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

Submission Title: Propagation Channel Parameters of UWB Communication Applications for Human BAN (HBAN) Use Cases

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Re: In response to call for technical contributions

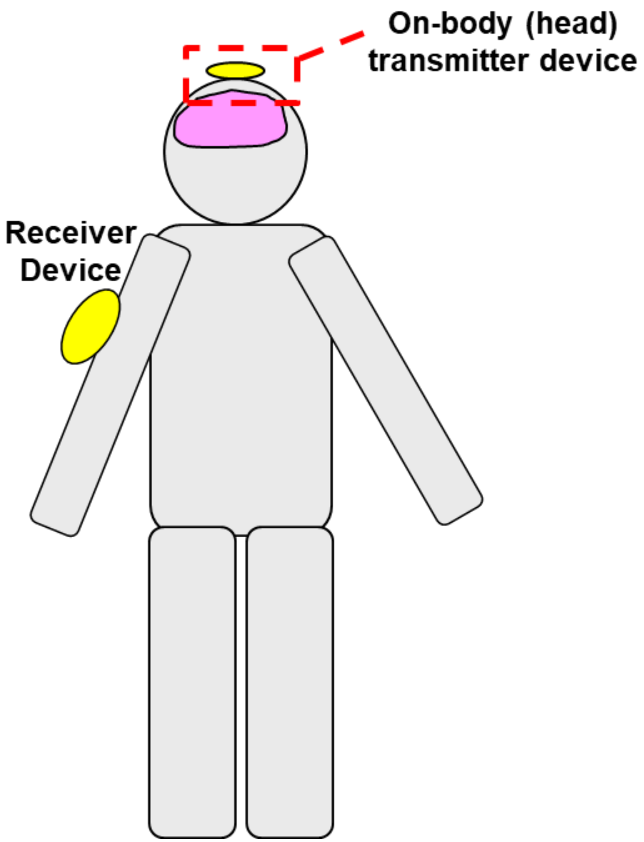
Abstract: This provides of fundamental propagation channel parameters including path loss characteristics for UWB communication applications for BCI use case.

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

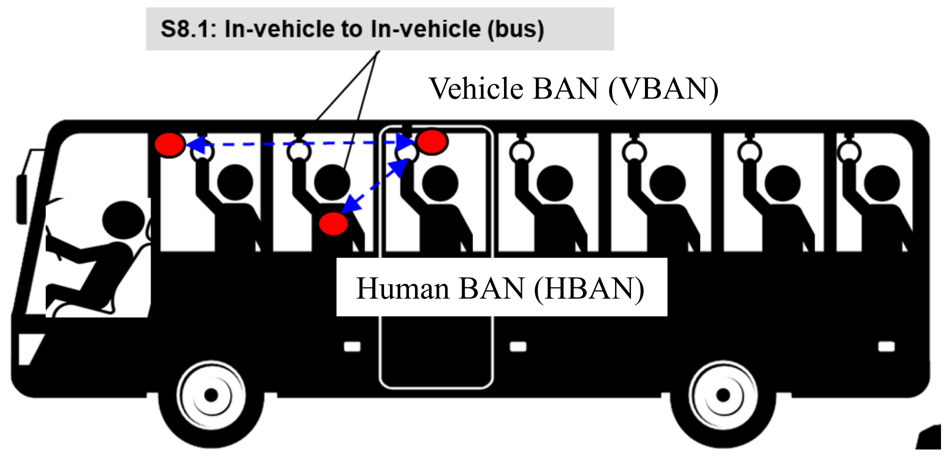
Propagation Channel Parameters of UWB Communication Applications for Human BAN (HBAN) Use Cases

Daisuke Anzai, Sho Asano, and Takumi Kobayashi
Nagoya Institute of Technology (NIT)

UWB communication applications



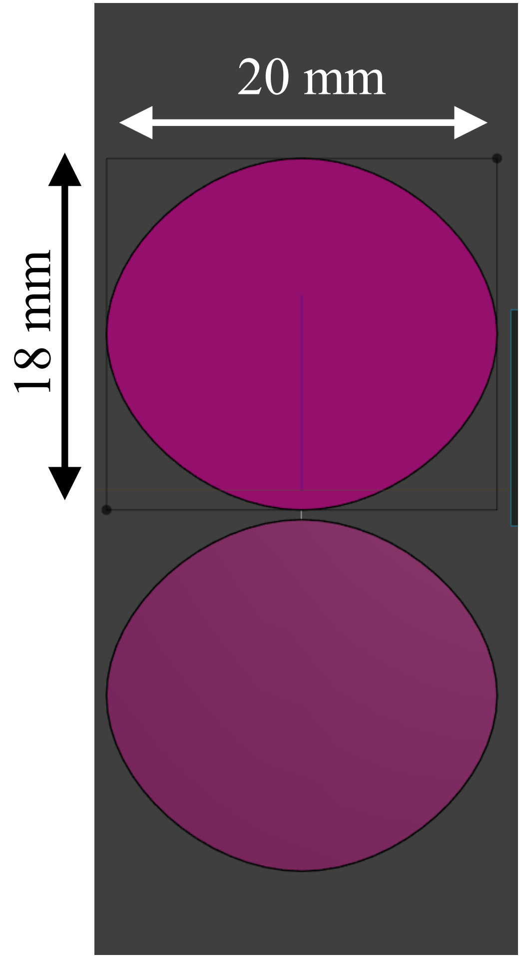
Brain-computer interface (BCI) model[1]



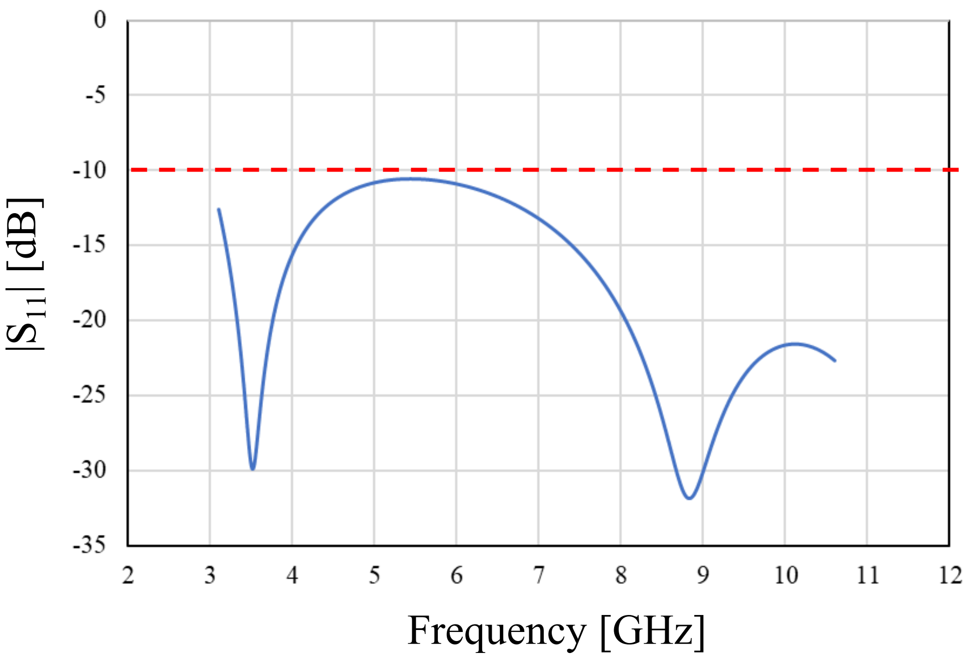
Passengers bus model[1]

