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Statistical evaluation of Seasonal Impact on WCDMA network in South-East Nigeria

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Abstract: This work presents a statistical evaluation of seasonal effect on the WCDMA network in the urban terrain of south-eastern Nigeria (Onitsha). Seasonal impact on signal reception is often times neglected when characterizing a WCDMA propagation environment. As shown in this work, the received signal strength (RSS) and level of signal attenuation measured during the different seasons differs as can be seen in both the measured value and the path loss exponent computed. The path loss exponent obtained indicates the rate of signal attenuation in the area. An accurate knowledge of this key performance indicator can assist mobile cellular network designers in deploying accurate path loss prediction models that will be used for cellular network planning and verification.

Keywords: RSSI**,** Signal attenuation, Path loss exponent, Shadowing effect, Path loss Model, Seasonal impact, WCDMA

1.1 Introduction

Natural and man-made structures such as high rise buildings, office structures or clustered trees in suburban areas, with sizes ranging from a few meters to tens of meters, dramatically influence the wireless propagation channel. These features are usually similar or greater in size than the wavelength of the transmitted signal and may both block, scatter or reflect the radio signal. These contributions reach the Mobile by way of multiple paths, in addition to that of the direct signal. The presence of the various forms of precipitation such as rain, snow, cloud and fog in the propagation path are always capable of introducing major attenuation to the propagation channel. Rain fade, primarily due to the absorption of propagation signal by atmospheric rain, snow or ice are prevalent at high frequencies. This results to the degradation of the transmitted signal due to the electromagnetic interference of the leading edge of a storm front. Rain fade can be caused by precipitation at the uplink or downlink location. However, it does not need to be raining at a location for it to be affected by rain fade as the signal may pass through precipitation many miles away, especially if the antenna has a low azimuth. About 5 to 20 percent of signal attenuation as a result of rain fade is caused by rain, snow or ice on the uplink or downlink antenna reflector or feed horn (Das et al, 2010). Since rain is a non-homogeneous process in both time and space, specific attenuation varies with location, time and rain type. Rain attenuation modelling is usually done in terms of Drop Size Distribution (DSD) (Crane, 1996), (Thurai et al, 2007). Rain DSD varies with rain rate as well as with location and thus the same rain rate can correspond to different DSD. The DSD depends strongly upon the local climate of the region studied, (Maitra, 2004).

Wind in itself doesn't affect the propagated signal but it does put an external force (wind loading) on the antenna system that can cause it to move or come out of alignment. The solution to this is to install antenna systems to withstand local wind patterns. Most antenna systems are designed to withstand wind gusts up to 177 km/h (varies by manufacture). Hence, in addition to the expected distance power decay, two main effects are characteristic in mobile propagation: shadowing and multipath. This leads to a reduction in power density (attenuation) as the signal propagates through space, and this phenomena is known as path loss. Path loss is defined as the difference in decibel between the effective transmitted power and the received power and it includes the effect of antenna gains. It can also be defined as signal attenuation as a positive quantity measured in decibel (dB). Path loss may be due to many effects, such as refraction, diffraction, reflection and multi-path propagation.

Shadowing is the effect that the received signal power fluctuates due to objects obstructing the propagation path between transmitter and receiver, therefore envisaging Shadowing effect becomes more critical in assuring quality of service. Moisture such as fog, rain, and snow (depending on its water content) adds attenuation to the signal's path. The moisture content in any of these is critical. Fog (Harmattan), even though dense, has very low moisture when it comes to its effect on RF signal. With snow it all depends on its density. Snow typically has less moisture content than actual rain. Rain depends on the amount of rainfall (measured in mm/h) and the size of the raindrops. The heavier the raindrops and higher the velocity of rainfall the higher the attenuation. Also, the amount of attenuation that rain can cause depends on the frequency being used. The lower the frequency the less attenuation. The higher the frequency the higher the attenuation (Diana et al, 2012).

Table 1: Typical Path loss Exponents (Rappaport, 2007)

Environment	**Path loss Exponent, η**
Free Space	2
Urban cellular/PCS	2.7 to 4.0
Shadowed urban cellular/PCS	3 to 5
Indoor LOS	1.6 to 1.8
Obstructed Indoor	4 to 6
Obstructed in factories	2 to 3

Outage in communication due to shadowing and seasonal variation is a challenge in assuring service and hence should be reasonably predicted to compensate for the losses. The extent to which signal attenuation occurs in a communication channel can be determined by the path loss exponent whose value is normally in the range of 2 to 6. Table 1 shows the typical value of path loss exponent for most environments.

