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VARIATIONS OF GSM PATH LOSS EXPONENT WITH PROPAGATION DISTANCE AT L-BAND FREQUENCIES IN DIFFERENT MICROCELLULAR ENVIRONMENT OF SOUTHWESTERN NIGERIA

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ABSTRACT: *Propagation path loss exponent is an important component of system design, and knowing the values helps to avoid surprises when the actual service begins. The path loss exponent is known to be critical in establishing the coverage of any new cellular network. Estimating the path loss exponent of any environment requires raising new data sets, which can be accomplished by conducting experiments. With this objective, the present study reports the L-band signal RSS level measurements of 6 GSM base stations in the urban, suburban and rural environments of Ondo and Ekiti States in the Southwestern region of Nigeria. Using a Sony Ericsson TEMS phone monitoring device—connected to a laptop equipped with TEMS software and base station cell reference—and a GPS device, RSS measurements were performed in each sector of the base station up to 1200 m, employing a single sector verification method. The values of path loss exponents were computed from the deduced values of path loss at 50 m intervals up to distances of 1200 m. Close to the base station, the following exponent values were observed—between 2.0 and 3.8 in the urban environment, 2.0 to 2.8 in the suburban environment while for the rural environment, 1.5 to 2.6 we're observed. After the breakpoint distance, higher path loss exponent values of up to 6 was recorded in the urban environment, exponent value of up to 4.3 was observed in the suburban environment and up to 3.5 exponent value in the rural environment. It was also observed that the rural environment presented the longest breakpoint distance of 500 m. The high path loss exponents observed, especially in the urban environment, could cause GSM operators to rethink the margins they have provided. This study is useful for the design of upcoming network systems in these regions and in similar regions.*

KEYWORDS: Breakpoint Distance, Propagation Distance, Path Loss, Path Loss Exponent.

INTRODUCTION

Communication engineers and scientists are in general concerned about how to apply radio frequency (RF) channel parameters, which comprises the area and environmental parameters. Among such parameters is path loss exponent, which specifies the rate at which a signal reduces in strength with increase in distance of separation between the receiver and transmitter. A distinctive mean path loss exponent (*n*) is allocated to each propagation environment which can only be experimentally determined. Path loss exponent would help in propagation model formulation that appropriates for certain geographical areas, determines signal strength and examines the percentage of how signals received are affected due to attenuation, thus, enhancing accurate network design in order to improve the quality of signal strength of GSM. Based on this assertion, various researches have been and are still ongoing to determine the suitable transmitting and receiving parameters, propagation models, coverage failure and the general standards that will ensure quality of service of GSM networks.

LITERATURE REVIEW

In the work of Prasad and Ratnamala, (2010), carried out an experimental investigation of macro-cellular mobile radio propagation analysis at 1.8 GHz over urban regions of Delhi, they suggested that the future generation design of mobile communication networks are critically dependent on the suitability of path loss estimation models. To investigate radio frequency channel behaviour, they conducted experimental measurements of received signal strength in the dense urban region of New Delhi, at 1.8 GHz frequency bands for six GSM base stations transmitting at power of +45 dBm and antenna height between 22 and 40 m. The values of path loss exponent and signal break point distances between 200 and 400 m were deduced and the results they observed were compared with cost-231 Hata, roof top diffraction, regression line and cost-231 Walfisch Ikegami (WI) path loss prediction models, and their standard deviation were also computed. It was observed that the regression line model presented the least deviation from the actual values followed by the roof top diffraction path loss model.

In conclusion, they explained the variations in observed results in terms of horizontal and vertical signal propagation mechanism. Following the same method, Prasad *et al.,* (2011), in their work, emphasized that wireless propagation modelling is a vital part of designing a cellular network system, and that testing different available path loss model values with path loss values generated experimentally helps in identifying an appropriate path loss model that can be employed for the design of mobile communication systems for future generations. They presented the results of RSS level measurements of eleven GSM base transmitter stations in the suburban, urban and dense-urban regions of Delhi over northern India. The estimated path loss was compared with values from Analysis of Wire Antennas and Scatterers (AWAS) electromagnetic code, Cost-231 Hata, ITU-R and Demitry Walfisch-Ikegami wireless propagation models. Based on the comparisons, mean prediction errors and standard deviations were deduced. Path loss exponents as functions of distance from the base transmitter stations were calculated. In general, high path loss exponent values of about 5 to 7 were observed at closer distances to the base stations; it fell steeply to about a value of 4 around 200 to 400 m and remained constant for the remaining distances. According to their findings, the AWAS path loss code and ITU-R model exhibited good fits with the actual path loss values when compared with the other models.

