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EFFECT OF FOLIAGE ON MOBILE RADIO PROPAGATION CHARACTERISTIC IN MTN NIGERIA AND AIRTEL NIGERIA (A CASE STUDY OF MAIDUGURI METROPOLIS)

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ABSTRACT

This research investigated the effects of foliage on mobile networks. The wet season is known to be characterized by increase in foliage due to increased moisture content. Global System for Mobile Communications (GSM) signal strength measurements of two networks were taken during the dry season and repeated during the wet season at the same point. These data were then analyzed using the systematic approach of collecting and collating relevant data to determine the relationship between the signal strength loss, foliage depth and frequency. To ensure greater accuracy of results, two networks (Airtel and MTN) were considered. Furthermore, signal strength measurements were conducted in Maiduguri city and Auno rural area around Maiduguri. GSM signals were discovered to suffer greater losses during the rainy season due to increased foliage. Losses of between -4dBm and -10dBm were observed in rural and suburban areas while the losses observed in the metropolis were between -0dB and -4dBm These losses, though not significant in urban areas, were significant in the rural and

suburban areas. The result obtained for the developed Maiduguri model is observed to be within the range when compared with Wiessberger and ITU models.

KEYWORDS: BTS: Base station, EIRP: effective isotropic radiated power, CCIR: Consultative Committee on International Radio GSM: Global System of Mobile Communications.

INTRODUCTION

Since the introduction of GSM into Nigeria in early twentieth century mobile telecommunications industry has grown tremendously. This growth made it possible for urban as well as rural populace to gain access to mobile phones. However, this growth came with attendant problems, some of which include poor signal reception at various points, dropped calls, and congestion. GSM service providers in Nigeria have thus been trying to evolve methods of tackling these problems. Some of these problems are not peculiar to any specific region whereas others are. For instance, the vegetation cover in an area could pose specific problems to the operators and thus solutions peculiar to these environments need to be sought. Nigeria as a country has a varied vegetation which ranges from thick vegetation in the South to the savannah grassland in the middle belt to the semi- desert or Sahel savannah regions of the extreme North. The extreme north region of Nigeria experiences between 4 to 6 months (between April and October) of rain every year. The increased in earth moisture content during this period gives rise to ground conductivity and foliage. This condition will affect GSM signal strength. For GSM operators to ensure continuous quality service delivery, the relationship or effects of ground conductivity and foliage on signal strength needs to be understood particularly in the specific region where such networks are deployed.[1] Carried out measurements and analysis for signal attenuation through Date Palm trees in North Abu Dhabi, United Arab Emirates. This region is an arid/semi desert region. The results obtained showed significant additional losses of up to 20 dB due to foliage, these measurements were however taken at a frequency of 2.1 GHz which is much higher than the frequency used by mobile networks in Nigeria. A research on effect of foliage in a small forestry area in Akure, field strength meter type UNAOHM Model EP742A was used and a yagi array receiving antenna covering both VHF and UHF frequency bands was used for the measurement,[2,3] carried out campaign in two forested channels in Calabar city of Nigeria, statistical data of signal strength outside and inside the channel at different depth to determine foliage loss was obtained, instrument used is digital community access cable