In this paper, measurement based path loss exponent and shadowing parameter are derived for a path loss model and are used to assess the extent of signal attenuation due to shadowing effect and seasonal variation noticed from a six (6) month routine monitoring of the received signal level measured from the base station in one of the telecommunication companies in Onitsha, Nigeria. The measurements were carried out in an urban non-line-of-sight environments with clustered high rise buildings and scanty trees.

2.0 Material and methods

2.1 Mobile Radio Propagation Path loss Model

There exists a number of empirical path loss models which can be used to predict both large-scale and medium-scale coverage for mobile communication system design. Some of these path loss models are: the log-distance path loss model, the log-normal path loss model, Hata Propagation Model and COST 231-HATA Model. In this work, the log-normal path loss model is used because of its compensation of the shadowing effect in the computation.

Experiments reported by Egli in 1957 showed that, for paths longer than a few hundred meters, the received (local-mean) power fluctuates with a 'log-normal' distribution about the area-mean power. By 'log-normal' it meant that the local-mean power is expressed in logarithmic values, such as dB or neper and has a normal (i.e., Gaussian) distribution. These effects are best described (in a large scale) by the path loss exponent which defines the rate of change of attenuation that the signals suffer as it propagates from the transmitter to the receiver. The average large-scale path loss for an arbitrary transmitter to receiver separation is expressed as a function of distance as, (Smith, M.S. et al, 2000).

$$P_L(dB) = P_L(d_0) + 10\eta Log(\frac{d_i}{d_0}) \quad (1)$$

Where, $P_L(d_o)$ = the path loss at close in reference distance otherwise known as reference path loss, η is the path loss exponent, d_o is close in reference distance, d_i is distance at intervals from the Base Station (BS) to Mobile Station (MS).

It was shown by Azubogu et al (2011) that for any value of d_i, the path loss $P_L(dB)$ is a random variable with a log-normal distribution about the mean value due to shadowing. To compensate for shadow fading, the path loss beyond the reference distance can be written as:

$$P_L(dB) = P_L(d_0) + 10\eta Log\left(\frac{d_i}{d_0}\right) + \varsigma \tag{2}$$

This is known as the log-normal shadowing model, where ς is the shadowing factor and is a Gaussian random variable (with values in dB) and standard deviation σ (also in dB). The standard deviation of the shadowing factor is known as the location variability.
The standard deviation is given as (Erceg et al, 1999):

$$\sigma = \sqrt{\sum \frac{[P_L(d_i) - P_L(d_0)]^2}{N}} \tag{3}$$

Where $P_L(d_i)$ is the measured path loss at distance d_i , $P_L(d_o)$ is the estimated path loss using equation (1) and N is the number of measured data points.

2.2 Test Bed Description

The field measurements were carried out in the urban city of Onitsha. The Onitsha environ majorly comprises of densely situated two (2) to three (3) storey buildings, a few trees and random settlers. In order to accommodate the two climatic conditions in Nigeria namely: Rainy Season and dry season and to specially accommodate the Harmattan, the measurement spanned June 2016 to January 2017 using existing WCDMA cellular mobile network operating at 2112 MHz band. Two (2) base stations located in this urban environment are used for this work. The base stations studied are ONT 007 (located at Con oil filling station by bridge head, Onitsha, Anambra State Nigeria) and ONT 029 (located at Creek road Onitsha, Anambra state, Nigeria).

Figure 1: Google map image of Onitsha Urban

2.3 Data Collection Method

A series of drive test was carried out to actually capture the received signal strength variation in the area under study. Drive testing is a method of measuring and assessing the coverage, capacity and Quality of Service (QoS) of a mobile radio network. The technique required the use of a vehicle containing mobile radio network air interface measurement equipment that can detect and record a wide variety of the physical and virtual parameters of mobile cellular service in a given geographical area. Measurements of the mean received signal strength indicator in dBm were taken for the mobile terminal using the mobile phone.

Figure 2: Image of Drive Test Equipment used

The data obtained from the base stations were based on automated logs outputted from the investigation/monitoring software called Transmission Evaluation and Monitoring System (TEMS). The system was queried to output readings of the received signal strength from a distance of 100m (as the starting or reference point) and then readings were taken at 100m intervals up to a distance of 1200m. Due to the presence of several micro cells in the area, quick handovers to neighbouring cells deterred any effort of carrying out a purely single cell verification; rather a combination of both single cell and cluster cell verification was employed (i.e. a situation where more than one cell is monitored on a drive test).

