International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 2– No.7, May 2012 – www.ijais.org

Comparison of Propagation Models for GSM 1800 and WCDMA Systems in Selected Urban Areas of Nigeria

N.T. Surajudeen Bakinde, N. Faruk, A. A. Ayeni, M. Y. Muhammad, M.I Gumel
[1]Department of Electrical and Electronics Engineering, University of Ilorin, Ilorin, Nigeria
[2,3,4]Department of Telecommunication Science, University of Ilorin, Ilorin, Nigeria
[5]Huawei Technologies & Co. Ltd, Kano, Nigeria

ABSTRACT

A comparative analysis of radio propagation models for wideband code division multiple access (WCDMA) and global system for mobile communications (GSM) is carried out in this work using a drive test data collected from Kano City coordinates (11°30′N 8°30′E11.5°N 8.5°E) and Abuja City coordinates (9°4′0″N 7°29′0″E) in Nigeria, which are all urban areas. The COST 231 has been used in a previous work by this research group and concluded that COST 231 is more suitable for use in the GSM 1800 band for Kano environment. This further research includes the newer and more advanced technology as the deployment is increasing on daily basis worldwide. In all of the measurements taken, path loss was found to vary directly with frequency. It is found that COST 231 and Hata give fairer results for Kano and Abuja environment from our study. It was further noticed that, the suitability in terms of predicting signal level swings between Hata and COST 231 for varying sites and frequency. For both cities, the values of root mean square error (RMSE) and square of correlation value (R^2) was found to be optimum for GSM 1800 and very high for WCDMA. This means, no generic model is suitable for use, as each model differ in their applicability over different sites and frequency. For effective signal prediction and coverage performance, Hata or COST 231 model need to be modified to suit the environment and the technology.

Keywords

Radio Propagation, GSM, Path loss, Multipath effect, WCDMA

1. INTRODUCTION

While second generation (2G) systems are widely deployed across the globe, in the developing countries third generation (3G) network coverage is still limited. Wideband code division multiple access (W-CDMA) has emerged as the mainstream air interface solution for the third-generation networks. In Europe, Japan, Korea, and the United States, WCDMA systems are currently being standardized. The standards bodies include: European Telecommunications Standards Institute (ETSI) in Europe, Association of Radio industries and Business (ARIB) in Japan, Telecommunications Industry Association (TIA) and T1P1 in the U.S.A. and Telecommunications Technology Association (TTA) in South Korea. The fast development during recent years has been due to the Japanese initiative. In the beginning of 1997, ARIB decided to proceed with detailed standardization of WCDMA. The technology push from Japan accelerated standardization in Europe and the United States. During 1997, joint parameters for Japanese and European wideband CDMA proposals were agreed upon. The air interface is now commonly referred to as WCDMA. In January 1998, strong support behind WCDMA led universal mobile telecommunications service (UMTS) to choose it as their interface for frequency-division duplex (FDD) frequency bands in ETSI. The selection of wideband CDMA was also backed by Asian and American GSM operators [1].

The performance of any wireless communication systems depends on the propagation characteristics of the channel. Channel characteristics have an impact on the design of the transmission strategy. Received signal prediction models play an important role in the RF coverage optimization and efficient use of the available resources. These models can differ in their properties with locations due to different terrain environment. Therefore, extensive study on the effects of radio propagation path-loss had drawn a considerable attention.

Ekpeyong *et. al.* [2] studied comparatively three propagation models, COST 231, ECC 33 and the Lee path loss model for UMTS based cellular systems, with the goal of reporting through computer simulation, the most reliable one, suitable for efficient coverage planning. Faihan & Adel in [3] presented a received signal level prediction model based on the measurement taken in Riyadh urban area. In their work, long-distance propagation model was used to estimate path loss parameters from the measured data. Zia, in [4] also presented seasonal pathloss modeling at 900 MHz for Oman city, where Hata model was adopted and modified. The modified Hata equation gave a better performance with MSE of less than 6 dB. Similar work was carried out by Vishal *et al* in [5] whereby they modified Hata model for Mehuwala, Dehradun. Before modifying a model, there is need to provide a comparative assessment of the models.

Data collected from drive tests conducted in Kano State and the Federal capital territory (FCT), Abuja city, Nigeria for both the GSM and WCDMA are used to compare the most widely used propagation models for the purpose of comparison and finding the most suitable model for the two technologies that will assist Engineers in carrying out effective planning for improved service. This work is different from the aforementioned research work because data collected from drive tests are in comparing the chosen propagation models. The paper is organized as follow; Section 1 present related work; Section 2 gives recent trends of WCDMA in Nigeria; Section 3 provides review of the path-loss models used; Section 4 gives details on the drive tests and the simulations. Analysis of the results obtained is in Section 5 and conclusion from the work is in Section 6.