[1]IEEE 802.15-22-0344-02-006a

UWB antenna at 3.1 - 10.6 GHz band

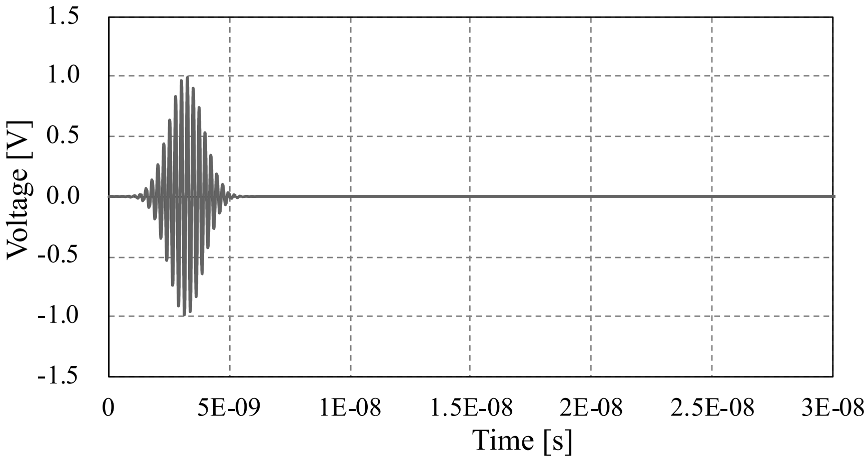


- ✓ Frequency: 3.1 – 10.6 GHz
- ✓ Planar elliptical dipole antenna
- ✓ Element size: 20 mm x 18 mm x 1 mm
- ✓ Interval between each element: 0.5 mm

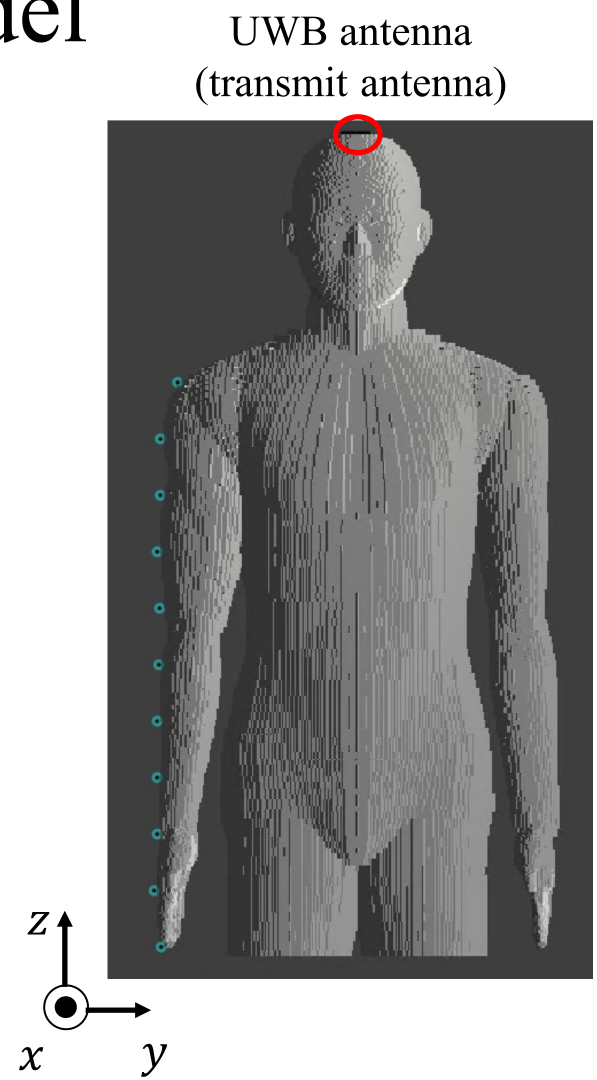


Simulation model

- ✓ Frequency: 3.4 – 4.8 GHz
- ✓ Frequency-dependent finite-different time-domain (FDTD) method
- ✓ Multi-size voxel model (min. size: 0.5 mm)
- ✓ Homogeneous human model (Japanese male developed by NICT, Japan)

