

Multipath Characteristics of MIMO Channel at the UHF band for Wireless System in the Urban Area

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Abstract — Multiple-input multiple-output (MIMO) systems at the UHF bands is interest for wireless communication applications. When designing and evaluating such systems, knowledge of realistic propagation conditions is required. In this paper, the development of wideband MIMO channel sounder and a pilot measurement result is described for research on the multi antenna radio propagation characteristics considering urban environment at UHF band. We developed 4 by 4 MIMO (BW: 50 MHz) channel sounder using the high speed switching mechanism and periodic pseudo random binary signals method considering next generation mobile communication system. A pilot measurement campaign at the urban area of Jeju Island is presented for confirmation of system performance. From the analysis of measurement data, RMS delay spread is 1700 ns and 200 ns respectively. From the experiment results, operation of this measurement system is confirmed considering research for wideband path loss exponent factor at 781 MHz.

Keywords — Radio propagation, MIMO, channel, delay spread, path loss

I. INTRODUCTION

By the rapid increase of demand for wireless communications and the explosive increase of the mobile communication services, researches for channel characteristics of urban radio channel of the UHF band's are required. Also, a rapid growth of radio services leads to the deficiency of the frequency resources and this phenomenon is clearly appearing at the lower frequency than 1 GHz bands. Due to this reason, analysis of propagation characteristics in the UHF band is needed for mobile wireless communications.

Mobile communication systems require higher bit rates and data capacity. MIMO systems are possible these requirements neither increasing the transmission power nor the frequency range allocated by taking advantage of multiplicity and diversity. But we need to consider realistic propagation condition, when designing and evaluating such system [1]-[9].

This paper presents construction of measurement system and results from urban MIMO measurement campaign at 781 MHz. Multipath characteristics for the 4×4 MIMO channels are extracted from the measured data. In this document, we

measured the characteristics of the wave propagation at 781MHz bands as a candidate frequency of new services.

From the analysis, it was deduced that this method is applicable with good accuracy for urban area in the Korea. Currently, we proposed some parameters to add in the TABLE 9 of REC. ITU-R P. 1411-5 [11], [12].

II. MEASUREMENT SYSTEMS

Measurements are performed the urban area in the Jeju Island using antenna array mounted on two cars.

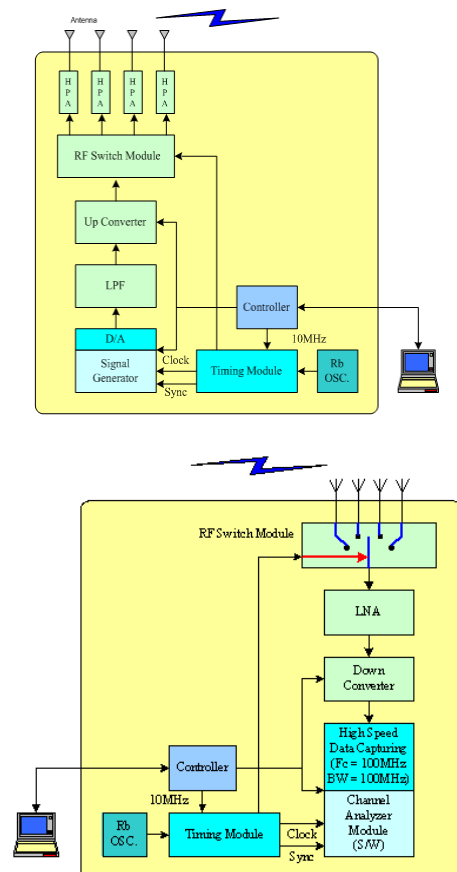


Figure 1. Measurement system configuration(top: Tx, bottom: Rx)

The channel sounder is acted with pseudo noise (PN) mode, 50Mcps, 20ns resolution, and maximum delay time is 40.96μs. Table 1 represents the specification of the channel sounder.

TABLE 1. SPECIFICATION OF THE CHANNEL SOUNDER

Items	Specifications
Frequency	781 MHz
Bandwidth	50 MHz
Maximum Tx power	40 dBm
Minimum Rx level	-97 dBm
VSWR	1.5:1
Input impedance	50 ohm
Chip Rate	50 Mcps
PN length	31 ~ 4095 chips
Resolution	6 m, 20 ns
Frequency stability	10^{-11}

The transmitter in the measurement system is capable of transmitting the 10-W carrier wave at 781MHz. It was located at a base station (BS) with the antenna height (h_b) of 5 m. The mobile station (MS)'s antenna with the antenna height (h_m) of 5 m was set on the end of the rooftop of the motor vehicle because the reflection to the rooftop of vehicular could be ignored. Also, the half-wavelength dipole antennas with the vertical polarization were used for both the transmission and reception. Channel sounder used the high speed switching mechanism and periodic pseudo random binary signals method considering next generation mobile communication system.

III. MEASUREMENTS

The measurement environment shown in Table 2 and Figure 2 is urban area in the Jeju-island. They have many high-rise buildings and wide roads with heavy traffic. The measurement was performed at the 2 places of urban area in Table 2, at 200 test points of each place, and over 100 times of each test point.