2. WCDMA IN NIGERIA

The first African use of 3G technology was a 3G video call made in Johannesburg on the Vodacom network in November

2004. The first commercial launch was by Emtel-ltd in Mauritius in 2004. In late March 2006, a 3G service was provided by the new company Wana in Morocco. In May 2007, Safaricom launched 3G services in Kenya while later that year by Vodacom Tanzania also started providing services. In Egypt, Mobinil launched the service in 2008 and in Somaliland. Telesom started first 3G services on 3 July 2011, to both prepaid and postpaid subscription customers. Telecommunication networks in Nigeria like Globacom, Airtel and MTN provide the 3G services to their numerous customers [6]. The coverage is still limited.

Long term evolution (LTE), the next-generation Mobile Broadband technology, has now reached one million connections only a year and a half after the first commercial network launches and 300 million expected by 2015. The rate of WCDMA HSPA adoption in its first six years is ten times greater than the take up of GSM mobile phones when they were first introduced in the mid-1990s. There are now more than 19 million HSPA connections being added each month and it is predicted that the industry will reach one billion HSPA connections by the end of 2012 [7].

3. PATH-LOSS MODELS

The most important aspect of any radio propagation is how field strength varies as a function of distance and location. This property is usually captured in the concept of path loss. Pathloss tends to increase linearly with the logarithm of the carrier frequency [8]. This is also known as large scale fading, which account for the attenuation of the signal level. Other forms of fading are; the small scale fading which causes signal distortion, dissipation and are, relatively insensitive to the carrier frequency, but effects can depend on the service bandwidth. Multipath could arise from diffraction, scattering and reflection of related objects such as building and cars in the physical environments.

The existing path-loss models can be classified into: theoretical and empirical models. Theoretical models predict transmission losses by mathematical analysis of the path geometry of the terrain between the transmitter and the receiver and the refractivity of the troposphere [9]. Empirical models on the other hand add environmental-dependent loss variables to the free-space loss to computes the net path loss in the corresponding environment. This method requires that measurements be made and so considered more accurate in view of its environmental compatibility.

Path-loss models are needed for effective wireless design. These models help via simulation to predict signal level and coverage. Path-loss along with the transmitter power and the gain at each end of the radio path, the analyst/designer can determine how much power is received from particular transmitter. In this work, we consider only the empirical models which use measurement data to model a path loss equation. The aim of the work is to make a comparative analysis of existing propagation models for use in GSM and WCDMA Wireless Communication Systems in two selected Urban Area of Nigeria.

3.1 Free Space Loss

By free space is meant a clear and unobstructed line-of-sight transmitter-receiver (T-R) terrain. The free space propagation model predicts that received power decays as a function of the distance, between the transmitter and the receiver, raised to some power [9].

The generic free space path loss (FSPL) in dB can be obtained from equation (1).

$$P_L(dB) = 32.44 + 20\log(f_c) + 20\log(d) \text{..........(1)}$$

Where, P_L (dB) is the FSPL in dB, f_c is the carrier frequency in MHz and d is the T-R distance in km.

3.2 Hata Model

Hata model is the best known path loss model [10] and its empirical parameters for the cellular environment with base stations height above roof top (i.e. macro cells) is given by Hata and is based on measurement in Japan. Hata used the information from the field strength curve produced by Okumura and produced a set equation for path loss. Hata model is valid in the frequency range of 150 MHz to 1500 MHz at the distance of 1-20 km. Hata pathloss can be determined by using expression 2

$$\begin{aligned} L_{50} &= 69.55 + 26.16\log f_c - 13.82\log h_t \\ &- a(h_r) + (44.9 - 6.55\log h_t)\log d \text{............(2)} \end{aligned}$$

And

$$a(h_r) = 3.2*(\log(11.75*h_r)^{\wedge 2} - 4.97$$

For large city, $f_c \geq 300MHz$

3.3 The Cost 231 Model

The European Co-operative for Scientific and Technical Research formed the COST 231 committee to develop an extended version of the Hata model such that applicability to 2 GHz is possible. Path loss in this model is computed as given in expression 3.

$$\begin{aligned} L_{50}(urban) &= 46.3 + 33.9\log f_c - 13.82\log h_t \\ &- a(h_r) + (44.9 - 6.55\log h_t)\log d + C_m \text{.....(3)} \end{aligned}$$

$C_m = 0dB$ for medium sized city and suburban areas and $3dB$ for metropolitan centers.