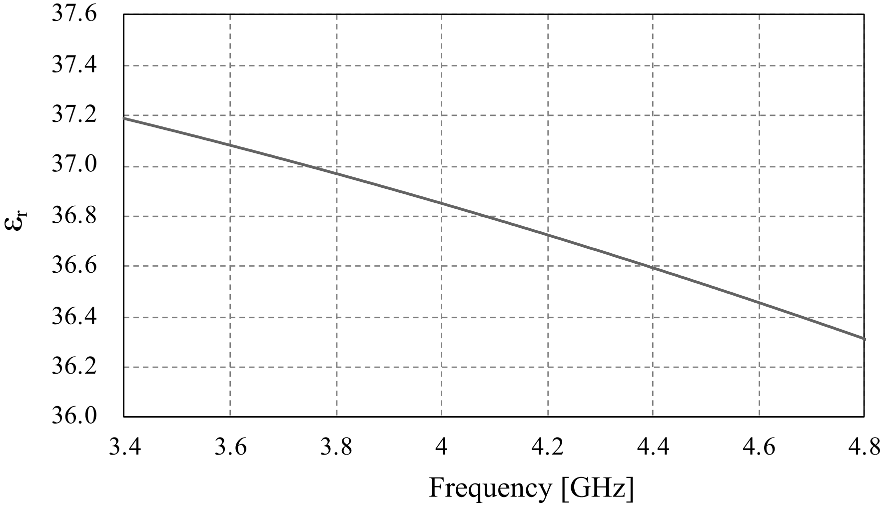


Transmitted signal waveform

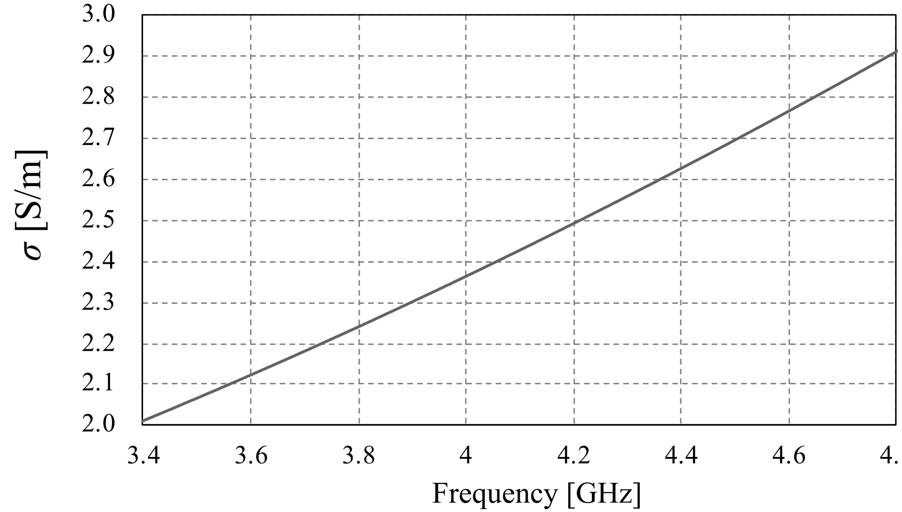


Dielectric constants of human model

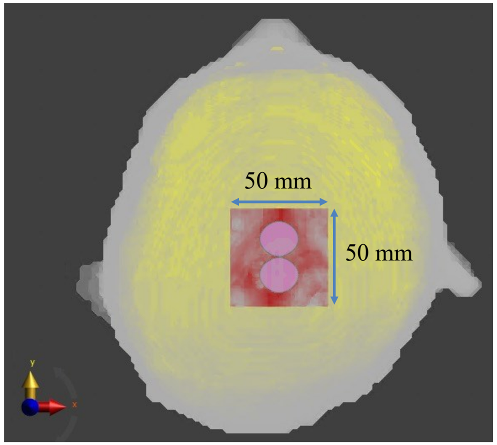
Relative permittivity

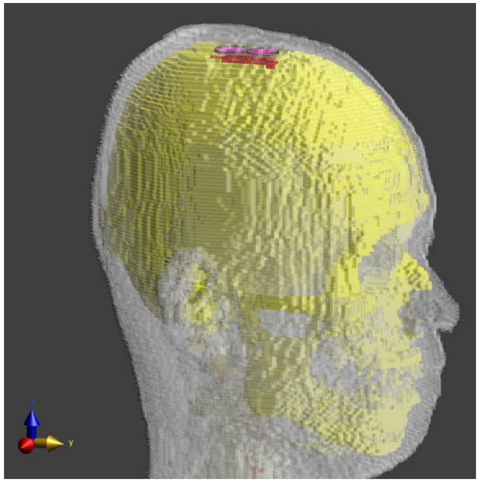


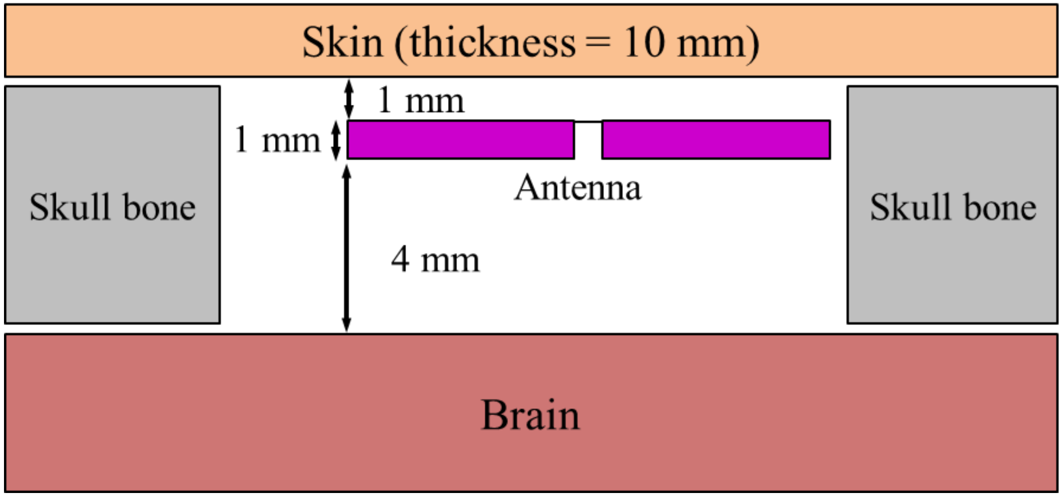
Conductivity



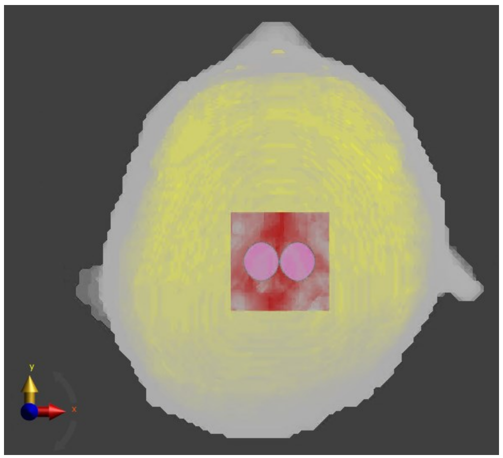
Simulation model for BCI case (Forward antenna direction)

