Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Ranging Accuracy Evaluation under TG6ma Communication Scenarios
Date Submitted: July 30th, 2025
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Re: In response to call for technical contributions

Abstract: This provides a preliminary investigation of the effect of interference cancellation on UWB ranging accuracy under multiple BAN coexistence situations, and some simulation results are discussed.

Purpose: Material for discussion in P802.15.6a TG corresponding to comments in EC Meeting

Ranging Accuracy Evaluation under TG6ma Communication Scenarios

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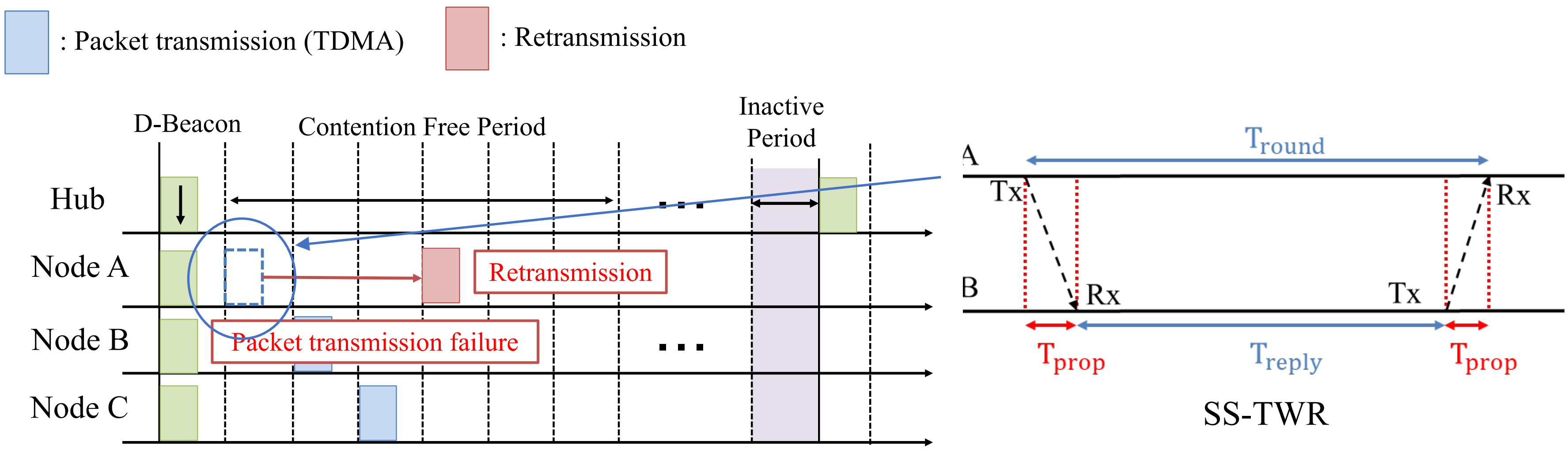
Introduction

- Ranging is a key issue in various kinds of UWB applications, including IEEE 802.15.6ma, 4ab, and 4z
- UWB techniques have the potential to achieve high accuracy in supporting important applications in HBAN and VBAN
- It is important to discuss the ranging accuracy under multiple BAN coexistence situations under the BAN channel models

UWB ranging in CFP

- It is more realistic that ranging is performed in contention free period (CFP), which results in the realization of both data transmission and ranging in the same period



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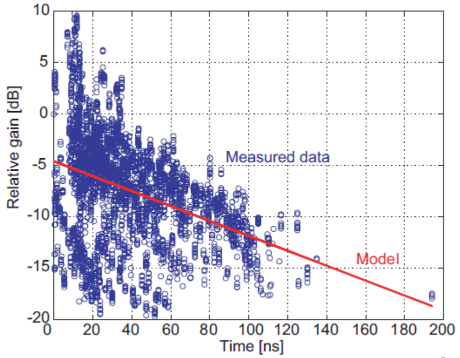
Propagation model in a hospital room[1]



