Channel Measurement and Characteristics Analysis on 3.5GHz Outdoor Environment

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Abstract— **If the channel characteristics of an outdoor cell are known, it makes it possible to use the optimal frequency and to optimize the system design. This paper presents the correlations between channel parameter Path Loss (PL), root mean square Delay Spread (DS), and K-factor established based on channel measurements. The channel measurements were performed in a 3.5 GHz Non-Line of Sight (NLOS) environment. We measured the channel characteristics in Dunsan area in Korea using a channel sounder and 1×1 antennas. The correlations between channel parameters show that the wireless channel characteristics can be determined and effective communication system design can be produced for use in similar environments.**

Keywords-Channel parameter; Mobile communication; Correlation coefficients.

I. Introduction

It is important to analyze the radio channel parameters from the latest high-speed wireless communication [1]. A sharp demand for wireless communications requires the development and optimization of the next generation mobile communication system. Development of efficient frequency use and study of a wireless transmission technology having high competitiveness is based on the understanding of the correct radio channel characteristics. Radio channel characteristics are based on the channel parameter analysis. Channel parameter analysis is helpful in understanding the characteristics of the propagation channel space and have a significant impact on the design of the mobile system. Current wireless channel models were established through measurement of a wide range of channel 800MHz ~ 2.5GHz band. Typically, it is used to establish, based on the channel model for the International Telecommunication Union (ITU) standard channel model [2]. Propagation Modeling and Analysis for the current below 6GHz band is being studied in major countries such as the United States, Europe, Japan progress. In addition, the international standards organization [ITU, Institute of Electrical and Electronics Engineers (IEEE), 3rd Generation Partnership Project (3GPP), WINNER] has proposed a standard and modeling results of the analysis method [3].

Recently, many countries and international standardization organizations are working to examine the next-generation mobile (5G) wireless communication system using a range of frequencies below 6GHz. Therefore, it is determined that the prior studies of the same frequency band are necessary in Korea. International standards organizations have classified bandwidth utilization as high as 3GHz ~ 4GHz frequency among the next generation of mobile communications. In this paper, the selection of a 3.5GHz band and the analysis of the propagation characteristics of the channel parameters are measured and presented based on the correlation between the parameters. Analysis of the channel in such an environment will facilitate the system design of future communication systems.

This paper is organized as follows. Section 2 is an introduction section; Section 3 presents the channel characteristic parameters and correlation analysis with related measurement data; Section 4 provides a summary and conclusions of the this paper.

II. Measurement System

A. System environments

This study analyzes the propagation characteristics in the frequency band of 3.5GHz for a 5-generation wireless mobile communication system. We focused on the primary channel characterization of the physical channel. Hence, we constructed a measurement system to analyze the propagation characteristics.

We took our measurements on the Dunsan area using 1×1 antennas and a channel sounder from the Korea Electronics and Telecommunications Research Institute (ETRI). We were using the channel sounder to the system. Further details are shown in Table 1.

Table I. Channel Sounder System

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

The measurement frequency was 3.5 GHz and Pseudo Random Noise Sequence (PN Codes) was using 32768 chips. The sample data was the transmission of two million per second, the maximum transmit power of 33dBm is Tx.

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Antenna gain is 5.82dBi in one. We used a 1-by-1 antenna, i.e, Single-Input Single-Output (SISO).

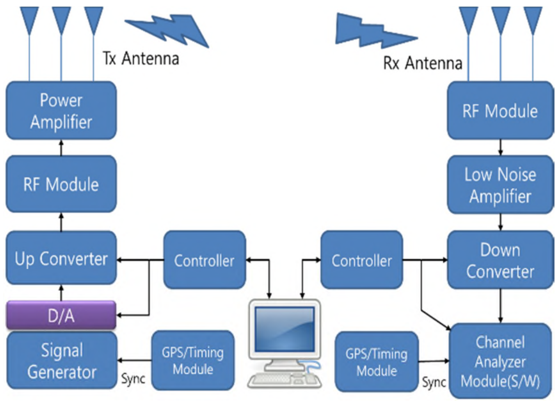

Figure 1. Measurement system configuration

Figure 1 presents our measurement system. Transmission is sent using 209*10^6 samples of data, and the communication takes place via an antenna through the RF module and the Power Amp. Align the synchronization via GPS and Timing Module. In the receiver, the signal is received via the IQ Data RF Module. Also, the channel parameters are derived from the S/W.

