Path Loss Model with Multiple-antenna

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Abstract— In this paper, we propose a path loss model with the multiple antennas using diversity effect. Currently wireless communication systems use the multiple antennas in order to improve the channel capacity or diversity gain. However, until recently, many researches on path loss model only consider geographical environment between the transmitter and the receiver. There is no study about path loss model considering diversity effect. Nowadays wireless communication use the multiple antennas and we in common find examples using diversity scheme that is method in order to enhance a channel capacity. Moreover we anticipate that it work harder in future researches. But in this communication system, path loss model isn't established that predict strength of received signal. So, in order to predict strength of received signal, we take changing SNR by diversity gain. When exceeding the number of antennas of receiver are 7 in proposed model, diversity effect is saturated. Therefore we consider the number of antenna of receiver until 10. We find RMSE between proposed model and value of calculation is 1. We calculate the diversity gain by conventional BER curve. Proposed model can predict loss of received signal in system using multiple antennas system using multiple antennas.

1. INTRODUCTION

With the rapid development of technology and human civilization, in the downtown area, it is easy to find a high structure. Due to the effect of various objects, multi path effect is occurred and it has brought the fading effect.

For this reason, we can use diversity to raise the lowering of transmission quality and meet maximally the users' needs that desire the high quality. In the diversity mechanics, there are several methods, such as space diversity using two antennas that are separated in two or more, polarization diversity receiving horizontal polarization and vertical polarization separately, frequency diversity using two or more frequencies at the same time.

In this paper, we used the space diversity which utilizes multiple antennas. We used this, because of techniques that improve the communication capacity proportional to the number of antennas such as MIMO. MIMO is currently being used in the fourth generation movement communication, besides we can easily find the case that using multi-antenna like MRC (Maximal Ratio Combining) [1] technique, STBC (Space-Time Block Code) [2]. At present, there are many models for analyzing the loss of the current path, but some models have difficulty in order to apply the variety of environment comprehensively Representative such as Hata model [3, 4] which is path loss model, the research about the model for predicting the path loss of receiver's and transmitter's in an environment of urban and suburban which is urbanized and open area, has been proceeded [5, 6]. However, studies in a system environment using multiple antennas, has been considered relatively less. Therefore, it is necessary to model the path loss model by analyzing diversity gain accurately using multiple antennas. In this paper, we will explain the receive diversity and general loss model which is basis of this study. If there are 10 or more antennas, the effect of diversity converges to a constant value, in the proposed path loss models we take into account 10 antennas. Also, we consider the BER of the received signal, from to which is guaranteed the guarantee QoS (Quality of Service). In Rayleigh channels, we analyze the proposed model by divided into two environments that the case of using modulation schemes of BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Amplitude Modulation). It modeled the path loss model using interpolation and curve fitting.

2. RECEIVE DIVERSITY

Using receiver has many antennas; receiver diversity scheme has a diversity gain. That is to say it is system using one transmit antenna and multiple receive antennas [7]. When non-selective fading channel, SIMO (single input multiple output) channel is given by

$$H = [h_1\ h_2\ \dots\ h_{N_R}]^T \tag{1}$$

When transmit signal is, reception signal is given by

$$y = \sqrt{E_s} Hx + z \tag{2}$$

Here, y is reception signal vector of $N_R \times 1$, z is AWGN having characteristic of $E\{zz^H\} = N_0 I_{N_R}$. There are several main synthesis scheme which is a SC (selection combining), MRC (maximal ratio combining) and EGC (Equal gain combining). MRC scheme apply independent superposition to all branch [7]. Superposition value is calculated by SNR of each branch. When superposition value of each branch is and receive signal is from each branch.

$$y_{\mathrm{MRC}} = \sum_{i=1}^{N_R} G_i y_i \tag{3}$$

Here, transmit signal is $y_i = h_i x_i + n_i$, $E\{|x_i^2|\} = 2E$. n_i has of power spectrum, which is noise component from each branch. So we present as follows

$$y_{\mathrm{MRC}} = \sum_{i=1}^{N_R} G_i h_i x_i + \sum_{i=1}^{N_R} G_i n_i \tag{4}$$