MATERIALS AND METHOD

The measurement campaign was performed at three different environments namely: urban, suburban and rural environments over two selected states in Southwestern part of Nigeria, within the rainforest zone. The urban base stations investigated consist of Maryhill and Isolo base stations in Ado-Ekiti, Ekiti State and Akure, Ondo State respectively. For the suburban environments, the base stations investigated are Oye-Ekiti base station in Ekiti State and Mobil base station in Ondo State, while in the rural environments, the base stations investigated include llupeju base station in Ekiti State and Odigbo in Ondo state. Details of the base stations and characteristics of each of the sites are shown in Table 1.

The received signal strength (RSS) of the various GSM base stations were monitored with a Sony Ericsson test phone (W995) in the net monitor mode, used generally as a drive-in tool for planning cellular networks, along with digital GPS (MAP766CSX) to determine altitude, latitude and longitude; the test phone has a sensitivity of -110 dBm. Both were plugged to a laptop equipped with investigation TEMS software and cell reference of the base stations. The receiving equipment was installed in a vehicle moving at a permissible speed. 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 transmitting power is +40 dBm for the 0.9 GHz and +44 dBm for 1.8 GHz bands. The downlink received signal strength was monitored by the measurement setup. The observed signal levels were converted into path loss values for more analysis using the method in (seasonal). Figure 1.0 and 2.0 show one of the experimental sites and the measurement setup. Intensive drive test was conducted along all identified routes in all the proposed environments. 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.

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

BS name	Cell id	Coordinate h(Lat/Long)	Elevation (m)	Antenna height (m)	Frequency (GHz)	Tx gain (dB)
Maryhil	EK2225	7.629275/5.231178	547	36	1.8	17
Isolo	OD2543	7.254400/5.197166	352	36	1.8	17
Oye-Ekiti	EK4406	7.784006/5.329048	543	34	1.8	17
Mobil	OD4747	6.751561/4.874220	87	34	1.8	17
Ilupeju	EK3471	7.810266/5.329048	632	32	0.9	14
Odigbo	OD3835	6.788646/4.874220	129	32	0.9	14

Figure 1: Photographs of One of the Investigated Base Stations

Figure 2: Measurement Instrumentation Setup

Path loss Exponent and Breakpoint Distance

Empirical measurement studies have shown that the path loss exponent—estimated from measured path loss values—changes after a certain distance (Rappaport, 2001). In this study, the values of path loss exponent were computed from the deduced values of path loss at 50 m intervals up to distances of 1200 m using:

$$Pl_m(dB) = Pl_0(dB) + 10n(\frac{d_i}{d_0}) \quad (1)$$

where Pl_m is the estimated path loss from measured RSS at different distances, Pl_0 denotes the path loss at reference distance (d_0) of 50 m, d_i is the distance in meters.

From the work of Ojo *et al.* (2014), Pl_0 can also be estimated by using:

$$Pl_0(dB) = 20\left(\frac{4\pi d_0}{\lambda}\right) \quad (2)$$

where λ is the wavelength conforming to 0.9 and 1.8 GHz for this study and *n* is the path loss exponent deduced with separation between base transmitter stations (BTS) and mobile station (MS) for every investigated sector of the locations considered.