2.3 Data Presentation And Analysis

The measured received signal levels (in dBm) for each site visited and their mean is shown in tables 2 and 3. Due to variations in the measurements of the received signal strength, the mean values are used for the model development. The path loss for the various months is also shown along with the received signal levels. The path loss is obtained as follows:

$$P_L = P_t - P_r \qquad (4)$$

P_L = Path loss
P_t = Transmitted Power
P_r = Received Signal Strength Indicator

Where the transmit power for the base stations (ONT 007 and ONT 029) is 44.7dBm (Source: Globacom Nigeria).

Table 2: Received Signal Strength Indicator (RSSI) and Path loss for site ONT 007

Distance (m)	RSSI (dBm) June 2016	RSSI (dBm) December 2016	RSSI (dBm) January 2017	RSSI (dBm) Average	Path loss $P_t - P_r$ (dB)
100	-40.20	-41.40	-42.30	-41.30	86.00
200	-47.10	-44.70	-42.30	-44.70	89.40
300	-50.30	-45.30	-46.30	-47.30	92.00
400	-45.80	-51.40	-53.10	-49.50	94.20
500	-60.00	-62.80	-57.20	-60.00	104.70
600	-76.30	-60.10	-63.10	-66.50	111.20
700	-72.50	-69.30	-71.20	-71.00	115.70
800	-65.50	-73.40	-74.10	-71.00	115.70
900	-71.50	-78.30	-78.50	-76.10	120.80
1000	-85.40	-78.10	-80.10	-81.20	125.90
1100	-96.00	-84.30	-85.20	-88.50	133.20
1200	-88.20	-91.80	-90.30	-90.10	134.80

Table 3: Received Signal Strength Indicator (RSSI) and Path loss for site ONT 029

Distance (d) (m)	**RSSI (dBm) June 2016**	**RSSI (dBm) December 2016**	**RSSI (dBm) January 2017**	**RSSI (dBm) Average**	**Path loss $P_t - P_r$ (dB)**
100	-57.00	-55.60	-55.50	-56.03	100.73
200	-58.20	-63.50	-68.30	-63.33	108.03
300	-61.50	-65.30	-65.10	-63.97	108.67
400	-69.90	-68.60	-71.60	-70.03	114.73
500	-64.30	-67.80	-74.10	-68.73	113.43
600	-72.00	-70.40	-72.10	-71.50	116.20
700	-73.90	-70.80	-73.40	-72.70	117.40
800	-73.10	-76.10	-74.90	-74.70	119.40
900	-78.20	-80.00	-79.90	-79.37	124.07
1000	-81.30	-78.90	-83.10	-81.10	125.80
1100	-86.10	-87.10	-88.30	-87.17	131.87
1200	-90.10	-91.20	-92.10	-91.13	135.83

