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Characterization of Propagation Path Loss at 1.8 GHZ: A Case Study of Benin-City, Nigeria

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Abstract: This study investigates the propagation path loss characteristics of GSM signals in Benin City, Nigeria. Propagation path loss characteristics of Benin City were investigated using fifteen different environments which reflect an exhaustive measurement and good representation of the City. Consequently power received (Pri) was measured from a distance (d) from the base station for various environments investigated. The data was analyzed to determine the Propagation path exponent and path loss characteristics. The path loss of Benin City ranges from 2.8 to 3.7 with average determined to be 3.8.

Key words: Propagation path loss, GSM signals, path loss exponent, location variability

INTRODUCTION

One of the most important characteristics of the propagation environment is the path (propagation) loss. An accurate estimation of the propagation losses provides a good basis for a proper selection of base station locations and a proper determination of the frequency plan. By knowing propagation losses, one can efficiently determine the field signal strength, Signal-to-Noise Ratio (SNR), carrier-to-interference (C/I)[1-3].

The enormous growth in mobile cellular networks raises the need for a reliable network planning tools to speed the process from network design to implementation. Many macro radio coverage-planning tools include simple path loss prediction algorithms, including prediction of diffraction loss and clutter loss. These algorithms give good prediction for flat and modest rolling areas. However, for all areas dominated by hills and mountains, these algorithms will fall short of giving good prediction[4,5].

The quality of coverage of any wireless network design depends on the accuracy of the propagation model. For accurate design, the propagation models are estimated from signal strength measurement taken in the area of interest[4,5].

Many countries of the world like Japan, United States, United Kingdom, Portugal etc have obtained their own propagation data including Propagation path loss exponent for their various Cities[2,6]. Unfortunately, to the best of the authors' knowledge, no study has been embarked upon in this country with a view to have propagation path loss exponent for our various Cities for GSM signals.

INVESTIGATED ENVIRONMENTS

The past study revealed that determining the path loss exponent of the City requires taking measurement at various high and low environments or taking exhaustive measurement round the City to cover all possible terrain conditions[2,7,8].

In this study, the focus is on the second approach using mobile network sites in Benin City. The locations of the sites and radio paths investigated are listed in Table1. Fifteen locations were investigated. The locations were well spread out to reveal all possible topology obtainable in the City.

MEASUREMENT CONDITIONS

Measurements were taken at four different times with an interval of approximately three months. The measurements were carried out between the following periods;

- November 2003 to February 2004
- April to June 2004
- August to October 2004
- January to March 2005

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Table 1: Table showing site locations and environments investigated

S/N	Site location	Propagation path
1	GRA	Boundary road
2	Ikpoba hill	Benin-Agbor road
3	Uwelu road	Uwelu road
4	Ugbowo	Technical college road
5	University of benin	Faculty of Engineering
6	Sapele road	Sapele road
7	Emotan college	Wire road
8	Igbesawan	Igbesawan(Akpakpava-Ist east circular)
9	Ugbor	Ugbor road
10	Ekhenwan	Ekhenwan road
11	Airport road	Airport road
12	Siluko road	Siluko road
13	Mission road	Mission road
14	Aduwawa	Aduwawa road
15	Benin-Lagos road	Benin-Lagos road

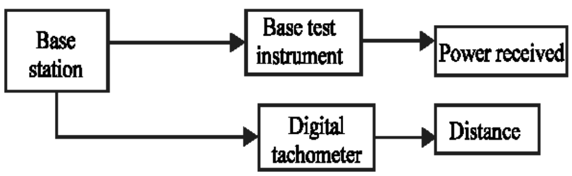

Fig. 1: Schematic diagram of measurement setup of Path loss

This was to allow for a good span to various possible climatic conditions. The measurements were taken in the active mode and not in the idle mode; this ensured that the mobile phone was in constant touch with the Base Station[1,3,9,10]. The measurements were carried out on the BCCH control channel and therefore were not affected by frequency hoping and downlink power control algorithms.