The path loss exponent is known to be critical in establishing the coverage of any cellular network (Ojo *et al.*, 2014). It is assumed to be 2 in free space and when there are obstacles in transmitter-receiver paths, it assumes larger values. Based on Equation (1), various path loss exponents of all the sectors and for all the base stations investigated at 50 m intervals were computed. The distance of the breakpoint, depending on the Fresnel zone is expressed as (Fengyu *et al.*, 2013):

$$r_b = 4\frac{h_b h_m}{\lambda} \quad (3)$$

where h_b and h_m are respectively the base antenna height and mobile receiver height, and λ is the wavelength. The breakpoint distance r_b in equation (3) is based on the presumption that signal propagation paths are free of high obstructions (Fengyu *et al.*, 2013). In this study, the breakpoint was deduced as the distance at which the path loss exponents, as functions of separation of base station from mobile station, change (Prasad and Ratnamala, 2010).

RESULTS

The path loss exponent variations of the three sectors, for all the base stations considered in the different environments of the two States investigated at 0.9 and 1.8 GHz frequency bands, are depicted in Figures 3 to 8.

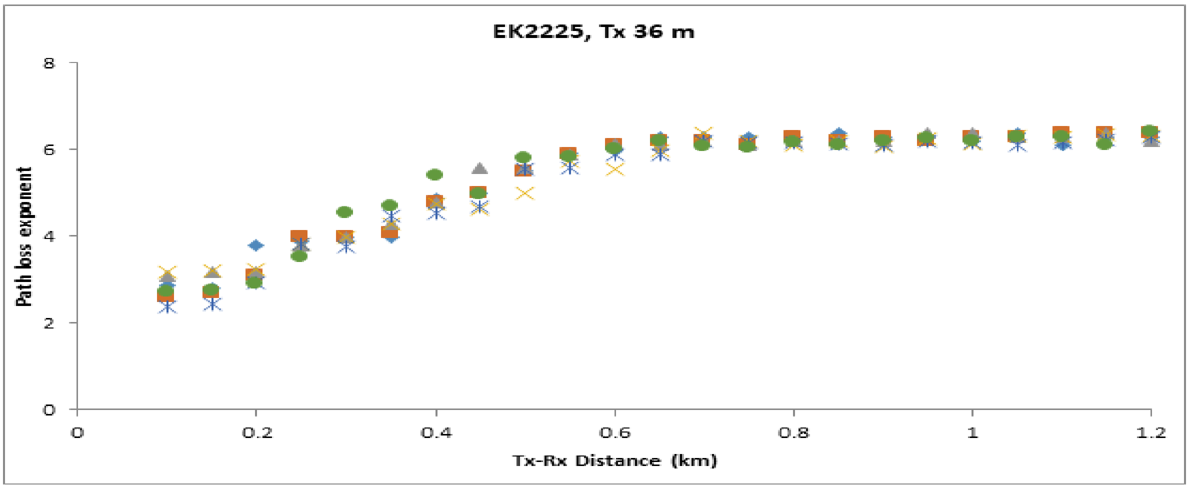

Figure 3: Path loss exponent variations with Tx-Rx separation for Maryhill base station