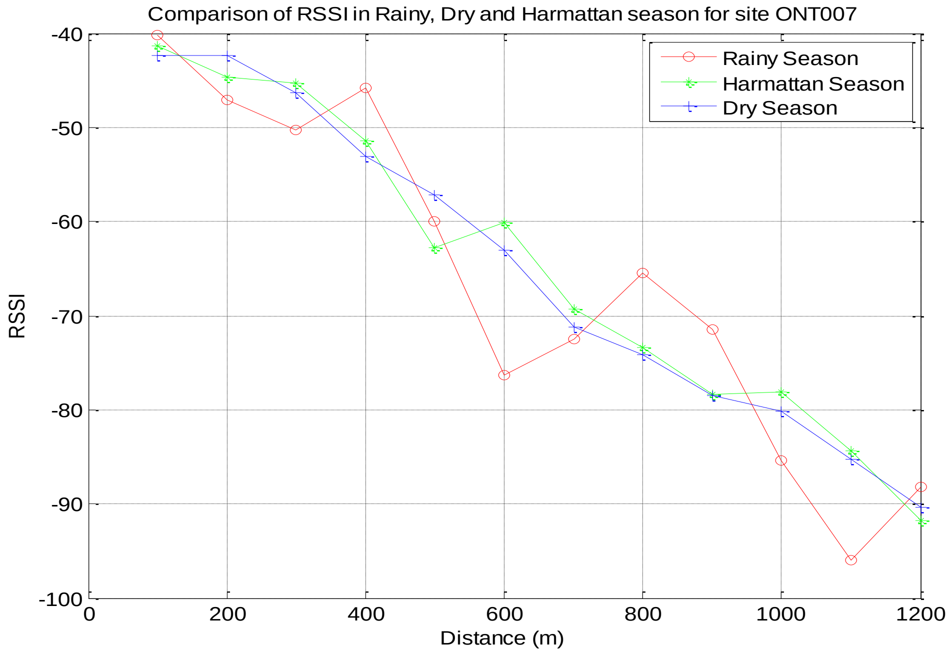

Figure 3: Comparison of RSSI for different seasons for ONT 007

The signal strength received by the mobile equipment as shown in the tables depends largely upon shadowing effect, multipath fading, seasonal variations and distance of the Mobile Unit (MU) from the Base Transceiver Station (BTS). These factors account for the variations of signal strength as recorded in Tables 2 and 3. The plots of the mean value of their received signal strength along with the comparison of the RSSI for different seasons are plotted against distance using Matlab software. As can be seen in Fig. 3, the RSSI at any particular distance from the base station differs in different seasons of the year. From the plot it is seen that the signal strength fluctuates with distance and depending on the power control algorithm in use, the received power varies with distance, nature of terrain and even weather conditions. For instance, at a distance of 1000m, the RSSI for rainy season is -85dBm while that of harmattan is -78dBm and that of dry season is -80dBm. Variations like this if not properly factored in would lead to poor characterization of the propagation environment. The average of the RSSI for the three seasons is calculated and plotted in fig. 4. While fig. 5 and fig. 6 presents the same information for ONT 029

