Determination Of Path Loss Exponent And Shadowing For Wireless Network In Outdoor Environment

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***Abstract*— In this paper, the determination of path loss exponent and shadowing for wireless network in outdoor environment for the 1800GHz frequency band is presented. The field measurement study site was the region surrounding the Faculty of Engineering in the main campus of University of Uyo, The received signal strength intensity (RSSI) from the 1800GHz network base station was captured using G-NetTrack Lite 8.0 android app installed on smart phone. The measured RSSI values were used in link budget analytical expression to determine the measured pathloss. . The results showed that the pathloss exponent for the case study site is 2.31 while the shadowing parameter is 4.69. The results are comparable with published works which state that the range of values for pathloss exponent is from 2 dB to 6 dB and the range of values for shadowing parameter is 4 dB to 13 dB. Furthermore, the pathloss exponent and shadowing parameters were used in the prediction of the pathloss for the study area and the prediction performance in terms of root means square error (RMSE) value of 7 dB was obtained.**

Keywords*— *Path Loss Exponent, Link Budget, Shadowing, Pathloss Model, Wireless Network, Log – Distant Path Loss, Empirical Measurement

1. Introduction

Today, the whole world is enjoying the numerous benefits of wireless communication technologies [1, 2, 3, 4,5, 6,7, 8,9]. As such, the adoption of the wireless communication technologies has continued to grow and to permeate other areas of applications. The rising Internet of Things (IoT) applications also depends on reliable deployment of wireless communication networks [10,11, 12,13, 14,15, 16,17, 18,19, 20, 21]. In view of these, researchers and industrial experts are at the fore front to come up with technological solutions that will ensure reliable wireless communications for the diverse application areas.

In all, one of the inevitable issues regarding the deployment of wireless communication network is the path loss that is normally caused by several factors 22,21, 23,24, 25,26, 27,28, 29,30, 31,,32, 33,34, 35,36, 37,38,39]. The losses can limit the network achievable transmission range and performances [40,41, 42,43, 44,45, 46,47,48, 49,50,51,52,53,54,55,56,57,58,59]. Most of the prominent causes are obstacles along the signal path and such obstacles cause shadowing [60,61,62,63,64,65,66]. In practice, path loss models have been developed to define the path loss in respect of the different factors or parameters that can be associated with the loss in the signal strength. One of such path loss model is the log – distant path loss model [67,68,69,70,71]. In this model, there is path loss exponent which is the gradient of the path length component in the model. In order to accurate estimate path loss in a given environment using the log – distant path loss model, the path loss exponent must be determined. Also, the model has the shadowing effect which also need to be determined. Therefore, in this paper, the determination of path loss exponent and shadowing effect based on empirical measurement is presented. The details of the empirical measurements and accompanying computations for the determination of the appropriate path loss exponent and shadowing parameters values for the case study sight are presented.

2. Methodology

The log – distant path loss with shadowing, denoted as PL_d is computed using the analytical model expressed as;

$$PL_d = \overline{PL_{d_0}} + 10n\log_{10}\left(\frac{d}{d_0}\right) + \sigma \quad (1)$$

Where σ is used to represent the shadowing parameter and n σ is used to represent the pathloss exponent. In order to determine n and σ, empirical measurement of pathloss, PL_d was conducted in a case study site. The 1800GHz frequency was considered in the study and the study site is the region surrounding the Faculty of Engineering in the main campus of University of Uyo, as shown in the Google map screenshot of Figure 1. The received signal strength intensity (RSSI) from the 1800GHz network base station was captured using G-NetTrack Lite 8.0 android app installed on smart phone. The android app captures both the RSSI and the geo-coordinates of the data collection points. The data points geo-coordinates were used alog with the geo-coordinates of the base station to determine the distance of the path length (d). The measured RSSI were used to determine the measured pathloss using the expressions in equation 1 and equation 2. The measured received signal strength intensity (RSSI) and the corresponding measured pathloss are shown in Table 1, as well as in Figure 2 and Figure 3.

$$PL_{m(dB)} = P_t + G_t + G_r - RSSI \quad (2)$$

Where P_t =30 W which is equivalent to 44.77 dBm, G_t = 10. dBi and G_r = 0. dBi, hence,

$$PL_{m(dB)} = 54.77 - RSSI \quad (3)$$

Figure 1 Google map screenshot of the case study site which is a region surrounding the Faculty of Engineering in the main campus of University of Uyo,

