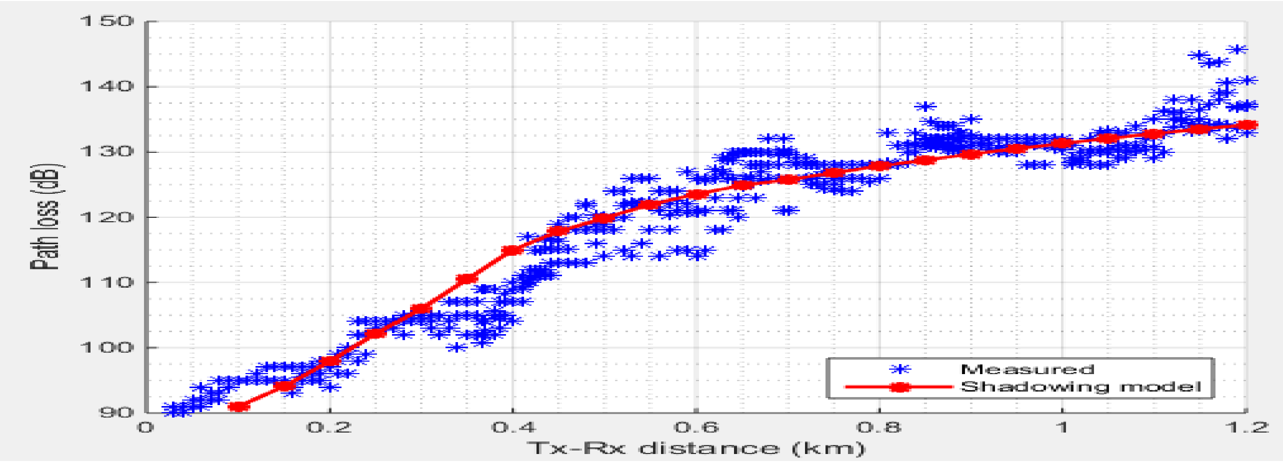

Figure 10. Comparison of Shadowing model with dry season measured path loss values for Oye-Ekiti base station.

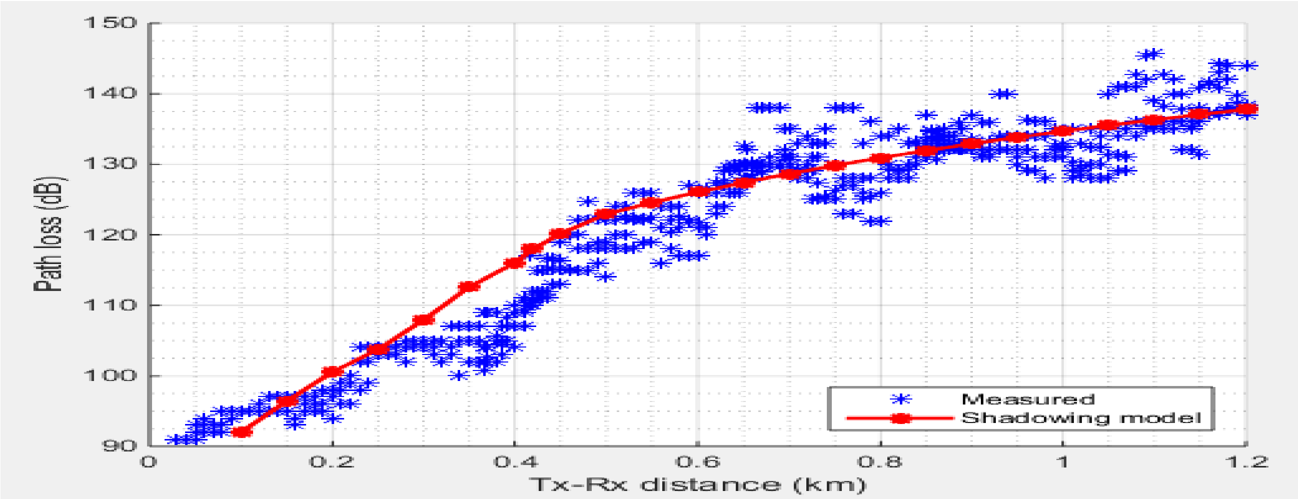

Figure 11. Comparison of Shadowing model with wet season measured path loss values for Oke-Ibukun base station.