PDP model : $h(t) = \sum_{l=0}^{L-1} a_l \exp(j\varphi_l)\,\delta(t - t_l)$

Amplitude $10\log_{10}|a_l|^2 = \gamma_0 + 10\log_{10}\left(\exp\left(-\frac{t_l}{\Gamma}\right)\right)$

Path arrival time $p(t_l|t_{l-1}) = \lambda\exp(-\lambda(t_l - t_{l-1}))$

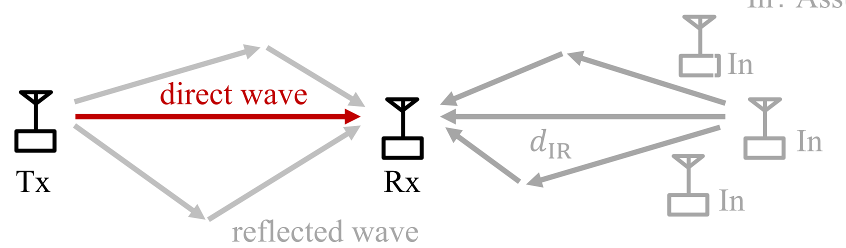
Number of the arrival paths $p(L) = \frac{\bar{L}^L \exp(-\bar{L})}{L!}$

Parameters		Values
a_l	γ_0	-4.60 dB
	Γ	59.7
t_l	$1/\lambda$	1.85 ns
L	$\bar{L}$	20

a_l : Path amplitude
t_l : Path arrival time
φ_l : Path phase
$\delta(t)$: Dirac function
Γ : Exponential decay
γ_0 : Rician factor
L : Number of the arrival paths

[1]: K. Takizawa, T. Aoyagi, H. -B. Li, J. -i. Takada, T. Kobayashi and R. Kohno, "Path loss and power delay profile channel models for wireless body area networks," 2009 IEEE Antennas and Propagation Society International Symposium, North Charleston, SC, USA, 2009, pp. 1-4.

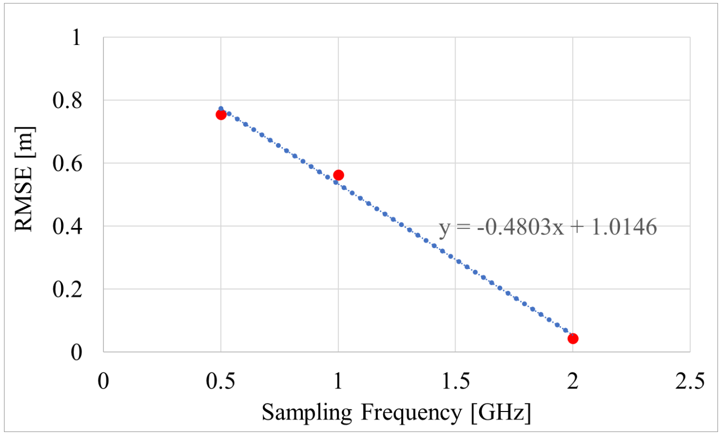
Ranging accuracy evaluation (SNR: 20 dB)



Fading: flat
Sampling frequency at receiver: 0.5, 1, 2 GHz
Cross-correlation detection
AWGN: SNR of 20 dB