(CATV) television analyser with 24 channels, the foliage loss in the two channel were found to be 3.24mdB and 2.23mdB respectively. A study found an average excess path loss of between 3 and 7 dB due to tree foliage for a carrier frequency of 3.676 GHz in a suburban setting outside Chicago Illinois was also observed.[4] Traffic analysis of the NITEL GSM network was carried out. To ensure network optimization, the prime concern was monitoring and forecasting the network usage by measuring, analysing and interpreting traffic data In the same vein.[5] Similarly a research conducted into the prediction of seasonal trends in cellular dropped call probability in the United States. The work which focused on the effect of atmospheric refraction concluded that the effect of foliage path loss would be greater during wet seasons.[6] Also a study investigates the effect of dry and wet earth on GSM signals, and the results indicated signal experience extra losses due to foliage within the range 3 dB to 6 dB at 1800 MHz and about 1 dB to 3 dB extra loss at 900 MHz Measurements were made by using Sony Ericsson phone K600i at 1800 MHz, and T610 at 900 MHz, though the research was conducted in Turkey within a forested area, main losses and effect observed was foliage losses. The intensity of these losses during the dry and wet seasons was compared and was found to be greater during the wet season.[7] Also a study examine the effect of dry and wet earth on GSM Signals, the results indicate signal experience extra losses due to foliage within the range 3 dB to 6 dB at 1800 MHz and about 1 dB to 3 dB extra loss at 900 MHz Measurements were made by using Sony Ericsson phone K600i at 1800 MHz, and T610 at 900 MHz. The research was conducted in Turkey within a forested area, main losses and effect observed was foliage losses. The intensity of these losses during the dry and wet seasons was compared and was found to be greater during the wet season.[8] Similarly,[9] in his work, concentrated on the network features and their effects on radio quality, his emphasis was on how to manipulate these features to improve network quality. It is therefore valuable to verify a particular model’s applicability to a given region based on historical use or comparison of the model prediction to measured results.

None of these studies, however, considered in great details the effect of increased foliage and depth of this foliage in relation to signal strength loss along the loss path occasioned by the rainy season on radio networks in a Sahel savannah terrain. All these works were carried out in regions whose vegetation’s are different from the sahel savannah vegetation predominant in the far North eastern region of Nigeria. Furthermore a model for Maiduguri metropolis and environment was established and difference in the propagation characteristics between urban and rural areas was investigated in this research.

Foliage Loss Models Used

Wiessberger Model

Wiessberger modified exponential decay model is given by:

$$L(dB)=\begin{cases}1.33f^{0.284}df^{0.588} & 14m\le df\le 400m\\ 0.45f^{0.284} & 0m\le df\le 14m\end{cases} \quad (1)$$

Where; *L:* Signal strength loss (dB)

Df: Depth of foliage in (m)

f: Frequency in (GHz)

The attenuation predicted by Wiessberger's model is in addition to free-space (and any other non-foliage loss). Wiessberger modified exponential decay model given in equation 1 applied when the propagation path is blocked by dense, dry, leafed trees found in temperate climate. It is important that the foliage depth be expressed in meter and that the frequency is in GHz. This model covers the frequency range from 230 MHz to 95 GHz.[10] It is applicable in situations where propagation is likely to occur through a grove of trees rather than by diffraction over the top of the trees.[10] Equation 1 reveals that foliage loss would increase as frequency and foliage depth increase.

Early ITU Vegetation Model

The early International Telecommunication Union, (ITU), foliage model was adopted by the Consultative Committee on International Radio (CCIR) in 1986 and is also known as the early ITU vegetation model. While the model has been superseded by a more recent ITU recommendation (ITU-R), it is an easily applied model that provides results that are fairly consistent With the Wiessberger model. The model is given in equation 2 below

$$L(dB) = 0.2f^{0.3}df^{0.6} \quad (2)$$

Where L; signal strength loss along the LOS path.

f; frequency in GHz

df; depth of the foliage along the Loss path in meter.

The ITU-R was developed from measurements carried out mainly at Ultra High Frequency (UHF), and was proposed for cases where either the transmitter or the receiver is near to a small grove of trees (foliage depth < 400 m). Thus a large portion of the signal propagates through the trees.[11] Equation 2 indicates that foliage Loss would increase with foliage depth and frequency. This is consistent with Wiessberger Model.

METHODOLOGY

In order to achieve the objectives of this investigation, a series of measurements of mobile radio signal strengths using Airtel and MTN base stations as reference points were carried out within Maiduguri metropolis. The method employed in this research was systematic approach of collecting and collating relevant data.[12] Thereafter, detailed analysis of the data was carried out from which valuable results were obtained. Part of the research objectives was to compare the propagation characteristics of urban, rural and suburban environments. Thus, Maiduguri metropolis and Auno rural area was chosen. Furthermore, two sets of measurements were taken; one during the dry season (Between the months of December 2015 and January 2016) and the other during the wet season (Between the months of September 2016 and October 2016).