After applied MRC scheme, power spectrum is given by

$$S_v = 2N_0 \sum_{i=1}^{N_R} |G_i|^2 \tag{5}$$

And momentary signal power is given by

$$P = 2E_s \left| \sum_{i=1}^{N_R} |G_i h_i|^2 \right| \tag{6}$$

Calculated average SNR of each branch based on the result is given by

$$\rho_{\mathrm{MRC}} = \frac{E_s \left| \sum\limits_{i=1}^{N_R} |G_i h_i|^2 \right|}{N_0 \sum\limits_{i=1}^{N_R} |G_i|^2} \tag{7}$$

Equation (8) is Cauchy-Schwartz's theorem.

$$\left| \sum_{i=1}^{N_R} |a_i b_i|^2 \right| \leq \sum_{i=1}^{N_R} |a_i|^2 \sum_{i=1}^{N_R} |b_i|^2 \tag{8}$$

When we exactly recognize channel information, the SNR of each branch is given by

$$\rho_{\mathrm{MRC}} = \frac{E_S}{N_0} \sum_{i=0}^{N_R} |G_i| \tag{9}$$

3. PATH LOSS MODEL WITH MULTIPLE-ANTENNA

Structure of array receiver's antenna is Figure 1 in this paper. Path Loss Model with multiple-antenna is modeled by target BER, the number of receive antennas and SNR that is connected with mutual characteristic. A Theoretical calculation of proposed model is simulated by MATLAB. Table 1 shows equation parameter in MATLAB.

Using MRC scheme in BPSK and QPSK at Rayleigh channel, non-selective fading channel, BER is calculated by a under processing.

$$P_b = \frac{1}{k} \left(\sum_{i=1}^{M/2} (w_i') \, P_i \right) \tag{10}$$

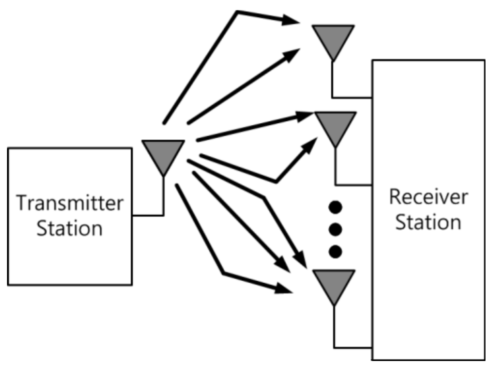

Figure 1: Structure of array receiver's antenna.

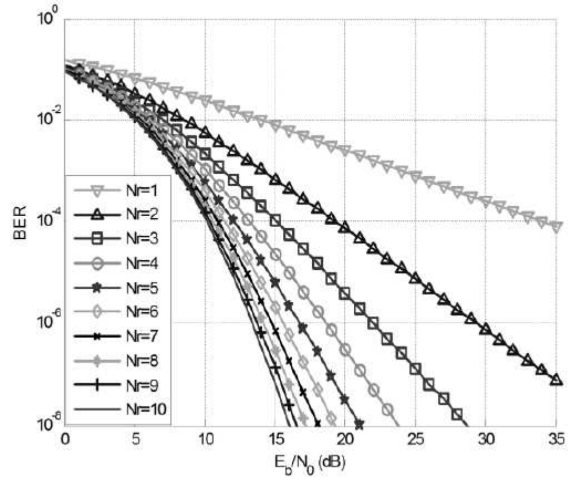

Figure 2: BER curve by the number of N_R.

Table 1: Parameter in equation.

