Proceedings of TENCON 2018 - 2018 IEEE Region 10 Conference (Jeju, Korea, 28-31 October 2018)

Extended Xia Semi Deterministic Model for a Frequency of 28 GHz

Supachai Phaiboon* and Pisit Phokharatkul**

*Department of Electrical Engineering, Faculty of Engineering, Mahidol University
Buddhamonthon 4 road., Buddhamonthon, Nakornpathom, 73170, Thailand
supachai.pai@mahidol.ac.th,
**Department of Electronic and Telecommunication Engineering, Faculty of Engineering, Kasem Bundit University
Pattanakarn road., Suanluang, Bangkok 10250, Thailand
pisit.pho@mahidol.ac.th,

***Abstract*— This paper presents a semi deterministic path loss model at frequency of 28 GHz for fifth generation (5G). We modified Xia model which was used for frequency of 0.9 GHz to 2.0 GHz with a correction factor in order to use for higher frequency. Two important parameters, average building height and distance of mobile from last roof top were considered while measured data in the dense urban environment around New York University's (NYU) Manhattan campus were used for modeling and verification. Comparisons between the modified and conventional models provide all NLOS propagation including transverse, lateral, and staircase.**

***Keywords*— Extended Xia model, semi deterministic model, Millimeter-Wave Omni-directional Path Loss.**

I. Introduction

Fifth generation (5G) mobile communication is developed to in order to provide high speed data rates to a mobile device. In order to install communication station, the propagation path loss models are one of important things for the best coverage areas. The semi-deterministic models in [1]-[5] are also widely used. They not only need the parameters of the empirical model but also require some information about buildings such as dimension and type of them together with wide and direction of road. This model provides more accuracy path losses and is used for planning and solving the communication system. For semi-deterministic models, Xia et al [3] proposed path loss formulas for micro-cells in low-rise and high-rise building environments. In case of non light of sight (NLOS), it requires a set of model parameters such as average building height and distance from mobile to last roof top and antenna heights as in our research [8],[9]. However The semi deterministic models such as Xia model or WI model are used for frequencies of 4G network. Therefore this paper presents an extended version of Xia model in order to develop the semi deterministic model for 5G networks at a frequency of 28 GHz.

II. Deterministic Xia Models

The original Xia model for low-rise environments with one five story building was applied to predict path loss because it needed 2 D maps of buildings for calculation. There are three routes for prediction namely, staircase route, transverse route and lateral route as shown in Figure 1. A transmitter (Tx) was located on the street in the middle of a building block. The original Xia path loss formulas for all non line of sight cases were written as,

$$\begin{aligned} PL(d) = {} & [139.01 + 42.59 \log f_G] \\ & - [14.97 + 4.99 \log fG]\operatorname{sgn}(\Delta h)\log(1+|\Delta h|) \\ & + [40.67 - 4.57\operatorname{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \\ & + 20\log(\Delta hm/7.8) + 10\log(20/dh) \end{aligned} \quad (1)$$

Where d is the mobile distance from transmitter (km). $[0.05 < d < 3]$, f_G is the frequency (GHz). $[0.9 < f_G < 2]$, Δh is the relative height of transmitter to average building height (m). $[-8 < \Delta h < 6]$, Δhm is the height of the last building relative to the mobile (m), dh is the distance of mobile from the last rooftop (m), hb is the transmitting antenna height from ground level (m), hm is the mobile antenna height from ground level (m) and λ is the wavelength (m).

Transverse route:

$$\begin{aligned} PL(d) = {} & [139.01 + 42.59 \log f_G] \\ & - [14.97 + 4.99 \log fG]\operatorname{sgn}(\Delta h)\log(1+|\Delta h|) \\ & +[40.67 - 4.57\operatorname{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \end{aligned} \quad (2)$$

Staircase route:

$$\begin{aligned} PL(d) = {} & [137.61 + 35.16 \log f_G] \\ & - [12.48 + 4.16 \log fG]\operatorname{sgn}(\Delta h)\log(1+|\Delta h|) \\ & +[39.46 - 4.13\operatorname{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \end{aligned} \quad (3)$$