d_{TR} = Determined by uniform random numbers of 3-4 m

d_{IR}: Determined by uniform random numbers of 1-6 m each



Technical requirement

Achieve a ranging accuracy of below 0.3 m

	0.5 GHz	1.0 GHz	2.0 GHz
RMSE [m]	0.754814	0.563771	0.044247

The sampling rate of 2 GHz satisfied the requirement

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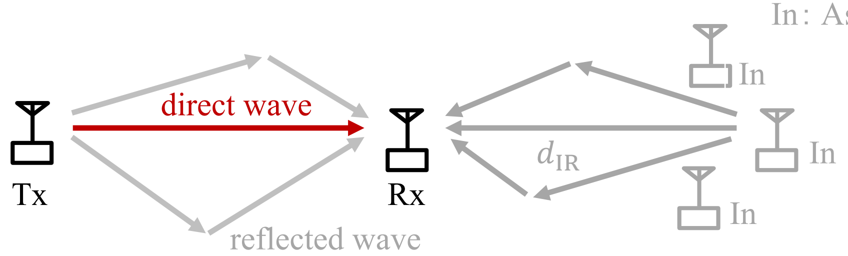
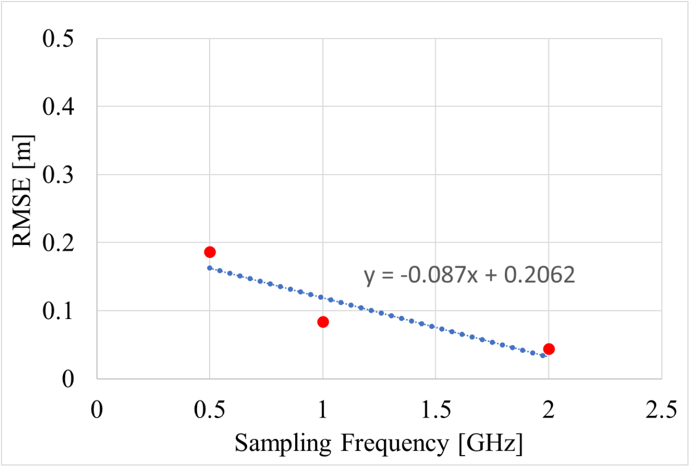
Ranging accuracy evaluation (SNR: 40 dB)



Fading: flat
Sampling frequency at receiver: 0.5, 1, 2 GHz
Cross-correlation detection
AWGN: SNR of more than 40 dB

d_{TR} = Determined by uniform random numbers of 3-4 m

d_{IR}: Determined by uniform random numbers of 1-6 m each



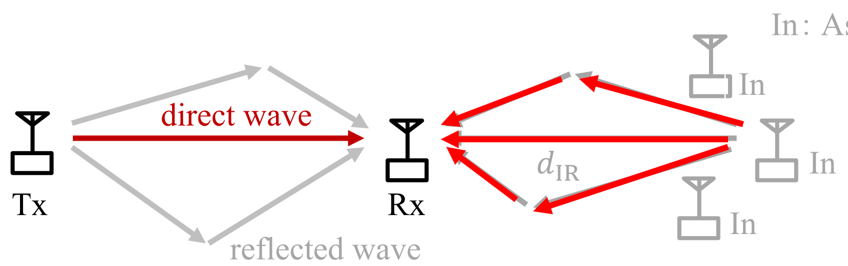
Technical requirement

Achieve a ranging accuracy of below 0.3 m

	0.5 GHz	1.0 GHz	2.0 GHz
RMSE [m]	0.186388	0.083677	0.044051

All sampling rates satisfied the requirement under clear channel condition

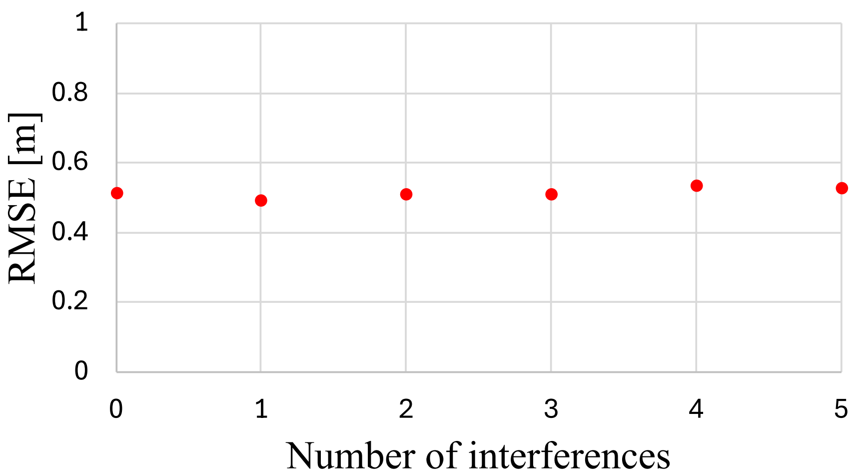
Ranging accuracy evaluation under coexistence scenario