Size of modulation constellation	M
Number of bits per symbol	k
Bit error rate	P_b
Power of the fading amplitude r	$\Omega = E[r^2]$, where $E[\cdot]$ denotes statistical expectation
Number of diversity branch	L
SNR per symbol per branch	$\overline{r_l} = (\Omega_l)\frac{kE_b}{N_0}/L$
Moment generating function for each diversity branch	$M_{r_l}(s) = \frac{1}{1-s\overline{r_l}}$

where, $w_i' = w_i + w_{M-i}$, $w_{M/2} = w_{M/2}$, w_i is a Hamming weight assigned symbol i.

$$\begin{aligned} P_i \; = \; & \frac{1}{2\pi} \int_0^{\pi(1-(2i-1)/M)} \prod_{l=1}^{L} M_{r_l}\left(-\frac{kE_b}{N_0}\frac{\sin^2[(2i-1)\pi/M]}{\sin^2\theta}\right)d\theta - \frac{1}{2\pi}\int_0^{\pi(1-(2i+1)/M)} \\ & \prod_{l=1}^{L} M_{r_l}\left(-\frac{kE_b}{N_0}\frac{\sin^2[(2i+1)\pi/M]}{\sin^2\theta}\right)d\theta \end{aligned} \tag{11}$$

We use Figure 2 shows BER calculated by Equation (10) and Equation (11) in BPSK and QPSK ($M = 2$ or 4) at Rayleigh fading channel.

When target BER, P_b is 10^{-4}, Figure 3 shows errors comparing $G(N_R)$ by curve fitting with theoretical calculation values. Table 4 shows $G(N_R)$ defined by curve fitting depending on each target BER, $P_b G(N_R)$ showing at Table 4 can presents $G(N_R) = a/N_R^b \cdot \log_{10}(N_R) + c$ using three coefficient. And the coefficient a, b, c is changed by target BER. We can analyze that three coefficients is result of function like $a, b, c = f(\text{BER})$ and the coefficient is estimated by an interpolation. Table 5 shows results estimated varying coefficient depending on target BER by interpolation.

We can find that path loss is changed by target BER and the number of antennas and finally, proposed path loss model with both elements is given by

$$\begin{aligned} G(N_R, \text{BER}) \; = \; & \frac{13.2525\,|\log_{10}(\text{BER})| - 9.115}{N_R^{-0.005|\log_{10}(\text{BER})|+0.37}} 10\log_{10}(N_T) \\ & +0.323(|\log_{10}(\text{BER})| - 0.34)^{1.75} + 0.357\,|\log_{10}(\text{BER})| - 0.326 \end{aligned} \tag{12}$$

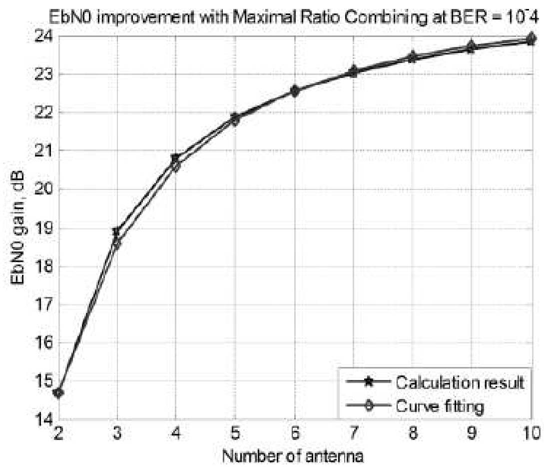

Figure 3: Curve fitting at BER $= 10^{-4}$.

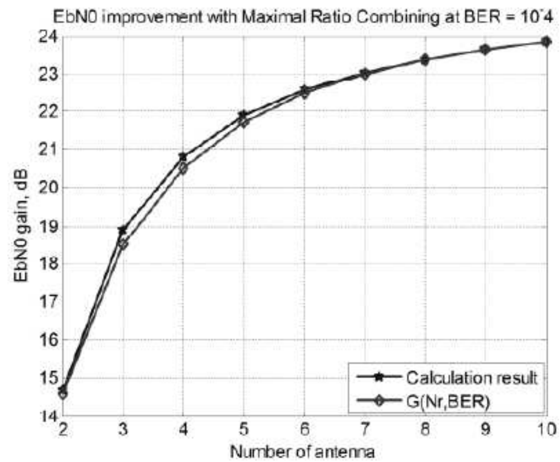

Figure 4: Curve fitting at $G(N_R, \mathrm{BER})$.