Table 1 The measured RSSI and the measured pathloss

S/N	Distance in 'm'	Average measured RSSI in dBm	Pt(dBm)	Gt(dBi)	Gr(dBi)	Measured Pathloss, Plm in dBm
1	100	-58.8	44.77	10.00	0.00	113.59
2	300	-64.2	44.77	10.00	0.00	118.95
3	500	-70.1	44.77	10.00	0.00	124.84
4	700	-82.6	44.77	10.00	0.00	137.40
5	900	-81.5	44.77	10.00	0.00	136.31
6	1100	-80.1	44.77	10.00	0.00	134.84
7	1300	-83.3	44.77	10.00	0.00	138.11
8	1500	-76.4	44.77	10.00	0.00	131.19
9	1700	-90.4	44.77	10.00	0.00	145.15
10	1900	-94.2	44.77	10.00	0.00	148.99
11	2000	-93.6	44.77	10.00	0.00	148.38

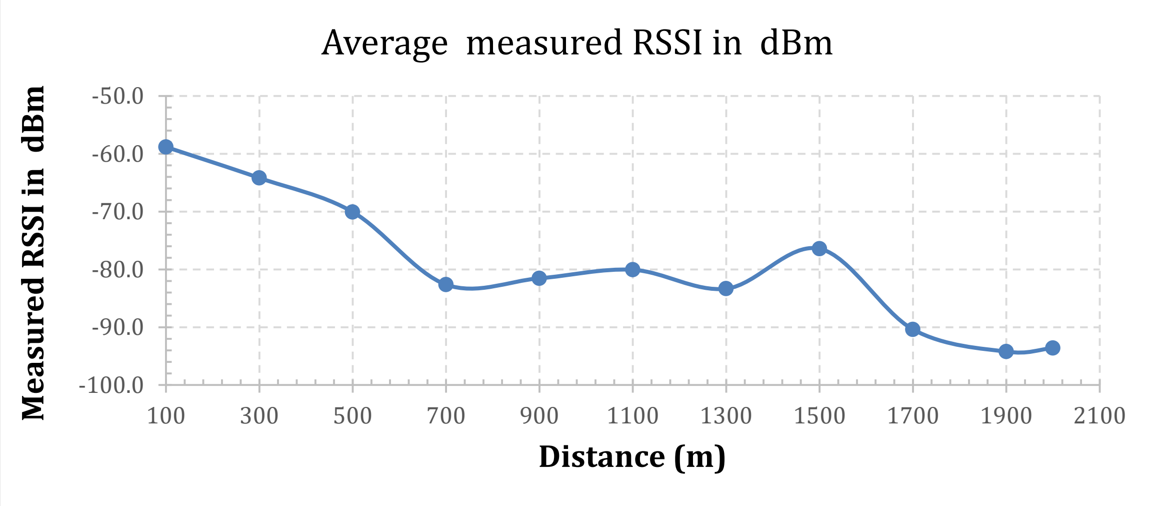

Figure 2 The graph of measured received signal strength intensity (RSSI) versus distance (d)

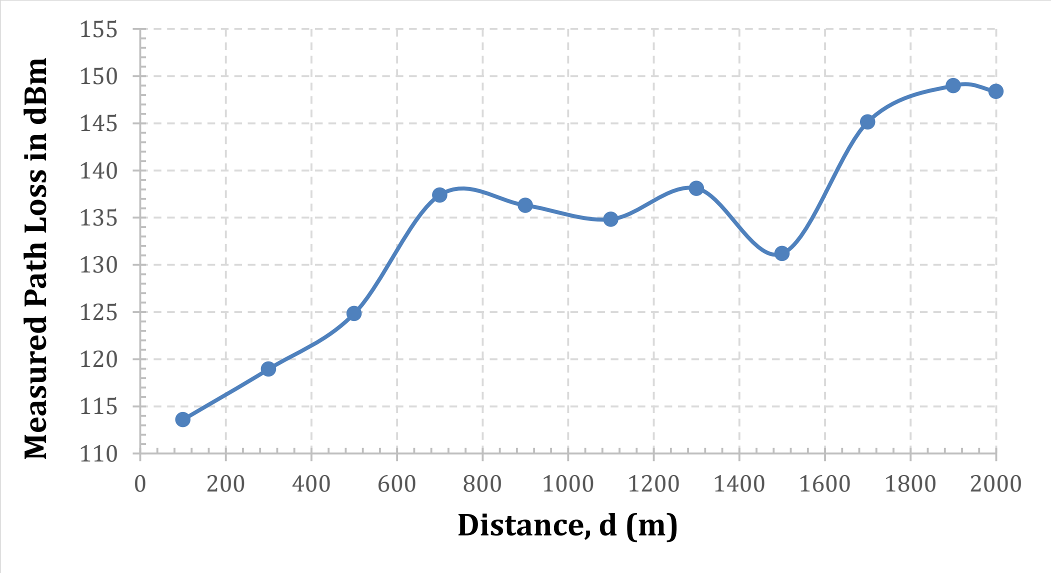

Figure 3 The graph of measured pathloss versus distance (d)

