Evaluation of the Effect of Atmospheric Parameters on Radio Pathloss in Cellular Mobile Communication System

Kalu Constance[1],Ozuomba Simeon[2], Ezuruike Okafor S.F.[3]
[1,2] Department of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom, Nigeria
[3] Department of Electrical/Electronic Engineering, Imo State Polytechnic, Umuagwo, Nigeria
([1]simeonoz@yahoo.com)

***Abstract*— In this paper, the effect of atmospheric parameters (temperature , pressure and relative humidity) on pathloss in cellular mobile communication system is examined. In the study statistical data of Received Signal Strengths (RSS) and weather parameters were obtain. The data on RSS and weather parameters, temperature, pressure and relative humidity are captured on two different days and at different time (morning, afternoon and evening) on each day. In particular, the empirical survey measurement is conducted for global system for mobile communication (GSM) network at 900 MHz frequency band where the GSM base station and site survey measurement points geo-coordinates are located in Uyo metropolis in Akwa Ibom State, Nigeria. From the RSS value, the measured pathloss was computed. Maximum error or disparity between the lowest and the highest measured pathloss values at that measurement point were obtained ; the lowest value was 3.68 dB at measurement point 2 , a distance of 0.642 km from the base station whereas the highest value was 15.00 dB at measurement point 14 , a distance of 0.1622 km from the base station. In all, the study results showed that there is significant correlation between the variations in the atmospheric parameters and the variations in the measured pathloss at any given point within the network coverage area. As such, appropriate pathloss model or appropriate pathloss tuning method that incorporates the atmospheric parameters can be more effective in modelling the pathloss at any given point within a network coverage area.**

***Keywords*— Received Signal Strengths, Pathloss, Atmospheric Parameters, Pathloss Model, Cellular Network**

I. INTRODUCTION

The reduction in power density of an electromagnetic wave as it propagates through space is referred to as pathloss [1, 2, 3, 4,]. It is a major component in the analysis and design of wireless communication system. Pathloss depends on frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors [6, 7, 8, 9, 10] . Propagation pathloss models are used for prediction of expected pathloss that wireless signal may experience as the propagates along the signal path [11, 13, 14]. Pathloss models play important roles in the design of wireless networks, especially in specifying key system parameters such as transmission power, frequency, antenna heights etc, as well as determining the network coverage area [6, 14, 15, 16, 17, 18, 19, 20].

Pathloss models can be broadly categorized into three types; empirical, deterministic and stochastic [7, 21, 22, 23]. Among these the empirical models which are based on observations and measurements are the most widely use. Despite their there wide applications none of the empirical pathloss models has factored in the effect of atmospheric parameters. Consequently, in this paper, the effect of atmospheric parameters, namely temperature, atmospheric pressure and relative humidity on pathloss is studied. The study is aimed at drawing attention of researchers to the significant effect of variation in atmospheric parameters on the measured pathloss. Also, the study seek to demonstrate through empirical data that variations in the atmospheric parameters can have significant effect on the measured pathloss at any given point within the network coverage area. Particularly, variation in atmospheric parameters can be employed in modeling the variation in measured pathloss at any given point within the network coverage area. In all, the study seeks to stir up further study in pathloss modeling and pathloss model tuning for cellular networks.

II. METHODOLOGY

The study is carried out to obtain statistical data of Received Signal Strengths (RSS) and weather parameters. From the RSS value, the measured pathloss are computed. The data on RSS and weather parameters, temperature, pressure and relative humidity are captured on two different days and at different time (morning, afternoon and evening) on each day. In particular, the empirical survey measurement is conducted for global system for mobile communication (GSM) network at 900 MHz frequency band where the GSM base station and site survey measurement points geo-coordinates are located in Uyo metropolis in Akwa Ibom State, with coordinates as shown in Table 1 and figure 1.