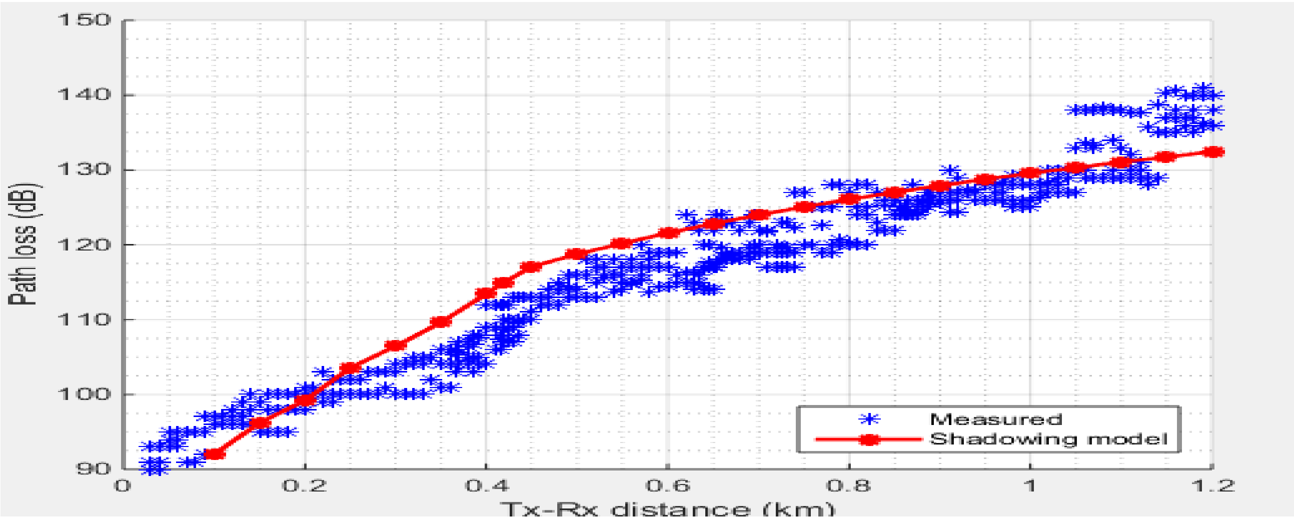

Figure 12. Comparison of Shadowing model with dry season measured path loss values for Oke-Ibukun base station.

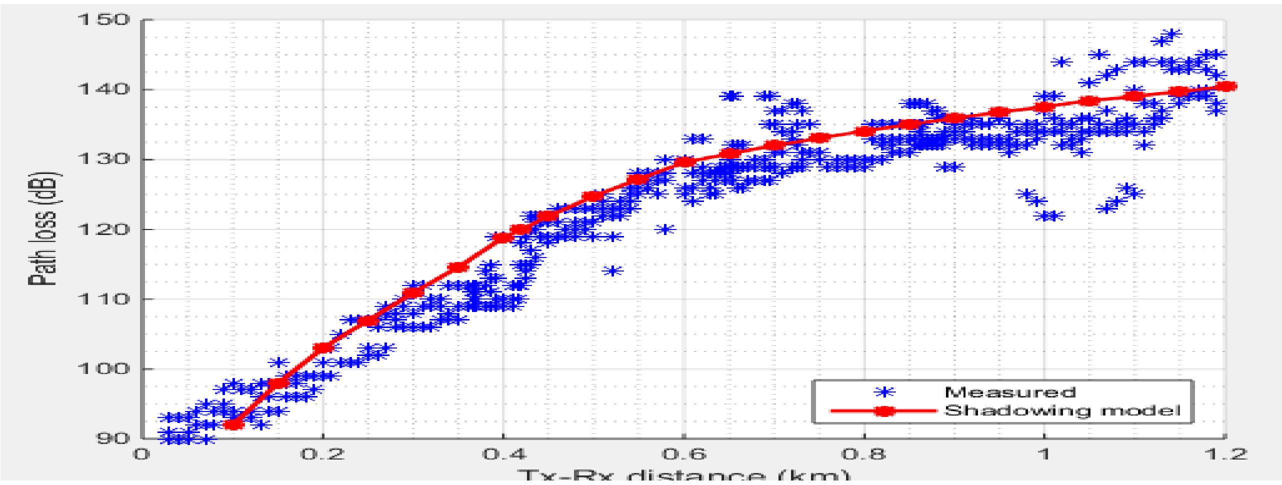

Figure 13. Comparison of Shadowing model with wet season measured path loss values for Ilupeju base station.

