

Statistical Site-General Channel Model for Outdoor MIMO Systems Based on a Path-Morphology Concept

#Won-Jeong Jeong¹, Min-Gyeong Seo¹, Tae-Hong Kim¹
Myung-Don Kim², Seok-Hee Bae³, Jeong-Ki Pack¹

¹Dept. of Radio Science & Engineering, Chungnam National University
220 Gung-dong, Yuseong-gu, Daejeon, Korea

²Electronics and Telecommunications Research Institute (ETRI)
138, Gajeong-dong, Yuseong-gu, Daejeon, Korea

³Radio Research Agency (RRA)
370-9, seolseong-myun, Icheon, Gyeonggi-do, Korea
jeong83@cnu.ac.kr, mkseo707@cnu.ac.kr, thkim@cnu.ac.kr
mdkim@etri.re.kr, joseph@kcc.go.kr, jkpack@cnu.ac.kr

Abstract

In this paper, we propose a new method of morphology classification considering the building height, density, etc. The characteristics of path loss, delay spread(DS), angular spread(AS) of Angle of Departure(AoD) and Angle of Arrival(AoA) for each morphology were investigated by analyzing the simulation results obtained by the ray-tracing technique and a statistical modelling of the building distribution. New MIMO(Multiple-Input Multiple-Output) channel models based on the path morphology concept are also proposed.

Keywords : MIMO Path morphology Ray tracing Statistical Modelling

1. Introduction

The use of high frequency band, broad band and MIMO antenna is expected in the next generation mobile communication system. By the rapid increase of demand for wireless communications and the explosive increase of the mobile communication services, researches for optimization of next-generation mobile communication system are required.

Propagation model can be classified into site-specific model and site-general model. Site-specific model such as in ITU-R Rec. P.1411[1] needs various information(average distance between buildings, width of street, etc.) and the application of such model to real environment is quite difficult and limited. In addition, site-general model such as IEEE[2], WINNER[3] model is to classify the wave-propagation scenario into urban, suburban, rural, open area, etc. and it also has some drawbacks when applying to the systems like MIMO, which require more information on the wave-propagation path.

In this paper, we introduced path morphology concept, and proposed the method of morphology classification considering the building height, density, etc. The characteristics of path loss, delay spread(DS), angular spread(AS) of AoD(Angle of Departure) and AoA(Angle of Arrival) for each morphology were analyzed using the statistical approach. The validity of the path morphology concept as well as the morphology classification is proved.

2. Channel modelling by path morphology

In a MIMO system for increasing the information capacity of channel, it is important to model the MIMO channel, based on the information on the morphology of each multipath. As shown in Fig.1, there are many other different path morphologies even in the same urban area. Path

morphology is the concept to classify the wave-propagation environment based on the building heights and densities along the propagation path.

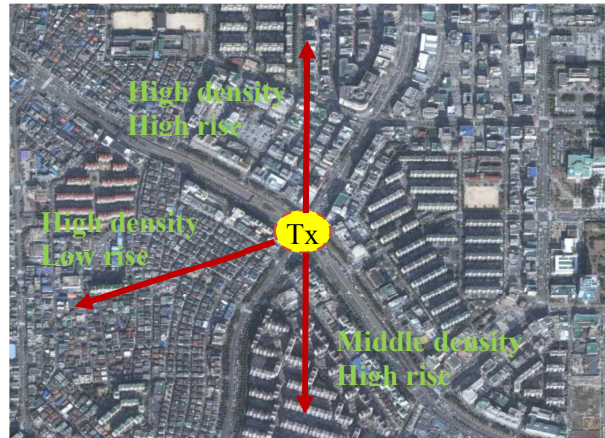


Figure 1 : Path morphology concept in a MIMO channel

In this paper, a wireless channel is classified into 9 categories by path morphology. The building height is categorized into high rise, middle rise and low rise. The building density is also categorized into high density, middle density and low density. The categorization is based on the GIS data base obtained from the satellite images. The characteristics for wave-propagation were analyzed by the simulation using ray-tracing technique, and the validity of the classification was verified.

In addition, measurement data obtained from Electronics and Telecommunications Research Institute(ETRI) were used to verify the simulation method. The measurement was performed in 9 sites. The modelling of the measurement sites was performed with the same building height and density, and the simulations using ray-tracing technique were performed with the same antenna height as the measurement. Fig.2 shows the modelling result for one of the measurement sites. It is not shown here, but the comparison of the simulation data with the measurement data showed that the simulation scheme works well.



Figure 2 : Measurement environment modelling (High rise, Middle density)

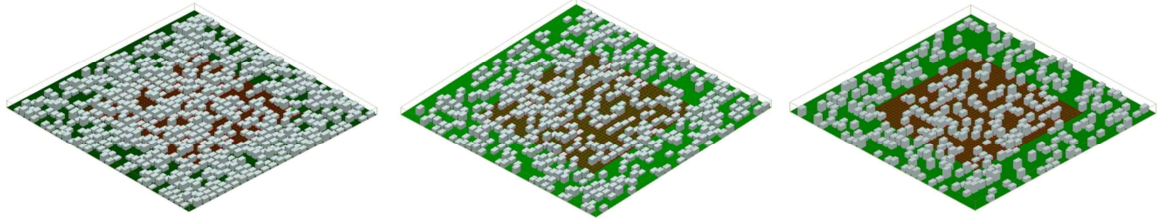
3. MIMO channel modelling using the statistical modelling approach

To derive the parameters for the MIMO channel model based on the path morphology concept, which is meaningful statistically so that it can be applied to various real environments, we developed a statistical modelling method. It should be noted that measurement data are very limited and not comprehensive.