Fading: flat
Sampling frequency at receiver: 0.5, 1, 2 GHz
Cross-correlation detection
AWGN: SNR of more than 40 dB

d_{TR} = Determined by uniform random numbers of 3-4 m

d_{IR}: Determined by uniform random numbers of 1-6 m each



No performance degradation was confirmed with M-sequence-based interference mitigation

Sampling frequency: 1 GHz

Coexistence of up to five interference nodes

M-sequence-based interference mitigation

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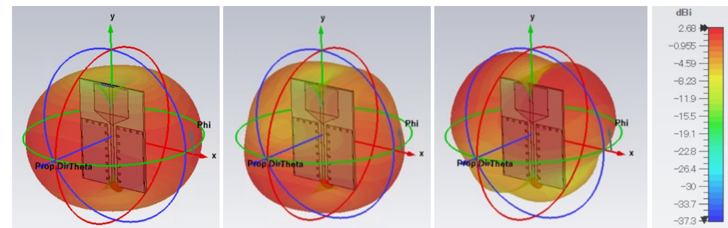
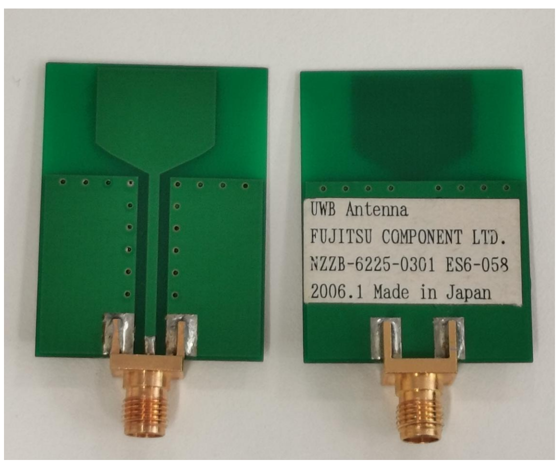
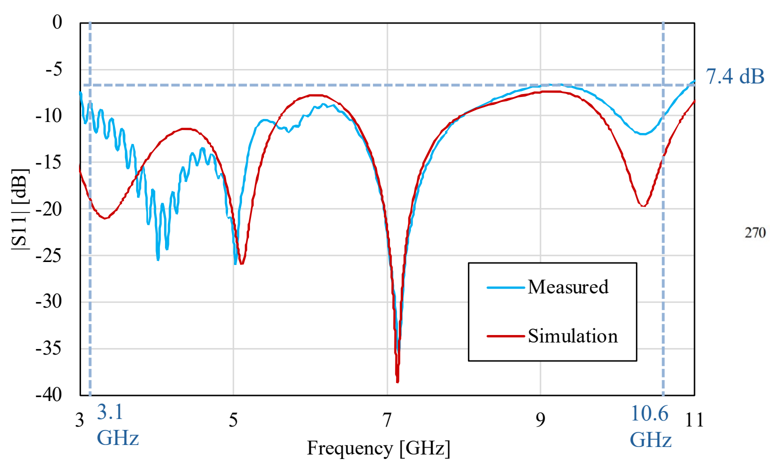
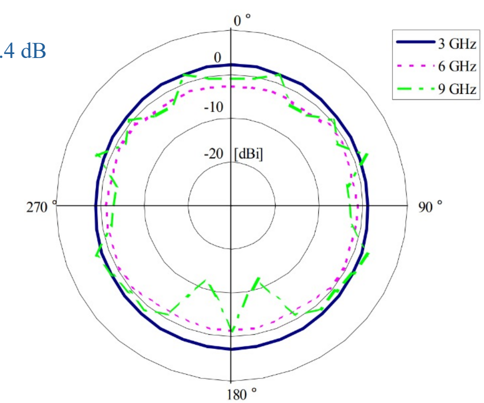
UWB antenna modeling



