Path Loss Analysis and Verification by Ray-Tracing for 3.5GHz Outdoor Environments

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***Abstract*— This paper presents the channel propagation characteristics analysis in 3500MHz outdoor environments and verification by Ray-Tracing simulations. Because we are studying small cell hot spot environment, we use 3500MHz. We describe a computer program to predict radio propagation in buildings, based on site-specific information, such as wall locations and building materials. Line-of-sight, specularly transmitted, specularly reflected, and non-specularly transmitted and reflected rays are included in the model. Actually, we considered two places, each one with different environmental conditions: one was Dunsan-dong and the second was the Electronics and Telecommunications Research Institute (ETRI). We measured the path loss and, to verify our measurement results, we compared them with Ray-Tracing results.**

Keywords- path loss; outdoor path analysis; Ray-Tracing.

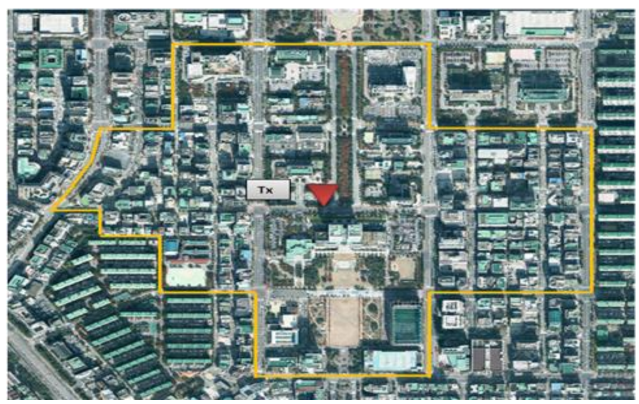
I. Introduction

The purpose of the experiment is to analyze the channel propagation characteristics. Currently, the rapid increase in demand for wireless communication and the explosive growth of the mobile communication service require optimization of the next generation mobile communication system. The development of efficient frequency use and study of competitive next generation radio transmission technology are based on the exact identification of the radio channel characteristics. Path loss is one of the many channel parameters that can represent radio channel characteristics. Also, microcellular path loss can be predicted from the Ultra High Frequency (UHF) [1]. Finally, the experiment was difficult to execute because of poor meteorological conditions such as rain, preventing the progress of the experiment.

In this paper, we present results that were obtained in the ETRI and Dunsan- dong outdoor environments. We used a lisotropic antenna with 3500MHz frequency. Many people claim that 3500MHz is the frequency of 5G. For this reason, we decided to analyze the 3500MHz. The power was different in the two locations: for ETRI, it was 0.974W and for Dunsan-dong it was 2W. We focused on propagation characteristics, which are important for the development and validation of a realistic channel model. No experiment was performed in bad weather, so there were difficulties or obstacles in that regard. We compared the measurement results and simulation results from the Ray-Tracing 3D simulator to verify our data. This paper is structured into 4 sections. In Section II, we explain the measurement environments. In Section III, we perform channel characteristic analysis and in Section IV we deal with verification of path loss analysis using Ray-Tracing. We conclude in Section V.

II. Measurement Evironments

The measurements were performed in 2 places in Daejeon using an antenna array mounted on a car. These places are shown in Figure 1. We used a 1-by-1 antenna, i.e, Single-Input Single-Output (SISO) and the wideband radio channel measurement system was the channel sounder.



(a) Dunsan- dong

(b) ETRI

Figure 1. Measurement area

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As shown in Figure 1, the measurement scenarios consist of 2 different Tx locations and Rx routes. Dunsan-dong Tx is inside a building and ETRI is in stadium. During the measurements, the Tx was stationary at each site, while the Rx was driven along the measurement routes. TABLE I shows the detailed information of the measurement places.

TABLE I. THE DETAILED INFORMATION OF MEASUREMENT PLACES

Location	Feature
Dunsan dong	· High-rise buildings (above 10 floors) and many lanes road , heavy traffic
ETRI	· Low-rise buildings (above 6 floors) and many lanes road , light traffic

Antenna was located in the middle of the rooftop on the motor vehicle at a base station (BS) with the antenna height of 7.3 m. The mobile station (MS)'s antenna with the antenna height of 2 m was set on the end of the rooftop on the motor vehicle because we could ignore the reflection since the absorber was installed on the rear surface of the vehicle. TABLE II shows the information related to the channel sounder system.

