Review of Environment and Earth Sciences
2014 Vol.1, No.2, pp. 46-61
ISSN(e): 2313-8440
ISSN(p): 2409-2150
DOI: 10.18488/journal.80/2014.1.2/80.2.46.61

EFFECTS OF CLIMATIC CHANGE ON GSM SIGNAL IN LAGOS METROPOLITAN TERRAIN

Shoewu, O[1] --- Akinyemi, L.A[2] --- Edeko, F.O[3]

[1]*Department of Electronic and Computer Engineering, Lagos State University, Epe Campus, Epe, Lagos, Nigeria*

[2]*Department of Electronic and Computer Engineering, Lagos State University, Epe Campus, Epe, Lagos, Nigeria*

[3]*Department of Electrical and Electronics Engineering, University of Benin, Edo State, Nigeria*

ABSTRACT

The nexus of this study is to examine thoroughly the dependence of climatological parameters on GSM signal, especially in a metropolitan terrain. To validate this work, field measurements were carried out in the ITU regions of Lagos metropolitan area. The measurement system consisted of live documented radio base stations (BS) data transmitting at 13GHz, 15GHz and 23GHz in seven sites that constituted a metropolitan environment. The seven sites were segmented into non-urban (rural), suburban, urban, Ex-urban, dense-urban, micro-urban and peri-urban propagation environment. The Rain outage of the annual unavailability of the region of metropolitan data was collected using a Lenovo Laptop with installed path loss software alongside a licensed key called DONGLE. Results of this effort reveal that climate change affects signal propagation.

Keywords: Climate, Environments, Path loss, Signal, Parameters, Matlab, Season, Data rain outage.

Contribution/ Originality

This study reveals how climate change affects the signal propagation of radio waves in two different seasons. It also explores some of the areas that were not considered such as suburban, peri-urban areas by other authors. This paper primary contribution is in the determination of unavailability of rain outage from the metropolitan areas. This research study therefore shows that climate affects signal propagation depending on climatic parameters (rain and harmattan), frequency of transmission and ITU regions of propagation (which justifies the size of rain and harmattan intensity) in Nigeria.

1. INTRODUCTION

Climate is a key factor most likely to be considered during GSM transmission planning. The Climate change, however, is the state of the climate that can be identified by changes in the mean and variability of its properties. Climate change refers to a change of climate that is attributed directly or indirectly to human activities that change the composition of the global atmosphere.

One of the most important considerations during GSM transmission planning is the climatic condition of the environment. The Radio signals while propagating through the atmosphere suffer refraction. It is known that the refractive characteristics of the neutral atmosphere depend on its composition;mainly ambient temperature and water vapour [1-3]. Due to global warming,there has been a drastic change in temperature, pressure, water vapour and other atmospheric parameters making them rise beyond their normal ranges. Since water vapour is a polar molecule, the dipole moment is induced when microwave signal propagates. However, the polarity of propagation is a determinant when the water vapour reorients them. This causes a change in refractive index of the atmosphere and the refraction introduces uncertainties in the time of arrival due to excess path lenght or delay(cm) [4, 5]. The term delay refers to change in path length due to change in refractive index during the propagation of radio signals through the atmosphere duly constituted by several gases. Their combined refractive index is slightly greater than unity which gives rise to a decrease in signal velocity.This eventually increases the time for the signal to reach the receiving level(RxLev) by mobile phones.The Receiving level(RxLev) is the vector summation of plane waves originated antenna. A decrease in signal velocity however affects the annnual unavailability of the signal.

2. THEORETICAL PROPAGATION MODEL

This work introduces the basic theoretical propagation models which are initially put into consideration and are now being classified into Free space model, Smooth plane earth propagation, Cost – 231, Hata, Okumura – Hata Model, Exponential decay model, the ITU-R (maximum alternation) model.

2.1. Free Space Propagation Model Analysis

Free space transmission is the primary consideration in all the wireless communication systems. In propagation model, Free space begins when a wave is not reflected or absorbed through the normal propagation. It connotes that equal radiation of signals in all directions from the radiating source and propagates to an infinite distance with no reduction of signal strength. Hence, free space attenuation, in other words, every communication system takes into consideration free space loss. The path loss increases as the frequency of propagation increases. For a particular unit of distance, this happens in the sense that higher frequencies definitely have smaller wavelengths in order to cover a specific distance [6].

2.2. Analysis of the Free Space Model

Consider the Figure 1 below in which the radiated power at some distances from a transmitting antenna is inversely proportional to the square of the distance from the transmitting antenna is inversely proportional to the square of the distance from the transmitting antenna distance from the transmitting antenna

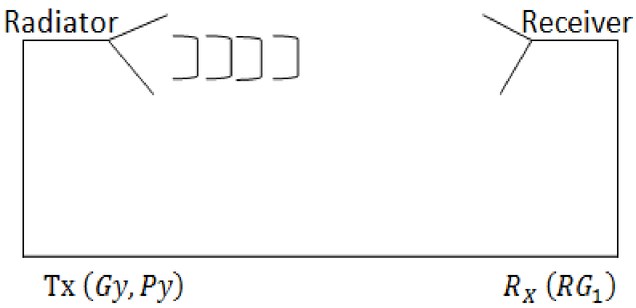


Figure-1. Free Space Model Diagram

Therefore, the power density at the receiver in watt/m² is given as

$$power\ density = \frac{Transmitter}{Surface\ Area} \quad (1)$$

Where the surface area is tangent to the measurement point with the antenna at the centre. Mathematically, it can be expressed as

$$S_R = S_T \frac{1}{4\pi d^2} \quad (2)$$

Then, the effective power density =Power density * gain

$$S_{RE} = \frac{S_T G_T}{4\pi d^2} \quad (3)$$

The antenna gain

$$G_T = \frac{4\pi A_T \eta_T}{\lambda^2} \quad (4)$$

Where A_T is transmitting antenna Area and η_T is the antenna efficiency.