3. Results and discussion

The measured pathloss and their corresponding distance were used to determine the pathloss exponent, n and the shadowing parameter, σ. The layout of the intermediate computation values are given in Table 2. The computation of N and σ based on the values in Table 2 are given in equation 5 to equation 9. In all, the pathloss exponent, n is found to be 2.31 while the shadowing parameter, σ is 4.69. The results are comparable with published works which state that the range of values for n is from 2 dB to 6 dB [72,73,74,74] and the range of values for σ is 4 dB to 13 dB [72,73,74,74]. The pathloss exponent and shadowing parameters were used in the prediction of the pathloss for the study area and the error performance in terms of root means square error (RMSE) value of 7 dB was obtained, as shown in Table 3, where RMSE is given in terms of measured pathloss, Plm and predicted pathloss, Plp as follows ;

$$\text{RMSE} = \sqrt[2]{\left\{\frac{1}{N}\left[\sum_{i=1}^{i=n}\left|P_{lm(i)} - P_{lp(i)}\right|^{2}\right]\right\}} \qquad (4)$$

The graph of the measured and predicted pathloss versus distance are shown in Figure 4.

Table 2 Measured RSSI, Measured Pathloss and the components used for the computation of n and σ

S/N	d (m)	Measured Pathloss, Plm (dBm)	Predicted Pathloss, Plp in dBm	Plm - Plp (dBm)	(Plm - Plp)^2
1	100	113.589	113.589 + 0n	0 + 0 n	0
2	300	118.948	113.589 + 4.8n	5.3588 + 4.8 n	23.04 n^2 -51.44448 n + 28.71673744
3	500	124.835	113.589 + 7n	11.2455 + 7 n	49 n^2 -157.437 n + 126.46127025

4	700	137.395	113.589 + 8.5n	23.8055 + 8.5 n	72.25 n^2 -404.6935 n + 566.70183025
5	900	136.307	113.589 + 9.5n	22.7176 + 9.5 n	90.25 n^2 -431.6344 n + 516.08934976
6	1100	134.834	113.589 + 10.4n	21.2444 + 10.4 n	108.16 n^2 -441.88352 n + 451.324531359999
7	1300	138.105	113.589 + 11.1n	24.5155 + 11.1 n	123.21 n^2 -544.2441 n + 601.00974025
8	1500	131.194	113.589 + 11.8n	17.6042 + 11.8 n	139.24 n^2 -415.45912 n + 309.90785764
9	1700	145.146	113.589 + 12.3n	31.5565 + 12.3 n	151.29 n^2 -776.2899 n + 995.81269225
10	1900	148.992	113.589 + 12.8n	35.4028 + 12.8 n	163.84 n^2 -906.31168 n + 1253.35824784
11	2000	148.383	113.589 + 13n	34.7931 + 13 n	169 n^2 -904.6206 n + 1210.55980761
		J(n)	**1089.14267588888 n^2 -5034.3383691539 n + 6059.94206465**		

$\mathrm{J(n)} = \sum_{i=1}^{N}\left(\boldsymbol{P}_{\mathbf{LM(i)}} - \boldsymbol{P}_{\mathbf{LP(i)}}\right)^{2}$ (5)

Where $\boldsymbol{P}_{\mathbf{LM(i)}}$ **is measured pathloss and** $\boldsymbol{P}_{\mathbf{LP(i)}}$ **is computed pathloss. Now,**

$\mathrm{J(n)} = \sum_{i=1}^{N}\left(\boldsymbol{P}_{\mathbf{LM(i)}} - \boldsymbol{P}_{\mathbf{LP(i)}}\right)^{2}$ where N =11

J(n) =**1089.14267588888 n^2 -5034.3383691539 n + 6059.94206465** (6)

$\frac{\delta(n)}{\delta(n)} = 2178.285352\,n - \mathbf{5034.3383691539}$ (7)

$$\frac{\delta(n)}{\delta(n)} = 2178.285352\,n - \mathbf{5034.3383691539} = 0$$

$n = \frac{\mathbf{5034.3383691539}}{2178.285352}$ =**2.311147327** $\approx \mathbf{2.31}$ (8)