Data Collection

The various steps taken in the course of this research were as follows:

a) Signal strength of Airtel and MTN networks at various points in Maiduguri Metropolis and environs during the dry season was measured.
b) Signal strength of same networks at same places in (a) was measured during the wet Season.
c) Evaluation, analysis and comparison of obtained data using graphs.
d) Comparison of measured results with existing prediction models on effects of wet Season on GSM signals.
e) Measurement of foliage depth at various points in Maiduguri metropolis and environs

Measuring Instrument used in taking the Readings

The equipment used for taking the measurements of the signal strength measurement is the Sagem OT290 phone. It is specialized equipment used by many telecommunications companies in Nigeria for monitoring their networks. It is capable of measuring received signal power in decibel (mill watts) (SAGEM, 2003). The equipment has the facility to indicate the particular base station whose signal strength is being measured. Hence care was taken to avoid measuring signal strengths from different base stations at the same point on different occasions.

Measurement Procedure

Before conducting signal strength measurements, the particular base station of interest is identified and a signal strength measurement is taken at the base station. Thereafter, further measurements are taken at progressive intervals and test points (TPs) of 1 km from the station up to a maximum of 5 km for rural areas. Within Maiduguri Metropolis however, further measurements were taken at a progressive interval of 200 meters. To ensure greater accuracy, measurements were taken 2 to 3 times at each test point and a mean value was recorded. The base station (BTS) antenna is a tri sector vertical dipole directional antenna mounted at 37m above the ground for the GSM 900. The transmitted power for the antenna is 42 dBm while the antenna gain (G_T) is 18.5 dB and a minimum received power level for good links is from -90dBm (Huawei Technology, 2003).

RESULTS AND DISCUSSION

Global System for Mobile Communications (GSM) signal strength measurements of two networks were taken during the rainy seasons at the base station point (200 meters apart) and these measurements were repeated during the dry season. These data were then analyzed using the systematic approach of collecting and collating data to determine the relationship between the signal strength and foliage. Table 1 and table 2 below shows results obtained from measurement conducted along Bama road Maiduguri (urban area) for wet and dry season respectively.

Table 1: Signal Strength Measurements along Bama Road Maiduguri (Wet Season).

Test point	Distance from base station(m)	Received signal strength (dB)	Foliage depth (m)	Frequency Giga Hz	Wiessberger Loss model	ITU-R loss model	Developed Maiduguri loss model
TP1	0	-54	0	0.9	0	0	0
TP2	200	-61	20	0.9	7.51	1.169	8.75
TP3	400	-62	38	0.9	10.95	1.718	12.07
TP4	600	-67	56	0.9	13.76	2.16	14.65
TP5	800	-68	72	0.9	15.95	2.52	16.62
TP6	1000	-70	97	0.9	19.01	3.02	19.28
TP7	1200	-73	118	0.9	21.33	3.39	21.27
TP8	1400	-80	141	0.9	23.69	3.77	23.25
TP9	1600	-86	165	0.9	25.98	4.15	25.15

Table 2: Signal Strength Measurements along Bama Road- (Dry Season).

Test point	Distance from base station(m)	Received signal strength (dB)	Foliage depth (m)	Frequency Giga Hz	Wiessberger Loss model	ITU-R loss model	Developed Maiduguri loss model
TP1	0	-58	0	0.9	0	0	0
TP2	200	-60	13	0.9	5.83	0.902	7.0
TP3	400	-64	33	0.9	10.10	1.57	11.2
TP4	600	-65	50	0.9	13.76	2.03	13.8
TP5	800	-70	65	0.9	15.02	2.37	15.78
TP6	1000	-70	83	0.9	17.34	2.74	17.84
TP7	1200	-73	102	0.9	19.58	3.10	19.77
TP8	1400	-74	121	0.9	21.65	3.44	21.54
TP9	1600	-87	150	0.9	24.56	3.91	23.98

The differences in signal strengths between the measurements taken during the wet and dry seasons computed in Table 1 and 2 above constitute the additional losses due to increase in foliage during the wet season.