978-1-5386-5457-6/18/$31.00 ©2018 IEEE

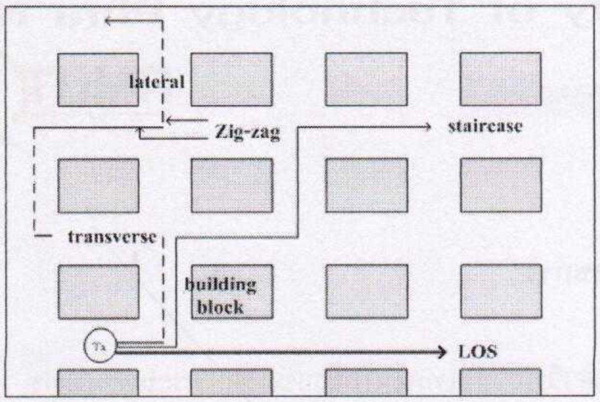


Fig. 1 Geometry of Xia model

Lateral route:

$$PL(d) = [127.39 + 31.63 \log f_G] - [13.05 + 4.35 \log fG]\text{sgn}(\Delta h)\log(1+|\Delta h|) + [29.18 - 6.70\text{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \quad (4)$$

III. Measurement and Location

This paper used measured data in the dense urban environment around New York University's (NYU) Manhattan campus at both 28 GHz [6],[7]. These measurements will be Omni directional large-scale line-of-sight (LOS) and non-line-of-sight (NLOS) directional measurements. The NYU, the building density is about 65% while the building height is about 5-50 m. The measurement procedure and description of the equipment can be found for details in [1]. The transmitting antenna heights are 7 and 17 m. The receiving antenna height is 1.5 m.

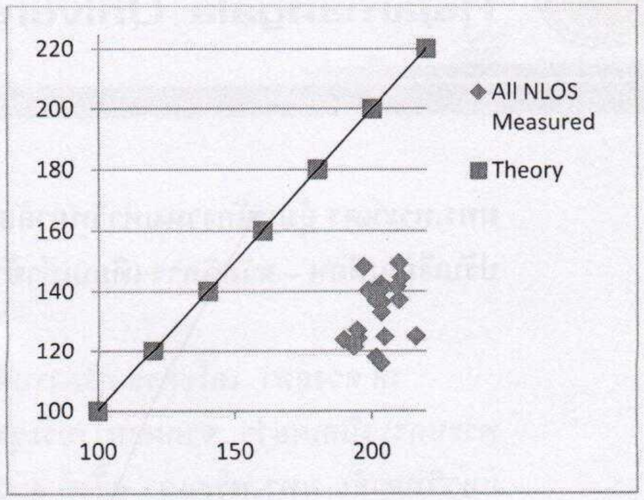
In this paper, the important parameters for deterministic model such as propagation routes, average building height and distance from last roof top are used. These parameters are obtained from local surveying in the city. All measurement data are shown in the appendix.

IV. Results and Analysis

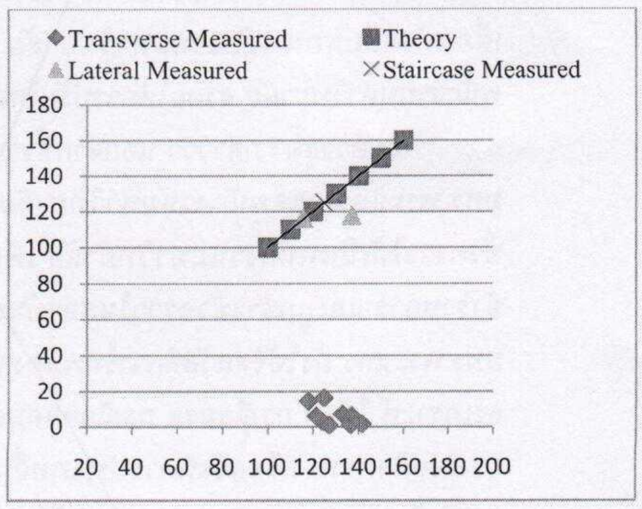
The extended Xia model at frequency of 28 GHz is as following.