TABLE II. CHANNEL SOUNDER SYSTEM

Item	*Specification*
Center Frequency	*3.5 GHz*
PN Length (Pseudo Random Noise Swquence)	*32768 chips*
Number of Antenna	*Tx : 1, Rx : 1*
Antenna Height	*Tx : 7.3 m, Rx : 2 m*
RX ADC	*Sampling : 209MSa/s*
Tx Output Power	*Max. +33dBm*
Tx/Rx Antenna Gain	*5.82dBi*

The measurement frequency was 3.5 GHz and PN length was 32768 chips. The sample data was the transmission of two million per second, the maximum transmit power of 33dBm in Tx. SISO was the antenna that we used.

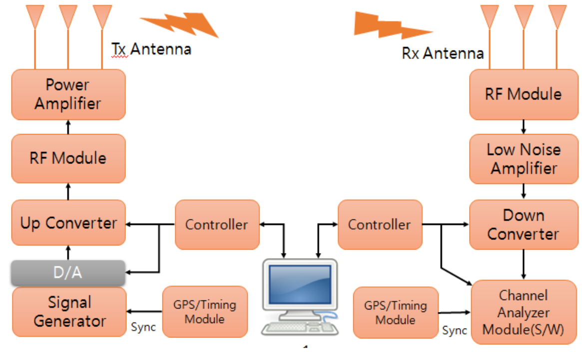

Figure 2. Measurement system configuration

Figure 2 shows our measurement system. The transmission data consisted of $209*10^6$ samples, and the communication took place via an antenna through the RF (Radio Frequency) module and the Power Amp.

III. CHANNEL CHARACTERISTIC ANALYSIS

Path loss is a major element in planning cell coverage. In the UHF (Ultra High Frequency) band case, there are many existing models. For example, Kronrcker model, Weichelberger model, etc. But, there are few studies on peer to peer signal attenuation at 700 MHz frequency. The propagation of energy from the transmitter to the receiver occurs in various modes. Because of this, it is important to recognize the path loss dependence. The path loss is extracted from the measurements and comparisons are made with the results [2][3].

The distance-dependent part of the path loss is modeled to be a function of the geometrical distance, d, as

$$P_L(d) = L_0 - 10n\log_{10}\left(\frac{d}{d_{\text{ref}}}\right) + X_\sigma, \qquad [\text{dB}] \qquad (1)$$

where L_0 is the initial value at the reference distance d_{ref} and n is the path loss index, and X_σ is standard deviation. The measured received power values indicate that the path loss decreases when the receiving vehicle moves because that path loss is reduced in a logarithmic form [4].

Measurement was performed at each place per 100 m, and over 100 times of each test point. Path loss occurs when the signal passes through a radio channel. Figure 3 shows the path loss that occurs when the car moves 10m~500m .

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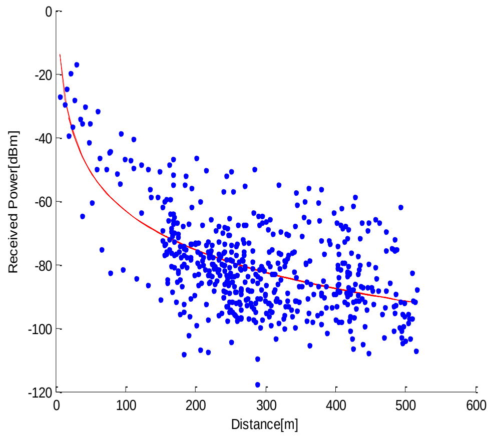
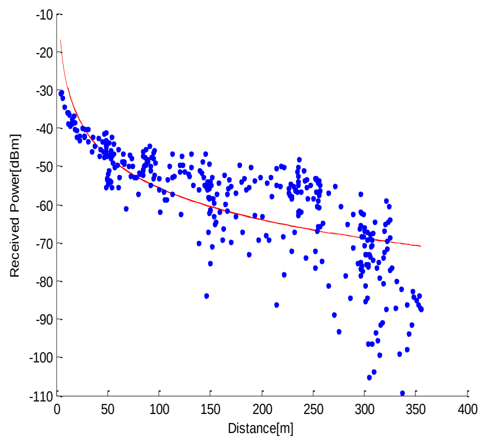