TABLE 2. MEASUREMENT ENVIRONMENT

Area	Location	Feature
Urban	Jeju Island	High-rise buildings (above 20 floors) at one side of 8 lanes road (30m wide) and no building at the other side of road



Figure 2. Measurement location in the Jeju Island

They have many high-rise buildings and wide roads with heavy traffic. The measurement was performed at the 2 places of urban area in Table 2, at 200 test points of each place, and over 100 times of each test point.

IV. RESULTS

The radio wave's strength is attenuated due to the absorption by mostly oxygen and vapor when the wave propagates through the atmosphere. And, the attenuation unit of dB/km means the attenuation coefficient in atmosphere and depicts the attenuation per unit distance. In general, the attenuation coefficient on the communication applications is approximately 15dB/km.

To estimate the propagation characteristics and define appropriate wireless environment, most researchers has been studying and developed the propagation models such path loss and delay profile [10].

The propagation models are developed using the statistical method based on measurement or theoretical approach method. Especially, the theoretical scheme is very effective method rather than statistical methods, because of the analysis speed's improvement and the accuracy.

A. Path loss

Path loss is the most fundamental measure of channel quality. In decibels, path loss, PL, is defined as

$$PL = P_t + G_t + G_r - G_r \quad [\text{dB}] \quad (1)$$

where P_t and P_r are the time-averaged power levels (in dBm) at the output of the transmitter and the input of the receiver, respectively, and G_t and G_r are the gains (in dBi) of the transmitting and receiving antennas. The relationship between path loss and the distance, d , between the transmitter and receiver generally follows a power-law relation and can be described by

$$PL(d) = PL_0 - n \cdot 10 \log_{10} \frac{d}{d_0} + X_\sigma \quad [\text{dB}] \quad (2)$$

where PL_0 is the value of path loss (in dB) at the reference distance d_0 , n is the distance exponent, and X_σ is a zero-mean Gaussian random variable with standard deviation σ . The random variable X accounts for the location variability or shadow fading that is generally attributed to differences in the degree to which the path is obstructed at different points throughout the coverage area. Path loss result is shown in Figure 1 with fitting result.

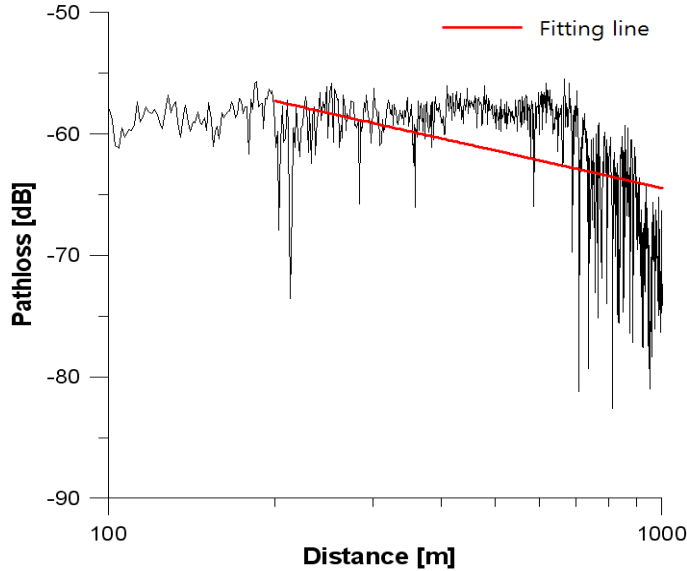


Figure 3. Path loss in the urban area

Path loss was calculated for every measured data set of power profiles in the delay spread results. It is shown in Figure 2. Path loss exponent is 10.42 with the initial value -42.30.

B. Delay spread

Delay spread is due to multipath reflections and causes to the inter symbol interference (ISI). Therefore, the maximum data rates on the communication applications could be limited by ISI.

The delay spread is calculated from power delay profiles given by the square of magnitude of the channel impulse response. The parameters chosen to provide the statistical description of the multipath effects are the mean and standard deviation of R.M.S delay spread. The threshold is used determining the multipath if the power delay profiles have enough peak-to-spurious dynamic range to ensure the integrity of the results. For the results reported in this document, the threshold was set 20 dB below the peak of power delay profile. Table 3 shows the measurement results of the mean R.M.S delay spread and their standard deviations in the urban area.