3.4 The Lee Model

LEE model has also been widely used in the prediction of path loss in macro-cell applications, particularly for systems operating near 900 MHz and for ranges greater than 1.6 km [11]. LEE model is also used to predict area-to-path loss. The model specifies distinct parameters for varying region types. LEE path loss model is given by equation 4.

$$\begin{aligned} &LEE(dB) = Lo + 10*\gamma*\log(d) + \\ &10*n*\log(f) + L1 + L2 \text{............................(4)} \end{aligned}$$

And;

$$L1 = -20*\log(h_t)$$

$$L2 = -10*\log(h_r)$$

Where n and γ are given by measurements. n takes a value, 2 for suburban/open areas and 3 for urban areas, while the values of γ varies depending on the geographical area. In this work, 3.0, 3.84 and 49.5 were used for n, γ and Lo respectively.

4. SIMULATIONS AND DRIVE TESTS

4.1 Simulation Procedure

Visual basic codes were generated to simulate the pathloss equations for both WCDMA and GSM systems. In both case, an average antenna height of 30 m was used and receivers height 1.5 m for both cities. Table 1 show the parameters used in the simulations. The program was designed, in a single run, to generate and store data for pathloss and received signal level in iterations of the frequency and distance for all the models. For the WCDMA, a fixed frequency of 2112.40 MHz was used since WCDMA system is code based planning, while, for every simulation, different frequency of the BTS was used in the simulation for GSM. Thereafter, the results are exported into excel sheet for comparative analysis with the drive test results.

Table 1. Simulation Parameters

Quantity	**WCDMA**	**GSM**		
Area Type	High density Urban			
Node Type	***NodeB***	***BTS1***	***BTS2***	***BTS3***
Frequency (MHz)	2112.40	1835.2	1836	1837.2
Antenna Height (m)	30			
Mobile Station height (m)	1.5			
Transmitter's Power (W)	430	80		
Transmitter's power (dBm)	56.33	49.03		
Cable Loss (dB)	1.65	1.65		
Antenna gain (dB)	18	18		
EIRP (dBm)	72.68	65.38		

4.2 Drive Test

A drive test was conducted in two urban cities, in Nigeria. Kano State, with coordinates (11°30′N 8°30′E11.5°N 8.5°E) and Abuja city coordinates (9°4′0″N 7°29′0″E). Kano State is located at the north west of the country with average building height of 10m. Its metropolitan population is the second largest in Nigeria after Lagos State. The Kano Urban area covers 137 sq. km with a population of 2,163,225 at the 2006 Nigerian census. The Metropolitan Area covers 499 sq. km. Abuja is the capital city of Nigeria. It is located in the centre of Nigeria, within the Federal Capital Territory (FCT). According to 2006 population censors data, Abuja had a population of 776,298 [12] with a population density of 1,100/ km^2 making it one of the top ten most populous cities in Nigeria. Using specially configured dual band handset, GPS and Probe Dongle all coupled to a laptop placed in a vehicle which was driven around through a predefined route. All the drive tests were conducted inside the metropolis. The routes covered in Kano city were: Hotoro-NNDC Quarters, Hotoro-Kaduna-Zaria highway along the eastern bypass road and Bayero University, Kano. While, the routes covered in Abuja city were: Federal housing estate, Labor House, Gwarimpa housing estate and Airport Road. (*see* figures 1a and 1b). While driving was going on, the handset was configured to automatically make calls to a fixed destination number. Each call lasted for 30 seconds hold time and the call was dropped. The phone remained idle for some period of time then another call was made.

Measurements were made and graphs plotted, of received signal strengths, against frequency on one hand and distance of travel, between mobile station and base station, on the other. The process was repeated for Path loss against frequency on one hand and distance on the other. Finally, plots of received signal strength against MS-BTS distance was made on a single graph, with the measured values, in the drive test, imposed.