(a) Dunsan - dong



(b) ETRI

Figure 3. Received level of our measured data

Comparing the two measurement areas, we can see that the Dunsan - dong has a large power attenuation. It means that, when the radio wave moves in the wireless channel, lots of elements interrupt the flow of the radio wave. Actually, high rise buildings, large pedestrian population and vehicles added a lot more distractions. Table 3 shows the measurement environment by a constant value.

TABLE III. COMPARE THE MEASUREMENT ENVIRONMENT BY A CONSTANT VALUE

Measurement conditions					***Path loss (P_L)***		
Area	***f*(GHz)**	**h_b(m)**	**h_m(m)**	**d_{ref}(m)**	**l_0**	***n***	**X_s(dB)**
ETRI	3.5	7.5	2.0	20	4.367	3.43	11.2
Dunsan-dong					-20.06	4.2	8.91

According to the above results, path loss characteristic is distance-dependent. Dunsan-dong PL Initial Value and PL index are much bigger than ETRI. But the result of standard deviation is different; ETRI is bigger than Dunsan – dong.

IV. VERIFICATION OF PATH LOSS ANALYSIS USING RAY-TRACING METHOD

A. *Ray-Tracing simulation configuration*

To verify the validity of the measurement results, we made a simulation based on the ETRI and Dunsan-dong cases. Then, we compared the simulation results with our measurements. We made a 3D model similar to the real environment for Ray-Tracing simulation. In the Ray-Tracing we used quality of the material. A software application has been written to implement the model as an automated propagation prediction tool. The program uses Ray –Tracing to account for all possible propagation paths. Ray-Tracing is commonly used for computer image rendering and for computer animation. Ray-Tracing is used instead of electromagnetic image theory so various channel geometries can be considered. Image theory is cumbersome when randomly oriented objects or multiple reflections are considered. As computation times increase, Ray-Tracing acceleration techniques are employed to combat the computational requirements of Ray-Tracing. In Ray-Tracing we set up some materials [5].

Floor and buildings are concrete, forest and trees are wood, and finally, tennis court is sandy soil. Figure 4 and 5 show the Ray-Tracing simulation configuration for ETRI and Dunsan – dong, respectively.