From the table 1 and 2 above, the received signal strength (dB) at a distance of 200m from the base station shows a signal strength of -61, -62, -67, -68, -70, -73, -80 and -86 dB was observed during the wet season, while -60, -64, -65, -70, -70, -73, -74 and -87 dB was observed during the dry season. It was observed that the loss differences between TPs in terms (Wiessberger, ITU and Maiduguri) models for dry and wet season is within the range of 0 - 4 dB was noted. It shows an improvement in the signal strength during the dry season due to less foliage.

Figure 1 and 2 below shows losses experience by the signal at different foliage depth at some distance from the base station of the transmitter using Wiessberger model, ITU –R model and the developed Maiduguri model along Bama Road for wet and dry seasons. The mean signal strength difference between the two seasons was obtained; these represent additional propagation losses due to increased foliage which is the main feature that characterize the wet season. Conversely, additional losses with mean values of between 0dB and 4dB were observed in the urban centre during the wet seasons.

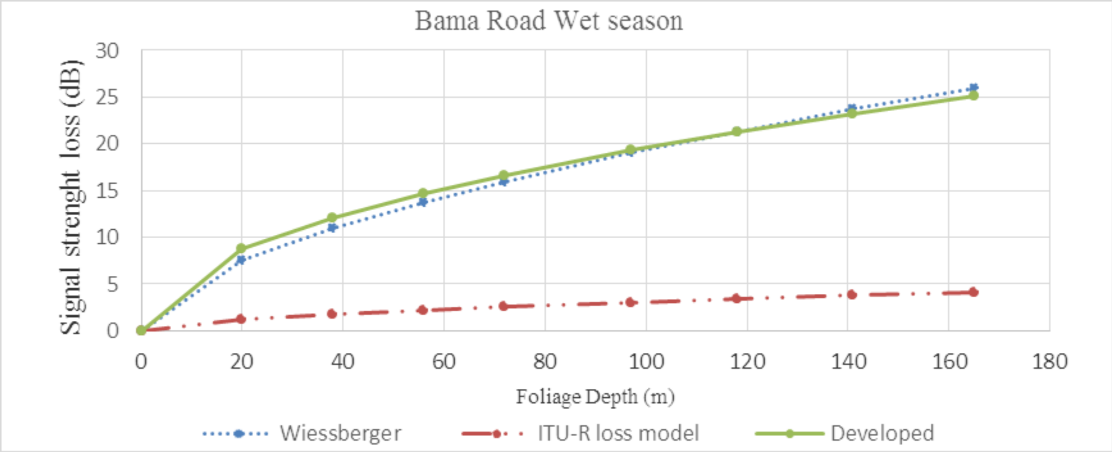

Figure 1: Shows losses experience by the signal at different foliage depth at some distance from the base station of the transmitter for wet season along Bama Road, Maiduguri.

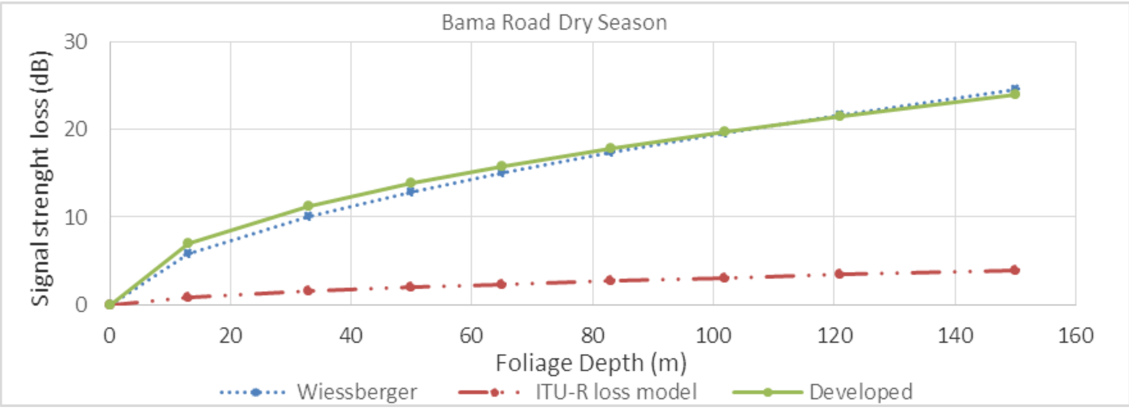

Figure 2: Shows losses experience by the signal at different foliage depth at some distance from the base station of the transmitter for dry season along Bama Road, Maiduguri.