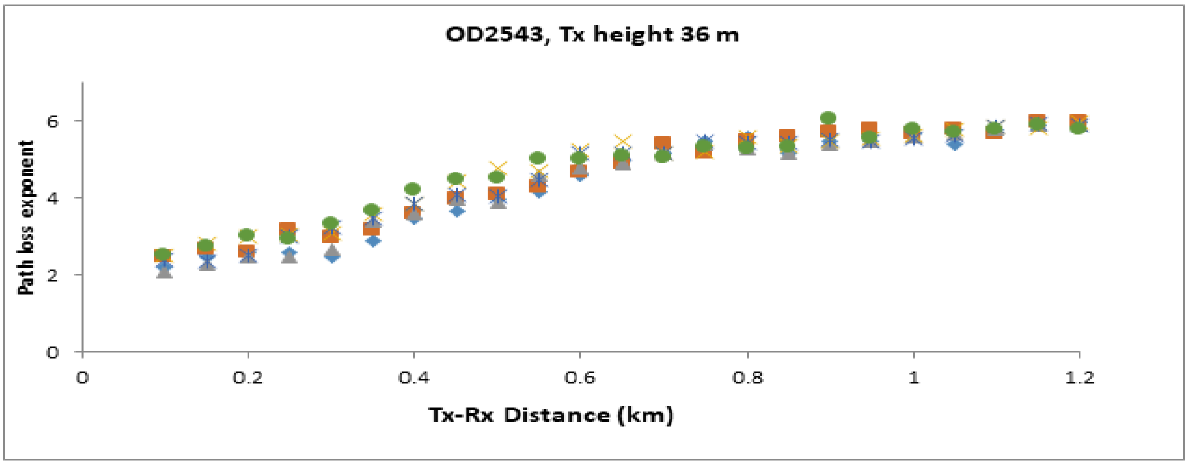

Figure 4: Path loss exponent variations with Tx-Rx separation for Isolo base transmitter

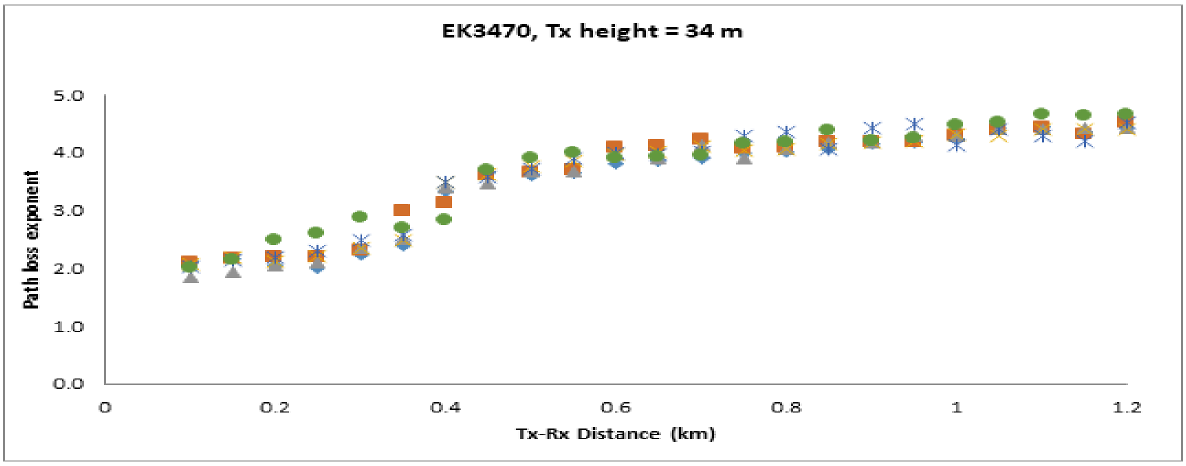

Figure 5: Path loss exponent variations with Tx-Rx separation for Oye-Ekiti base station