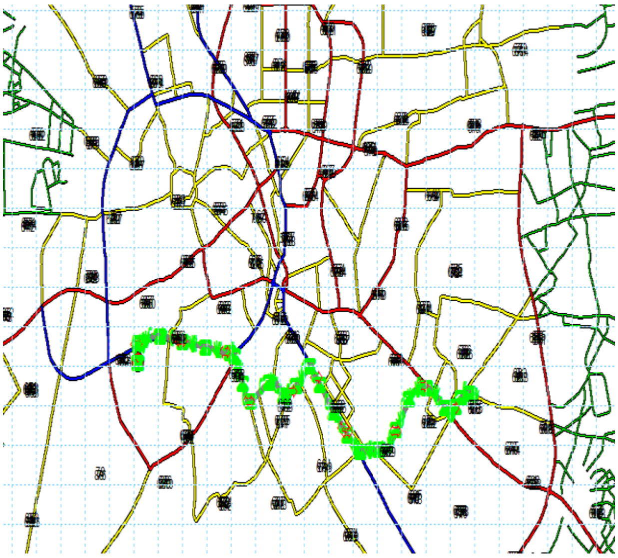

Fig. 1a

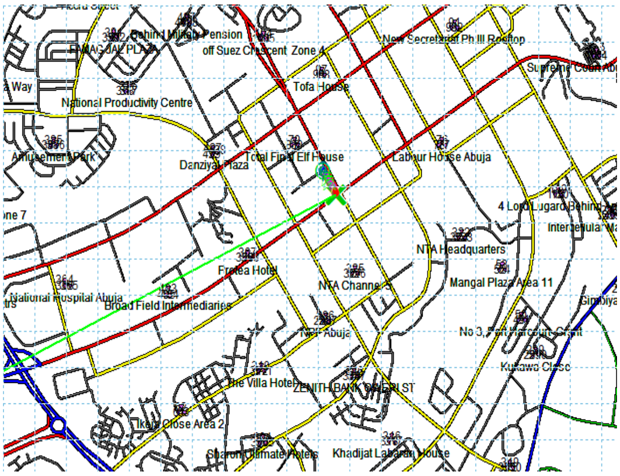

Fig 1b

Fig1: Screenshot showing the routes of the driving test

5. RESULTS AND ANALYSIS

Understandably, severe fading was noticed (figures 2 and 3) on all measurements in this exercise. This can be accounted by a variety of factors earlier enumerated.

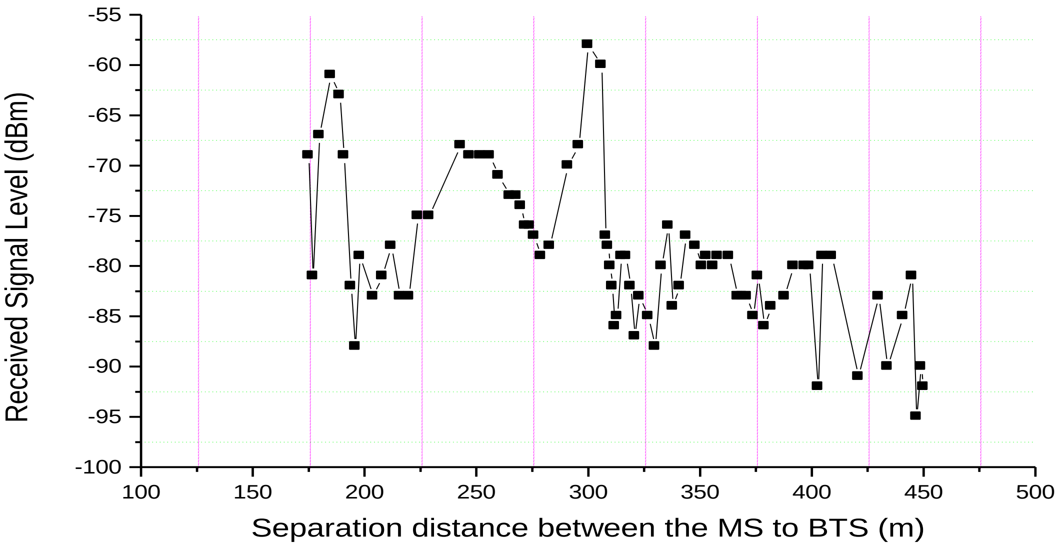

Fig 2: Variation of received signal with distance at 1837.2 MHz Kano State Meausrement.