The receiver would also be of the same type as the transmitter so that the receiver's Area A_R and the receiver's efficiency η_R diminished the receiver's power by the power factor $A_R \eta_R$

$$S_R = S_T G_T A_R \eta_R \frac{1}{4\pi d^2} \quad (5)$$

Noting that the receiver gain is also given as

$$G_R \lambda^2 \frac{1}{4\pi} = A_R \eta_R \quad (6)$$

Substituting equation (5) into equation (6)

$$S_R = \frac{S_R G_T G_R}{\left(\frac{4^2 \pi^2 d^2}{\lambda^2}\right)} \quad (7)$$

Equation (7) can equally be expressed in decibel (dB) as follows [7]

$$10\log_{10} S_R = 10\log_{10} S_T + 10\log_{10} G_T + 10\log_{10} G_R - 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (8)$$

Radiator

Equation (8) is called Transmitter- Receiver Formula.

Therefore, in an isotropic medium, antenna transmits signals evenly and equally in all directions. Hence, for basic transmission free space path loss denoted as L, is defined as the reciprocal of equation (10) which is the ratio of transmitted power to the received power usually expressed in decibel. For transmission between isotropic antennas, the gain of the receiver and transmitter assumes the value of unity (1) [6-8].

$$L = (S_T/S_R) = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (9)$$

Expressing equation (9) in decibel (dB)

$$\mathrm{L(dB)} = S_T - S_R = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (10)$$

2.3. The Investigated Environment

This investigation was carried out by sampling the three ITU regions in Nigeria at different climatic seasons of rain (May- June) and harmattan (November - March).The Test was carried out within the three sites in the different regions [6, 9, 10].

Figure-1. Map of Nigeria/Rain zone in reference to ITU-R P.837-1

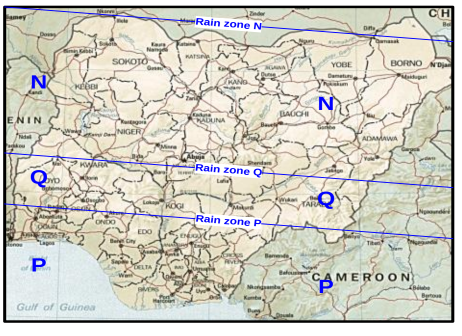


Figure-2. The N-Region

Figure-3. The P- Region

Figure-4. The Q- Region

2.4. Measurement Procedure

The measurement system consisted of live documented radio base stations (BS) in the data base sytem of the computer system with installed PATHLOSS software transmitting at 13GHz, 15GHz and 23GHz respectively. Rain outage of the annual unavailability and specific attenuation of the region were collected from the PATHLOSS software [10].A licensed key called DONGLE was used in activating it. The system was connected to the internet in order to get the Google earth data and the regions. The Data from the field measurement were then compared with those of the ITU models.

2.5. The Ionosphere Propagation and Atmospheric Index Model

Ionosphere is the product of solar and cosmic radiation acting on the atmosphere to dissociate free electrons. Basically, the cosmic radiation combining with solar in order to dissociate free electron is what is called ionosphere propagation.

There is absorption at the lower useful range and there is a maximum usable frequency above which ionosphere is largely transparent and is influenced only propagation by the phenomenon known as Faraday rotation. The ionosphere is the upper region of the atmosphere. The free electrons density dissociated is reproduced by Ne and the amount of electrons it can dissociate is represented by N [3, 4].

Therefore, the resulting free electron density is the range 10^{9}- 10^{12} electrons/m^3. There are three (3) destructive layers of atmosphere. The D-layer is prominent in the day time and varnishes at night. It is characterized by high electron collision frequency and absorption is high in D-layer. The other layers are called E and F layers and these two layers are very important for communication system between 3-40 MHz. During the day, the F-layer splits into two F_1 and F_2. Electrons are 1,800 times higher than all other ionized particle in the ionosphere. So, the motion of electrons determines the dielectric properties of the ionosphere under the action of electromagnetic fields.

Therefore plasma radian frequency for electrons in ionosphere environment for electrons is given as

$$W_p = \sqrt{\frac{N_e e_e^2}{\varepsilon_0 M_e}} \quad (11)$$

Where plasma frequency of ionosphere environs

$$W_c = 2\pi f_c \quad (12)$$

Cyclotron frequency of ionosphere atmosphere environs

$$f_c = \frac{e_c}{M_e}\frac{B_0}{2\pi} \quad (13)$$

Where $\left(\frac{e_c}{M_e}\right)$ = Electron charge to mass ratio typically has a value of 1.76×10^{11} C/Kg

The effective dielectric constant of plasma having a collision frequency of V is given and the critical frequency is given as

$$V = 1 - \frac{\left(\frac{W_p^2}{W_c}\right)}{1-\frac{5W+W_c}{W}} \quad (14)$$

(1) Ionosphere Reflection

For horizontal polarization

$$\eta_v = \frac{\cos\varphi-\sqrt{\varepsilon d-sin^2\varphi}}{\cos\varphi+\sqrt{\varepsilon d-sin^2\varphi}} \quad (15)$$

For the vertical polarization

$$n_v = \frac{\varepsilon d \cos\varphi - \sqrt{\varepsilon d - \sin^2\varphi}}{\varepsilon d \cos\varphi + \sqrt{\varepsilon d - \sin^2\varphi}} \quad (16)$$