Table 1 : The geo-coordinates of the empirical GSM network site survey measurement points and the distance of the measurement points from the GSM base station

Measurement Point Number	Latitude	Longitude	Distance From Base Station; d (km)
1	5.037535	7.898945	0
2	5.0381	7.89855	0.0766
3	5.038034	7.898325	0.0884
4	5.037951	7.89811	0.1035
5	5.037771	7.897817	0.1278
6	5.037575	7.897483	0.1622
7	5.037424	7.897223	0.1913
8	5.037398	7.896844	0.2335
9	5.037395	7.896464	0.2756
10	5.037393	7.896082	0.3179
11	5.037418	7.895499	0.3824
12	5.037515	7.894953	0.4427
13	5.037688	7.894642	0.4775
14	5.037778	7.894444	0.4999
15	5.037846	7.894155	0.5323
16	5.037908	7.893972	0.553
17	5.038064	7.893549	0.6013
18	5.038196	7.893194	0.642
19	5.038316	7.892644	0.7041

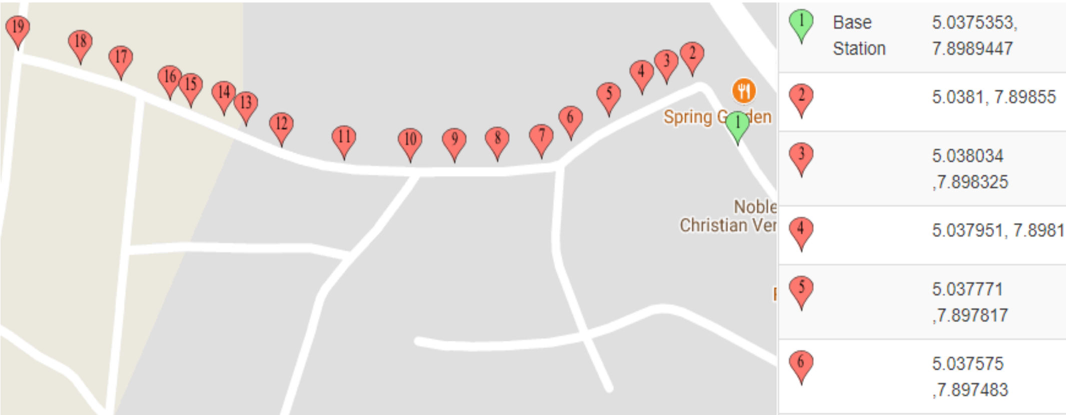

Figure 1: Google map visualization of the geo-coordinates of the empirical GSM network site survey measurement points and the geo-coordinates of the GSM base station

The measurement of the longitude, latitude, RSS, temperature, pressure and relative humidity are made using android application running on Samsung Galaxy S4 mobile phone handset. The android application termed UNIUYO Enhanced Site Survey Android Application (UESSAP) is locally developed specifically for this purpose to enable simultaneous measurements of the geo-coordinates, the RSS as well as the temperature, pressure and relative humidity. However, the same measurements can be done with a combination of available android applications such as Cellmapper android application, Netmonitor android application and MYGPS coordinate android application, along with android applications for measuring temperature, pressure and relative humidity.

The measurement procedure is as follows:

Step 1: The GSM network base station covering the study area is identified and its geo-coordinates are obtained using the UESSAP android application running on the Samsung Galaxy S4 mobile phone handset.

Step 2: The route for the site survey is selected and the site survey measurement points are identified and marked. The geo-coordinates of the empirical GSM network site survey measurement points and the geo-coordinates of the GSM base station are then stored in a Microsoft Excel file. A total of 18 measurement points are marked, starting from place marker 2 to place marker 19 on figure 1.

The distance between the measurement points geo-coordinates determined using Haversine Haversine formula (Eq 1) is used to calculate the distance (shown in Table 1 and figure 2) between each of the measurement points geo-coordinates and the geo-coordinates of the GSM base station.

Figure 2: Google map visualization of the total distance covered in the empirical GSM network site survey measurement

$$d = 2r\left\{\sqrt[2]{\sin\left(\frac{LAT_2-LAT_1}{2}\right)^2 + \cos(LAT_1)\cos(LAT_2)\sin\left(\frac{LONG_2-LONG_1}{2}\right)^2}\right\} \quad (1)$$

$$\text{LAT in Radians} = \frac{(\text{LAT in Degrees} * 3.142)}{180} \quad (2)$$

$$\text{LONG in Radians} = \frac{(\text{LONG in Degrees} * 3.142)}{180} \quad (3)$$

Where LAT1 and LAT2 the latitude of the coordinates of point1 and point 2 respectively; LONG1 and LONG2 the longitude of the coordinates of point1 and point 2 respectively; R = radius of the earth = 6371 km , d =the distance between the two coordinates and R varies from 6356.752 km at the poles to 6378.137km at the equator.