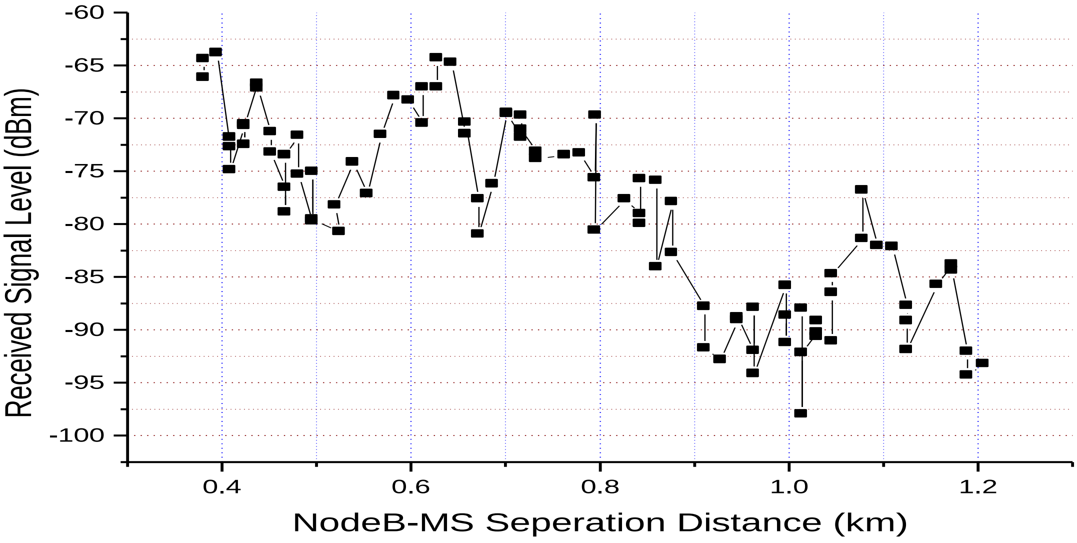

Fig 3: Received Signal level for NodeB along Airport Road Abuja City

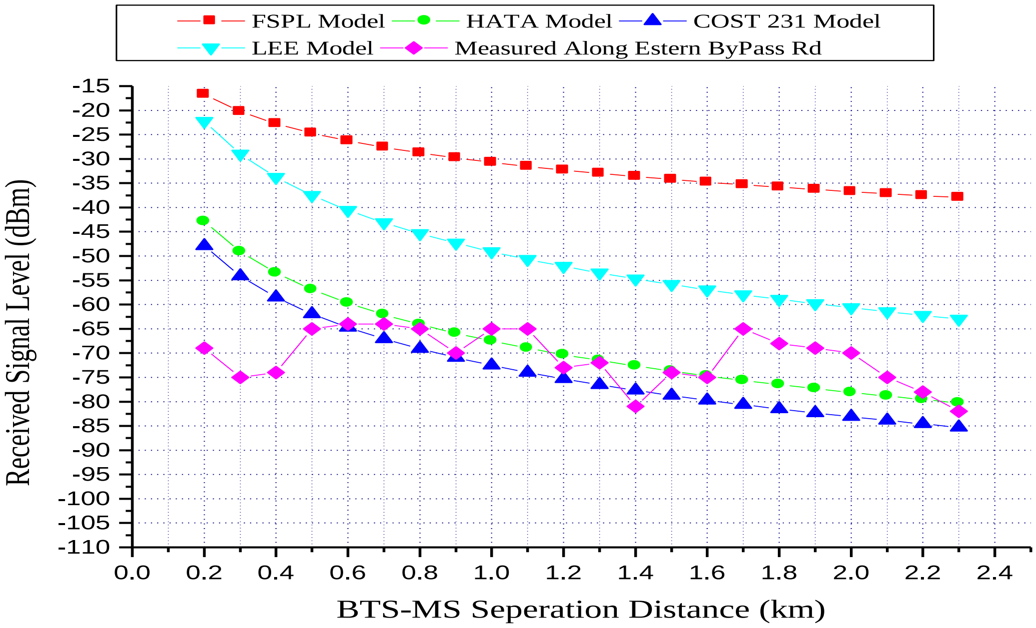

Fig 4: Received signal Level with Distance for BTS frequency 1835.2 MHZ

Figs. 2 and 3 show the variation of received signal with distance for GSM BTS in Kano state operating on 1837.2 MHz and Abuja Node B repectively. The figures show the flunctuations of the signal levels as the results of fading. As we drove from the starting point of the drive test, the receiver power changes significantly. This is because of multipath fading; meaning, transmitted signal takes multiple paths to the receiver. The received signal amplitude at the mobile changes with its position. Both dificts the same pattern as we move away from the transmitter, the received signal amplitude degrade. Same results were obtained for all the BTSs and NodeBs examined thorughout the dirve test. Except for some exceptional cases where, the signal amplitude decrease with increase in distance and later increase for short distance as a result of line of sight between the TX and RX, possibly due to valley in between or we drove high the hill and then descend.