From figure 1 and 2 above, a difference of 0.84dBm to 1.71dBm was experience between the dry and wet season, with a mean signal strength loss difference of 1.13dBm using the developed Maiduguri model. This indicates an improvement during the dry season compared to the wet season due increase in foliage depth and moisture content of the earth surface during the wet season. When the obtained results were compared with both the Wiessberger and ITU models, an agreement was seen. Both models revealed that mobile network signals suffer greater losses when there is increased foliage.

Signal strength difference between the 2 seasons in the urban centres observed and the mean signal strength difference obtained -0.89dB as captured in table 3 below.

Table 3: Signal Strength Difference from Bama Road Maiduguri (Urban Area).

Test Point	Distance from Base Station (m)	Received Signal Strength (wet) (dBm)	Received Signal Strength (dry) (dBm)	Signal Strength Difference (dBm)
TP 1	0	-54	-58	-4
TP 2	200	-61	-60	-1
TP 3	400	-62	-64	-2
TP 4	600	-67	-65	2
TP 5	800	-68	-70	2
TP 6	1000	-70	-70	0
TP 7	1200	-73	-73	0
TP 8	1400	-80	-74	-6
TP 9	1600	-86	-87	1
Mean Signal Strength Difference (dBm)	-0.89			

It was observed from the table above that during the wet season there is an additional loss in the signal strength due to increase in foliage and distance from the base station which causes the signal to be attenuated along the propagation path. The received signal strength for both wet and dry and season decrease with increase in distance from the base station, Though during the wet season the decrease is significant compared to that of dry season.

Analysis of Rural Areas

Similarly, signal strength measurements of two networks were taken from the base station point (1km apart) and these measurements were also repeated during the dry season. These data were then analyzed using the systematic approach to determine the relationship between the signal strength and foliage. Table 4 and 5 below shows results obtained from measurement conducted along Auno Village (rural area) for wet and dry season respectively.

Table 4: Signal Strength Measurements along Auno village (wet season).

Test point	Distance from base station(m)	Received signal strength (dB)	Foliage depth (m)	Frequency Giga Hz	Wiessberger Loss model	ITU-R loss model	Developed Maiduguri loss model
TP1	0	-52	0	0.9	0	0	0
TP2	1000	-69	65	0.9	15.02	2.37	15.78
TP3	2000	-93	101	0.9	19.47	3.089	19.68
TP4	3000	-98	145	0.9	24.10	3.84	23.58
TP5	4000	-92	210	0.9	29.90	4.79	28.37
TP6	5000	-102	258	0.9	33.79	5.42	31.45

Table 5: Signal Strength Measurements along Auno village (dry season).

Test point	Distance from base station(m)	Received signal strength (dB)	Foliage depth (m)	Frequency Giga Hz	Wiessberger Loss model	ITU-R loss model	Developed Maiduguri loss model
TP1	0	-52	0	0.9	0	0	0
TP2	1000	-61	30	0.9	9.53	1.49	10.72
TP3	2000	-88	75	0.9	16.34	2.58	16.95
TP4	3000	-91	131	0.9	22.68	3.61	22.41
TP5	4000	-84	186	0.9	27.88	4.46	26.70
TP6	5000	-98	198	0.9	28.92	4.62	27.56

The differences in signal strengths between the measurements taken during the wet and dry seasons computed in Table 4 and 5 above form additional losses due to increased foliage during the wet season. It was observed that at a distance of 1 km – 5km from the base station, signal strength reads -69, -93, -98, 92, and 102 dB was observed during the wet season, while -61, -88, -91, -84, and -98 dB was read during the dry season. Also observed that the loss differences between TPs in terms (Wiessberger, ITU and Maiduguri) models for dry and wet season is within the range of 4 - 10dB loss was noted. This signifies that mobile network experience greater losses in the rural areas when compared to urban centers (0-4dB loss). In addition, it shows improved signal strength during the dry season when compared to wet season due to less foliage in the rural areas as well.