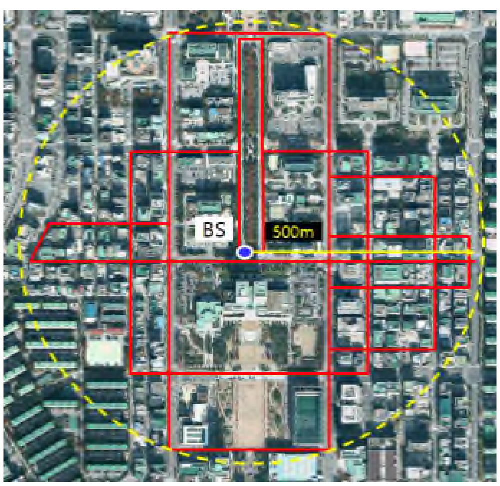

Figure 2. Dunsan measuring area

B. Measurement Scenario

In this study, we measured the propagation characteristics. Our selected area was Dunsan, characterized by an urban environment within about 1 km. Figure 2 shows an aerial photograph of the building location and the area of the measurement region. A Base Station (BS), as shown in Table 1, is installed in the antenna height of 7.3m and a Mobile Station (MS) has been set on top of the roof of a car at 2m. MS is moving along a path within 500m around the BS, measuring the radio wave, and storing the measured data. We analyze the channel parameters based on the stored data.

III. CHANNEL CHARACTERISTIC ANALYSIS

A. Path Loss (PL)

Signal passing through a radio channel results in path loss. When the path loss is caused by the encounter, each reflection, diffraction, scattering will have a different value according to the surrounding environment and the distance between the transceiver. The power value changes according to the distance and has the following distribution [4].

$$P_L(d) = L_0 - 10nlog_{10}\left(\frac{d}{d_{def}}\right) + X_\sigma \qquad (1)$$

where L0 is the initial value, and n is the index of the path-loss. Figure 3 illustrates the received power according to the distance measured from Dunsan area.

The measured reception power value is reduced to a logarithmic function type according to distance. This is meant to increase their element to interrupt the flow of the radio wave according to the distance between the transmitter and the receiver. In fact, the high buildings and large floating population and vehicle were acting as impediments.

The received power value measured in the region Dunsan follows the following distribution.

$$P_{L_d}(d) = 20.06 - 4.204 \times 10\ log_{10}\left(\frac{d}{d_{def}}\right) + 8.91 \qquad (2)$$

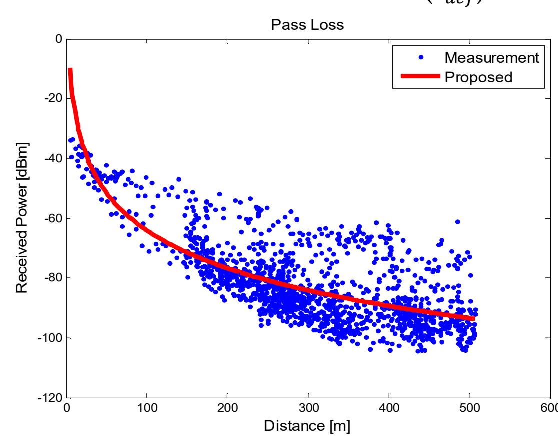

Figure 3. Path loss according to the distance

Figure 2 shows the distance away from the BS that tends to be much higher with respect to the number of buildings. Figure 3 shows the tendency on the received power distribution to increase with the distance; at 500m point, the power received shows a big difference of 40dbm.

B. Delay Spread (DS)

Delay spread is due to multipath reflections and influences the Inter Symbol Interference (ISI). Therefore, the maximum data rates on the communication applications could be limited by ISI.