The refraction index is given as

$$n = \sqrt{\varepsilon d} = \sqrt{1 - \frac{N_e e_e^2}{\varepsilon_0 M_e W^2}} \quad (17)$$

$$n = \sqrt{1 - \frac{81 N_e}{f^2}} = \sin \emptyset i = \quad f_c = \sqrt{81\, N_{max}} \quad (18)$$

Where i = incident angle

Hence, the maximum usage frequency is given as

$$f_c \sec\theta i = MUF \quad (19)$$

In other words, N_{max} is the value that makes n equal to zero i.e. n = 0

2.6. Atmosphere Reflection Model for Radio Wave Propagation Signals

Elementarily, atmosphere comprises a number of gases vapour, water and water molecules which are tightly depended on the rural and local geographical properties of the study area which can be time, day or climatic weather condition i.e Raining season, Harmattan, dry or wet season. Relatively, the biological vegetation such as trees, buildings also contributes to the effect of radio signals when transmitting the signal from one point to another which increases the density of the atmosphere. The factor may sum up to make the atmospheric pressure and density to be thicker and bust resulting affects the communication systems signal propagation. Hence, in order to have full understanding of path loss propagation in the GSM environment, the analysis of atmospheric refraction must be well understood [2, 5].

For a normal condition, the atmospheric parameters such as density, pressure and so on vary with the height giving rise to the propagation of velocity differential between the upper and the bottom of the wave front. Considering the upper velocity to U_P and the bottom velocity to be U_B, the mathematical model for the velocity is partially given as [11]

$$\frac{\partial U}{\partial t} = \frac{\partial U_P}{\partial t} - \frac{\partial U_B}{\partial t} \quad (20)$$

It is noted that the density of the atmosphere is related to the communication signals speed, frequency of the propagation and the wavelength of the propagation. Normally, the electromagnetic wave propagates at the speed of light in free space as a result of the type and the nature of material used in the atmospheric environment which thus affects the GSM parameters such as wavelength, frequency and velocity. The equation above takes into account the aforementioned parameters such as frequency of propagation, wavelength antenna height (mobile and base station) and the speed of the signal propagation [7, 11, 12]. The path length of the atmosphere is given as

$$P_{L\,atm} = 20\log(f_c) + 20\log(h_B) + 20\log(H_m)$$

The length atmosphere and the perception are closely related by

$$4P_{L\ \text{preparation}} = P_{L\ \text{atmosphere}} \quad (21)$$

Also, considering a closed pipe closed at one end in atmospheric model

Atmospheric model for a pipe

$$4L = \lambda \quad (22)$$

Where λ = wavelenght in metres, L = length of the pipe. By relating equation (22) with the fundamental frequency of propagation as

$$F_0 = 4L = \lambda \quad (23)$$

Also, the velocity of the signal is however related with the frequency of propagation by the equation below

Veocity = frequency × wavelength

$$V = f' \lambda' \quad (24)$$

Also, $V_0 = f_0 \lambda_0$ velocity $= \frac{\text{Distance}}{\text{Time}}$ (25)

$$L = \lambda/4 = \frac{f_0}{4} \quad (26)$$

By taking the partial derivative of equation (26) with respect to time, it gives

$$\frac{\partial V}{\partial t} = f' \frac{\partial \lambda'}{\partial t} + \lambda' \frac{\partial f'}{\partial t} \quad (27)$$

Where $\lambda' = \lambda_0/4$, $f' = f_0/4$ (28)

$$\frac{\partial V}{\partial t} = \frac{1}{4}\left[f \frac{\partial \lambda}{\partial t} + \lambda \frac{\partial f}{\partial t}\right] \quad (29)$$

Equation (29) is known as speed of propagation for atmospheric environment.

The path length associated with the participation in the atmosphere is given as

$$4P_{L\ \text{ppt}} = P_{L\ \text{atmosphere}}$$

$$P_{L\ \text{ppt}} = \frac{P_{L\ \text{atmosphere}}}{4}$$

$$P_{L\ \text{ppt}} = \frac{20\log_{10}(V/\lambda) + 20\log_{10}(h_B) + 20\log_{10}(h_m)}{4} \quad P_{L\ \text{ppt}} = 5\log_{10}(f) + 5\log_{10}(h_B) + 5\log_{10}(h_m)$$

2.7. ITU Model and Crane Model

The models used to determine the rain rates in a certain area or region are basically two, namely the ITU and Crane model. The two models have the same background but differ in the formula but however share the same regression coefficient.

(a) **ITU Model**: this is the type of model used in determine the rain rate of a particular region. It is based on equation which covers all the regions. The first step is to determine the 99.9 fade depth and that is given by

(b) $Atten_{0.01} = kRR^{\alpha}.d.r$ (35)

Availability for 99.9%

Where RR is actually the 99.9% rain rate for the region

kRR^{α} is the specific attenuation and that is dB/Km

d is the link distance (km)

r is the distance factor given similar to refractive index

$$r = \frac{1}{1+\left(\frac{d}{d_0}\right)} \quad (36)$$

d_o = effective path length = $35e^{-0.015RR}$

K and α are giving in two ITU publications.

K = 0.324, α = 0.95 and 95Km/hr = RR for Lagos environs.