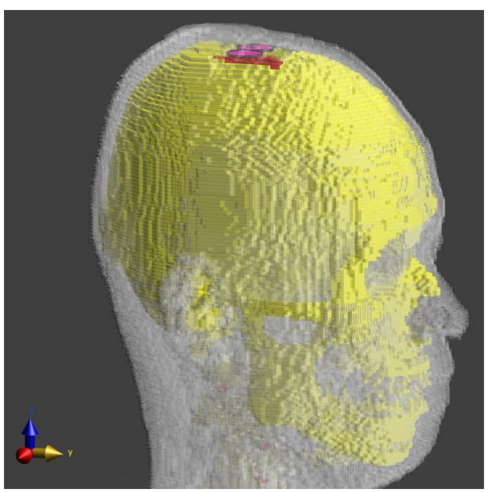


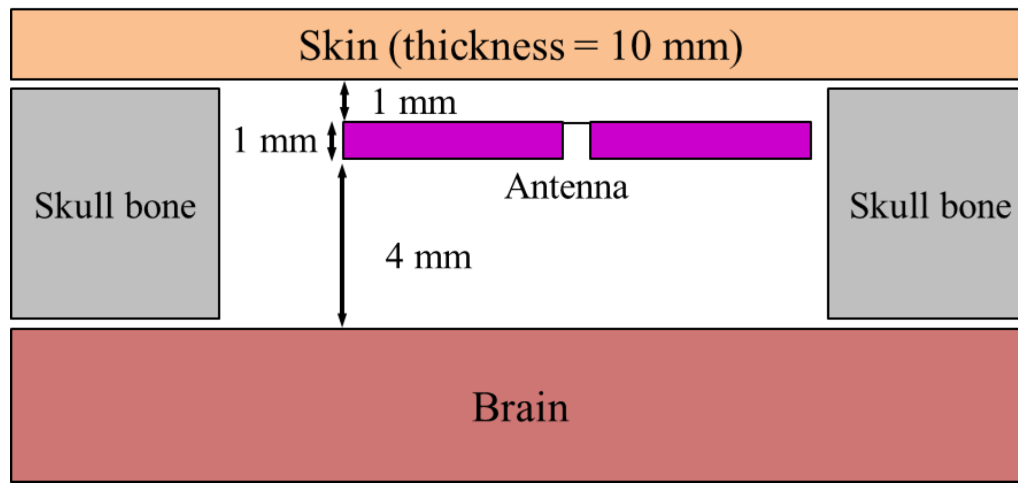




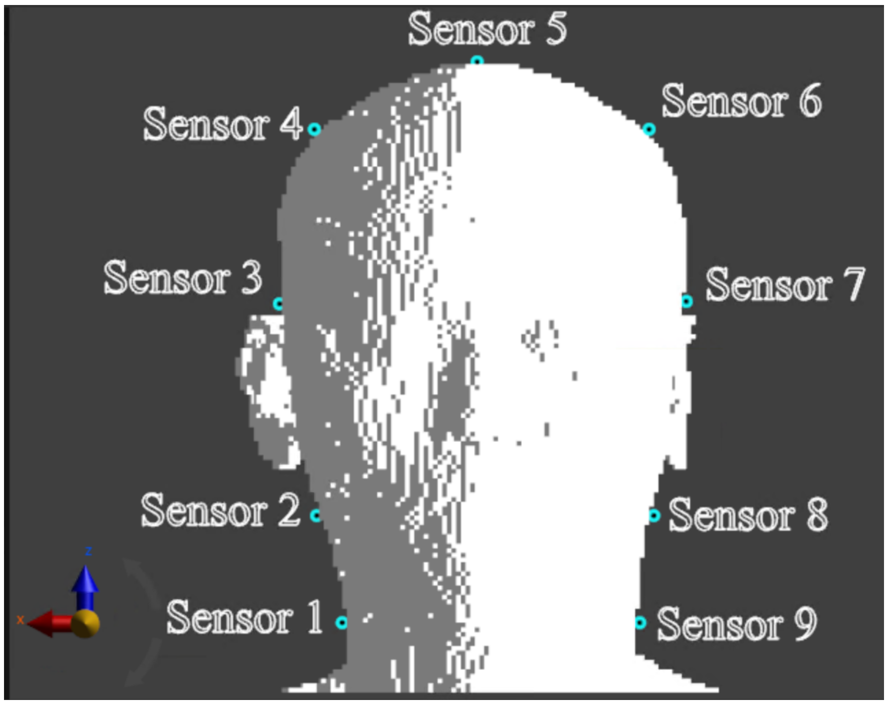
Simulation model for BCI case (Sideways antenna direction)