Fig. 4 Illustrates the received signal level with distance for BTS with frequency 1835.2 MHZ measured along eastern bypass road of Kano city. For each measured point, three measured values were taken and the average was used during analysis. This is compared with the predictive signal level using the empirical models.

The average received signal level obtained are; -32.76 dBm, -69.85 dBm, -74.86 dBm, -51.49 dBm and -69.05 dBm for FSPL, Hata, COST 231, LEE and measured signal respectively. It can be seen that, Hata and COST 231 shows better agreement with the measured values. In order to examine the goodness of logarithmic fit, the root mean squared errors (RMSE) have been calculated. RMSE of 1.15 dB and 8.41 dB for Hata and COST 231 respectively was obtained; therefore, Hata model gives better prediction in this site.

Further analysis, on another BTS with operating frequency of 1836 MHz in Fig 5, shows similar trends. The maximum cell radius was 1.2 km. The deviation from the mean in this site was found to be higher than in Fig 4. The average signal over the distance of 1.2 km was found to be -28.16 dBm, -61.76 dBm, -66.77 dBm, -42.68 dBm and -72.09 dBm for FSPL, HATA, COST 231, LEE and measured signal respectively. The RMSE was found to be 11.58 dB and 7.46 dB for HATA and COST 231 model respectively. In this site, it can be concluded that COST 231 provides better signal prediction with the measured signal despite the RMSE was still above the acceptable value of 6 dB [13].