(b) **Crane Model**

It is divided in segments and the segments are based on distance and rain rate.

$$Atten = \frac{kRR^{\alpha}(e^{Y\delta}-1).dB}{Y} \quad 0<d<\delta(RR)\text{km} \quad (37)$$

$$Atten = kRR^{\alpha}\left|\left(\frac{e^{Y\delta(RR)}-1}{Y}\right)+\left(\frac{e^{z.d}-e^{z.\delta}}{Z}\right)e^{0.83-0.17\ \text{In(RR)}}\right. \quad \delta(RR) < d < 2.25\text{km}$$

Where $\delta(RR)$ = function of rain rate

δ = 3.8 – 0.16 In (RR)km

$$Y = \alpha.\left|\frac{0.83-0.17\ In(RR)}{\delta(RR)}\right. + 0.26 - 0.03\ In(RR) \quad (27)$$

$$Z = \alpha.(0.026 - 0.03\ In(RR)) \quad (39)$$

3. DATA COLLECTION

Table-1. Outage values of Environment 1

Environment 1			
Field Measurement		ITU MODEL	
(13GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.01	N	0.012	N
0.012	Q	0.014	Q
0.07	P	0.11	P
(15Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.011	N	0.013	N
0.013	Q	0.014	Q
28.13	P	32.14	P
(23GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.01	N	0.018	N
0.014	Q	0.019	Q
29.87	P	37.67	P

Table-2. Outage values of Environment 2

Environment 2			
Field Measurement (13GHz)		ITU MODEL (13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.013	N	0.017	N
0.016	Q	0.019	Q
0.041	P	0.043	P
(15GHz)		(15Ghz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.014	N	0.017	N
0.045	Q	0.048	Q
25.34	P	27.75	P
(23Ghz)		(23GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0120	N	0.019	N
0.0210	Q	0.025	Q
34.60	P	36.90	P

Table-3. Outage values of Environment 3

Environment 3			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0103	N	0.0105	N
0.0102	Q	0.0104	Q
0.0125	P	0.0129	P
(15Ghz) (15GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.01041	N	0.0107	N
0.01051	Q	0.0109	Q
24.75	P	30.30	P
(23GHz) (23Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0221	N	0.0219	N
0.0113	Q	0.0108	Q
34.27	P	40.75	P

Table-4. Outage values of Environment 4

Environment 4			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0172	N	0.0170	N
0.0174	Q	0.0172	Q
0.0197	P	0.0194	P
(15Ghz) (15GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0143	N	0.0140	N
0.0138	Q	0.0132	Q
26.90	P	29.65	P
(23GHz) (23Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0164	N	0.0161	N
0.0216	Q	0.0212	Q
42.50	P	48.75	P

Table-5. Outage values of Environment 5

Environment 5			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0220	N	0.0215	N
0.0123	Q	0.0187	Q
0.0334	P	0.0329	P
(15Ghz) (15GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0271	N	0.0269	N
0.0297	Q	0.0285	Q
33.48	P	37.40	P
(23GHz) (23Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0321	N	0.0325	N
0.0350	Q	0.0357	Q
31.24	P	36.84	P

Table-6. Outage values of Environment 6

Environment 6			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.01341	N	0.0136	N
0.01371	Q	0.0139	Q
0.0153	P	0.0157	P
(15Ghz) (15GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.01421	N	0.0428	N
0.01491	Q	0.0497	Q
28.23	P	34.85	P
(23GHz) (23Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0139	N	0.0141	N
0.0155	Q	0.0162	Q
31.80	P	37.94	P

Table-7. Outage values of Environment 7

Environment 7			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0134	N	0.0137	N
0.0142	Q	0.0148	Q
0.0158	P	0.0160	P
(15Ghz) (15GHz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0174	N	0.0181	N
0.0191	Q	0.0194	Q
25.37	P	30.32	P
(23GHz) (23Ghz)			
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0172	N	0.0174	N
0.0191	Q	0.0195	Q
40.74	P	48.17	P

Table-8. Specific attenuation values of Environment 1

Environment 1			
Field Measurement		ITU MODEL	
(13GHz)		(13GHz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
4.96E+17	N	4.93E+17	N
4.87E+17	Q	4.84E+17	Q
1.90E+15	P	1.88E+15	P
(15Ghz)		(15GHz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
2.9E+16	N	2.86E+16	N
2.82E+16	Q	2.81E+16	Q
1.69E+13	P	1.63E+13	P
(23GHz)		(23Ghz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
2.00E+17	N	1.99E+17	N
1.97E+17	Q	1.96E+17	Q
5.55E+13	P	5.52E+13	P

Table-9. Specific attenuation values of Environment 2 **Table-10.** Specific attenuation values of Environment 3

Environment 2

Field Measurement (13GHz) Specific Attenuation(dB)	ITU Rain Region	ITU MODEL (13GHz) Specific Attenuation(dB)	ITU Rain Region
3.87E+15	N	3.85E+15	N
3.77E+15	Q	3.67E+15	Q
2.68E+13	P	2.64E+13	P

(15Ghz) Specific Attenuation(dB)	ITU Rain Region	(15GHz) Specific Attenuation(dB)	ITU Rain Region
2.70E+10	N	2.69E+10	N
2.65E+10	Q	2.63E+10	Q
1.45E+12	P	1.42E+12	P

(23GHz) Specific Attenuation(dB)	ITU Rain Region	(23Ghz) Specific Attenuation(dB)	ITU Rain Region
2.24E+16	N	2.10E+16	N
1.89E+16	Q	1.97E+16	Q
4.60E+12	P	4.58E+12	P

Environment 3

Field Measurement (13GHz) Specific Attenuation(dB)	ITU Rain Region	ITU MODEL (13GHz) Specific Attenuation(dB)	ITU Rain Region
5.56E+13	N	5.54E+20	N
5.54E+13	Q	5.37E+20	Q
3.73E+11	P	3.74E+17	P

(15Ghz) Specific Attenuation(dB)	ITU Rain Region	(15GHz) Specific Attenuation(dB)	ITU Rain Region
4.17E+19	N	4.09E+19	N
4.01E+19	Q	3.99E+19	Q
3.97E+17	P	3.85E+17	P