Figure 3 and 4 below shows Signal Strength loss against foliage depth at Auno village experience by the signal at different foliage depth at some distance from the base station of the transmitter using Wiessberger, ITU-R and developed (Maiduguri) model (Airtel) for wet and dry seasons.

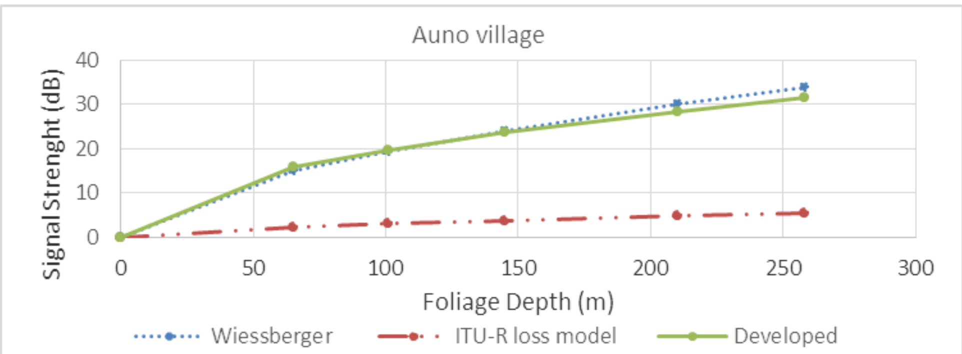

Figure 3: Signal Strength loss against foliage depth at Auno village of Wiessberger, ITU-R and developed (Maiduguri) model (Airtel) for wet season.

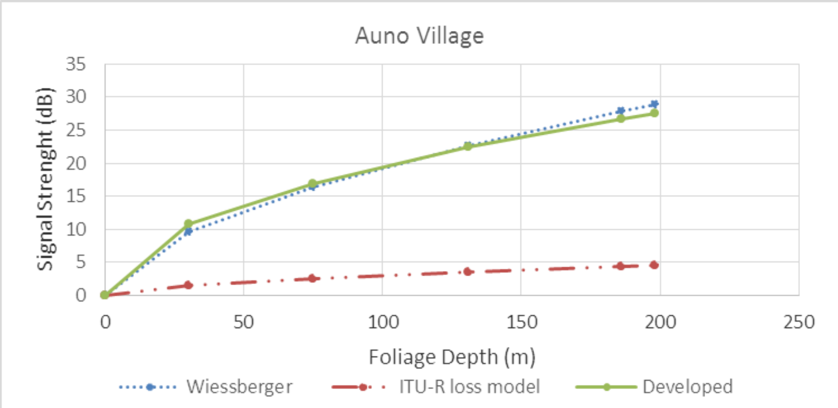

Figure 4: Signal Strength loss against foliage depth at Auno village of Wiessberger, ITU-R and developed (Maiduguri) model (Airtel) Wet season.

From figure 3 and 4 above indicate a difference of 1.17dBm to 5.08dBm was experience between the dry and wet season, with mean signal strength loss difference of 2.42dBm using the developed Maiduguri model which revealed an improvement during the dry season compared to the wet season due to increase in foliage depth and moisture content of the earth surface during the wet. When the obtained results were compared with both the Wiessberger and ITU models, an agreement was seen. Both models revealed that mobile network signals suffer greater losses when there is increased foliage.

Signal strength difference between the 2 seasons in the rural areas observed and the mean signal strength difference obtained -5.33dB was captured in table 6 below.

Table 6: Signal Strength Difference Measured from Auno Village (Rural).

