A PATH LOSS CHARACTERIZATION OVER 2 GHz BY MEASUREMENT IN 800 MHz AND 5 GHz BANDS

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1. Introduction

Some higher-frequency bands, for example 3-5 GHz band, are expected to be used for the next generation mobile communications. For the system designs and link budget calculations, some path loss prediction models shall be applied. On this purpose, some models have been established, such as COST 231 Walfisch-Ikegami model [1]. However those support the frequency only under 2 GHz, thus, not directly applicable to the range of 3-5 GHz. There have been several approaches taken to cover the range [2, 3]. The authors also tried to establish some path loss characterization over 2 GHz frequency by measurement both in 800 MHz and 5 GHz bands, targeting mid-sized city and based on the Walfisch-Ikegami model.

In this paper, we present the characteristics of measured path loss in the 800 MHz and the 5 GHz bands assuming the macro-cellular environment where the base-station antenna is set on the roof of a high building. The measurement is described in Section 2. And in Section 3, we attempt the extension of the applicable frequency range of the Walfisch-Ikegami model using the characteristics of the measured data. Then the conclusions follow in Section 4.

2. Measurement

We measured the path loss characteristics at the 800 MHz band (845 MHz) and the 5 GHz band (4950 MHz) in Iwaki-city, Fukushima Prefecture, Japan. Iwaki-city is a provincial midsized city in the North-East of Japan. The 5 GHz transmitting antenna was set on the roof of a 9-storey building at the same position as the base station antenna of an 800 MHz cellular system. The receiving antennas for both of the 800 MHz and 5 GHz bands were set on the rooftop of the measurement vehicle at a height of 2.5 m. The measured path loss data were averaged over 30 m square receiving areas.

Figure 1 shows the path loss characteristics against the horizontal distance from the transmitting antennas in the NLOS (Non-Line-Of-Sight) situation. The log

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approximation lines at the 800 MHz and the 5 GHz are also shown, both obtained from the measured data. The lines for the free space path loss (FSPL) cases are also provided for reference. The propagation constants in the 800 MHz and the 5 GHz are observed as 3.6 and 4.0, respectively. The median value of the path loss difference over the measurement area is measured as 16.7 [dB], and this value is almost the same as that in the FSPL, 15.4 [dB].

3. Application and extension of Walfisch-Ikegami model

We attempt to extend the frequency range of the existing path loss model using the measurement data. The Walfisch-Ikegami model (WI) in COST231 was selected as the base, because this model is a well-established theoretical model on which the prediction formula in ITU-R Recommendation for the short-range below 1km [4] is based.

3.1. Comparison of estimated and measured data

Firstly, we use WI to obtain the estimated path loss characteristics of the measurement area in the 800 MHz and the 5 GHz, and we compare the estimates with the measured data. Table 1 summarizes the sets of parameters and values of the measurement area used for the prediction. Figure 2 shows the comparison of the estimates with the measurements. The median values of the differences (“measurement” - “estimate”) in the 800 MHz and the 5 GHz are 5.5 [dB] and -9.2 [dB], respectively. The deviations of the measurements from the estimated line of the 800 MHz are attributed to the differences between the models and the actual configuration of the buildings of the measured area. On the other hand, considerably large offset is seen between the estimates and the measurements in the 5 GHz. The formula of WI has characteristics where path loss value rapidly increases in the frequency range over 2 GHz. The offset shown in Figure 2 indicates that the characteristics should be corrected to extend the applicable frequency range up to the higher frequency.

Table 1 Measurement area parameters applied to prediction formula

Variable	Parameter	Applied value
Average building separation [m]	b	6.7
Street width [m]	W	16.6
Average building height [m]	h_r	7.2
BS height [m]	h_b	36.0

Variable	Parameter	Applied value
MS height [m]	h_m	2.5
Street angle [deg]	θ	Extracted at each point
Distance from BS to MS [km]	d	
Frequency [MHz]	f	845.0 / 4950.0

3.2. Frequency range extension of WI to 5 GHz

Focusing the frequency characteristics of L_{msd} of WI formula [1] which express the loss between transmitting antenna and the rooftop nearest the receiving antenna, we consider the following three methods to extend the frequency range.

Two of the methods are to optimize the coefficients of the formula by minimizing the

RMS (Root Mean Square) of estimation errors. Here we define the term on frequency characteristics among the terms of L_{msd} as L_{fmsd_f}. L_{msd_f} in dB is expressed as follows:

$$L_{msd\_f} = [-4 - 1.5(f/920 - 1)]\log f. \quad \text{[dB]} \tag{1}$$

We consider the following two types of the expressions:

$$L_{msd\_f} = \begin{cases} [a + b(f/c - 1)]\log f & \text{(Extended WI (1))} \\ a\log f + b & \text{(Extended WI (2))} \end{cases} \tag{2}$$

where a, b and c are constants. We optimize the RMS values using the measured data.

Another method is to minimize the change of the frequency characteristics of the original WI. As described in the previous section, the path loss difference between the ones at the 800 MHz and the 5 GHz is measured at 16.7 dB. Assuming that the path loss is proportional to the exponential of the frequency, it can be re-stated as proportional to the 2.2 power of the frequency. This provides the major characteristics of the estimation model. Meanwhile, as WI has been widely used and well established below 2 GHz, the formula shall be regarded as the basis of the estimation model. We obtain the extended model (extended WI (3)) using these frequency characteristics by the following steps. (See Figure 3.)