(23GHz) Specific Attenuation(dB)	ITU Rain Region	(23Ghz) Specific Attenuation(dB)	ITU Rain Region
2.97E+13	N	2.95E+13	N
2.05E+13	Q	2.01E+13	Q
7.52E+11	P	7.50E+11	P

Table-11. Specific attenuation values of Environment 4 **Table-12.** Specific attenuation values of Environment 5

Environment 4

Field Measurement (13GHz) Specific Attenuation(dB)	ITU Rain Region	ITU MODEL (13GHz) Specific Attenuation(dB)	ITU Rain Region
7.07E+16	N	7.04E+13	N
7.03E+16	Q	7.01E+13	Q
3.95E+10	P	3.87E+10	P

(15Ghz) Specific Attenuation(dB)	ITU Rain Region	(15GHz) Specific Attenuation(dB)	ITU Rain Region
4.75E+18	N	4.71E+18	N
4.71E+18	Q	4.69E+18	Q
3.89E+15	P	3.85E+15	P

(23GHz) Specific Attenuation(dB)	ITU Rain Region	(23Ghz) Specific Attenuation(dB)	ITU Rain Region
4.52E+16	N	4.48E+16	N
4.01E+16	Q	3.97E+16	Q
6.75E+14	P	6.75E+14	P

Environment 5

Field Measurement (13GHz) Specific Attenuation(dB)	ITU Rain Region	ITU MODEL (13GHz) Specific Attenuation(dB)	ITU Rain Region
6.45E+16	N	6.40E+16	N
6.43E+16	Q	6.00E+16	Q
3.71E+13	P	3.70E+13	P

(15Ghz) Specific Attenuation(dB)	ITU Rain Region	(15GHz) Specific Attenuation(dB)	ITU Rain Region
5.74E+14	N	5.73E+14	N
5.70E+14	Q	5.68E+14	Q
2.88E+11	P	2.84E+11	P

(23GHz) Specific Attenuation(dB)	ITU Rain Region	(23Ghz) Specific Attenuation(dB)	ITU Rain Region
4.75E+16	N	4.73E+16	N
4.46E+16	Q	4.43E+16	Q
5.42E+12	P	5.40E+12	P

Table-13. Specific attenuation values of Environment 6

Environment 6			
Field Measurement (13GHz)		ITU MODEL (13GHz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
4.12E+15	N	4.10E+15	N
4.09E+15	Q	4.07E+15	Q
2.89E+11	P	2.85E+11	P
(15Ghz)		(15GHz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
2.56E+12	N	2.52E+12	N
2.04E+12	Q	2.01E+12	Q
1.07E+9	P	1.03E+9	P
(23GHz)		(23Ghz)	
Specific Attenuation(dB)	ITU Rain Region	Specific Attenuation(dB)	ITU Rain Region
3.67E+15	N	3.61E+15	N
3.05E+15	Q	3.01E+15	Q
7.67E+9	P	7.53E+9	P

Table-14. Specific attenuation values of Environment 7

Environment 7			
Field Measurement (13GHz)		ITU MODEL (13GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0134	N	0.0137	N
0.0142	Q	0.0148	Q
0.0158	P	0.0160	P
(15GHz)		(15Ghz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0174	N	0.0181	N
0.0191	Q	0.0194	Q
25.37	P	30.32	P
(23Ghz)		(23GHz)	
Outage (min/year)	ITU Rain Region	Outage (min/year)	ITU Rain Region
0.0172	N	0.0174	N
0.0191	Q	0.0195	Q
40.74	P	48.17	P

3.1. Analysis and Discussion of Data (Harmattan)

The method used in analyzing the data was the Matlab computer program. The method shows signal attenuation at different frequencies and ITU regions. During the harmattan season, in the N and Q regions there was more signal attenuation compared to the P region at different frequency.

Figure-5. Graph Of Outage Of Environment 1,2, and 3 at 13ghz

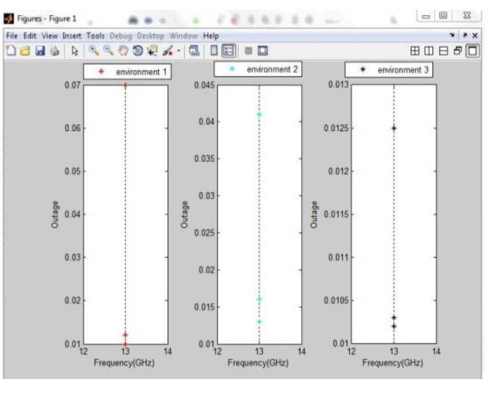
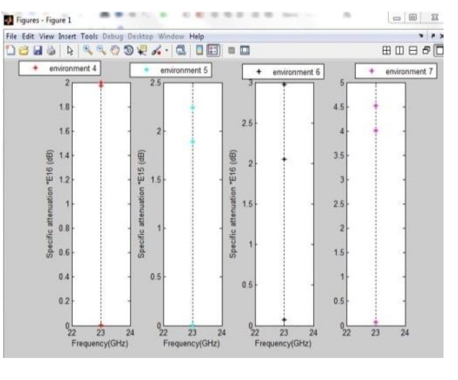


Figure-16. Graph Of Specific Attenuation Of Environment 4,5,6,and 7 at 23GHz



This analysis can be observed in both the ITU model and the field measurement. Also in the harmattan season, it can be observed that there will be higher signal attenuation when transmitting at a lower frequency in the n and q regions compared to the p region.