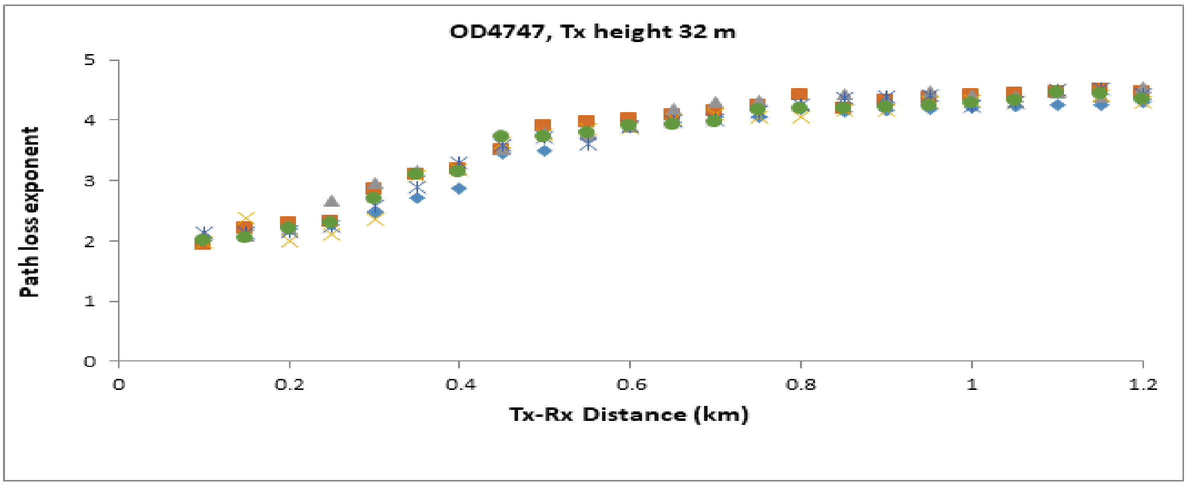

Figure 6: Path loss exponent variations with Tx-Rx separation for Mobil base station

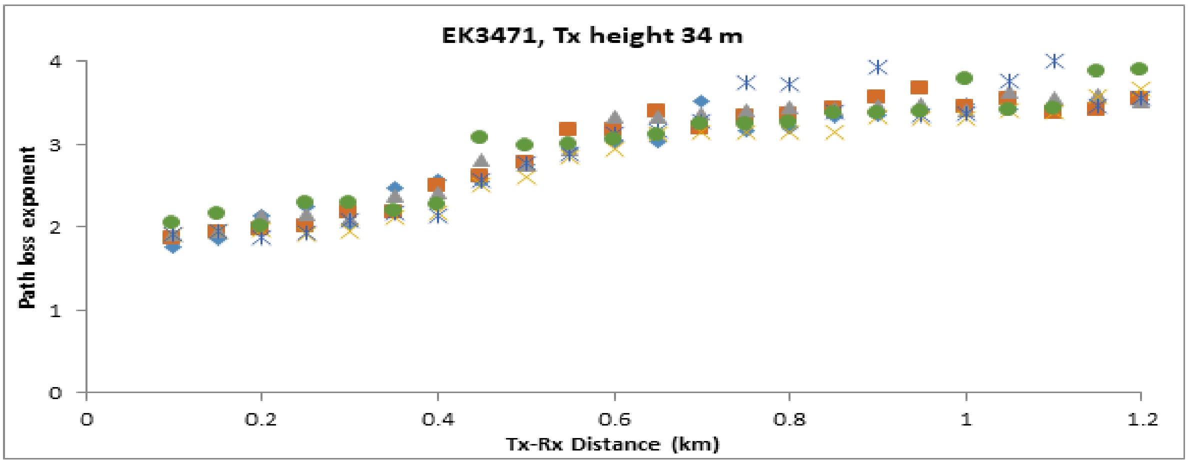

Figure 7: Path loss exponent variations with Tx-Rx separation for Ilupeju base station.