Measurement procedures: Using the measurement setup in Fig. 1 which comprises of a test handset equipped with net-monitor software in conjunction with a digital Tachometer model DT-207L to determine distance (d) from the base station. Consequently, measurement of power received at a distance (d) was conducted on the environment in Table 1. For every site undertaken, power received at a distance 100 m from base station was measured and subsequently power received at a distance interval of 100 m from the initial test point up till the distance of 1 km was measured.

DATA COLLECTION AND PRESENTATION

Power received with corresponding distance from the base station was measured in each of the environments investigated. Fifty (50) samples of Pri were taken at each of the test locations along the radio paths investigated. The average power received (MPri) for each environment was computed for analysis as presented in Tables 2-4.

ANALYSIS OF PATH LOSS DATA

Method of analysis: The use of Mat lab computer program was employed in the analysis using the least square approach. This method finds the values of the constant γ in the chosen equation using best-fitted curve approach. This is justified by the fact that the estimates obtained are the most precise, unbiased estimates that are linear functions of the observations[11].

The application of this method falls under two categories; that in which the equation to be fitted is linear in the co-efficients and that in which it is non-linear in some of its co-efficients.

Analysis of data: Let L, d and γ represent the path loss, distance from the base station and path loss exponent, respectively. Most generic system studies address networks in which all mobile units have the same area-mean received power expressed as;[11-15].

$$L = d^{\gamma} \quad (1)$$

Where γ is exponential path loss.
Hence

$$\gamma = \frac{10\log L}{10\log d} \quad (2)$$

Let Z represents the ratio of 10logL to that of log d, it follows that

$$\gamma = \frac{Z}{10} \quad (3)$$

From Eq. 2, it can be seen that a plot of 10 Log (L) against log (d) will yield a gradient equivalent to the path

Table 2: Mean power received and standard deviation for site1 to site 5

d (m)	Mpr (-dB) Site 1	SD1 (dB)	Mpr (-dB) Site 2	SD2 (dB)	Mpr (-dB) Site 3	SD3 (dB)	Mpr (-dB) Site 4	SD4(dB)	Mpr (-dB) Site 5	SD5 (dB)
100	83.23	3.47	81.89	2.16	82.48	3.59	80.54	2.61	80.19	2.98
200	87.97	6.22	86.27	3.71	88.32	3.91	87.62	3.95	89.06	5.90
300	90.76	5.38	91.55	3.48	92.70	5.45	89.96	4.30	91.41	5.82
400	98.23	8.18	93.35	8.08	97.88	4.80	95.89	3.60	97.85	6.34
500	91.90	9.08	95.34	5.43	100.33	3.37	101.27	5.77	98.43	4.58
600	102.27	9.88	101.02	6.35	100.08	6.23	104.06	5.46	99.28	4.35
700	103.67	5.10	101.47	5.63	101.97	4.84	105.96	4.96	101.32	5.31
800	109.35	6.04	110.54	6.80	106.21	4.98	109.65	4.49	107.95	4.95
900	116.42	4.07	115.73	4.00	110.09	6.33	111.69	5.60	110.94	6.94
1000	118.32	2.95	117.27	4.86	117.37	4.70	116.03	5.02	118.77	4.49

Table 3: Mean power received and standard deviation for site6 to site 10

d (m)	Mpr (-dB) Site 6	SD6 (dB)	Mpr (-dB) Site 7	SD7 (dB)	Mpr (-dB) Site 8	SD8 (dB)	Mpr (-dB) Site 9	SD9 (dB)	Mpr (-dB) Site 10	SD10 (dB)
100	81.54	4.10	80.54	3.42	79.70	2.65	77.55	2.33	83.11	3.31
200	88.07	3.89	86.12	6.33	88.21	4.83	86.40	3.61	89.63	3.85
300	89.56	5.55	89.91	5.51	93.43	3.21	91.13	3.92	92.08	4.77
400	93.50	6.22	95.04	4.66	97.33	2.55	95.90	4.55	97.25	6.02
500	95.94	9.10	97.19	6.50	99.14	5.90	98.00	3.21	99.49	7.44
600	98.33	6.76	100.38	6.26	103.23	6.11	99.96	3.67	101.36	5.19
700	100.63	7.07	102.52	5.29	105.66	6.85	101.52	4.82	102.88	5.86
800	106.26	6.29	104.71	5.90	108.35	5.88	104.16	4.97	107.62	6.55
900	108.50	7.48	107.35	5.68	109.54	5.27	105.23	5.19	111.76	7.83
1000	110.35	7.71	108.75	6.57	111.69	6.17	107.44	5.33	115.59	8.21