All NLOS:

$$PL(d) = [69.26 + 42.59 \log f_G] - [14.97 + 4.99 \log fG]\text{sgn}(\Delta h)\log(1+|\Delta h|) + [40.67 - 4.57\text{sgn}(\Delta h)\log(1+|\Delta h|)]\log d + 20\log(\Delta hm/7.8) + 10\log(20/dh) \quad (9)$$



(a) All NLOS



(b) Separated routes

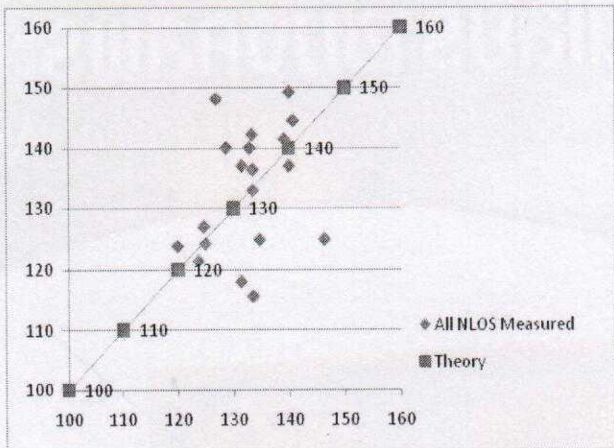
Fig. 2 Conventional Xia path loss model in dBm

Transverse route:

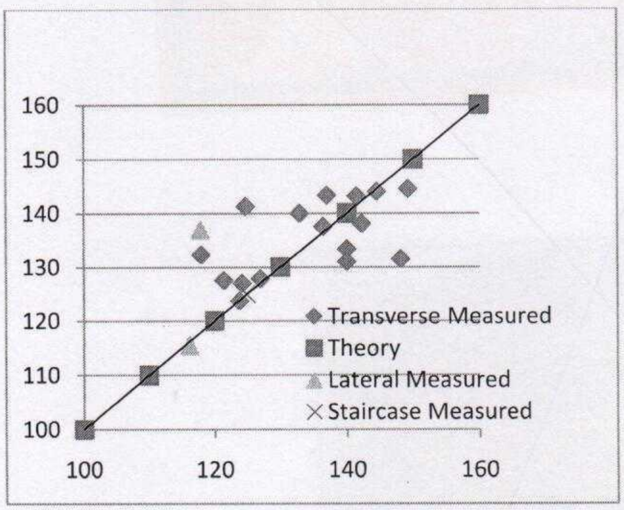
$$PL(d) = [84.66 + 42.59 \log f_G] - [14.97 + 4.99 \log fG]\text{sgn}(\Delta h)\log(1+|\Delta h|) + [40.67 - 4.57\text{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \quad (10)$$

Staircase route:

$$PL(d) = [77.51 + 35.16 \log f_G] - [12.48 + 4.16 \log fG]\text{sgn}(\Delta h)\log(1+|\Delta h|) + [39.46 - 4.13\text{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \quad (11)$$



(a) All NLOS



(b) Separated routes

Fig. 3 Extended Xia path loss model in dBm

Lateral route:

$$PL(d) = [70.89 + 31.63\ log\ f_G] - [13.05 + 4.35\ \log fG]\text{sgn}(\Delta h)\log(1+|\Delta h|) + [29.18 - 6.70\text{sgn}(\Delta h)\log(1+|\Delta h|)]\log d \quad (12)$$

Figure 2 and 3 show comparison between measurement and prediction of the conventional and extended models respectively. The separated routes provide an accuracy comparing with the all NLOS as shown Fig. 3 a) and b).

Note that the model is only used for a frequency of 28 GHz however the other frequencies need new adjustment of the arbitrary constants.

V. Conclusion

We present the extended Xia path loss models in case of line-of-sight (NLOS) at a frequency of 28 GHz. We used measured data in the dense urban environment around New York University's (NYU) Manhattan campus for fitting. The parameters for semi deterministic model such as propagation routes, average building height and distance from last roof top are obtained from local surveying. The results shown that the NLOS of Xia semi deterministic models provide an accuracy especially in case of separated routes comparing with the all NLOS case.