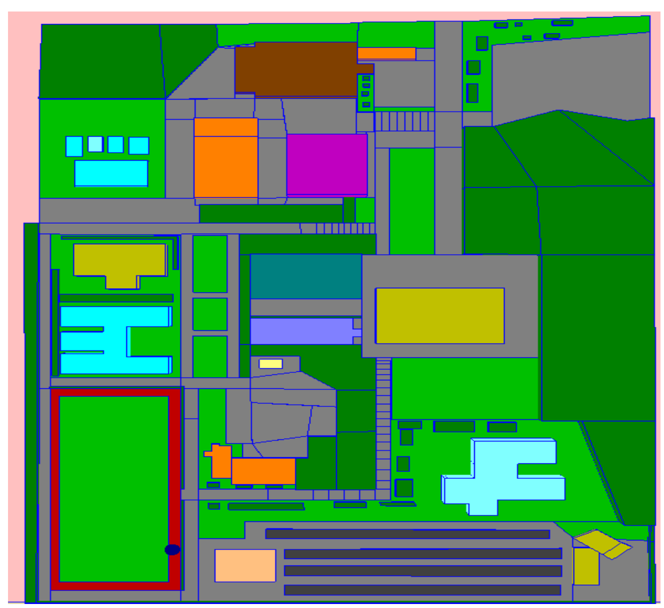


Figure 4. Simulation configuration of ETRI case

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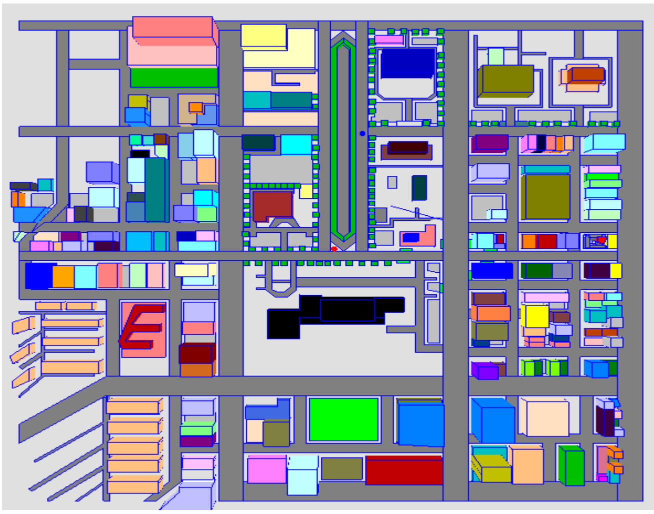
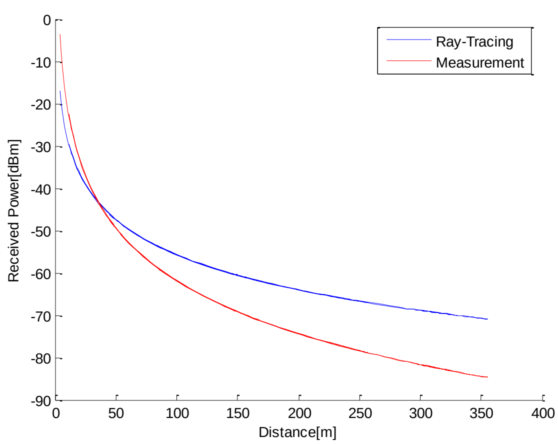


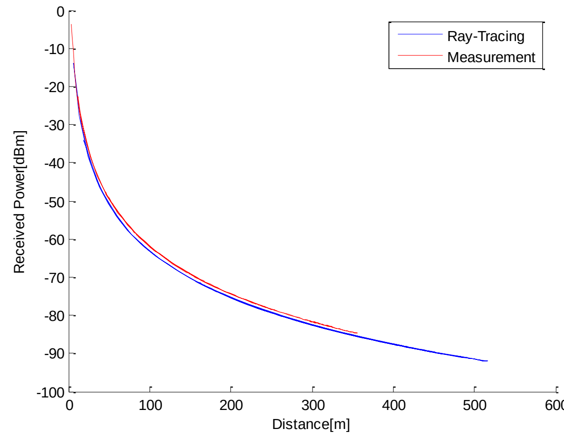
Figure 5. Simulation configuration of Dunsan - dong case

B. *Verification of our measurement result*

Figure 6 shows a comparison between Ray-Tracing and our measurement data. The red line represents the measurement results and the blue line is the Ray-Tracing simulation result. In ETRI, the result of Ray-Tracing and measurement are little bit different. The reason is that, in ETRI, there are many hills and it is very difficult to express that in Ray-Tracing. This is this reason why the graph is not perfect match. But, in Dunsan-dong, the 2 graphs are similar.



(a) ETRI



(b) Dunsan - dong

Figure 6. Comparison between Ray-Tracing and measurement

V. CONCLUSION

We presented a measurement system, and measured the characteristics of the wave propagation in the outdoor environment at 3500MHz. We deduced path characteristics for SISO wireless mobile communication systems in the outdoor environments from the measured data. Also, we compared path characteristics with simulation results obtained by Ray-Tracing. From the comparison results, we conclude that there is little difference in path characteristics. Path loss characteristics have different trend in the Dunsan-dong and ETRI case. In ETRI, there are many different materials so, the graph is a little different. So, we need to make a new path loss model for new mobile communication system. Finally, to verify the validity of the analysis results, the measurement data is compared to simulation results. The measurement data and simulated data show similar inclination, which leads us to believe that our measurements are correct.

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