In the morning of the first day of the site survey the UESSAP android application running on the Samsung Galaxy S4 mobile phone handset is used to measure and store the longitude, latitude, RSS, temperature, pressure and relative humidity at each of the 18 measurement points, starting from place marker 2 to place marker 19 on figure 1. The data are stored in the Microsoft Excel file.

Step 3:

Step 3.1: Each of the measured RSS value is converted to measured pathloss ($PL_{m(dB)}$) using the modified link budget formula in Eq 4 (Ajose and Imoize, 2013; Rappaport 2002; Seybold 2005):

$$PL_{m(dB)} = \text{EIRP (dBm)} - P_r \text{(dBm)} = \text{EIRP}_t \text{(dBm)} - \text{RSS(dBm)} \quad (4)$$

where $PL_{m(dB)}$ is the measured pathloss for each measurement location at a distance d(km) ; Pr is the mean Received Signal Strength (RSS) in dBm = the measured received signal strength and EIRP is the Effective Isotropic Radiated Power in dBm . In this study EIRP = 53.5 dBm.

Step 3.2: The measured pathloss values in dB obtained by substituting the value of EIRP (dBm) and the measured RSS(dBm) into Eq 4. The data are stored in the Microsoft Excel file.

Step 4: Step 3 is repeated for the afternoon and evening of the first day and also for the morning, afternoon and evening of the second day of the site survey. In all, six different site survey data sets are collected.

III. RESULT AND DISCUSSION

` The measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) for the first and second day of the network site survey are shown in Table 2, Table 3, Table 4, Table 5, Table 6 and Table 7.

The measured pathloss (dB) for the morning, afternoon and evening of the first and second day of the network site survey is given in Table 8 and Figure 3.

Table 2 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Morning Of The First day of The Network Site Survey

S/N	Distance (km)	Received Signal Strength (RSS) in dBm	Air Temperature (Celsius)	Atmospheric Pressure(hPa)	Relative Humidity(%)
1	0.7041	-89.3	24.3	1007.2	100
2	0.642	-90.7	23.8	1007.1	100
3	0.6013	-92.1	23.3	1007.1	100
4	0.553	-95.6	23.4	1007.1	100
5	0.5323	-90.4	23.5	1007.1	100
6	0.4999	-95	23.4	1007.1	100
7	0.4775	-95.8	23.1	1007.1	100
8	0.4427	-87.2	23.1	1007.1	100
9	0.3824	-91.9	22.9	1007.1	100
10	0.3179	-81.7	22.8	1007.1	100
11	0.2756	-87.4	22.6	1007.2	100

12	0.2335	-88	22.4	1007.3	100
13	0.1913	-92.3	22.4	1007.3	100
14	0.1622	-81	22	1007.3	100
15	0.1278	-91.1	22.1	1007.3	100
16	0.1035	-84.8	22	1007.3	100
17	0.0884	-84.1	22.3	1007.3	100
18	0.0766	-87	22.6	1007.4	100
		Mean Value	22.9	1007.2	100

Table 3 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Afternoon Of The First day of The Network Site Survey