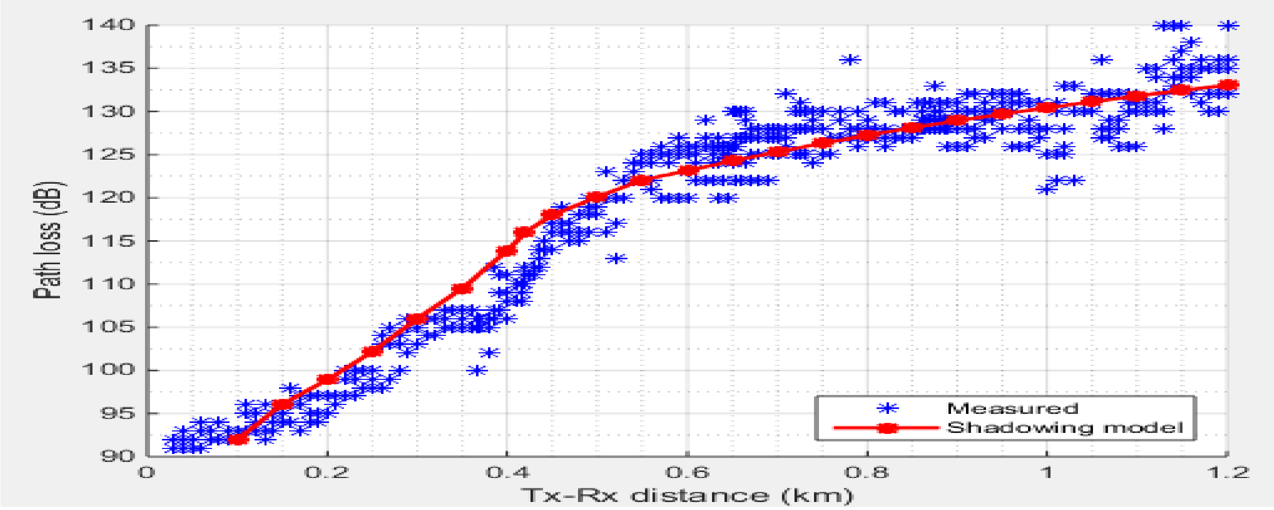

Figure 14. Comparison of Shadowing model with dry season measured path loss values for Ilupeju base station.

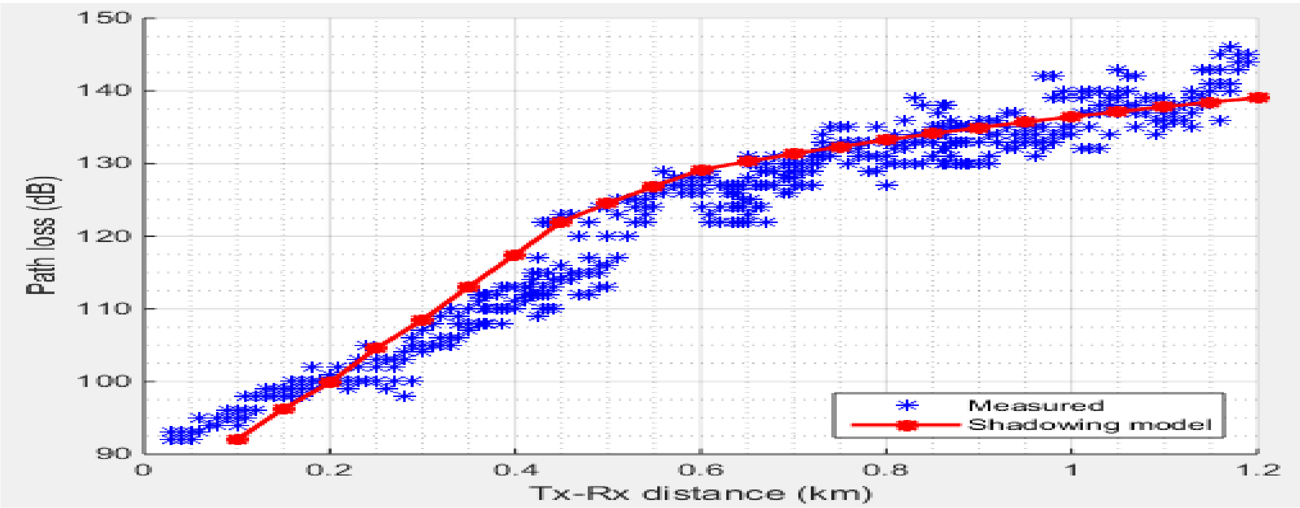

Figure 15. Comparison of Shadowing model with wet season measured path loss values for Odigbo base station.

