Evaluation of Wideband Channel for Bedside UWB Radio Link

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Abstract

In this paper, relationship between distance and received power using UWB in a bedside environment is studied. As a criterion of the measurement, received power is measured by a vector network analyzer, under the LOS environment and the NLOS environment. Using the response that is measured by a vector network analyzer, path-loss models are obtained and evaluated by the computer simulation. BER characteristic is evaluated using the IEEE802.15.4a signal for the path-loss model. As a result, it was shown that the obtained path-loss model well described the BER characteristic.

Keywords:

UWB, Bed side environment, Received power, IEEE802.15.4a, wireless sensor network, BAN

Introduction

In 2007, IEEE802.15.4a was standardized as a low-rate and low-power UWB system for sensor networks[1]. In recent years, the use of the wireless communication technology in the hospital is considered by reduce the work to a manageable level and the report the emergency call to center of the hospital[2]. It is demanded from the wireless communication technology used that medical device is low on the effect. So, the use of the UWB(Ultra Wideband) wireless communication with low transmitting power density is examined. When a wireless information network is composed in the hospital, and patient's biological information is measured automatically, a wireless communication in a bedside environment is necessary. In this paper, the feasibility of a stable communication was verified.

Propagation channel response measured in a bedside environment

Propagation channel response was measured by a vector network analyzer in a bedside environment. Two posture patterns were taken with the human body lying on asleep on the bed, and the human body lying upon face. Evaluated measurement is under the LOS(Line of Sight) environment and the NLOS(Non Line of Sight) environment. NLOS environment is blocked with the human body. The Propagation channel response measured in a bedside environment is shown in Figure 1.The transmission antenna is installed in the human body chest to mimic the medical device. The height of the receiving antenna has been changed with 100cm and 120cm. The position of the receiving antenna was changed, and the distance between antennas was varied from 0.7m to 2.2m, the measurement points was 468.
The size of the measurement room is 7×9m, and surroundings are composed of metallic walls. Using antenna was omni-directional planer antenna. The range of the frequency measued was 3GHz to 5GHz.

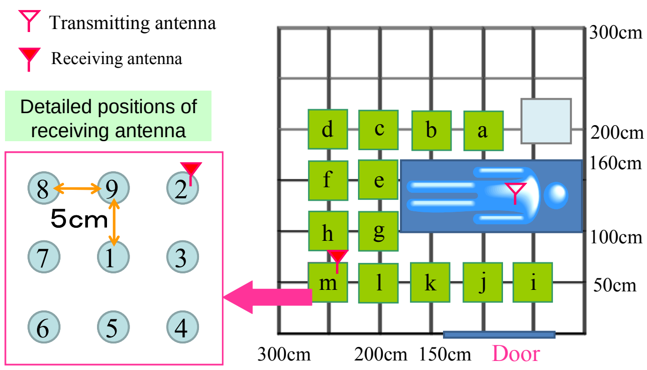

Figure 1 - Propagation channel response measurement in a bedside environment

Distance, received power and delay-spread

The S_{21} channel response from the transmission antenna to the receiving antenna was measured by a network analyzer. The peak power of the delay-profile obtained from the S_{21} characteristic was assumed to be the path-loss, and each value was taken at the specified points as in Fig. 1 Measured path losses vs distances between transmitting and receiving antennas are plotted in Fig. 2 for LOS environment and Fig. 3 for NLOS environment respectively. Approximation curve and free space propagation loss curve with measurements of relation between distance and path-loss are also shown in Figure 2 and Figure 3.

The approximation curve was obtained by the least square method. Under LOS environment, there was approximately 2dB difference with an approximation curve compared with a free space propagation loss curve. Moreover, under NLOS environment, there was approximately 20dB difference between a approximation curve and a free space propagation loss curve.

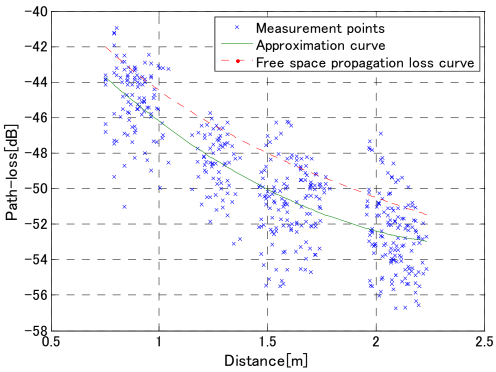

Figure 2 - Relation between distance and measured path-loss under LOS environment