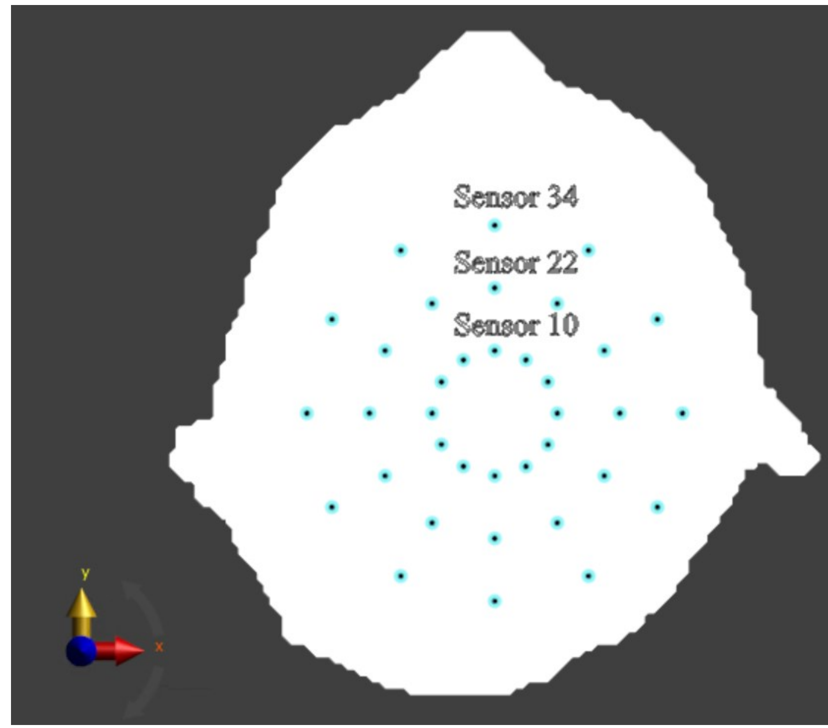




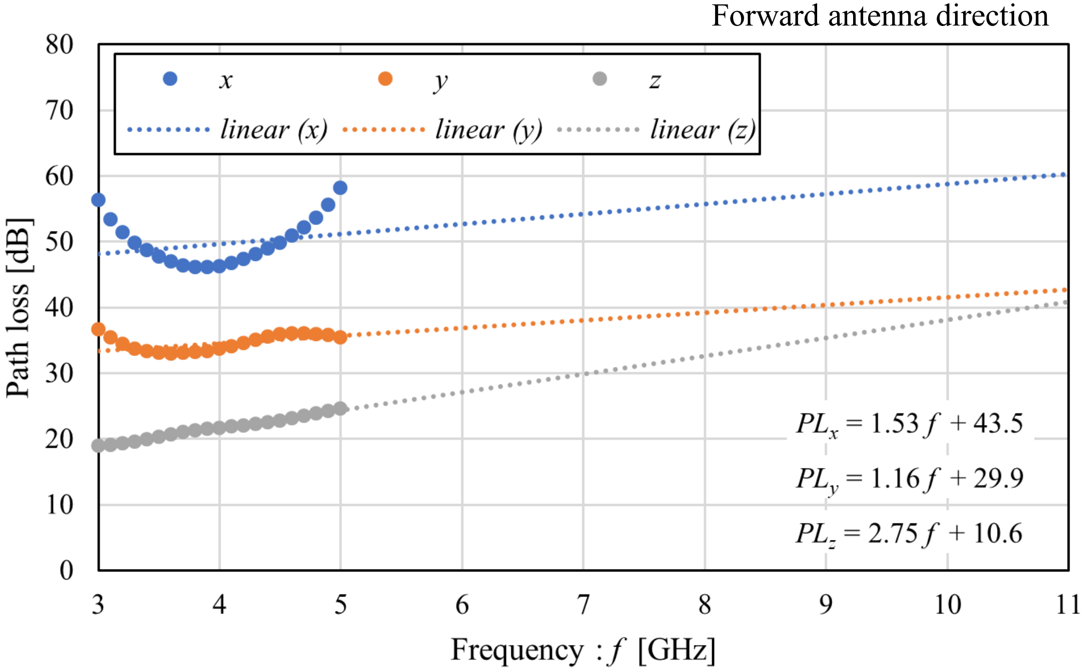


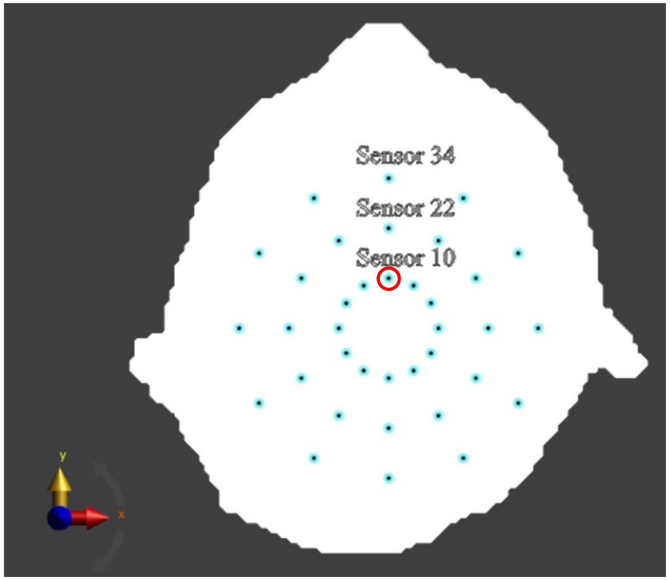
Simulation setup (Human head model)



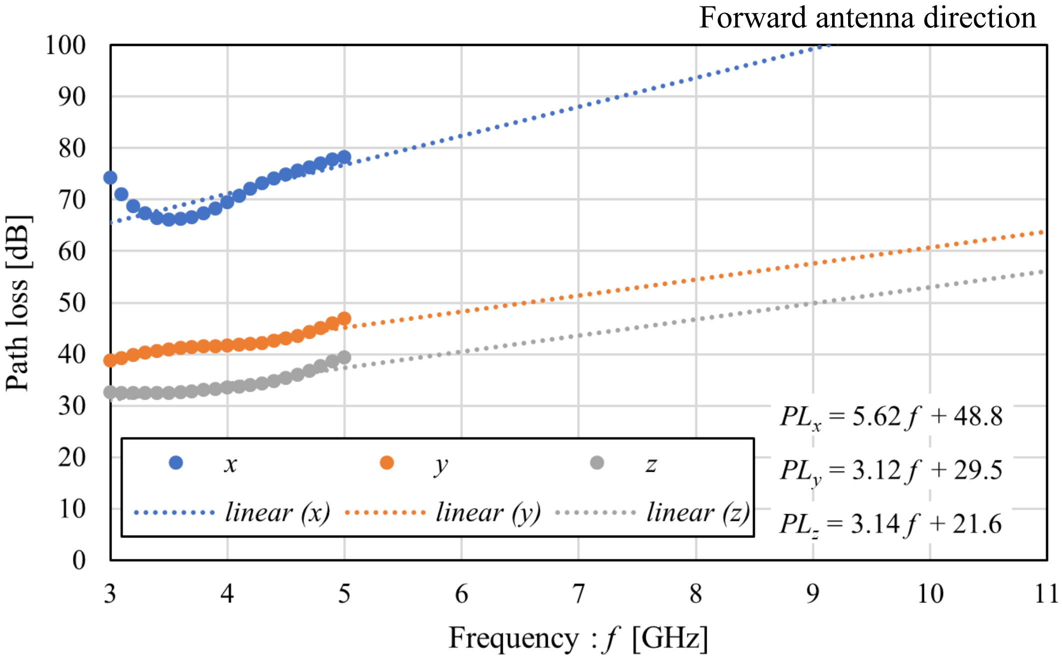


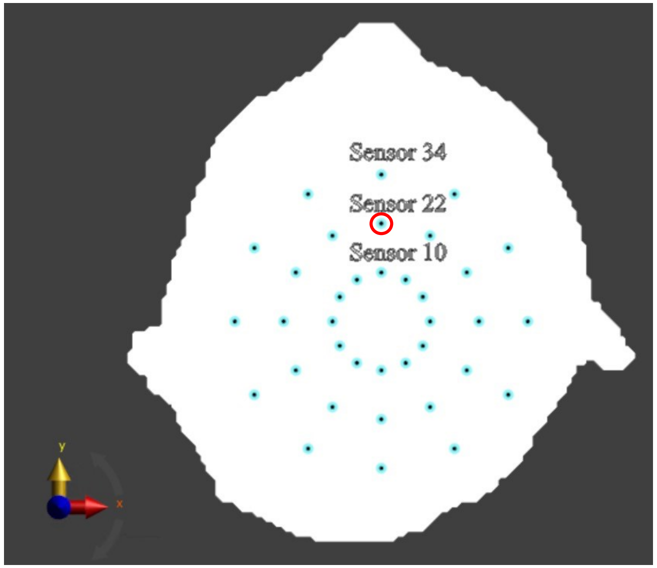
Path loss characteristics (Sensor #10)