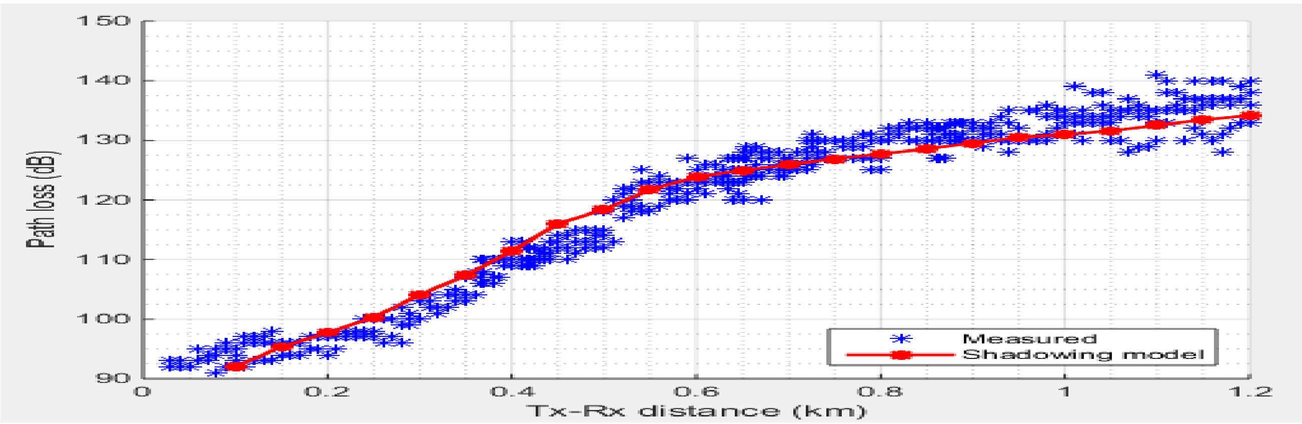

Figure 16. Comparison of Shadowing model with dry season measured path loss values for Odigbo base station.

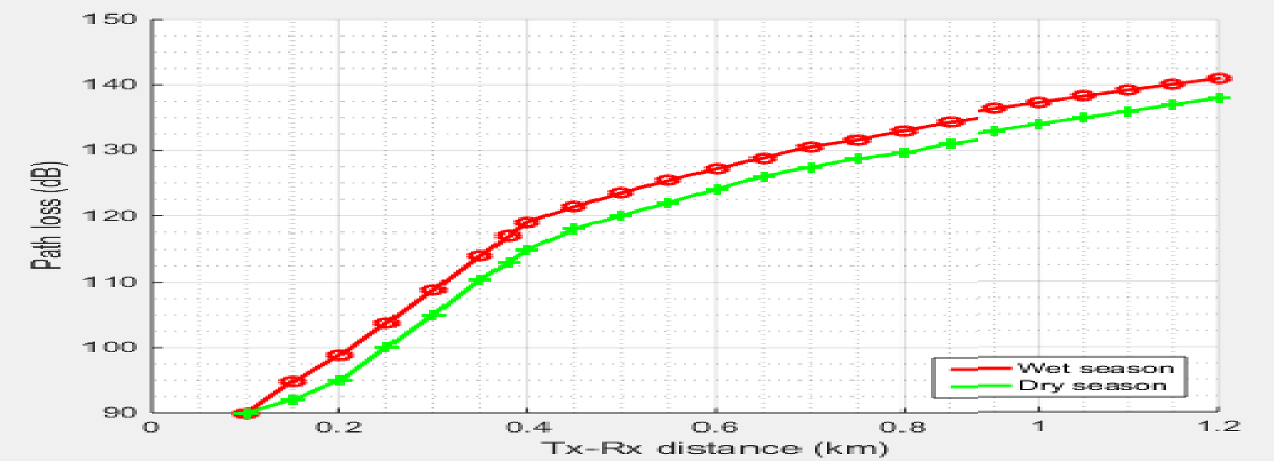

Figure 17. Difference in path loss between wet and dry season for Maryhill environment