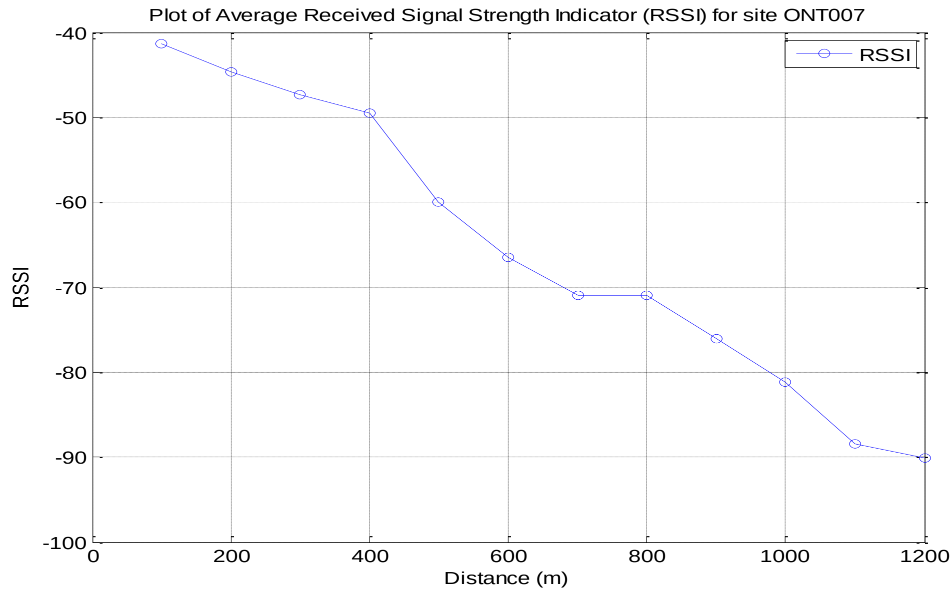

Figure 4: Average RSSI plot for ONT 007

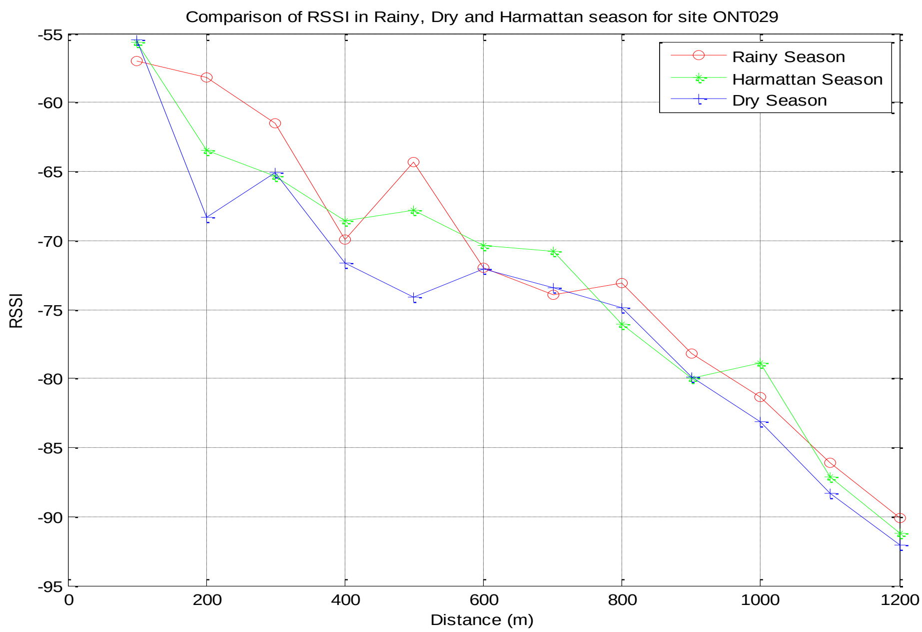

Figure 5: Comparison of RSSI for different seasons for ONT 029

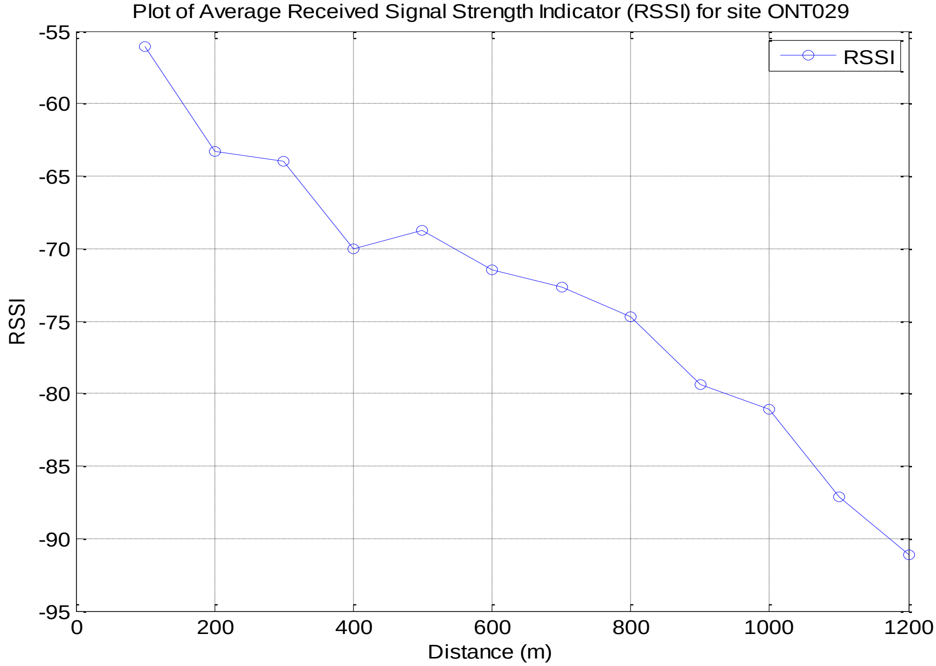

Figure 6: Average RSSI plot for ONT 029

Similar to what was observed in fig. 3, fig. 5 also depicts the variations that occur in the RSSI at different distances from the base station. To clearly see the variation that exists, the path loss exponent for these base stations are calculated. The path loss exponent is an important parameter that indicates the rate of signal attenuation in the area.

To obtain the path loss exponent η, the method of linear regression analysis is applied (Azubogu et al, 2011) such that from:

$$e(\eta) = \sum_{i=1}^{m}[P_L(d_i) - P_L(dB)]^2 \qquad (5)$$

Substituting equation (1) into equation (5) gives:

$$e(\eta) = \sum_{i=1}^{m}[P_L(d_i) - P_L(d_0) - 10\eta Log(\frac{d}{d_0})\ ]^2$$

Differentiating equation (5) with respect to n and equating to zero gives:

$$\frac{\delta e(\eta)}{\delta n} = -20\log(\frac{d}{d_0})\sum_{i=1}^{m}[P_L(d_i) - P_L(d_0) - 10\eta Log\left(\frac{d}{d_0}\right)] = 0$$

Solving for η $gives$:

$$\eta = \frac{\sum_{i=1}^{m}[P_L(d_i) - P_L(d_o)]}{\sum_{i=1}^{m}[10\log_{10}(\frac{d_i}{d_o})]} \qquad (6)$$

Where:

$P_L(d_i)$ is the average path loss and it is the difference between the transmitting power (P_t) in dB and received power (P_r) in dBm, $P_L(d_o)$ = the path loss at close in reference distance otherwise known as reference path loss, d_o is close in reference distance, d_i is distance at intervals from the BS to MS.