S/N	Distance	Received Signal Strength	Air Temperature	Atmospheric	Relative
1	0.7041	-85.5	36.0	1005.3	72.65571
2	0.642	-90.6	39.5	1005.1	67.50073
3	0.6013	-89.9	37.7	1005.0	70.52283
4	0.553	-90.9	41.7	1004.9	62.857323
5	0.5323	-91.0	39.2	1004.9	62.192505
6	0.4999	-90.3	39.6	1004.8	63.866512
7	0.4775	-94.4	36.7	1004.8	65.11625
8	0.4427	-90.5	36.5	1004.8	67.218796
9	0.3824	-85.0	35.3	1004.8	70.64967
10	0.3179	-81.2	35.4	1004.8	73.15703
11	0.2756	-83.9	35.9	1004.8	74.66163
12	0.2335	-83.4	34.5	1004.8	75.81324
13	0.1913	-88.7	32.9	1004.8	75.9744
14	0.1622	-78.4	33.5	1004.8	72.43555
15	0.1278	-89.6	37.6	1004.8	65.51128
16	0.1035	-82.5	41.0	1004.7	58.190796
17	0.0884	-81.8	40.6	1004.8	57.800457
18	0.0766	-80.1	38.1	1004.7	60.067104
		Mean Value	37.3	1004.9	67.56621183

Table 4 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Evening Of The First day of The Network Site Survey

S/N	Distance (km)	Received Signal Strength (RSS) in	Air Temperature (Celsius)	Atmospheric Pressure(hPa)	Relative Humidity(%)
1	0.7041	-85.5	24.7	1006.1	100
2	0.642	-89.2	24.8	1006.1	100
3	0.6013	-89.0	25.0	1006.1	100
4	0.553	-89.2	24.8	1006.0	100
5	0.5323	-89.9	25.0	1006.1	100
6	0.4999	-82.5	25.5	1006.1	100
7	0.4775	-90.5	24.8	1006.1	100
8	0.4427	-90.1	26.3	1042.5	103.6
9	0.3824	-86.4	25.3	1006.1	100
10	0.3179	-81.8	25.6	1006.2	100
11	0.2756	-83.2	25.6	1006.2	100
12	0.2335	-88.0	26.0	1006.3	100
13	0.1913	-90.0	25.9	1006.3	100
14	0.1622	-75.4	25.4	1006.3	100
15	0.1278	-87.8	25.2	1006.3	100
16	0.1035	-85.4	25.1	1006.4	100
17	0.0884	-79.7	25.2	1006.3	100
18	0.0766	-82.3	25.1	1006.4	100
		Mean Value	25.3	1008.2	100.2

Table 5 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Morning Of The Second day of The Network Site Survey

S/N	Distance (km)	Received Signal Strength (RSS) in	Air Temperature (Celsius)	Atmospheric Pressure(hPa)	Relative Humidity(%)
1	0.7041	-86.8	24.0	1006.4	100
2	0.642	-91.6	24.5	1006.3	100
3	0.6013	-92.3	24.7	1006.3	100
4	0.553	-93.8	24.9	1006.3	100
5	0.5323	-91.9	24.7	1006.3	100
6	0.4999	-96.1	25.5	1006.3	100
7	0.4775	-89.5	26.2	1006.2	100
8	0.4427	-87.7	25.5	1006.2	100
9	0.3824	-88.4	25.4	1006.2	100
10	0.3179	-85.5	25.6	1006.4	100
11	0.2756	-86.6	24.4	1006.4	100
12	0.2335	-89.1	24.2	1006.4	100
13	0.1913	-91.0	24.5	1006.4	100
14	0.1622	-75.6	24.5	1006.5	100
15	0.1278	-90.1	24.4	1006.5	100
16	0.1035	-86.5	24.2	1006.6	100
17	0.0884	-83.0	24.3	1006.6	100
18	0.0766	-83.4	24.3	1006.6	100
		Mean Value	24.8	1006.4	100

Table 6 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Afternoon Of The Second day of The Network Site Survey

S/N	Distance (km)	Received Signal Strength (RSS) in	Air Temperature (Celsius)	Atmospheric Pressure(hPa)	Relative Humidity(%)
1	0.7041	-83.3	33.3	1004.8	80.4
2	0.642	-92.9	32.1	1004.9	83.8
3	0.6013	-89.3	31.9	1004.9	83.6
4	0.553	-91.0	32.3	1004.8	79.7
5	0.5323	-90.4	35.7	1004.8	72.6
6	0.4999	-88.8	39.9	1004.7	62.2
7	0.4775	-87.6	41.2	1004.5	62.0
8	0.4427	-91.0	42.7	1004.4	57.0
9	0.3824	-89.7	41.5	1004.4	57.0
10	0.3179	-81.0	38.9	1004.4	62.0
11	0.2756	-85.7	37.8	1004.5	63.7
12	0.2335	-85.0	35.6	1004.5	68.4
13	0.1913	-86.8	35.4	1004.6	68.6
14	0.1622	-87.8	33.8	1004.6	70.1
15	0.1278	-83.7	33.6	1004.5	70.0
16	0.1035	-80.6	34.0	1004.6	70.3
17	0.0884	-83.0	34.3	1004.6	66.7
18	0.0766	-82.7	33.9	1004.5	68.8
		Mean Value	34.1	948.8	65.4