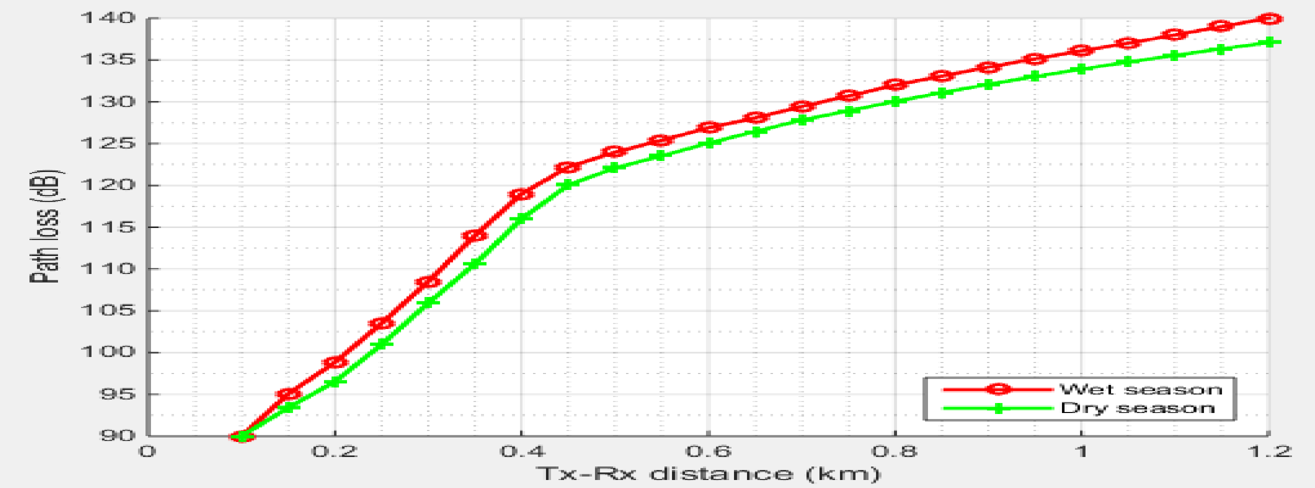

Figure 18. Difference in path loss between wet and dry season for Isolo environment

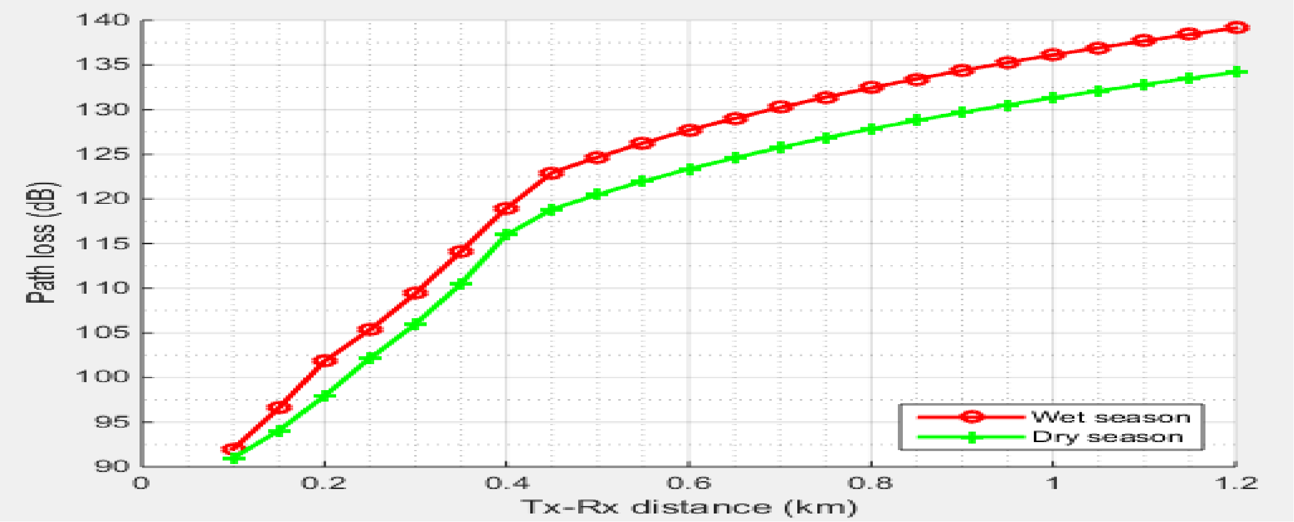

Figure 19. Difference in path loss between wet and dry season for Oye-Ekiti environment