1. Define the frequency characteristic of the existing prediction formula ranging from 800 MHz to 2 GHz as the reference curve.
2. Define the frequency characteristic of the extended formula “-8 log (f) + offset.” (In the expression of the original WI, other terms have frequency characteristics where are proportional to 3 powers of the frequency, thus the total frequency characteristics of the extended WI is proportional to the 2.2 power of the frequency.)
3. Optimize the “offset” to minimize the RMS of the difference in frequency domain between the reference curve and the frequency characteristics of the extended prediction formula in the range from 800 MHz to 2 GHz.

3.3. Estimation errors

From the results of the methods above, three extended L_{msd_f} are obtained as shown in Table 2. Figure 4 shows the comparison of the extended WI (1) with the measurements as an example. The graphs for the other two extended formula are almost the same as the extended WI(1). The statistics of estimating errors are summarized in Table 2.

Table 2 Extended prediction formula and their estimation errors statistics

	Expression of L_{msd_f}	Statistics of estimating errors			
		Median [dB]		RMS [dB]	
		800 MHz	5 GHz	800 MHz	5 GHz
WI in COST 231 (Original model)	$[-4-1.5(f/920-1)]\log f$	5.24	-9.24	8.35	11.69
Extended WI (1)	$[-4.4-0.27(f/1790-1)]\log f$	5.86	5.25	8.65	6.75
Extended WI (2)	$-7.97\log f + 11.5$	5.25	5.18	8.35	6.71
Extended WI (3)	$-8\log f + 13.4$	3.60	3.39	7.76	5.81

4. Conclusions

We measured the path loss characteristics at the 800 MHz and 5 GHz bands. Measured data indicate that the frequency dependence of the path loss is almost the same as that in the free space. Using this result, the applicable frequency range of the path loss prediction formula of the Walfisch-Ikegami model is extended up to 5 GHz. The estimation errors in 5 GHz band were greatly improved by the modified new formula.

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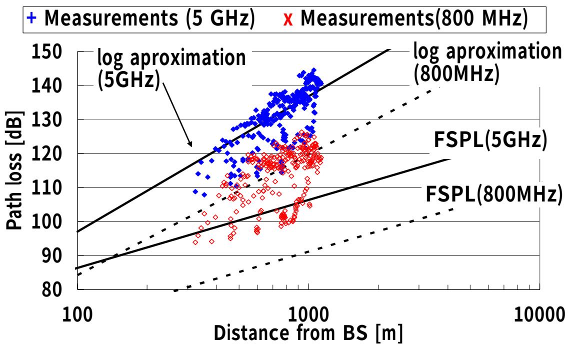

Figure 1 Measured path loss characteristics against distance.

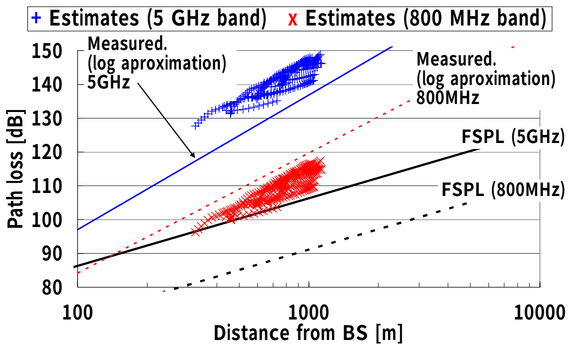

Figure 2 Comparison of estimates obtained using original WI with measurements.

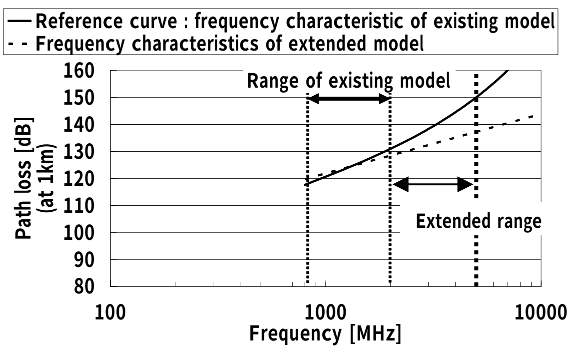

Figure 3 Frequency characteristics of extended prediction formula.

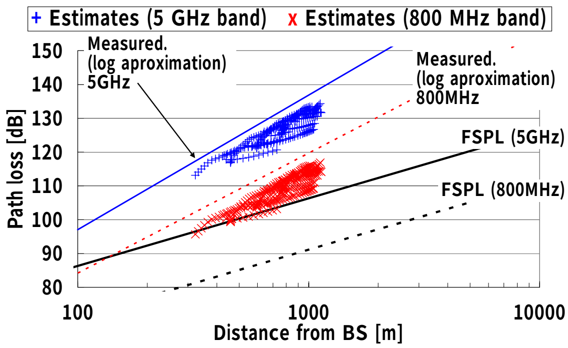

Figure 4 Comparison of estimates obtained using extended WI with measurements