(a) 3 GHz (b) 6 GHz (c) 9 GHz







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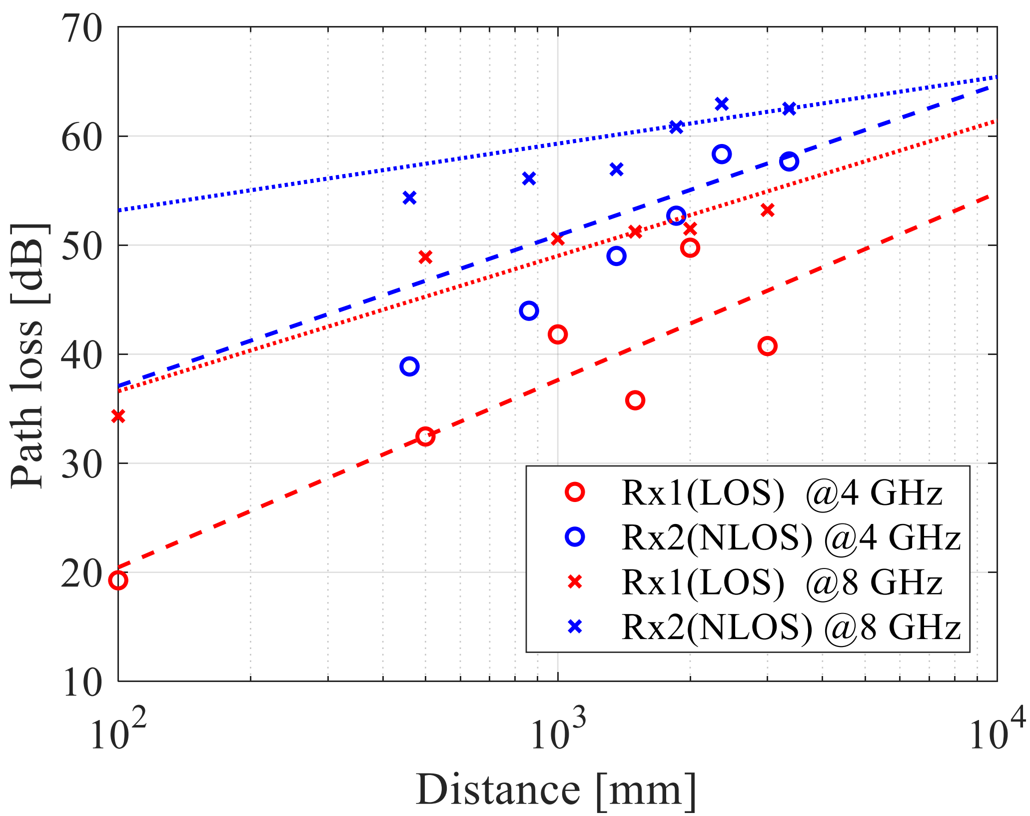
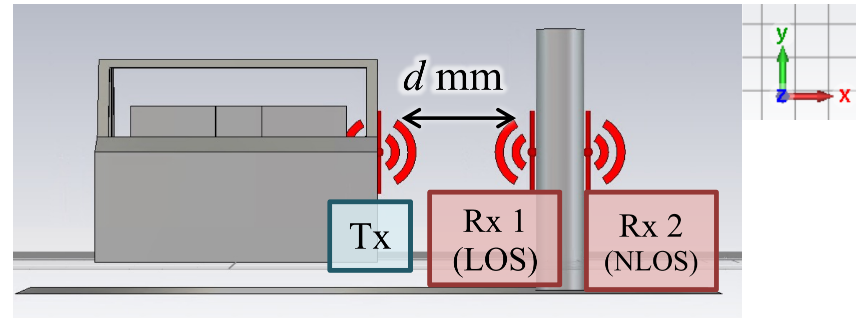
Simulation results