Figure-6. Graph Of Outage Of Environment 4,5,6,and 7 at 13GHz

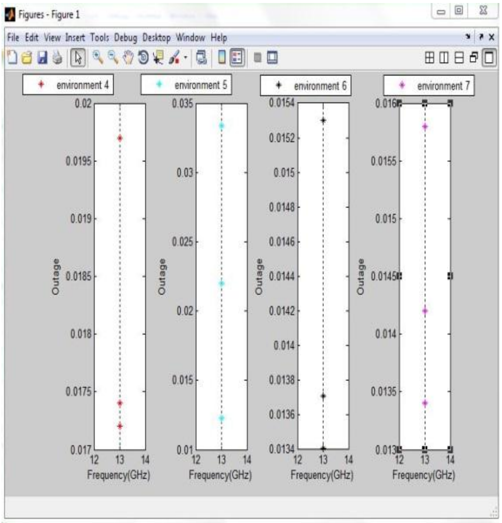


Figure-7. Graph Of Outage Of Environment 1,2,and 3 at 15GHz

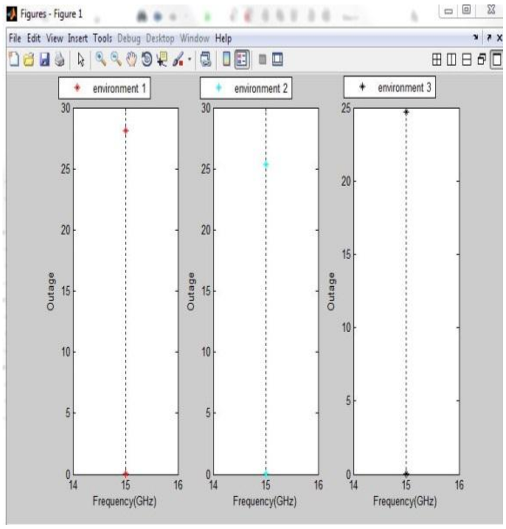


Figure-8. Graph Of Outage Of Environment 4,5,6,and 7 at 15Ghz

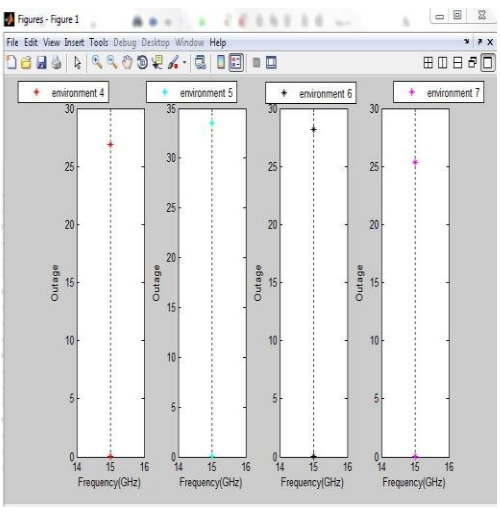


Figure-9. Graph Of Outage Of Environment 1,2,and 3 at 23GHz

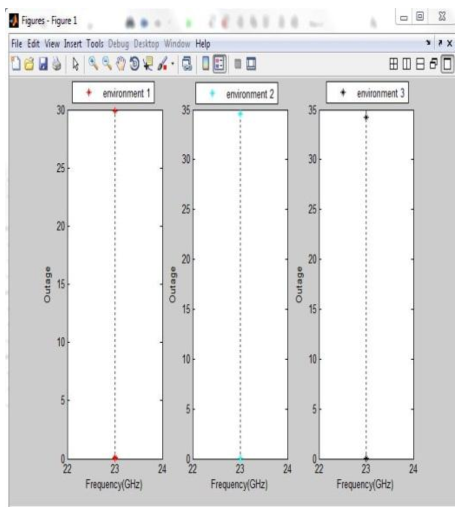


Figure-10. Graph Of Outage Of Environment 4,5,6,at 7 at 23GHz

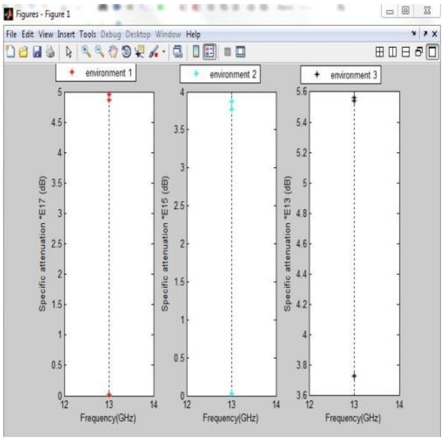


Figure-11. Graph Of Specific Attenuation Of Environment 1,2,3 at 13GHz

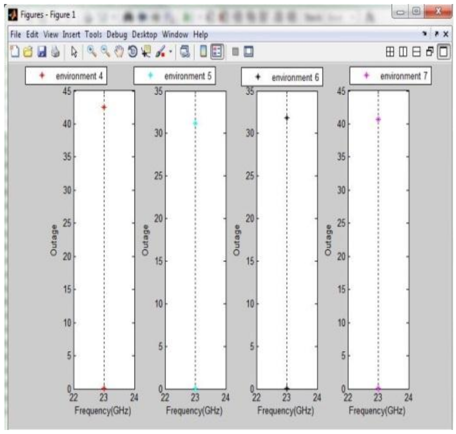


Figure-12. Graph Of Specific Attenuation Of Environment4,5,6,and 7 at 13GHz

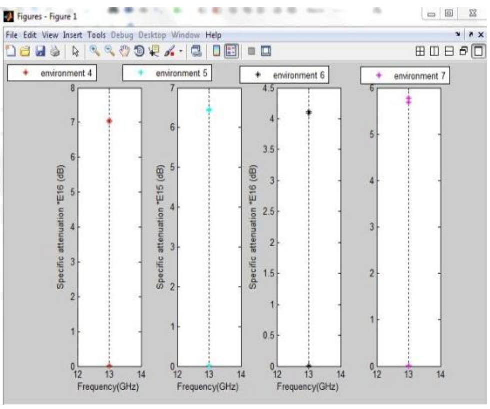
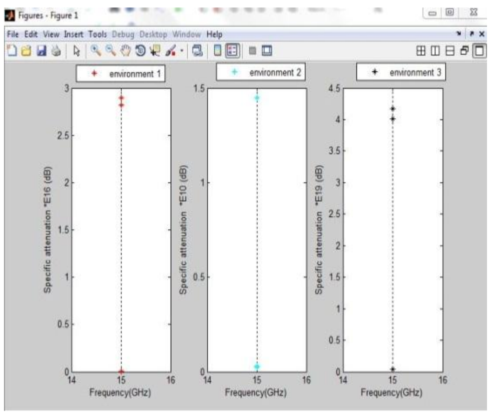