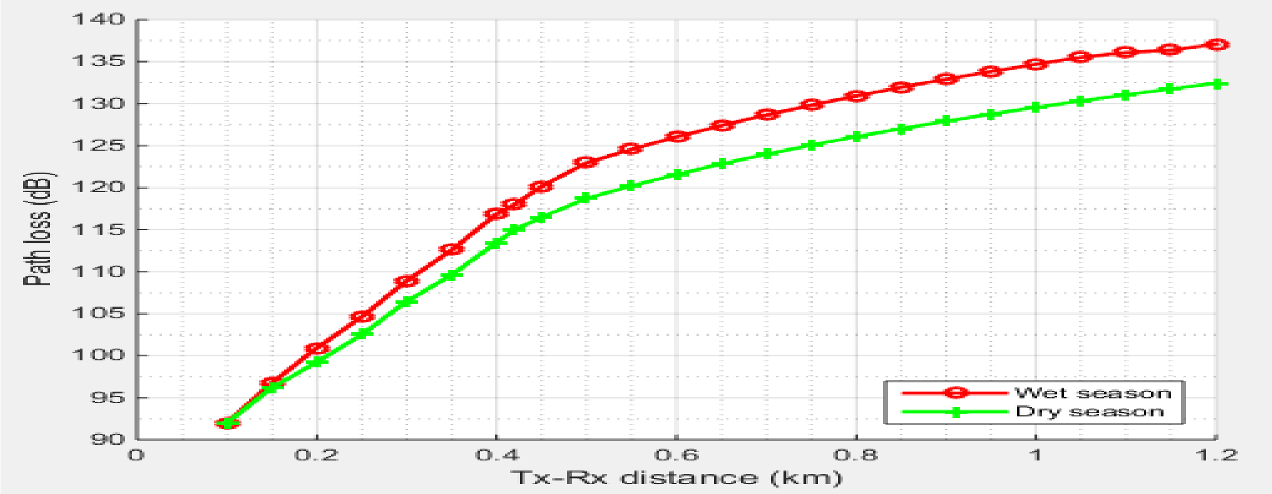

Figure 20. Difference in path loss between wet and dry season for Oke-Ibukun environment

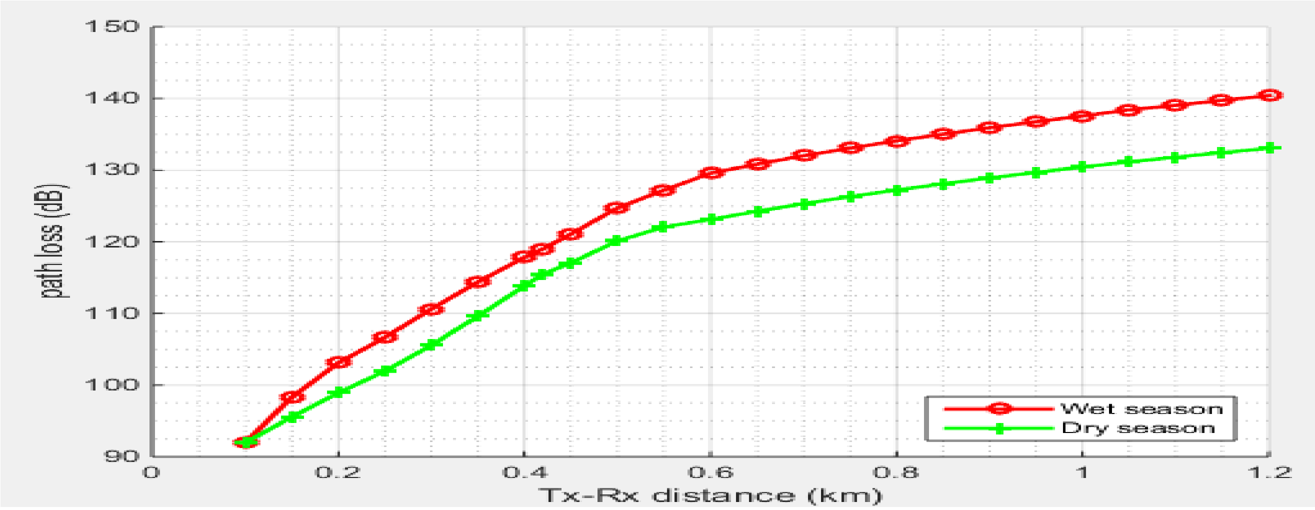

Figure 21. Difference in path loss between wet and dry season for Ilupeju environment