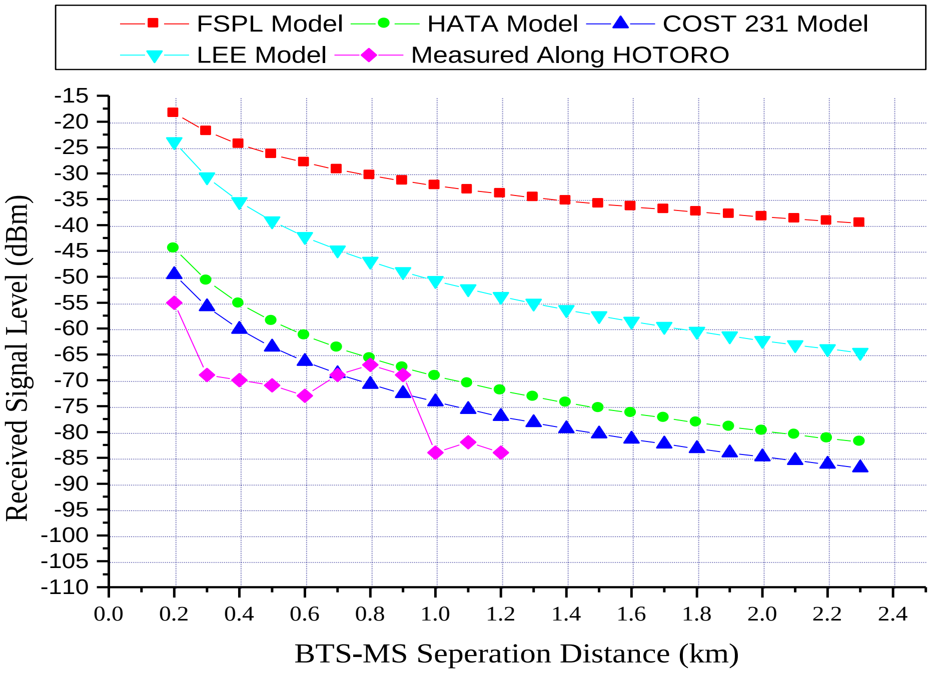

Fig 5: Received signal Level with Distance for BTS frequency 1836 MHz

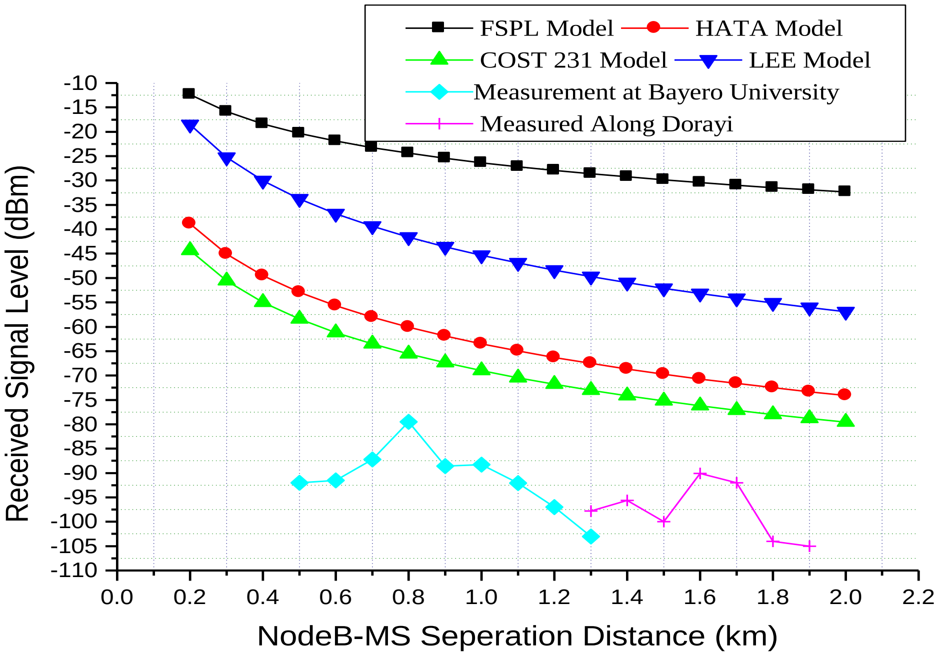

Fig 6: Received signal Level with Distance for NodeB frequency 2112.40 MHz

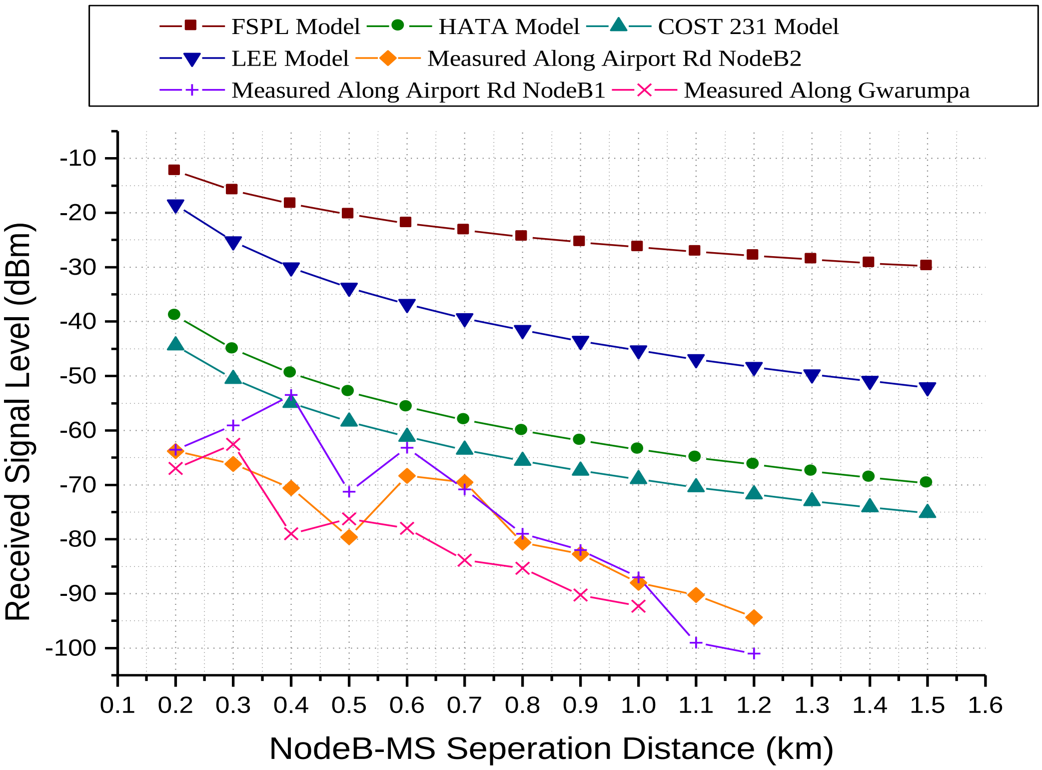

Fig 7: Received Signal level for NodeB Along Airport Road, Gwarumpa, Abuja City

In Fig 6, form the first site, measurement results were obtained at a distance from 500 m up to 1.3 km i.e (Measurements inside Bayero University, Kano), and the cell radius is about 800 m. While the second site measurements results were obtained at distance 1.3 km to 1.9 km (i.e about 600 m measured along Dorayi inside the metropolis). It can be seen for all the sites wider deviation from the predicted and the measured signal level were obtained which in turn, gives higher RSME values for all the models. Average signal level of -57.03 dBm, -62.52 dBm and -91.022 dBm were recorded for Hata, COST 231 and measured signal respectively.