Time delay spread is derived by calculating the signal level and the noise signal over a reference impulse signal. 1 sample corresponds to 0.48 us and multiplies the time and

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power values of a fading signal to calculate the Mean Excess Delay value [5].

$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \quad (3)$$

The RMS delay spread is defined as the square root of the second central moment of the Mean Excess Delay. Figure 4 shows the RMS delay spread in our scenario.

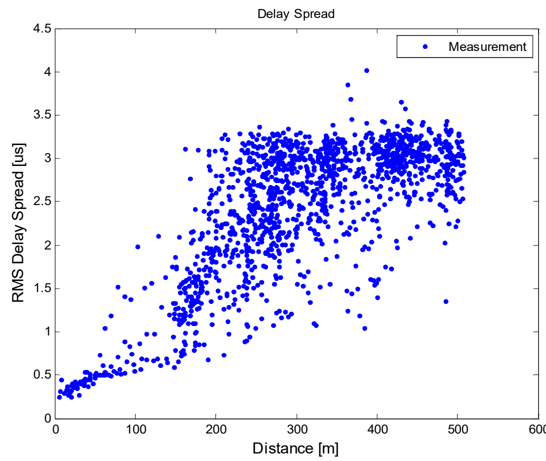

Figure 4. RMS Delay Spread according to the distance

As expected, the highest delay spreads are found mostly because of its high density of scattering.

C. K-factor

In many radio environments, the complex path gain consists of a fixed component plus a zero-mean fluctuating component. The ratio of the fixed and fluctuating power components is defined as the K-factor [6].

$$\mathrm{K[dB]} = 10log_{10}\frac{c^2}{2\sigma^2} \quad (4)$$

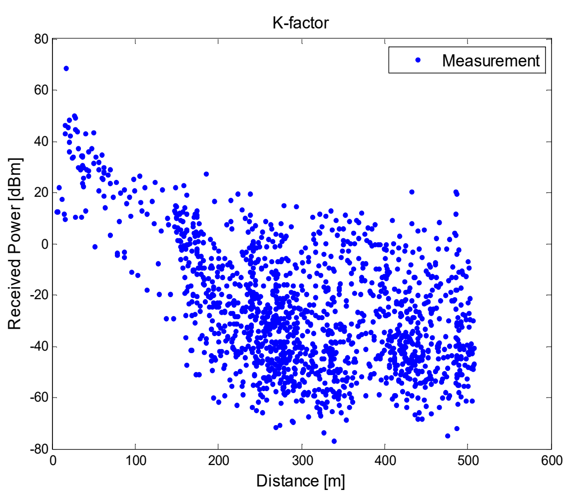

Figure 5. K-factor according to the distance

where c2 is the power of the LOS component and 2σ2 is the power of the NLOS component. The K-factor is an important parameter in a wireless channel system since it defines the power probability of the LOS component. The results are shown in Figure 5; they are calculated by the measured data is K-factor and tend to be inversely proportional with the distance. This means that, according to the increasing distance, the LOS signal component is reduced.

D. Channel Capacity

To derive the channel capacitor of performance in a wireless channel, the channel capacity from SISO radio channel is calculated by the following formula [7].

$$\mathrm{C} = log_2(1+\gamma) = log_2\left(1+\frac{P_t}{{\sigma_n}^2}|h|^2\right) \quad (5)$$

where γ denotes the total received signal-to-noise ratio and h represents the channel.

Figure 6 shows the cumulative distribution probability according to the channel capacity. Blue, red and black lines represent SNR 0, 10, 20dB, respectively. It can be seen that the channel capacitor is proportional to the SNR.