Test Point	Distance from Base Station (m)	Received Signal Strength (wet) (dBm)	Received Signal Strength (dry) (dBm)	Signal Strength Difference (dBm)
TP 1	0	-52	-52	0
TP 2	1000	-69	-61	-8
TP 3	2000	-93	-88	-5
TP 4	3000	-98	-91	-7
TP 5	4000	-92	-84	-8
TP 6	5000	-102	-98	-4
Mean Signal Strength Difference (dBm)	-5.33			

The mean signal strength difference between the two seasons was obtained; these represent additional propagation losses due to increased foliage which is the main feature that characterize the wet season. Conversely, additional losses with mean values of between -4dB and -8dB were observed in the rural area.

Both models revealed that mobile network signals suffer greater losses when there is increased foliage. The results obtained indicate a losses observed in the metropolis were between 2dB and -6dBm. Though not significant in urban areas, were significant in the rural and suburban areas. From the foregoing, mobile networks experience greater losses due to increased foliage in rural/suburban areas than in urban areas.

CONCLUSION

The results obtained from this research can therefore be summarized as follows: Mobile radio networks suffer greater attenuation during the wet/rainy season due to foliage. The effect of foliage is greater in rural areas than in urban due to the presence of more foliage cover and unpaved surfaces in the rural areas. There is an inverse relationship between foliage and GSM signal strength, hence Signal degradation is a function of the foliage density. The lower the foliage density the better the signal received. Therefore, foliage has a significant effect on GSM signal strength.

REFERENCES

1. S. Mohammed, et al. “Measurements and Analysis for Signal Attenuation through Date Palm Trees at 2.1 GHz Frequency”, *Sudan Engineering Society Journal*, 2006; 52(45): 17 -22.
2. Famoriji J. & Olasoji Y. O. “Radio Frequency Propagation Mechanisms and Empirical Models for Hilly Areas”. *Canadian Journal on Electrical and Electronics Engineering,* 2013; 4(2): 65 - 70.
3. Joseph A., Donathus E. B, Daniel E. O., “Novel Effect of Vegetation (foliage) On radio Wave Propagation” *International journal of engineering research and general science,* 2015; 3: ISSN 2091- 2730.
4. Batariere, M. D. et al. “Seasonal Variations in Path Loss in 3.7 GHz Band” *IEEE Radio and Wireless Conference*, 2008; 2: 399 – 402. ISSN: 2277-3754.
5. Olagoke, O.T. “Traffic Analysis of the Six Primary Centers in the Network of NITEL North/West Zone, Kaduna, MSc Thesis. Ahmadu Bello University Zaria, Nigeria, Electrical Engineering Department, 2005.
6. Bruce, L. C. “Prediction of Seasonal Trends in Cellular Dropped Call Probability. IEEE Proceedings of the International Conf. on Electro/ information Technology, 2006; 613-618.

7. Karlsson, R. E. S., C. Berglund, and N. Lowendahl, "The Influence of Trees on Radio Channel at Frequencies of 3& 5 GHz", *IEEE VTS* 54th Vehicular Technology Conference, 2012.
8. Helhel, S et al. "Investigation of GSM Signal Variation Dry and Wet Earth Effects", A Progress Report in Electromagnetics Research, *Department of Electrical and Electronics Engineering, Akdeniz University Antalya, Turkey*. Retrieved from www.ieee.org on June 2009.
9. Abdullahi, T. S. "Network Optimization in a GSM System: A Case Study of MTN Nigeria Communications Limited. Ahmadu Bello University Zaria. Nigeria, Electrical Engineering Department, MSc Thesis, 2008.
10. Seybold, J. S. "Introduction to RF Propagation", New York: John Wiley & Sons Inc., 2005.
11. Meng, Y. S. et al. "Study of Propagation Loss Prediction in Forest Environment" School of Electrical and Electronic Engineering Nanyang Technological University Singapore. Singapore, MSc thesis Progress report, 2009.
12. Nigerian communication commission data sheet, www.ncc.gov.ng.