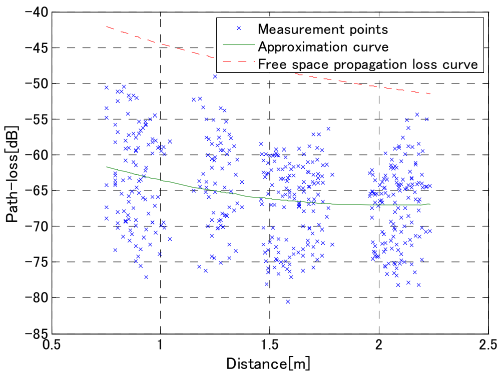

Figure 3 - Relation between distance and measured path-loss under NLOS environment

Relation between distance and delay-spread are shown in Figure 4 and Figure 5. It is understood that the delay-spread becomes larger as the distance becomes long.

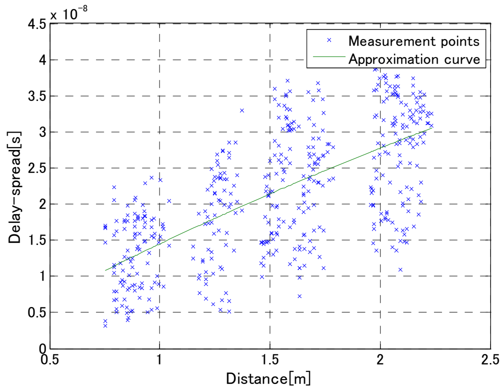

Figure 4 - Relation between distance and measured delay-spread under LOS environment

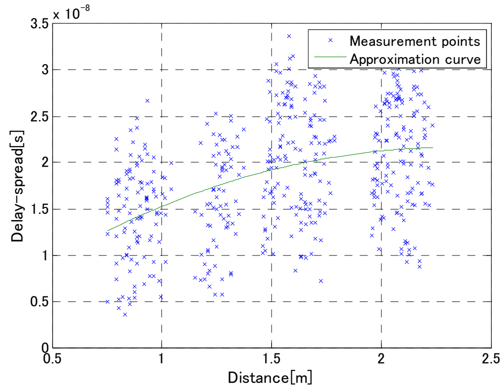

Figure 5 - Relation between distance and measured delay-spread under NLOS environment

The delay-spread is an index that shows broadening the amount of the delay has from the average, and the parameter that may influence bit error rate (BER). It is defined by Equation (1).

$$\Delta = \sqrt{\frac{1}{P_0}\int_{\tau 0}^{\tau 3}(\tau - D)^2 P_{av}(\tau)d\tau} \tag{1}$$

Probability density function and Comparison of correlation values

It is necessary to decide an error distribution function with the approximation curve of measurements to make the path-loss model of the distance and the received power. Three distribution functions are provided and compared with correlation values to decide which model best suits measured data.

Gaussian distribution as in Equation (2), Poisson distribution as in Equation (3), Rayleigh distribution as in Equation (4), and Weibull distribution as in Equation (5) are provided[3].

$$p_G(x) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} \tag{2}$$

$$p_p(x) = \frac{\mu^x}{x!}\exp(-\mu) \tag{3}$$

$$p_r(x) = \frac{x}{\sigma^2}\exp\left\{-\frac{x^2}{2\sigma^2}\right\} \tag{4}$$

$$p_W(x) = \frac{c}{b}\left(\frac{x}{b}\right)^{c-1}\exp[-(\frac{x}{c})^c] \tag{5}$$

In these distributions, σ, μ, b and c are parameters. The correlation value between measured received power by network analyzer and provided distribution was examined, which of Gaussian distribution, the Poisson distribution, the Rayleigh distribution, and the Weibull distribution. Comparison of correlation values of probability density function is shown in Table 1.

Table 1 - Comparison of correlation values of probability density function

Distribution	**Correlation value under LOS**	**Correlation value under NLOS**
Gaussian distribution	0.97734	0.70937
Poisson distribution	0.85701	0.31685
Rayleigh distribution	0.96211	0.45671
Weibull distribution	0.99034	0.8766

The correlation value when Weibull distribution was applied as a model was high in case LOS environment and NLOS environment. Weibull distribution was suitable as the selection of the model. Margin of error with approximation curve used for Weibull distribution are shown in Figures 6 and 7.