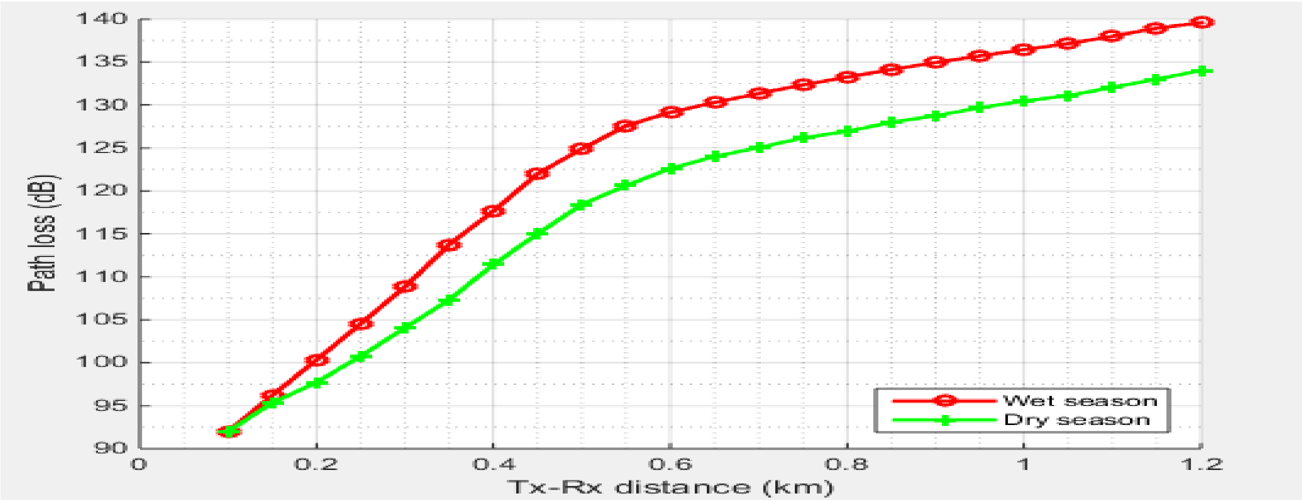

Figure 22. Difference in path loss between wet and dry season for Odigbo environment

4. Conclusion

This study investigated the effect of variation of seasons on wireless propagation characteristics in urban, suburban and rural environments of two states in Southwestern region of Nigeria. The two main factors considered which differentiate wet and dry seasons path losses were Increased foliage and ground conductivity. The results from this study showed that GSM signals suffer more losses during the wet season due to increased foliage and increased ground conductivity. These added losses were found to be more severe in the rural and suburban environment than the urban environment, the difference in propagation characteristics between the urban, suburban and rural environments is due to the fact that suburban and rural environments have more vegetation cover and unpaved surfaces which are capable of retaining more moisture than urban environments. The best way to estimate the losses due to seasonal variations is using the practical parameters derived from the signal strength in that specific season.

The overall results from this study provides GSM network operators with vital information for optimizing their networks, particularly in Southwestern part of Nigeria. Valuable data of additional losses GSM signals are likely to suffer during the wet season are herein provided for more proper planning and precise design of coverage link of GSM channels.

Nomenclature

P_L	Path loss (dB)
EIRP	Total power density
RSS_m	Measured received signsl strength (dBm)
P_T	Base station transmitted power(dBm)
G_T	Gain of base station transmitter(dB)
G_R	Gain of mobile receiver(dB)
L_R	Mibile receiver cable loss(dB)
L_T	Base station cable loss(dB)
do	Reference distance (m)
di	Other distances
n	Path loss exponent (m)
Tx	Transmitter
Rx	Receiver
Greek letter	
σ	Standard deviation

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