In Fig 7, three sites were used with two sites along airport road, and one along Gwarimpa estate. For the analysis, airport road Node B1 was used. It was found that for all the propagation models, the RMSE was very high. COST 231 shows a better result with 16.8 dB RMSE but the acceptable range is up to 6 dB. This shows that, the propagation models need to be modified to suits our environments to provide better coverage prediction. The value of R^2 was further computed. R^2 gives a measure of square of the correlation between the measured RSSI (Received signal level) values and RSSI predicted values.

R^2 always takes values between 0 and 1. As it reaches 1, the regression points tend to align more accurately along the model curve. COST 231 give 3.3 which is still consider unacceptable value.

5. CONCLUSIONS

Severe fading was noticeable in all the measurements as depicted in figures 1-2. This is obvious considering that these measurements were taken within the city. In all of the measurements, path loss was found to vary directly with frequency. It is found that COST 231 and Hata give fairer results for Kano and Abuja environment from our study. It was further noticed that, the suitability in terms of predicting signal level swings between Hata and COST 231 for varying sites. This means no generic model is suitable for use, as each model differ in their applicability over different terrain environmental condition. For effective signal prediction and coverage performance, Hata or COST 231 model need to be modified to suit our environment.

7. REFERENCES

[1] Son H. Tran and Susan T. Dinh 1999, Wideband CDMA Radio Transmission Technology: Lecture Note of EE6390 – Introduction to Wireless Communication Systems at University of Texas at Dallas, (December 6, 1999).

[2] M. Ekpenyong, J. Isabona and E. Ekong 2010, On Propagation Path Loss Models for 3-G Based Wireless Networks: A Comparative Analysis, Georgian Electronic Scientific Journal: Computer Science and Telecommunications, No.2 Vol. 25

[3] Faihan D. Alotaibi and Adel A. Ali. 2006 TETRA Outdoor Large- Scale Received Signal Prediction Model

in Riyadh Urban Area In Proceedings of IEEE WAMICON Clearwater, Florida, USA. 1-4244-0849-0.

[4] Zia Nadir 2011. Seasonal Pathloss Modeling at 900MHz for Oman In Proceedings of the International Conference on Telecommunication Technology and Applications, Singapore.

[5] Vishal Gupta, S. C. Sharma, M.C. Bansal., 2009. "Fringe Area Path loss Correction Factor For Wireless Communication", International Journal of Recent Trends in Engineering, Vol. 1, No. 2, (May 2009), 30-32.

[6] Wikipedia: http://en.wikipedia.org/wiki/3G [Accessed on 16/01/2012]

[7] Wireless Intelligence: http://www.wirelessintelligence.com/analysis/2011/06/wcdma-hspa-connections-pass-500-million/ [Accessed on 20/01/2012]

[8] M. Hata, 1980 "Empirical formula for propagation loss in land mobile radio services",IEEE Trans. Veh. Technol., vol. VT-29, 317–325, (Aug. 1980).

[9] Adeseko Ayeni, et al., 2012, "Comparative Assessments of some selected existing Radio Propagation Models: A study of Kano City, Nigeria", European Journal of Scientific research, Euro Journals Publishing, Inc. http://www.europeanjournalofscientificresearch.com/ISSUES/EJSR_70_1_12.pdf

[10] Spectrum planning Report, 2001, "Investigation of Modified Hata Propagation Models", Spectrum Planning Team, Radio Frequency Planning Group, Australian Communication Authority, Doc SP 2/01

[11] Faihan D. Alotaibi And Adel A. Ali., 2008, "Tuning of Lee Path Loss Model Based On Recent RF Measurements In 400 MHz Conducted In Riyadh City, Saudi Arabia", The Arabian Journal For Science And Engineering, Volume 33, Number 1b, (April 2008), 145-152

[12] Explore Abuja City". Stay in Abuja dot com. http://www.stayinabuja.com/aboutfct.php?c=explore. Accessed (April 10, 2012)

[13] J. Wu and D. Yuan, 1998. Propagation Measurements and Modeling in Jinan City, IEEE International Symposium on Personal, Indoor and Mobile Radio *Communications*, Boston, MA, USA, Vol. 3, 8-11 (September 1998), 1157-1159

.