References

[1] H. H. Xia "A Simplified Model for Prediction Path Loss in Urban and Suburban Environments," IEEE Trans Veh. Technol., vol.46, no.4, Nov.1997, pp.1040-1046

[2] D. Har, H. H. Xia, and H. L. Bertoni, "Path-Loss Prediction Model for Microcells," IEEE Trans Veh. Technol., vol.48, no.5, Sep. 1999, pp.1453-1462

[3] J. Walfisch and H. L. Bertoni, "A Theoretical Model of UHF Propagation in Urban Environments," IEEE Trans. Ant. Prop., vol. 36, no. 12, pp.1788–1796, 1988.

[4] F. Ikegami, S. Yoshida, T. Takeuchi, and M. Umehira, "Propagation Factors Controlling Mean Field Strength on Urban Streets," IEEE Trans. Antennas. Propag., vol. 32, pp. 822–829, 1984.

[5] A.Bhuvaneshwari1,R.Hemalatha, T.Satyasavithri," Semi Deterministic Hybrid model for Path Loss prediction Improvement" *Procedia Computer Science* 92, 2016 , *pp.*336 – 344

[6] G. R. Maccartney, *et al.* "mmWave Omnidirectional Path Loss Data for Small Cell 5G Channel Modeling" IEEE Access, vol. 3, pp. 1573-1580, Sept. 2015.

[7] T.S. Rappaport *et al.*"Overview of mmWave Communication for 5G Wireless Networks" *IEEE Trans. on Antennas. Propag., vol. 65, no. 12, pp. 6213-6230. Dec. 2017.*

[8] Phaiboon S, Phokharatkul.P. "Path loss prediction for low-rise buildings with image classification on 2-D aerial photographs." *Progress in Electromagnetic Research-pier* 95, 2009, *pp.*135-152.

[9] Phaiboon S, Phokharatkul P. "Comparison between mixing and pure Walfisch-Ikegami path loss models for cellular mobile communication network." *Proceeding of PIERS*; 2009 Mar 23-27, pp. 99-104.

APPENDIX : DATA FOR MODELING

TX	RX	Env	T-R(m)	PL(dB)	Path type	Environment category	Avrage building height(m) Tx = 7 m	Distance of mobile from the last rooftop (m)
COL1	1	L	31	92.3	LOS	AIR	0	0
COL1	2	N	61	123.8	TRANSVERSE	BUILDING	46.83	46.91
COL1	3	L	102	-				
COL1	4	N	118	136.4	TRANSVERSE	BUILDING	46.83	48.80
COL1	5	N	114	115.6	LATERAL	BUILDING	87.86	108.82
COL1	13	N	133	132.9	TRANSVERSE	BUILDING	46.83	86.04
COL1	14	N	165	137	TRANSVERSE	BUILDING	41.04	41.15
COL1	17	N	82	148.1	TRANSVERSE	BUILDING	56.83	57.69
COL2	1	L	53	0	LOS	AIR	0	0
COL2	2	N	73	121.4	TRANSVERSE	BUILDING	46.83	46.91
COL2	3	N	142	119	LOS	AIR	0	0
COL2	4	N	155	141.4	TRANSVERSE	BUILDING	46.83	48.80
COL2	13	N	141	124.8	TRANSVERSE	BUILDING	46.83	86.04
COL2	14	N	171	144.5	TRANSVERSE	BUILDING	41.04	41.15
COL2	17	N	112	142.2	TRANSVERSE	BUILDING	56.83	57.69
KAU	4	N	186	149.2	TRANSVERSE	BUILDING	45.95	92.12
KAU	10	N	77	124.2	TRANSVERSE	BUILDING	48.75	48.90
KAU	11	L	54	0	LOS	AIR	0	0
KAU	12	N	120	140	TRANSVERSE	BUILDING	39.06	40.95
KAU	13	N	112	-				
KAU	14	N	82	127	TRANSVERSE	BUILDING	46.83	65.13
KAU	16	N	96	140	TRANSVERSE	BUILDING	46.83	55.13
KAU	19	N	175	137	LATERAL	BUILDING	36.52	83.19
KAU	21	N	119	118	TRANSVERSE	BUILDING	36.52	48.40
KAU	30	L	53	94.6	LOS	AIR	0	0
KAU	31	L	33	88.4	LOS	AIR	0	0