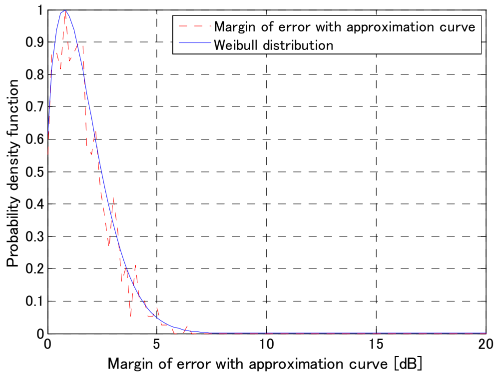

Figure 6 - Margin of error with approximation curve under LOS environment

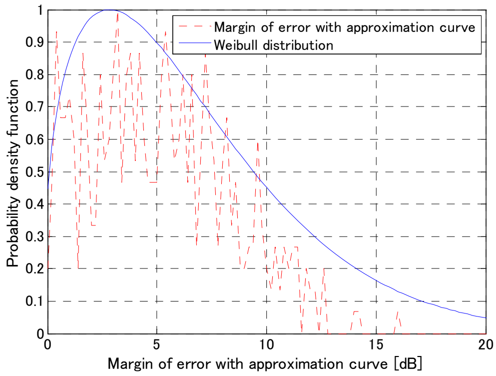

Figure 7 - Margin of error with approximation curve under LOS environment

Method of making path-loss model

Weibull distribution was adopted for the path-loss model by the correlation result. The path-loss model corresponding to the distance is defined by Equation (6).

$$PL(x) = A \times \lambda \exp(-\lambda \times x) + S \qquad (6)$$

In Equation (6), x is a distance and A, λ and S are parameters. S denotes shadow fading, and is approximated by Weibull distribution as described in the previous section.

By fitting the best curve, the following figures are selected: A=42.1 and λ=0.61 under LOS environment and A=45.5 and λ=0.62 under NLOS environment. Proposed path-loss model are shown in Figures 8 and 9.

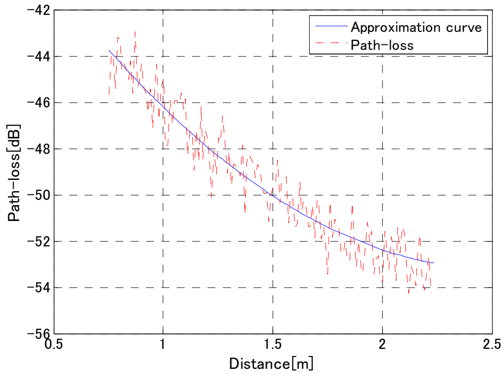

Figure 8 - Proposed path-loss model under LOS environment

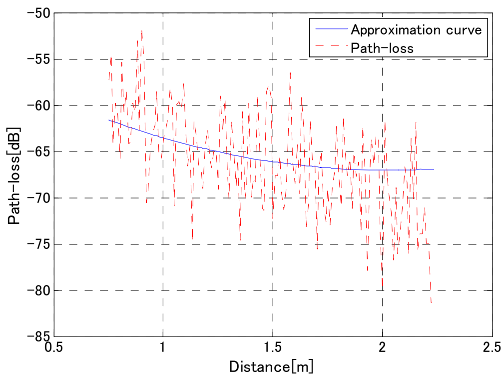

Figure 9 - Proposed path-loss model under NLOS environment

By using this model Bit Error Rate(BER) performance of IEEE802.15.4a system is examined. Eb /N0 in receiver is defined by Equation (7).

$$E_b / N_0 (d) = \mathrm{Ptx} - PL(d) - N + S \qquad (7)$$

In Equation (7), Ptx is transmission power, d is distance between transmitter and receiver, N is noise, and S is shadow fading. IEEE802.15.4a[4] signaling is binary PPM (Pulse Position Modulation), theoretical BER can be calculated by using complementary error function erfc. .

$$BER = \frac{1}{2} erfc\left(\sqrt{\frac{1}{2} E_b / N_0}\right) \qquad (8)$$

In this paper, the proposed path-loss model is evaluated by using Equation(6), (7) and (8).

Performance evaluation

Computation simulation using the Propagation channel response

The transmission simulation of IEEE802.15.4a that uses the calculation value by the path-loss model and the measured propagation channel response is compared and evaluated. Examples of measured delay-profile that converts propagation channel response into time-domain are shown in Figure 10 and Figure 11. It is understood that the amount of attenuation and the arrival time of the peak power have changed in each measurement point.