Table 7 Measure Received Signal Strength (RSS) in dBm, Temperature (^{0}C), Pressure(hPa) and Relative Humidity(%) For The Evening Of The Second day of The Network Site Survey

S/N	Distance (km)	Received Signal Strength (RSS) in dBm	Air Temperature (Celsius)	Atmospheric Pressure(hPa)	Relative Humidity (%)
1	0.7041	-90.9	25.2	1005.3	100.0
2	0.642	-92.8	25.7	1005.2	100.0
3	0.6013	-95.9	26.0	1005.2	99.2
4	0.553	-95.5	26.3	1005.2	97.6

5	0.5323	-96.6	26.3	1005.1	97.3
6	0.4999	-93.7	24.1	1005.1	100.0
7	0.4775	-94.0	24.4	1005.1	100.0
8	0.4427	-90.4	24.5	1005.0	100.0
9	0.3824	-85.5	24.6	1005.1	100.0
10	0.3179	-86.8	24.7	1005.2	100.0
11	0.2756	-87.2	24.7	1005.2	100.0
12	0.2335	-88.8	24.5	1005.2	100.0
13	0.1913	-82.7	24.6	1005.3	100.0
14	0.1622	-90.4	24.5	1005.3	100.0
15	0.1278	-86.7	24.7	1005.4	100.0
16	0.1035	-82.6	25.0	1005.4	100.0
17	0.0884	-84.4	25.1	1005.4	100.0
18	0.0766	-83.0	25.2	1005.4	100.0
		Mean Value	23.6	949.4	94.1

Table 8 Measured Pathloss (dB) For The Morning, afternoon and evening of the First and Second of The Network Site Survey

S/ N	Distanc e (km)	Measure d Pathloss	Measure d Pathloss	Measure d Pathloss	Measure d Pathloss	Measured Pathloss(dB) Day 2	Measure d Pathloss	Maximu m Error	Maximu m % Error
1	0.7041	142.7	138.96	138.94	140.23	136.78	144.34	7.56	5.53
2	0.642	144.2	144.08	142.66	145.04	146.34	146.25	3.68	2.58
3	0.6013	145.6	143.37	142.45	145.76	142.74	149.3	6.85	4.81
4	0.553	149.1	144.34	142.6258	147.25	144.45	148.98	6.47	4.54
5	0.5323	143.9	144.45	143.3511	145.3	143.81	150.05	6.70	4.67
6	0.4999	148.45	143.71	135.9665	149.55	142.21	147.12	13.58	9.99
7	0.4775	149.3	147.85	143.9665	142.93	141.06	147.46	8.24	5.84
8	0.4427	140.7	143.99	143.5946	141.18	144.45	143.82	3.75	2.67
9	0.3824	145.4	138.45	139.86	141.87	143.12	138.94	6.95	5.02
10	0.3179	135.2	134.63	135.23	138.93	134.47	140.23	5.76	4.28
11	0.2756	140.9	137.37	136.65	140.08	139.11	140.67	4.25	3.11
12	0.2335	141.4	136.81	141.41	142.58	138.45	142.21	5.77	4.22
13	0.1913	145.8	142.14	143.44	144.45	140.23	136.12	9.68	7.11
14	0.1622	134.45	131.81	128.86	129	141.22	143.86	15.00	11.64
15	0.1278	144.6	143.09	141.29	143.55	137.1	140.12	7.50	5.47
16	0.1035	138.2	135.94	138.86	139.9283	134.08	136.02	5.85	4.36
17	0.0884	137.5	135.23	133.14	136.45	136.45	137.84	4.70	3.53
18	0.0766	140.5	133.57	135.71	136.84	136.12	136.45	6.93	5.19
	Men	142.66	139.99	139.33	141.72	140.12	142.77	7.18	5.25