Table 2: Gain of signal strength by the number of N_R.

N_R	E_b/N_0	Gain of signal strength
1	33.981	0
2	19.284	14.697
3	15.082	18.899
4	13.174	20.807
5	12.103	21.878
6	11.419	22.562
7	10.948	23.033
8	10.603	23.378
9	10.34	23.641
10	10.133	23.848

Table 3: Gain of signal strength at target BER.

N_R	$P_b = 10^{-2}$	$P_b = 10^{-3}$	$P_b = 10^{-4}$	$P_b = 10^{-5}$	$P_b = 10^{-6}$
1	0	0	0	0	0
2	5.389	9.861	14.697	19.631	24.612
3	6.916	12.643	18.899	25.383	31.965
4	7.624	13.91	20.807	27.995	35.308
5	8.032	14.633	21.878	29.445	37.207
6	8.296	15.094	22.562	30.383	38.396
7	8.481	15.414	23.033	31.019	39.211
8	8.618	15.649	23.378	31.485	39.803
9	8.723	15.829	23.641	31.837	40.251
10	8.806	15.972	23.848	32.114	40.602

4. SIMULATION AND ANALYSIS

Table 6 shows parameter of simulation in order to confirm an accuracy of proposed model.

Figure 4 shows errors compared theoretical calculation result with proposed the path loss model in BPSK and QPSK using the Equation (12). When the target BER is $P_b = 10^{-6}$, each coefficient of $G(N_R, \mathrm{BER})$ is $a = 43.893$, $b = 0.35$, $c = 402302$. So $G(N_R, \mathrm{BER})$ is $\frac{43.895}{N_R^{-0.35}} 10 \log_{10}(N_T) + 4.2302$. Biggest error of $G(N_R, \mathrm{BER})$ is 0.411 dB at three antennas and we can conform RMSE is not up

Table 4: $G(N_R)$ by curve fitting.

Target BER	Equation by curve fitting
$P_b = 10^{-2}$	$G(N_R) = \frac{15.41}{N_R^{0.36}} \log(N_R) + 1.52$
$P_b = 10^{-3}$	$G(N_R) = \frac{15.41}{N_R^{0.36}} \log(N_R) + 1.52$
$P_b = 10^{-4}$	$G(N_R) = \frac{15.41}{N_R^{0.36}} \log(N_R) + 1.52$
$P_b = 10^{-5}$	$G(N_R) = \frac{15.41}{N_R^{0.36}} \log(N_R) + 1.52$
$P_b = 10^{-6}$	$G(N_R) = \frac{15.41}{N_R^{0.36}} \log(N_R) + 1.52$

Table 5: Estimating coefficient by interpolation.

Coefficient	Estimating Coefficient by Interpolation
a	$13.2525\lvert\log_{10}(\text{BER})\rvert - 9.115$
b	$-0.005\lvert\log_{10}(\text{BER})\rvert - 0.37$
c	$0.323(\lvert\log_{10}(\text{BER})\rvert - 0.34)^{1.75} + 0.357\,\lvert\log_{10}(\text{BER})\rvert - 0.326$

Table 6: Simulation parameters.

Parameters	Value
Diversity type	Maximal Ratio Combining
Modulation	BPSK or QPSK/16-QAM
Channel	Rayleigh fading channel

to 1. Previous results confirm that we can calculate path loss of communication system with multiple-antenna in BPSK and QPSK using the target BER and the number of receiver antennas.

5. CONCLUSION

In this paper, we propose the path loss model that result from the diversity gain in order to predict path loss of communication system with multiple-antenna. We define using the characteristic of the target BER, SNR, and diversity gain and calculate a change of path loss using the proposed model. The errors are under 1 dB at each number of receiver antennas. The proposed path loss model could be had difference of measured path loss in real practical environment because this model is modeled by the theoretical curve fitting and interpolation. But, this model can predict the path loss of communication system using with multiple-antenna and henceforward this model is a theoretical standard of comparison with measured path loss in real practical environment.

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