$\sigma^{2} = \frac{J(n)}{N}$ (9)

$\sigma^{2} = \frac{\mathbf{1089.14267588888\,n^{2}\ -5034.3383691539\,n\ +6059.94206465}}{11}$ (10)

$\sigma^{2} = \frac{242.393231}{11}$ =22.03574827

$\sigma = \sqrt{22.03574827} = 4.694224992 \approx 4.69$

Table 3 The measured and predicted pathloss and the prediction error in terms of RMSE

S/N	**Distance in 'm'**	**Average measured RSSI in dBm**	**Measured Pathloss, Plm in dBm**	**Predicted Pathloss , Ppred in dBm**	**Error**	**Square of Error**
1	100	-58.8	113.6	118.2836	-4.7	22.03575
2	300	-64.2	118.9	129.3106	-10.4	107.3793
3	500	-70.1	124.8	134.4379	-9.6	92.21668
4	700	-82.6	137.4	137.8151	-0.4	0.176556
5	900	-81.5	136.3	140.3376	-4.0	16.24554
6	1100	-80.1	134.8	142.3517	-7.5	56.51949
7	1300	-83.3	138.1	144.0285	-5.9	35.089
8	1500	-76.4	131.2	145.4648	-14.3	203.6679
9	1700	-90.4	145.1	146.7211	-1.6	2.481294
10	1900	-94.2	149.0	147.8375	1.2	1.333321
11	2000	-93.6	148.4	148.3523	0.0	0.000909
				RMSE		**7.0**

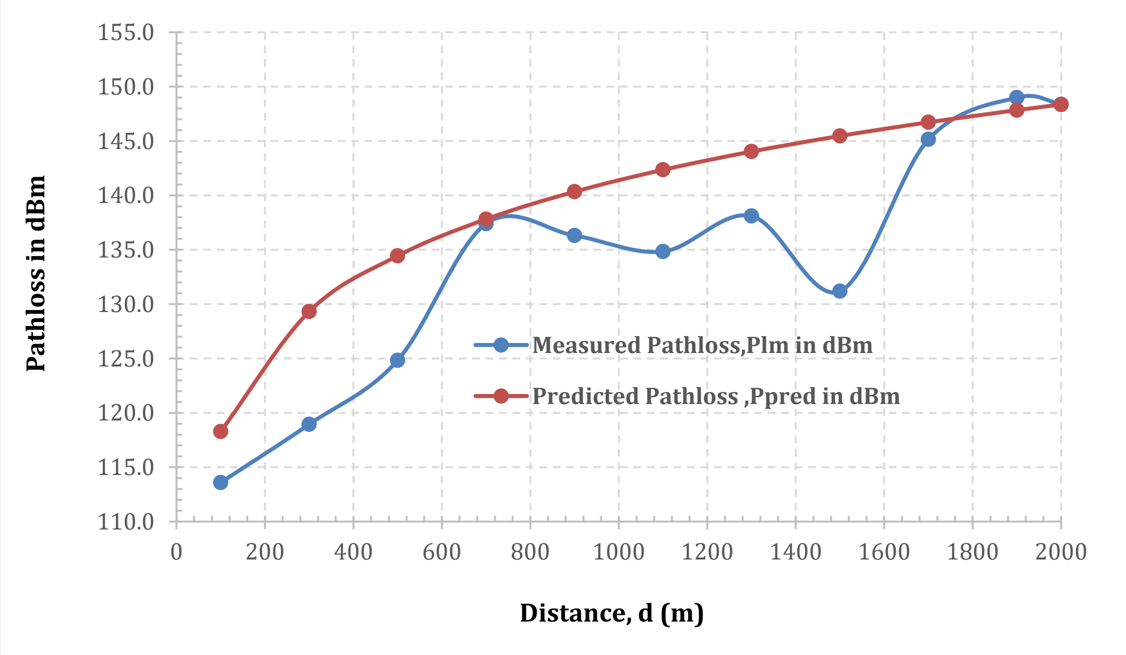

Figure 4 The graph of measured and predicted pathloss versus distance (d)

4. Conclusion

The determination of pathloss exponent and shadowing parameters for a case study site in University of Uyo permanent site is presented. The parameters were determined from an empirical measurement of received signal strength intensity (RSSI) in the study area. The RSS was then used to determine the measured pathloss from which the detail computation of the pathloss exponent and shadowing parameters were determined. The results are compared with already published range of values for such parameters and they are within the acceptable range.

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