Recommendation ITU-R P.1411-5 shows the characteristics of multipath delay spread for line of sight (LOS) case in urban

areas. The R.M.S delay spread at distance of d m follows a normal distribution with the mean value given by

$$a_s = C_a \cdot d^{\gamma_a} \quad [\text{ns}] \quad (3)$$

and the standard deviation given by

$$\sigma_s = C_\sigma \cdot d^{\gamma_\sigma} \quad [\text{ns}] \quad (4)$$

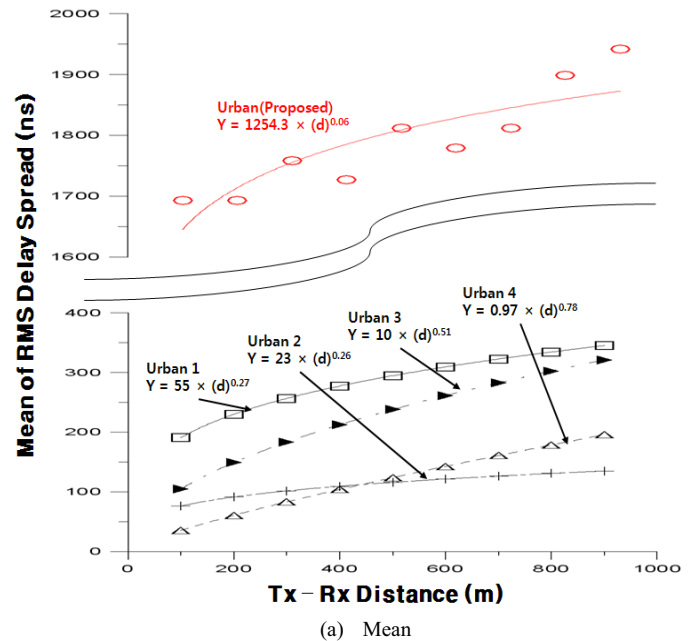
where C_a, γ_a, C_σ and γ_σ depend on the antenna height and propagation environment.

Using equation (3) and (4), the mean and standard deviation of R.M.S delay spread according to the distance is shown in Table 3 and Figure 4.

TABLE 3. R.M.S DELAY SPREAD MESUREMENT ENVIRONMENT

Measurement conditions				a_s		σ_s	
Area	f (GHz)	h_b (m)	h_m (m)	C_a	γ_a	C_σ	γ_σ
Urban (proposed)	0.781	5.0	5.0	1254.3	0.06	102.2	0.04
Urban1	2.5	6.0	3.0	55	0.27	12	0.32
Urban2	3.35-15.75	4.0	2.7	23	0.26	5.5	0.35
Urban3	3.35-8.45		1.6	10	0.51	6.1	0.39
Urban4	8.05	5	2.5	0.97	0.78	1.42	0.52

* f : frequency, h_b : height of base station, h_m : height of mobile station



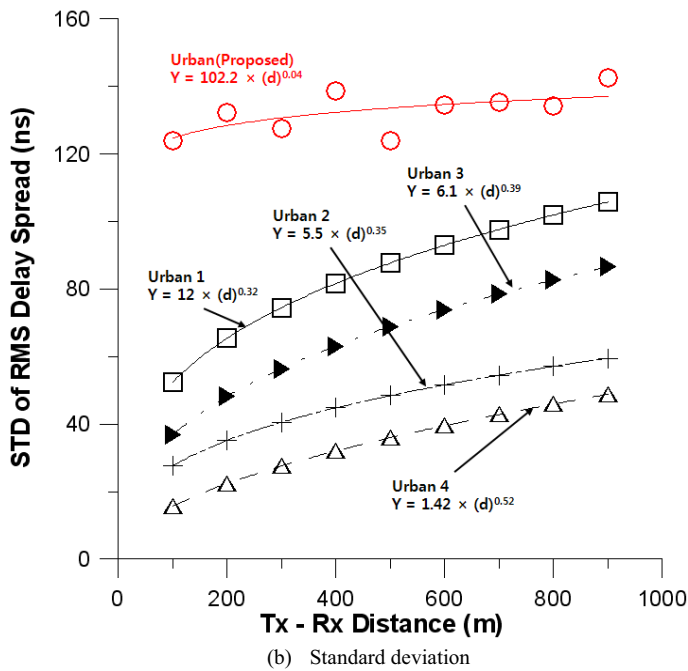


Figure 4. R.M.S delay spread versus distance

These coefficients are made based on measurements in urban areas for distances of 0~1000 m, under the LOS cases. From these results, we know that the R.M.S delay spreads derived from our measurements are bigger than the Urban of Rec. ITU-R P.1411-5.

C. Verification of measurement result

To verify the validity of measurement results, we compared with our result and reference result.

TABLE 4. COMPARISON OF MEASUREMENT AND REFERENCE DATA

Region	Frequency (MHz)	Delay Spread(ns)	Measurement site
Jeju Island (Korea)	781	1750 avg.	Urban
New York ^[3] City (USA)	910	1300 avg.	Urban

Above the result, our measurement data is bigger than New York case. But, both result have a similar value, it is mean that our measurement result are reasonable values. In this result, our measurement and analysis method at the UHF band is valid.

V. CONCLUSION

We constructed of measurement system and measured multipath channel characteristics in the urban area. And, we measured the characteristics of the wave propagation at 781MHz bands as a candidate frequency of new services.

Multipath characteristics for the 4×4 MIMO channels are extracted from the measured data. And, we compared with measurement data.

From the analysis, it was deduced that this method is applicable with good accuracy for urban area in the Korea. Currently, we proposed some parameters to add in the TABLE 9 of REC. ITU-R P. 1411-5.

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