Table 4: Mean power received and standard deviation for site11 to site 15

d (m)	Mpr (-dB) Site 11	SD11 (dB)	Mpr (-dB) Site 12	SD12 (dB)	Mpr (-dB) Site 13	SD13 (dB)	Mpr (-dB) Site 14	SD14 (dB)	Mpr (-dB) Site 15	SD15 (dB)
100	79.09	2.11	79.27	1.97	81.57	2.84	77.25	2.22	85.11	3.66
200	86.69	2.49	85.48	2.13	86.19	1.79	83.60	2.75	90.26	3.72
300	92.52	3.69	89.91	2.88	90.36	3.27	89.07	3.52	91.88	3.95
400	96.44	2.89	94.66	2.94	95.77	3.58	96.44	3.44	96.36	4.20
500	98.86	3.22	99.34	3.11	98.22	3.96	99.67	2.90	100.99	4.76
600	100.36	3.69	100.83	3.45	99.35	4.55	100.59	3.96	106.57	5.43
700	102.71	2.78	104.55	3.78	101.11	2.79	102.36	4.60	110.43	4.18
800	108.65	4.06	106.32	2.90	105.23	4.88	104.72	5.22	115.58	5.39
900	113.72	4.53	107.11	4.31	107.77	5.30	105.55	6.19	118.92	5.67
1000	121.07	4.67	108.49	4.98	109.46	6.10	107.89	6.70	122.00	5.92

loss exponent, hence the environments investigated were plotted as shown in Fig. 2 using Mat-lab program.

In a quest to have insight to the level of crowdedness of the environments investigated, a plot of standard deviation of the received power against distance from the base station was done for the environment investigated as shown in Fig. 3 The standard deviation is totally due to the variation of the terrain configuration and the human made structure. These plots give the Location variability of the Investigated environments.

DETERMINATION OF PATH LOSS EXPONENT

The values of path loss exponent (γ) and the intercept (C) obtained from the graphs are tabulated in Table 5. In order to determine the path loss exponent of the City, we propose that the average path loss exponent of the investigated environments be used as the path loss of the City. Thus

$$\gamma = 3.25$$

Let us assume that the propagation path loss characteristics of the city obeys the linear rule of the form;

$$L = \gamma \log(d) + Cavg \quad (4)$$

Cavg, represents the average of the intercepts of all the environments investigated. Using Table 2, 3, Cavg was calculated as 12.32, Substituting the values of γ and Cavg into Eq. 4 yields

$$L = 33\log d + 12.32 \quad (5)$$

Fig. 2: Combined path loss plot of the investigated environment

Fig. 3: Combined location variability plot of the environments investigated

Table 5: Table showing the values of γ obtained for the radio environments investigated

Environments	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
VALUES OF γ	3.4	3.5	3.1	3.5	3.3	2.8	2.9	3.2	2.9	3.0	3.7	3.7	2.8	3.2	3.8
VALUES OF C	9.5	6.1	18	6.4	11	22	20	15	19	19	1.1	1.1	22	12	2.6

Table 6: Table showing the path loss exponent and path loss characteristic of benin city

Path loss exponent	3.3
Path loss characteristics	33 Log d +12.32

RESULT PRESENTATION FOR PATH LOSS

From the analysis conducted, the value of the path loss exponent and the path loss characteristics of Benin City are presented in Table 6.