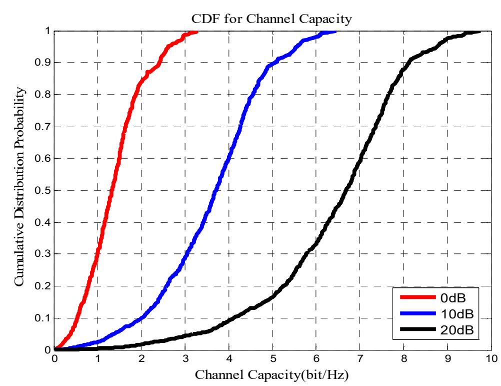

Figure 6. Cumulative Distribution Function for Channel Capacity

E. Correlation Channel Parameters

The correlation of the parameters observed in the measured data is reflected in joint power or probability distributions.

$$\rho_{xy} = \frac{C_{xy}}{\sqrt{C_{xx}C_{yy}}} \quad (6)$$

where Cxy is the cross-covariance of channel parameters x and y. The correlation between the different channel parameters is an important property when developing and evaluating channel models. The correlation coefficients for all of the combinations of the estimated channel parameters are shown in Figure 8. Figure 9 presents the analysis data from a similar environment at 300 MHz [8]. We can see a positive correlation in our scenario between the K-factor and DS in Figure 7.

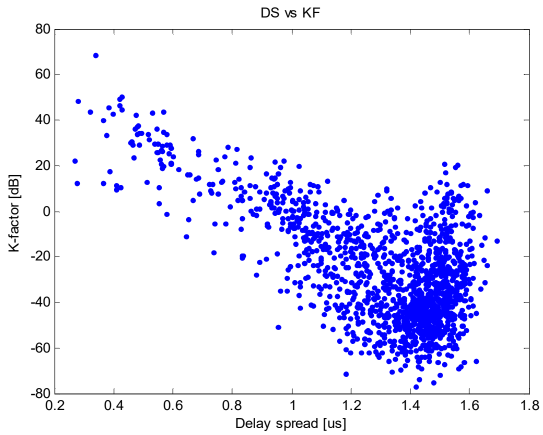

Figure 7. The Correlation for DS vs KF

	Distance	Path loss	DS	K-factor
Distance	1.0	-0.65	0.68	-0.44
Path loss	-0.65	1.0	-0.82	0.79
DS	0.68	-0.82	1.0	-0.63
K-factor	-0.44	0.79	-0.63	1.0

Correlation
-1 0 1

Figure 8. Correlation Coefficients

	Distance	Path loss	DS	K-factor
Distance	1.0	-0.87	0.50	-0.03
Path loss	-0.87	1.0	-0.74	0.35
DS	0.50	-0.74	1.0	-0.54
K-factor	-0.03	0.35	-0.54	1.0

Correlation
-1 0 1

Figure 9. Correlation Coefficients (300MHz)[8]

The correlation between the channel parameters is shown by the channel characteristic in the measured scenario. Generally, the DS values are observed to have a positive correlation, and the PL and K-factors are observed to have a negative correlation, according to the distance. The reduction of overall power explains the negative correlation of the PL and distance. The reduction of the LOS signal explains the negative correlation of the K-factor and distance. The strongest correlations between the distance and PL are observed in scenario. In this scenario, DS correlation value for PLs is -0.82. We can see a similar correlation between PLs and the DS when measured at 300MHz, -0.74. This means that the measurement environment seems similar according to distance. However, the correlation between distance and PLs exposes the difference between the Korean environment and the Swedish environment, are -0.65 and -0.87, respectively. The difference in the two environments is closely associated with the landscape, surroundings, and temperature. The amplitude of the multipath components is frequency dependent, resulting in different fading characteristics in the channel and also the channel parameters.

IV. CONCLUSION AND FUTURE WORK

In this paper, we presented the correlation between channel parameters at 3.5GHz, which is an important frequency band for radio services and new mobile communication. It was measured according to a receiver path in an urban area environment. We derived channel parameters, such as path loss, delay spread and K-factor for SISO wireless system from the measured data. Also, the correlation coefficients of the channel parameters were derived for the urban environment. High negative correlations between DS and PL are observed in this urban scenario. It means the generation of a large path loss. Similar correlations can be found with measurements at 300 MHz. But, the correlation between distance and k-factor shows the difference between the Korean environment and the Swedish environment. This difference shows the measurement frequency band and the difference between Korean and Swedish environments. Generalizations should be explained from the environment structure, propagation mechanism, and the inclusion of other related measurement results, which should be done in the future.

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