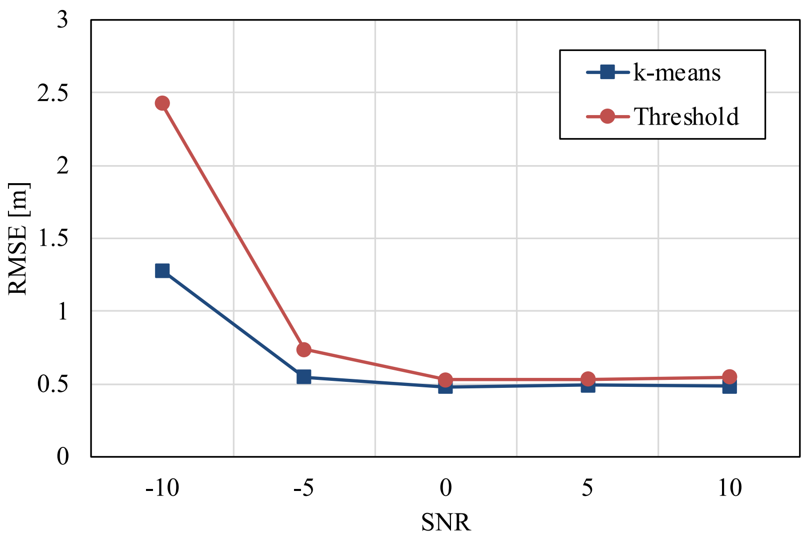


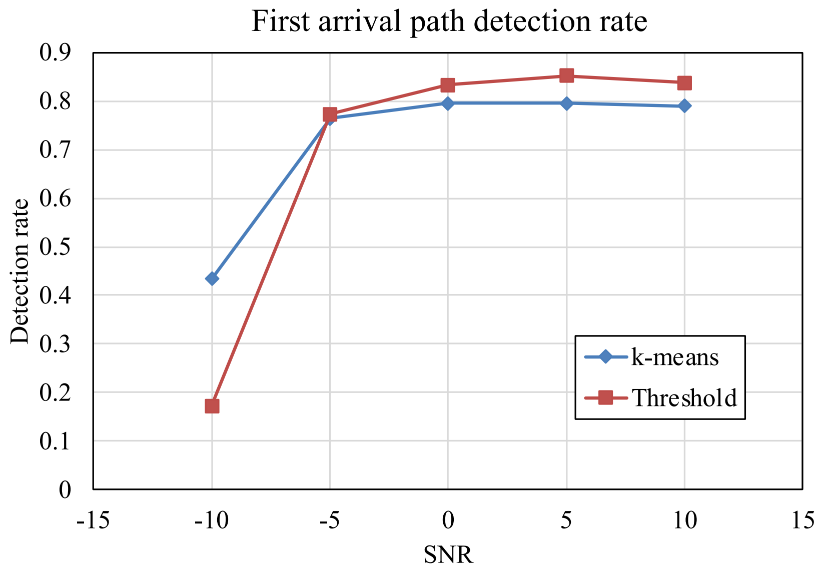


$$PL\ [\mathrm{dB}] = PL_0 + 10n\log_{10}\left(\frac{d}{d_0}\right)$$

Parameters	PL_0[dB] (d=1000 mm)	n	RMSE [dB]
Rx1 @4GHz	37.6	7.45	4.41
Rx2 @4GHz	50.9	6.00	2.07
Rx1 @8GHz	49.0	5.39	2.05
Rx2 @8GHz	59.3	2.66	1.43

Simulation results





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References

1. D. Anzai, I. Balasingham, G. Fischer, J. Wang, "Reliable and High-Speed Implant Ultra-Wideband Communications with Transmit–Receive Diversity," EAI/Springer Innovations in Communication and Computing, pp. 27-32, March 2020.
2. Y. Shimizu, D. Anzai, R. C-Santiago, P. A. Floor, I. Balasingham, and J. Wang, "Performance evaluation of an ultra-wideband transmit diversity in a living animal experiment" IEEE Trans. Microw. Theory Tech., vol. 65, no. 7, pp. 2596-2606, July 2017.
3. D. Anzai, K. Katsu, R. Chavez-Santiago, Q. Wang, D. Plettemeier, J. Wang, and I. Balasingham, "Experimental evaluation of implant UWB-IR transmission with living animal for body area networks," IEEE Trans. Microw. Theory Tech., vol. 62, no. 1, pp. 183-192, Jan. 2014.
4. J. Shi, D. Anzai, and J. Wang, "Channel modeling and performance analysis of diversity reception for implant UWB wireless link," IEICE Trans. Commun., no. E95-B, vol. 10, pp. 3197-3205, Oct. 2012.