DISCUSSION

The combined path loss and its location variability for different environments as shown in Fig. 2 and 3, respectively suggest the following:

- The location variability for environment 13 (mission road) was the highest followed by environment 6 (Sapele road) and next was environment 2 (Ikpoba hill) with peak location variability of 9.8 dB, 8.8 dB and 7.8 dB, respectively. The environment with the least path loss variation was that of 12 (Siluko road) followed by environment 11 (Airport road) with a peak location variability of 3 dB and 3.2 dB, respectively.

- Environment 15 (Benin-Lagos road) has the highest path loss exponent of 3.8 followed by environment 11 (Airport road) and environment 12 (Siluko road) with the same path loss exponent of 3.7. Environment 6 (Sapele road) has the least path loss exponent followed by environment 7 (Wire road) with values of 2.8 and 2.9, respectively.
- We have repetition of path loss exponent, which suggest similarities in the human made structure, multiple-path fading and the topology of the environment. These environments are 11 and 12 with exponent of 3.7, environment 2 and 4 with path loss exponent of 3.5, environment 7 and 9 with exponent of 2.9 and environment 6 and 13 with exponent of 2.8, respectively.
- We can therefore state that the path loss exponent of the city is between 2.8 and 3.7. The average value of path loss constant for Benin City is 3.3.

CONLUSION

One of the major parameters of interest in the analysis of radio-wave propagation of mobile communication is the propagation path loss characteristics of an environment The study embarked upon to investigate the behaviour of GSM signals in our own environment so as to determine the propagation path loss exponent reveals that the path loss exponent of Benin City is 3.3. With this parameter, mobile communication planning and propagation analysis of Benin City in future can be done with ease.

NOMENCLATURES

C	Carrier level
I	Interference level
Pri	Sample power received
MPri	Mean power received
L	Path loss
d	Distance from a base station
γ	Path loss exponent
Z	Ratio of 10 Log L to Log d
GSM	Global system of mobile communication
BCCH	Broadcast control channel

REFRENCES

1. Maurer, J., 2001. A realistic description of the environment for inter-vehicle wave propagation modeling, IEEE vehicular technology conference (VTC-fall), pp: 1437-1441.
2. Rautiainen, T., 2001. Verifying path loss and delay spread predictions of a 3D ray tracing propagation model in urban environment. IEEE.
3. Bargonovo, F., 1988. The impact of signal strength measures on the efficiency of dynamic channel allocation techniques, IEEE international conference on communications, pp: 1400-1404.
4. Takahashi, S., 2004. Distance dependence of path loss for millimeter wave inter-vehicle communication, IEEE Radio Engineering.
5. Iida, T., 2002. Wireless communication R and D in the science and technology policy in Japan, IEICE Transaction, pp: 419-427.
6. Sulonen, K., 2000. Comparison of evaluation methods for mobile handset antenna Proceeding of millennium conference on antennas and propagation (AP2000), Davos, Switzerland.
7. Li, J., 2000. Optimal dynamic mobility management for PCs network, IEEE/ACM transaction networking, pp: 319-327.
8. Bongsue, S., 2003. An efficient paging strategy based on paging agents of base stations in cellular mobile network, ETRIJ, pp: 55-58.
9. Dobkin, D., 2002. Indoor propagation and wavelength, wj communication J., pp: 1-3.
10. Kumar, S., 1999. Microwave indoor radio propagation measurements and modeling at 5GHZ for future wireless LAN systems, Asia pacific microwave conference (APMC'99), pp: 606-608.
11. Kimmo, K., 2001. Directional radio measurement at mobile station in different radio environments at 2.15Ghz, EPMCC, © 2001 by OVE.
12. Kato, A., 2001. Propagation characteristics of 60-Ghz millimeter waves for ITS inter-vehicle communications. IEIICE transaction, communication, pp: 2530-2534.
13. Thiago, H., 2001. A system for propagation analysis in mobile communication environments, Instituto Nacional de Telecomunicacoes.
14. Dons, G., 2003. Model system overview, COSMO newsletter, no. 3, Deutscher wetterdienst, offenbach, Germany, pp: 9-23.
15. Iskander, M., 2001. Outdoor/Indoor propagation modeling for wireless communication system, 2001 IEEE Antennas and propagation society Intl. symposium, pp: 150-153.