Figure-13. Graph Of Specific Attenuation Of Environment 1,2,3 at 15Ghz



3.2. Analysis and Discussion of Data (Rain)

In the raining season, from the analysis above there was more signal unavailability (outage) in the P region compared to the N and Q. As observed above, transmitting at a higher frequency will surely cause higher unavailability of signals in the P region compared to N and Q. Although, the graphs follow a linear pattern for each of the environments considered , however, the amount of signal unavailability differs from one region to another as well as from one environment to another as depicted in the various graphs shown below for different values of propagating frequency.

Figure-14. Graph Of Specific Attenuation Of Environment 4,5,6,and 7 at 15GHz

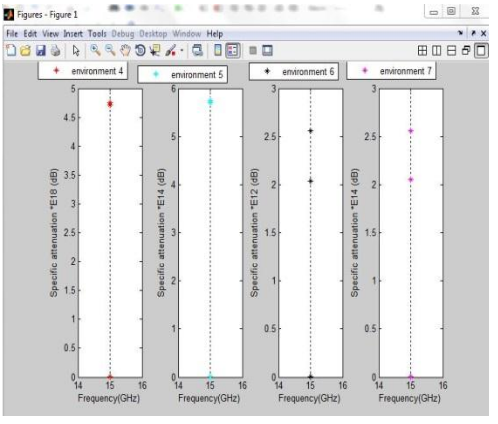
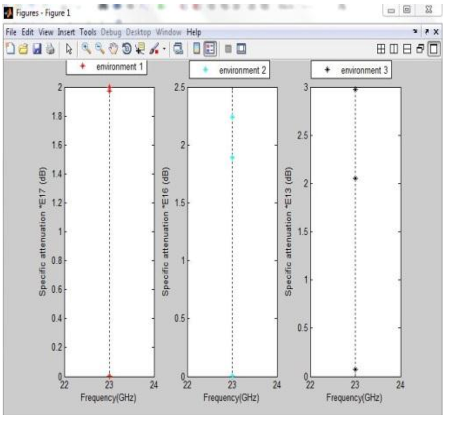
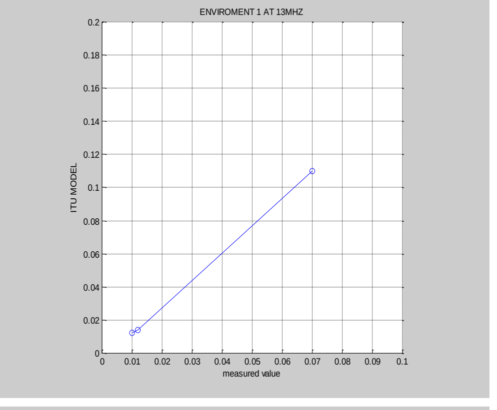
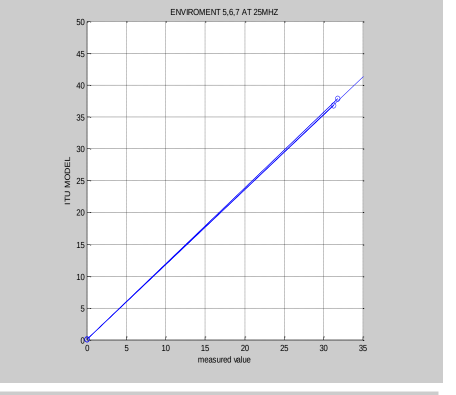
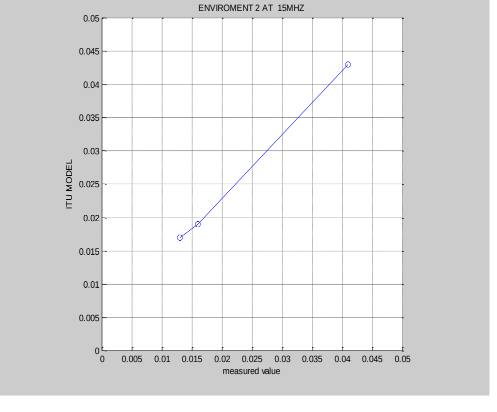


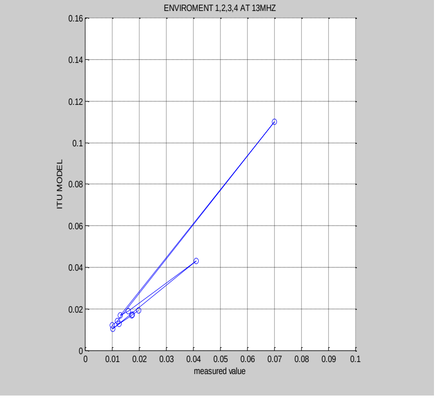
Figure-15. Graph Of Specific Attenuation Of Environment 1,2,3 at 23GHz