In the statistical modelling, the buildings are generated in fully random fashion. The building-height distribution was fitted well by Rayleigh distribution, and building locations are almost uniformly distributed.

As the building height decreases, the area of the building also decreases, and thus the area of the building were set as 30 m x 20 m, 25 m x 20 m, and 15 m x 10 m for high rise, middle rise, and low rise, respectively. The dielectric constant and conductivity of buildings are $\epsilon_r=7.0$ and

$\sigma=0.015$ S/m, and the thickness of concrete is 30 cm. Fig.3 shows some of the simulation environment, which are generated statistically.



(a) High density(40 %) (b) Middle density(30 %) (c) Low density(20 %)

Figure 3 : Example for modelling of propagation environment(high rise)

The modelling area is 1,000 m x 1,000 m, and the effective area excluding boundary area(shaded area in Fig.3), in which transmitter and receivers are located, is 600 m x 600 m. The 3,600 receiver antennas are located equally at 10 m distance, and at the height of 2 m from the ground. The pattern of the transmitting antenna is omni-directional and the transmitting antenna was located at 5 m. The operating frequencies are 2.3 GHz and 3.7 GHz, and the frequency of 3.7 GHz is candidate frequency for next-generation mobile communication, and the transmitting power is set to 35 dBm. Simulations were performed using ray-tracing technique to obtain the parameters for path loss, delay spread and angular spread.

The path-loss model used in this paper is given by equation 1[5].

$$PL[dB] = PL_0[dB] + 10n \log(d[m]) \quad (1)$$

in which PL_0 is the path loss at 1 m distance and n is the path loss exponent. The definitions used for DS, AoD and AoA are as usual.

The path loss exponent, DS, AoD and AoA for some path morphologies at 3.7 GHz are shown in Table 1 and 2.

Table 1 : Analysis of wave-propagation characteristics by density

Rise	Density	n	DS [nsec]	AS	
				AoD[°]	AoA[°]
High rise	High density	3.59	180	55.71	42.75
	Middle density	3.40	190	43.65	54.53
	Low density	3.21	293	29.90	56.93

Table 2 : Analysis of wave-propagation characteristics by building height

Rise	Density	n	DS [nsec]	AS	
				AoD[°]	AoA[°]
High rise	High density	3.59	180	55.71	42.75
Middle rise		3.43	195	29.28	47.58
Low rise		3.37	232	20.83	53.24

It is not fully shown here, but the wave-propagation characteristics were almost the same for both frequencies. The results show that the values of path loss exponent tended to increase as the building height and density increases. This is due to the increase of the multipath reflection as the building height and density increase. In case of DS, however, it is getting smaller as the building height and density become higher, and vice versa for AS of AoD. This is because the propagation distance becomes shorter when the building height and density is high. The tendency of AoA can be understood in the similar context. On the other hand, AoD gets larger for higher density and higher height, since rays with the larger AoD have better chance to reach the receiver points.

4. Conclusion

In this paper, a new path morphology concept was proposed to model the wave-propagation environments for the MIMO-like systems in which more detailed information on building distributions along the path. The wave-propagation environments were classified into 9 categories based on the GIS data for real environment. The statistical modelling method was also introduced, and the wave-propagation characteristics for 9 path-morphological environments at 2.3 and 3.7 GHz were analyzed using the ray-tracing simulation.

As discussed above, the characteristics of path loss, delay spread and angular spread can be well understood qualitatively. In addition, the quantitative analysis of the values of parameters for path loss, delay spread and angular spread shows that they are distinctive for 9 environments and the trend is well understandable, even though the whole numerical results are not shown here. The method of classification of wave-propagation environment using path morphology concept, the statistical modelling method for MIMO channels, and the propagation data about path-loss and multipath parameters at 3.7 GHz band were adapted to revise the Question ITU-R Rec.P.1411-5 in Working Party 3K in the 2010.

References

- [1] ITU-R, "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz", ITU-R Rec P.1411-5, 2009.
- [2] Vinko Eroeg, Zyray Wireless, et al., "TGn Channel Models", IEEE 802.11-03/940r, 2004.
- [3] WINNER II WP1: "WINNER II Channel Models", Deliverable D1.1.2, 2007.9.30.
- [4] Won-Jeong Jeong, Ji-Ho Yoo, Tae-Hong Kim, Myung-Don Kim, Hyun-Kyu Chung, Seok-Hee Bae, Jeong-Ki Park, "MIMO Channel Modelling using Path morphology", AP-S/URSI, 2010.
- [5] D. de Luca, F. Fiano, F. Mazzenga, C. Monti, S. Ridolfi, and F. Vallone, "Outdoor Path Loss Models for IEEE 802.16 in Suburban and Campus-Like Environments", ICC '07. Pp. 4902-4906, 2007

Acknowledgments

This work was supported by IT R&D program of KCC/KCA of Korea [09911-01104, Wideband Wireless Channel Modelling based on IMT-Advanced]