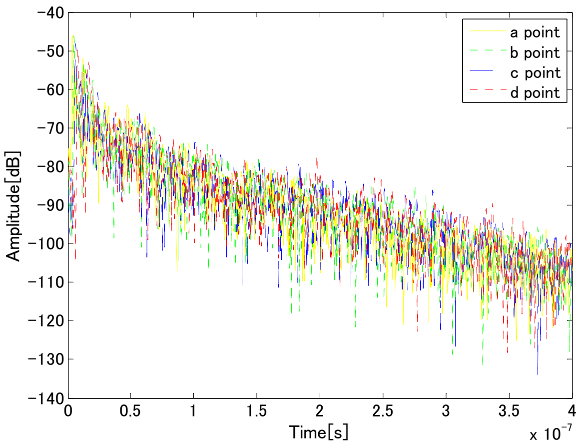

Figure 10 – Measured Delay-profile in measurement point under LOS environment

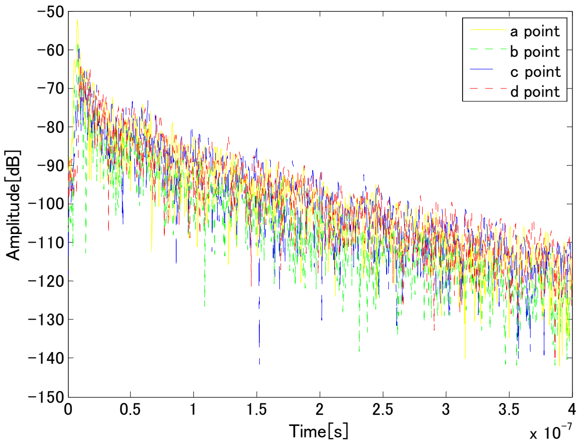

Figure 11 – Measured Delay-profile in measurement point under NLOS environment

Specifications using the simulation and IEE802.15.4a are shown in Table 2. The coherent detection was assumed in a receiver. Inter-symbol interference is not considered, and receiver assumes Rake reception of an infinite path. The Rake reception assumes all the available paths above 20dB from the peak path . To confirm the influence on the modulation method, the no error correcting code was assumed.

Table 2 - Simulation specification

Parameter	Value
Frequency Band (Carrier Frequency)	4.49GH z
Band width	499.2MHz
Spreading sequence	16chip
Transmitting power	-16.8 dBm
Primary Modulation	2PPM
Detection method	Coherent detection
Measurement time	400ns
Sample point	1601
Noise factor	6dB
Temperature	300 K

Simulation result

The BER characteristic as a simulation result is shown in Figure 12. The calculation value of the path-loss model is compared with the simulation value and an almost equal value under LOS environment, and more the calculation value of the path-loss model is compared with the simulation value and an almost equal value under NLOS environment. As a result, proposed path-loss model is effective to evaluate UWB transmission in bed side environments.

In LOS environment, transmitting power of 15.4a device can be reduced while maintaining BER performance at a certain level. Figure 13 indicates BER performance with 10 dB reduced transmitting power of -26.8dBm.