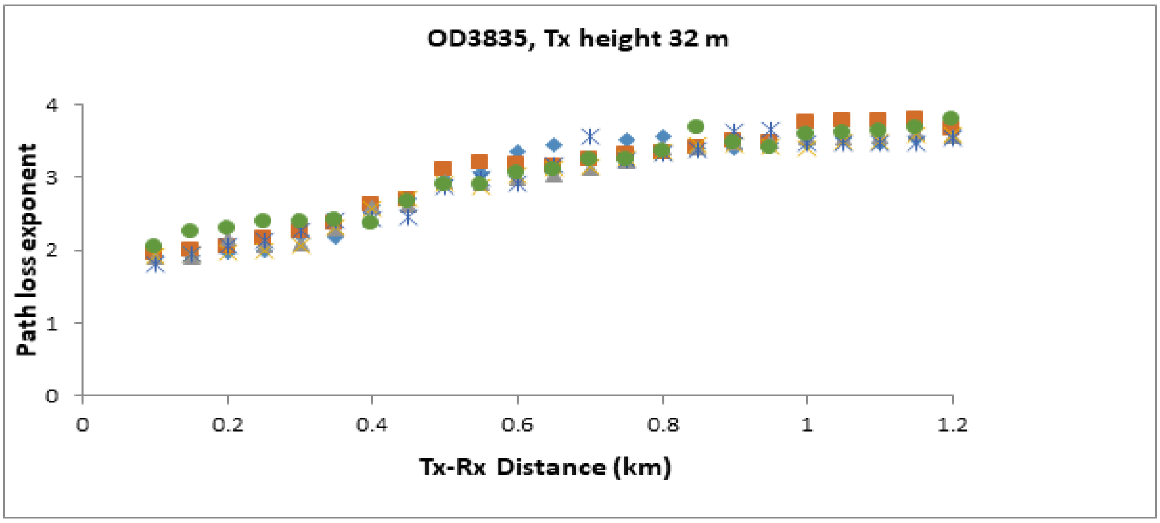

Figure 8: Path loss exponent variations with Tx-Rx separation for Odigbo base station

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Table 2: Break point of signal along propagation paths in the monitored environments

BS Name	Cell id	Environment	Breakpoint distance (m)
Maryhill	EK2225	Urban	400
Isolo	OD2543	Urban	400
Oye-Ekiti	EK4406	Suburban	400
Mobil	OD4747	Suburban	450
Ilupeju	EK3471	Rural	420
Odigbo	OD3835	Rural	500

DISCUSSION

Figure 3 is a typical average exponent values variation for a base station in Maryhill in Ekiti State. Exponent values of the order of 2.0 to 3.8 were observed for distances close to the transmitter, then the values rose steeply to an exponent value of 5.6 around a distance of about 400 m, and remained steady at 6 for the remaining distances. The path loss exponent variation at Isolo base station in Akure is presented in Figure 4; path loss exponent variation of about 1.8 to 3.0 was observed for distances close to the transmitter. This order rose from an exponent value of 3.0 to about 4.5 from a distance of 400 m and maintained a steady increase to 5.0 for the rest distances.

Figure 5 and 6 show typical path loss exponent variations for all the sectors of base stations considered in the suburban environments of the two states investigated at 1.8 GHz and 0.9 GHz frequency bands. A plot of typical path loss exponent value variation for the base transmitter of Oye-Ekiti is depicted in Figure 5. At near distances to the base station, exponent values of the order of 2.0 to 2.6 were observed, and this path exponent order rises steeply from value of 2.6 to about 3.5 at Tx-Rx separation of 400 m and becomes stable around 4.3. Figure 6 also presents the exponent value variation for the base station in Mobil in Ondo state. The result shows that path loss exponent rises from 1.8 to about 2.8 at closer distances to the base station and stabilizes around exponent value of 4.0, from a separation of 450 m from the base transmitter.

Figures 7 and 8 show typical path loss exponent variation for three sectors of base stations investigated in the rural environments of the two states, at 0.9 GHz frequency band. Figure 7 is a typical path loss exponent variation with propagation distance for Ilupeju base station in Ekiti state. At distances close to the transmitter, path loss exponent value of about 2.0 was observed; the exponent rises steeply to a value of about 3.3 at a distance of 450 m and maintains a value of around 3.0 to 4.0 for the rest of the separation distance. The changes of path loss exponent with propagation distance for Odigbo base station is shown in Figure 8. For this base station, path loss exponent values between 1.5 and 2.6 at closer distances to the transmitter were observed. At a distance of 500 m, the exponent value stabilizes at around 2.8 to 3.5. The observed break point distances for all the three environments were between 400 m and 500 m. Prasad and Ratnamala (2010) had observed similar break point distances in the urban and suburban areas of New Delhi, India at 1.8 GHz frequency band. The summary of the results are presented in Table 2.

CONCLUSION

In the macro-cellular urban, suburban, and rural environments of Ekiti and Ondo States of Nigeria, narrowband RSS measurements were carried out using the 1.8 and 0.9 GHz GSM bands, in the three sectors of the six base stations considered. Path loss exponents with distance of propagation were computed, with distances closer to the transmitter having lower exponent values until the breakpoint distance where higher values of path loss exponent values were recorded. The rural environment exhibited lower path loss exponent in all propagation distances when compared to the suburban and urban environments. This is as a result of the rural environment having signal propagation paths that are free of high obstructions and less high-rise buildings.

This study is useful for the design of upcoming network systems in these regions and in similar regions.

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