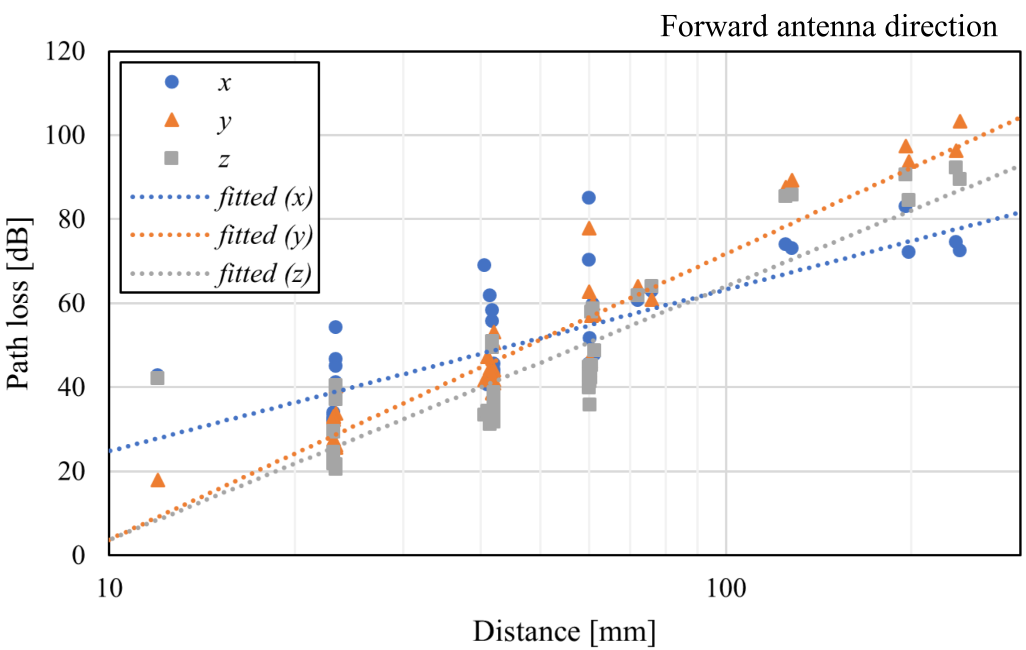


Path loss characteristics (Sensor #22)





Distance characteristics (Human head, BCI)



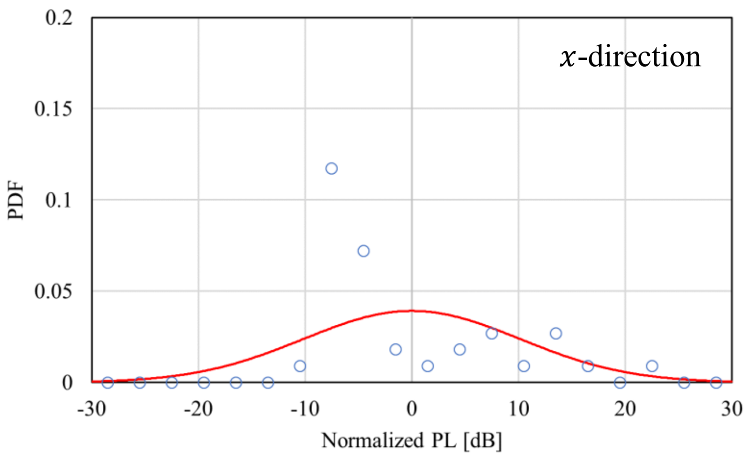
$$PL_{\mathrm{dB}} = PL_{0,\mathrm{dB}} + 10n \log_{10}\left[\frac{d}{d_0}\right]$$

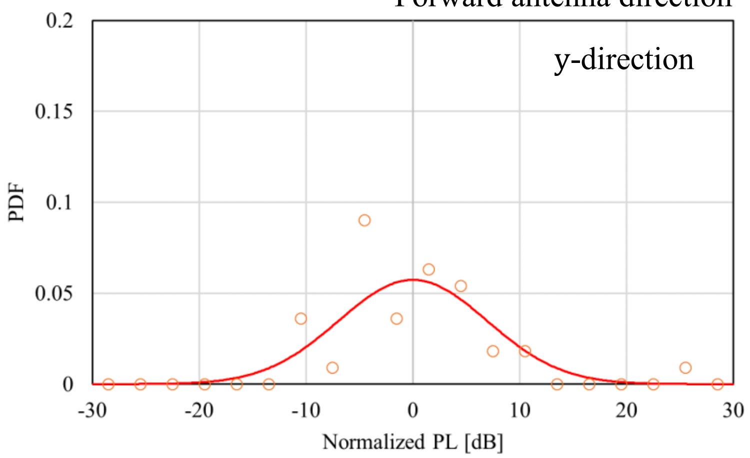
Directions	PL_0 [dB]	n	σ_s [dB]
x	24.84	3.84	9.52
y	3.78	6.80	7.27
z	3.73	6.03	9.31

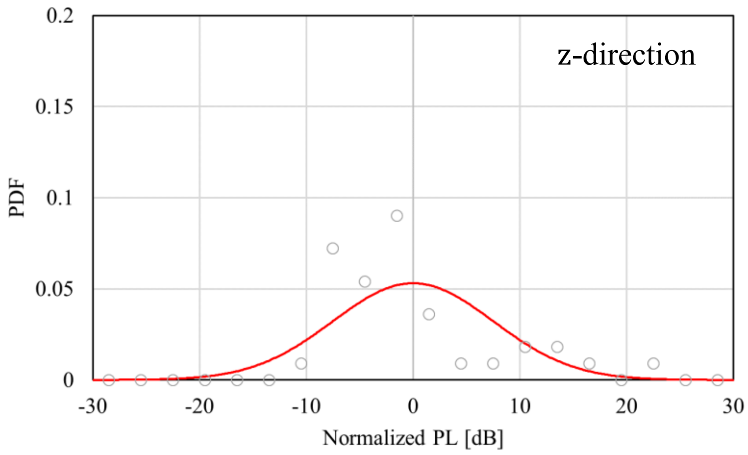
$d_0 = 10$ mm

Log-normal distribution (Human head, BCI)