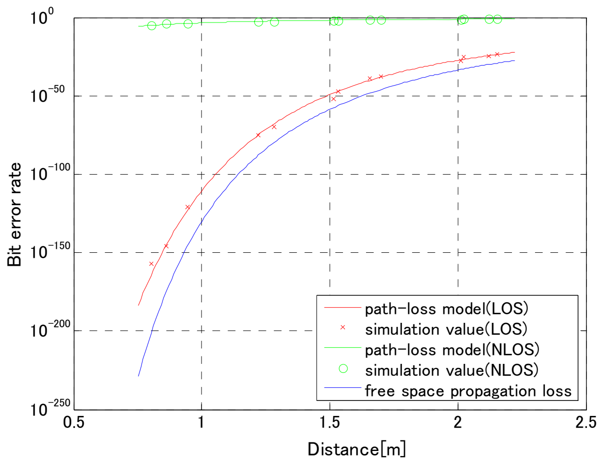

Figure 12 – BER Simulation result

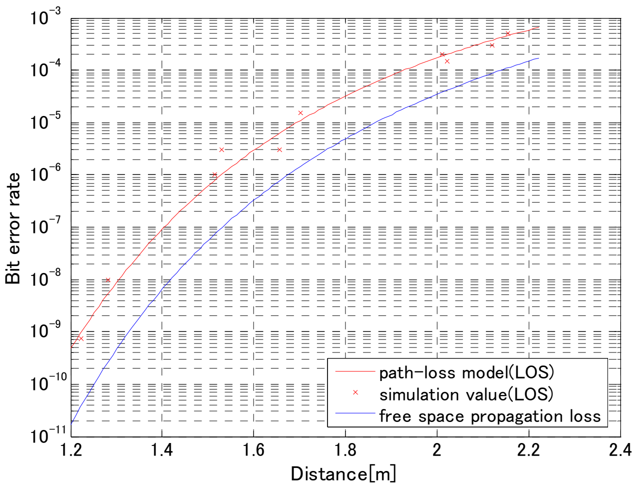

*Figure 13 – BER Simulation result **with 10dB lower Tx power***

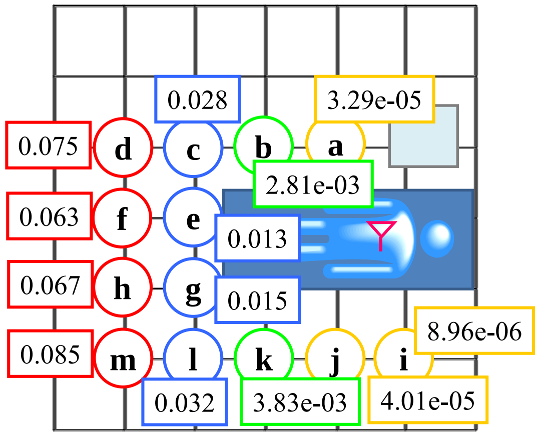

Figure 15 - BER evaluation with each measurement point under NLOS environment

BER evaluation with each measurement point

BER evaluations with each measurement point are shown in Figure 14 and 15. It is understood that BER characteristic deteriorated as the distance between the transmission antenna and receiving antenna becomes long. Good BER performance of 10^{-26} or less with each measurement point is observed under LOS environment,. However, under NLOS environment all the measurement points, BER of 10^{-6} or more are observ ed and the application of the error correcting code or other method is needed to improve performances in NLOS environment..

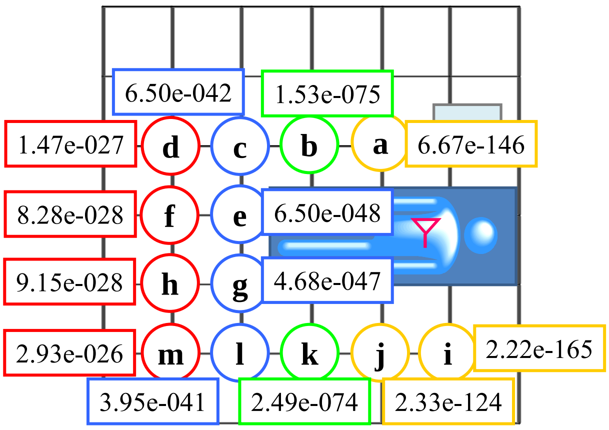

Figure 14 - BER evaluation with each measurement point under LOS environment

Conclusion

In this paper, relationship between distance and received power using UWB in a bedside environment is studied. Received power delay profile is measured by a vector network analyzer, under the LOS environment and the NLOS environment.

As a result, the approximation curve of measurements and the received power distribution from the received power error margin with measurements were studied, and it was shown that the distribution was modeled by the Weibull distribution.

It has been understood that the calculation value of the path-loss model is compared with the simulation value and an almost equal value under a bed side environment room of 7m×5m in the hospital. Using the response that is measured by a vector network analyzer, path-loss models are developed and evaluated by the computer simulation. BER characteristic is evaluated using the IEEE802.15.4a signal for the developed path-loss model. As a result, it was shown that the path-loss model well described the BER characteristic.

References

[1] M. Hasegawa, M. Kumazawa, K. Takizawa, T. Ikegami ,"Feasibility Study on detecting of IEEE802.15.4a signals," IEEE ICUWB2008

[2] U. Varshney et al., IEEE Communications Magazine, pp.49-55, Apr. 2006.

[3] SAYAMA SHUJI, ISHII, SEKINE, "Suppression of sea-ice clutter observed by a millimeter wave radar using a new log-Weibull/CFAR system" Transactions of the Institute of Electrical Engineers of Japan,VOL.126 pp 431-437, June 2006

[4] http://www.ieee802.org/15/pub/TG4a.html.

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