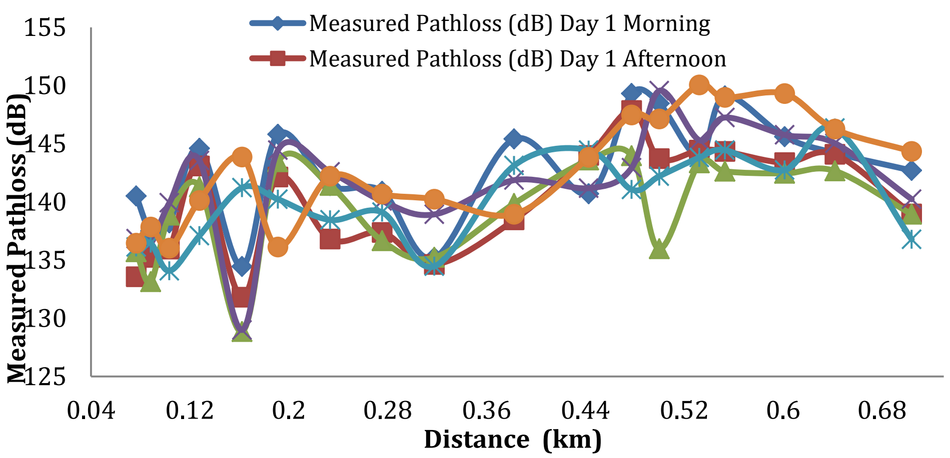

Figure 3 Measured Pathloss (dB) For The Morning, afternoon and evening of the First and Second of The Network Site Survey

From Table 8 and Figure 4 it can be seen that each measurement point different measured pathloss values are obtained in each of the six times the measurements were carried out. In Table 8 and Table 9 show that the measurement point 2, at a distance of 0.642 km from the base station has the lowest error (3.68 dB) between the lowest measured pathloss value and the highest measured pathloss value whereas the measurement point 14, at a distance of 0.1622km from the base station has the highest error (15.00 dB) between the lowest measured pathloss value and the highest measured pathloss value. Essentially, at different times of the day the measured pathloss values at any given point in the selected network coverage area are different.

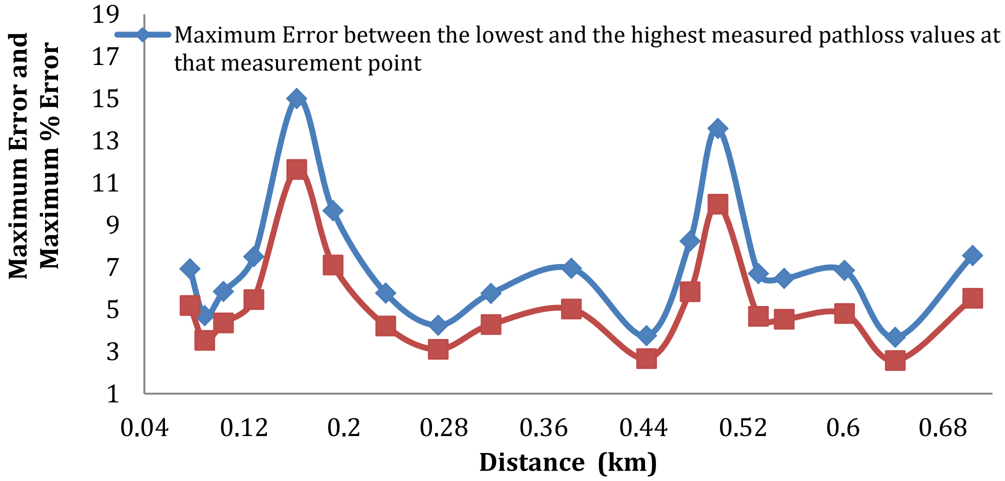

Figure 4 The Maximum error and Maximum % error between the lowest and the highest measured pathloss values at that measurement point

The variation can be in the measured pathloss values at any given measurement point can be further demonstrated by considering the measured pathloss at measurement point 18 (Table 9 and Table 10).