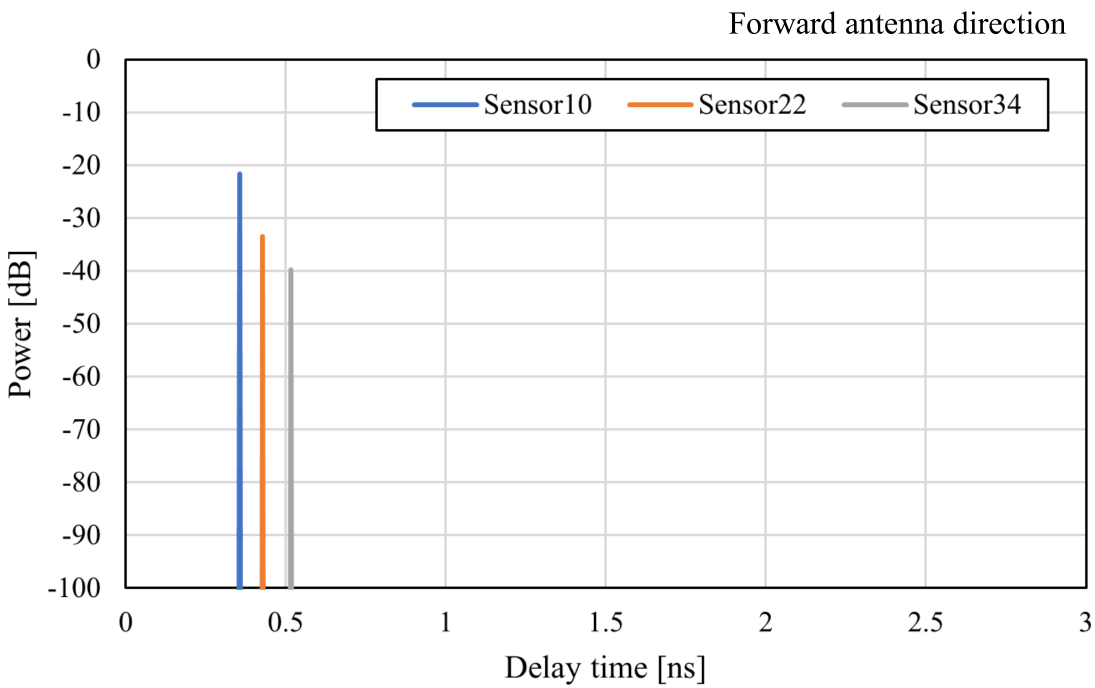
Forward antenna direction

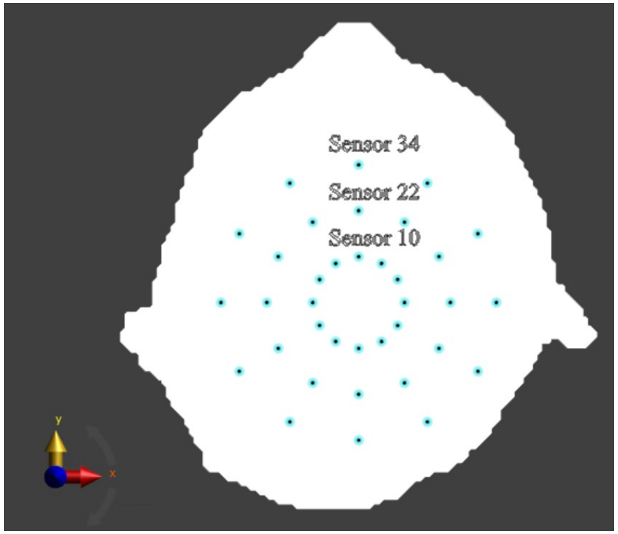




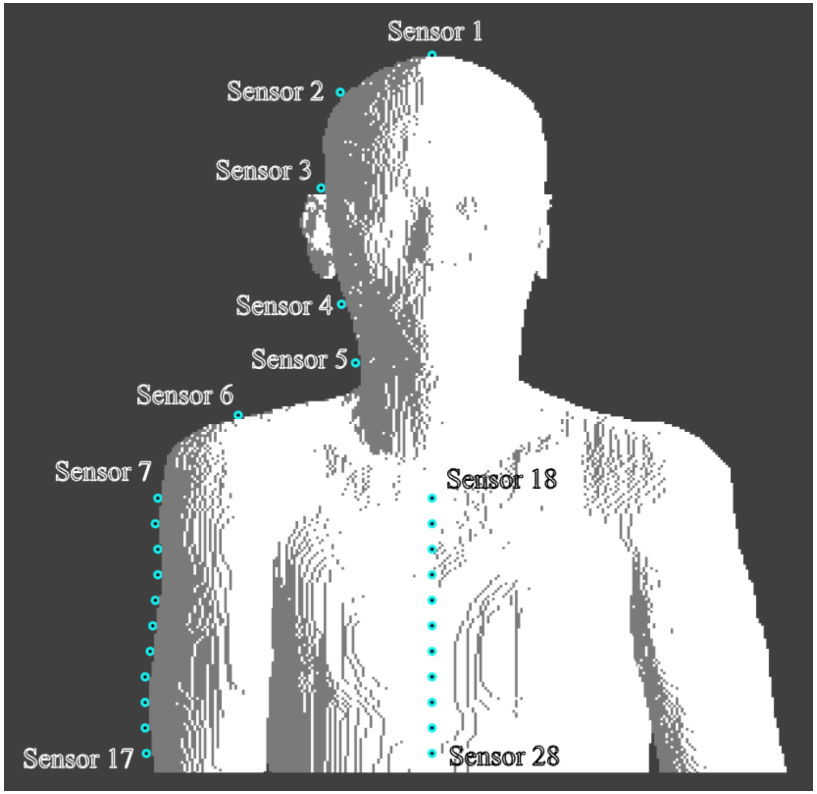


Power delay profile (Human head, BCI)