Applying equation (6) and equation (3) to table 2 using Matlab program, the Path loss exponent for ONT 007 was found to be 3.36 with a Shadow factor of 8.45 dB and $P_L(d_o)$ which is the path loss at close in reference distance otherwise known as reference path loss is 86.00dB.

Therefore the Path loss for ONT 007 is given as:

$$P_L(dB) = P_L(d_0) + 10\eta Log\left(\frac{d_i}{d_0}\right) + \varsigma$$

Substituting the values above into the equation gives:

$$P_L(dB) = 86 + 10(3.36)Log\left(\frac{d_i}{d_0}\right) + 8.45$$

$$P_L(dB) = 94.45 + 33.6Log\left(\frac{d_i}{d_0}\right)$$

Similarly for ONT 029, applying equation (6) and equation (3) to table 2 using Matlab program, the Path loss exponent was found to be 2.39 with a Shadow factor of 5.72 dB and $P_L(d_o)$ is 100.73dB.

Substituting the values above into the path loss model equation gives:

$$P_L(dB) = 100.73 + 10(2.39)Log\left(\frac{d_i}{d_0}\right) + 5.72$$

$$P_L(dB) = 106.45 + 23.9Log\left(\frac{d_i}{d_0}\right) \quad (7)$$

Where d_i and d_0 are variables depending on the choice of distance travelled and reference distance.

3.0 Results and Discussions

As depicted in the plots, it is evident that the signal loss in the environment shows a generally increasing trend with distance. It’s also shown that the received signal strength varies with distance and also with the season of the year. These varying results show that different seasons of the year play a major role in signal degradation/attenuation and should be considered during cell planning and verification. For instance the monthly path loss exponent for the month of June (Rainy season), December (Harmattan) and January (Dry season) for ONT 007 where computed using Matlab and the results showed a clear variation as shown in Table 4.

Table 4: Monthly Path loss Exponent

MONTH/SEASON	PATH LOSS EXPONENT (n)
June (Rainy Season)	3.65
December (Harmattan Season)	3.27
January (Dry Season)	3.18

From the results in table 4, the average value of the path loss exponent approximates to 3.36dB which is accurate and good because it falls within the path loss exponent for urban area cellular radio environment which theoretically ranges from 2.7 – 4.0 as shown in Table 1. The above table also shows that there will be more attenuation to wireless communication during the rainy season compare to other seasons of the year, followed by harmattan period. This means that both the mobile service users and service providers should prepare ahead of time for the inevitable variation in quality of service during the different seasons of the year.

4.0. Conclusion

Field surveys are a practical necessity to verify or correct the accuracy of terrain data, obstructions, and path loss data. This work having studied such effects as shadowing and seasonal variation on the propagated signal, it presents a statistically derived path loss model for microcellular wireless communications systems for urban cities in South-eastern Nigeria which compensates for both shadowing effect and signal attenuation in different seasons of the year. From the analysis carried out, it has been shown experimentally that fog (Harmattan) weather is better compared to the Rainy weather as shown by the path loss exponent which is an indicator of the level of signal attenuation. Rainy season has a higher path loss exponent ($n = 3.65$) as against that of harmattan ($n = 3.27$). Dry season has a lower path loss exponent ($n = 3.17$) because wind in itself doesn't affect the propagated signal but it does put an external force (wind loading) on the antenna system that can cause it to move or come out of alignment. There can be a stable transmission during rainy weather if there is space diversity, large antenna and also proper planning. Also note that this data can be affected by irregular and unforeseen weather conditions at different seasons of the year. The developed path loss model can be used for accurate path loss prediction of the received signal strength of the WCDMA based network. Also, the path loss exponent derived gives an insight into the rate of signal degradation for such areas and would serve as a correction factor in cases where such information is needed

5.0 Recommendation

The outcome of this work strongly suggests that for a proper wireless network planning, attenuation due to shadowing effect and seasonal variation should be one of the parameters to be taken into consideration. This should be considered during pre-installation planning in order to improve QoS and maintain good communication link quality.

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