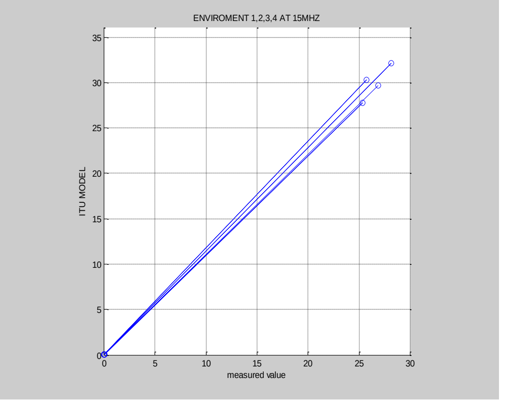


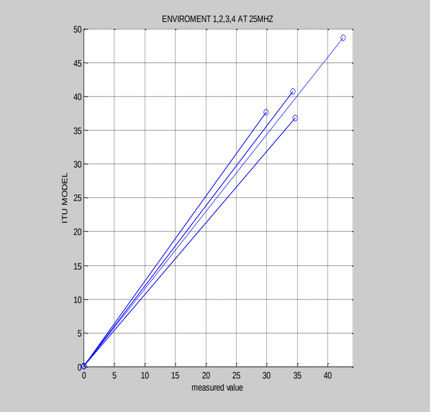


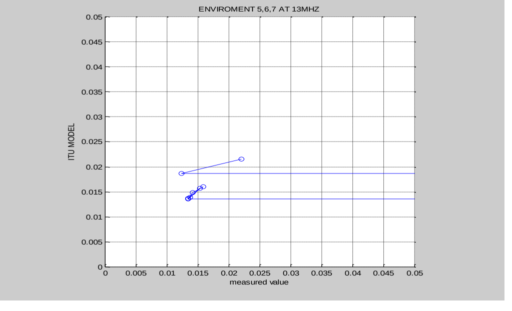


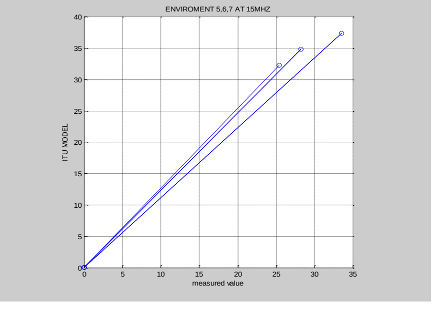












4. CONCLUSION

The outage and specific attenuation graphs above explain the relationship that exists between the specific attenuation of the signal, outage, frequency and the various ITU regions. This research study therefore shows that climate affects signal propagation depending on climatic parameters (rain and harmattan), frequency of transmission and ITU regions of propagation (which explains the size of rain and harmattan intensity) in Nigeria.

REFERENCES

[1] D. D. Dajab, "Perspectives on the effects of harmattan on radio frequency waves, department of electrical engineering, Ahmadu Bello University, Zaria, Nigeria," *Journal of Applied Sciences Research, INSInet Publication, Zaria,Nigeria*, vol. 2, pp. 1014-1018, 2006.

[2] B. Dominique, R. P. Neilson, J. M. Lenihan, and R. J. Drapek, "Climate change effects on vegetation distribution and carbon budget in the United States," *Ecosystems(Springer-Verag)*, vol. 4, pp. 164-185, DOI:10.100715110021-001-0002-7, 2001.

[3] M. Maiti, A. K. Datta, and P. K. Karmakar, *Effect of climatological parameters on propagation delay through the atmosphere*. India: Centre for Astroparticle Physics and Space Sciences, Bose Institute, Block-EN, Sector-V, Saltlake, Kolkata-700 091.

[4] L. W. Marvin, *The combined effect of temperature and humidity fluctuations on refractive index, Journal of Meteorology,vol.15,pg.43-49*. Argonne, ill: Argonne National Laboratory. 60439, 1976.

[5] Climate Change: Synthesis Report, "An assessment of the intergovernmental panel on climate change (IPCC)'s Fourth Assessment Report," IPCC. Available from:

http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (Also Available on Blackboard) 52 pages-textbook, 2007.

[6] O. O. Shoewu and L. A. O. Akinyemi, "The effect of climatic change on GSM signal propagation," *Research Journal of Computer Systems Engineering (RJSCE)*, vol. 04, 2013.

[7] S. Phaiboon, P. Phokharutkul, and S. Somkurnpanich, "Mobile propagation path loss models for suburban areas using fuzzy logic approximation," *IEEE Trans. On Communication, 0.7803 – 8560 – 8/04*, pp. 133–136, 2004.

[8] S. Paiboon, P. Phokharatkul, and S. SomkuarnPanit, "Propagation- path losses characterization for 800MHz cellular communications in Bangkok," *IEEE Trans.*, vol. 0-7803 – 5739 – 6/99, pp. 1209 m- 1211, 1999.

[9] S. Mohammed, R. Al-Basheir, M. Shubair, and S. M. Sharif, "Measurements and analysis for signal attenuation through date palm trees at 2.1GHz frequency," *Sudan Engineering Society Journal, Sudan Engineering Society*, vol. 52, pp. 17-22, 2006.

[10] S. Uzma, S. Imran, and R. Gulistan, *Rain outage predictions for gsm networks in Pakistan*. Taxila, Pakistan: Electrical Department, University of Engineering & Technology.

[11] D. A. Shalangwa and S. K. Singh, "Measurement and modeling of path loss for GSM 900 in subs urban environment over irregular terrain," *International Journal of Computer Science and Nationals Security*, vol. 10, pp. 268–274, 2010.

[12] S. Phaiboon, "Predicting pathloss for cellular mobile using fuzzy logic approximation. Faculty of Engineering, Mahidol University,Salaya, Nakornprathom, 73170, Thailand,Lecture Notes."