Table 10 shows that temperature and relative humidity have significant correlation of -0.61007115 and 0.626148719 respectively whereas the atmospheric pressure does not have significant correlation with the measured pathloss values at measurement point 18. Furthermore, while temperature has a negative correlation, the relative humidity have positive correlation with the measured pathloss values at measurement point 18.

Table 9 The measured pathloss and the measured atmospheric parameters at measurement point 18, at a distance of 0.7041 km from the base station.

	Air Temperature (Celsius)	Atmospheric Pressure (hPa)	Relative Humidity(%)	Measured Pathloss (dB)
First Day Morning	24.3	1007.2	100	142.7
First Day Afternoon	36.04711	1005.26	72.65571	138.96
First Day Evening	24.69905	1006.1	100	138.94
Second Day Morning	23.98758	1006.35	100	140.23
Second Day Afternoon	33.34524	1004.82	80.35391	136.78
Second Day Evening	25.24862	1005.25	100	144.34

Table 10 The correlation among the measured pathloss and the measured atmospheric parameters at measurement point 18, at a distance of 0.7041 km from the base station.

	Air Temperature (Celsius)	Atmospheric Pressure (hPa)	Relative Humidity (%)	Measured Pathloss (dB)
Air Temperature (Celsius)	*1*			
Atmospheric Pressure(hPa)	*-0.699384683*	*1*		
Relative Humidity(%)	*-0.996201692*	*0.648210665*	*1*	
Measured Pathloss (dB)	*-0.61007115*	*0.398534317*	*0.626148719*	*1*

Table 11 The measured pathloss and the predicted pathloss at measurement point 18

	Measured Pathloss (dB)	Predicted Pathloss (dB)	Error	$Error^2$
First Day Morning	142.7	141.212894	1.487106	2.21148541
First Day Afternoon	138.96	137.385692	1.574308	2.47844623
First Day Evening	138.94	141.52189	-2.58189	6.6661553
Second Day Morning	140.23	140.862527	-0.63253	0.40009002
Second Day Afternoon	136.78	138.975091	-2.19509	4.81842446
Second Day Evening	144.34	141.989589	2.350411	5.52442967
Regression coefficient between the measured pathloss and the predicted pathloss		0.648293172	RMSE	1.91915915

A multiple linear regression model used to predict the measured pathloss with the measured atmospheric parameters at measurement point 18 is given in Eq 5 . The regression coefficient between the measured pathloss and the predicted pathloss at measurement point 18 is significant with a value of 0.648293172; also the RMSE value is quite small with a value of 1.91915915 dB, as shown in Table 11.

$$\text{Predicted Pathloss (dB)} = 0.949042436\ T + 0.063377263\ P + 0.543176\ H \quad (5)$$

Although the model in Eq 5 and the correlation coefficient between the measured pathloss and the predicted pathloss in Table 12 in do not apply to the data at the other data measurement points nevertheless the results show that there is significant correlation between the variations in the atmospheric parameters and the variations in the measured pathloss at any given point within the network coverage area. As such, appropriate pathloss model or appropriate pathloss tuning method that incorporates the atmospheric parameters can be more effective in modelling the pathloss at any given point within a network coverage area.

IV. CONCLUSION

The study on the effect of temperature , pressure and relative humidity on pathloss for a 900 MHz GSM network is presented. Empirical measurement of Received Signal Strengths (RSS) and weather parameters were conducted in two different days and at different time (morning, afternoon and evening) on each day. From the RSS value, the measured pathloss are computed. Maximum error or disparity between the lowest and the highest measured pathloss values at that measurement point were obtained. The results showed that at different times of the day the measured pathloss values at any given point in the selected network coverage area were different. In all, the study results showed that there is significant correlation between the variations in the atmospheric parameters and the variations in the measured pathloss at any given point within the network coverage area. As such, appropriate pathloss model or appropriate pathloss tuning method that incorporates the atmospheric parameters can be more effective in modelling the pathloss at any given point within a network coverage area.

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