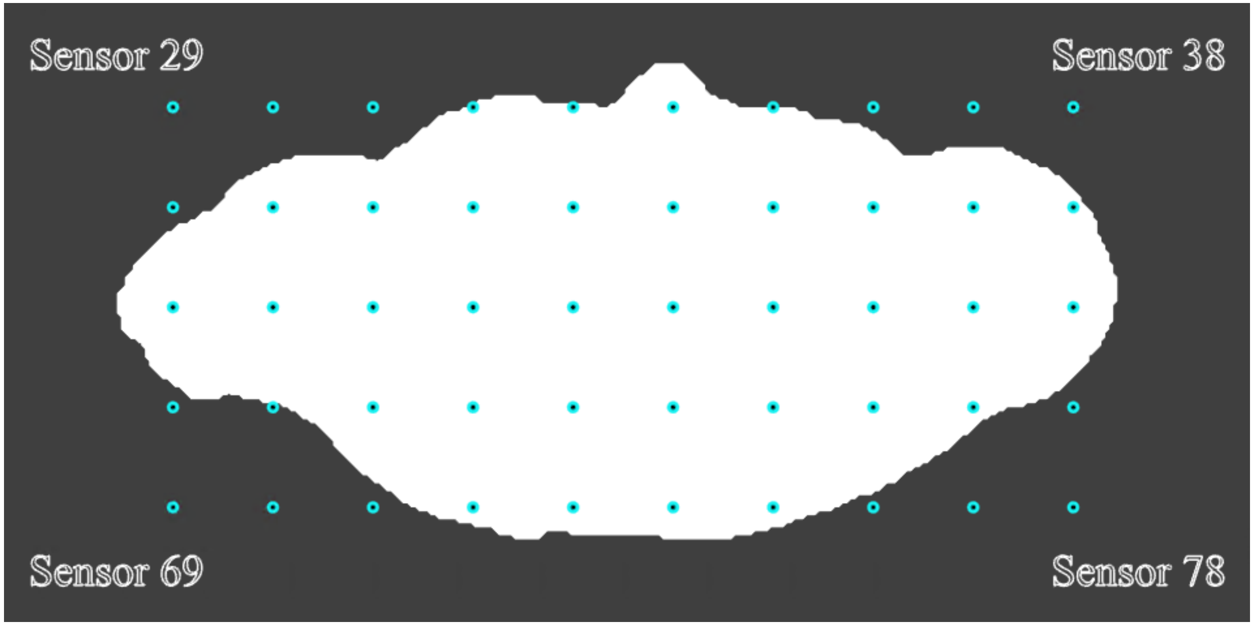
Simulation model (On-body model)



- ✓ 28 receivers were place on the body surface including head, arm, and chest

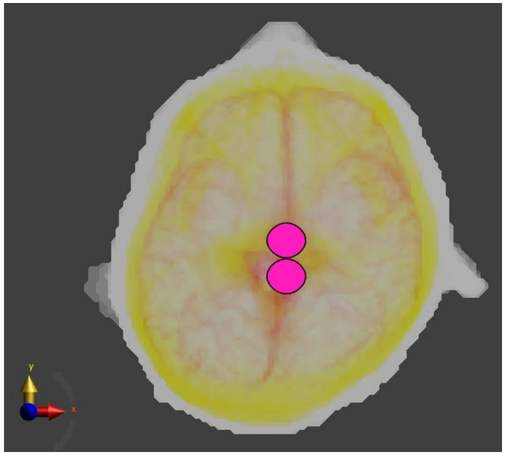
Simulation model (Off-body model)

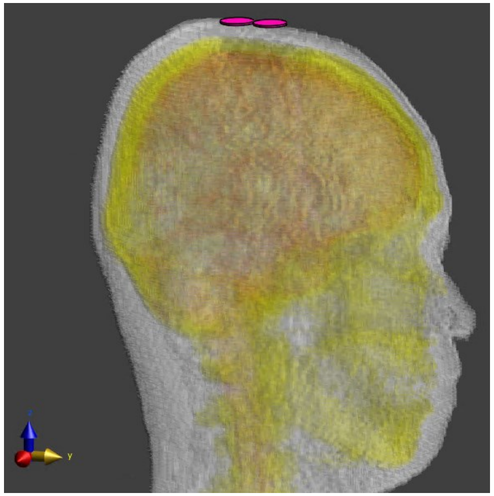
Top view

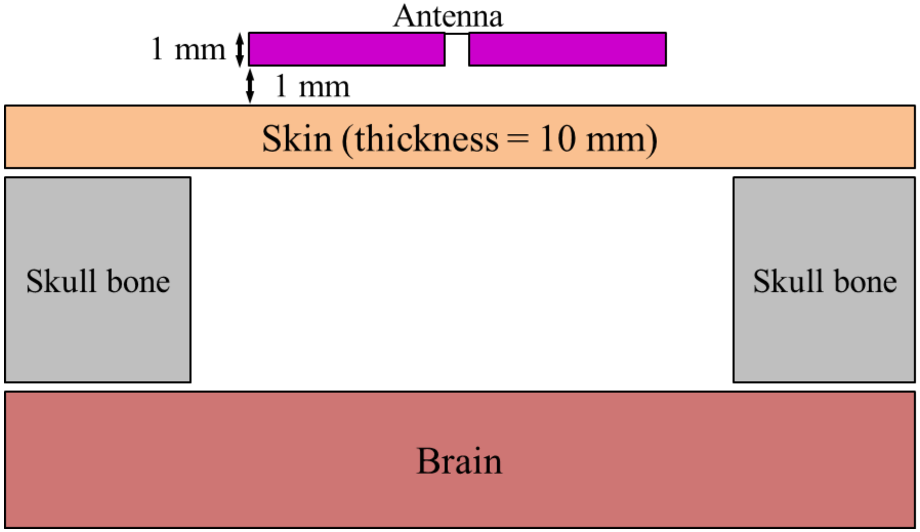


- ✓50 receivers (#29-#78) were placed at a height of 30 mm above the transmitting antenna (the top of the human head)
- ✓The interval of each receiver was set to 5 mm

Simulation model for BMI case (Forward antenna direction)

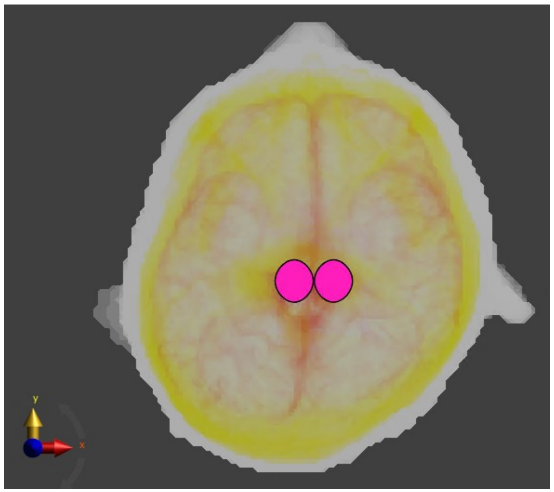


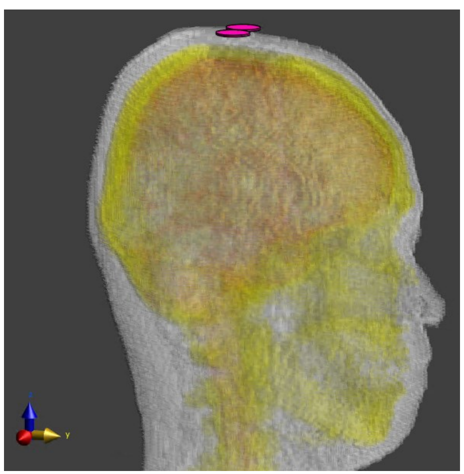


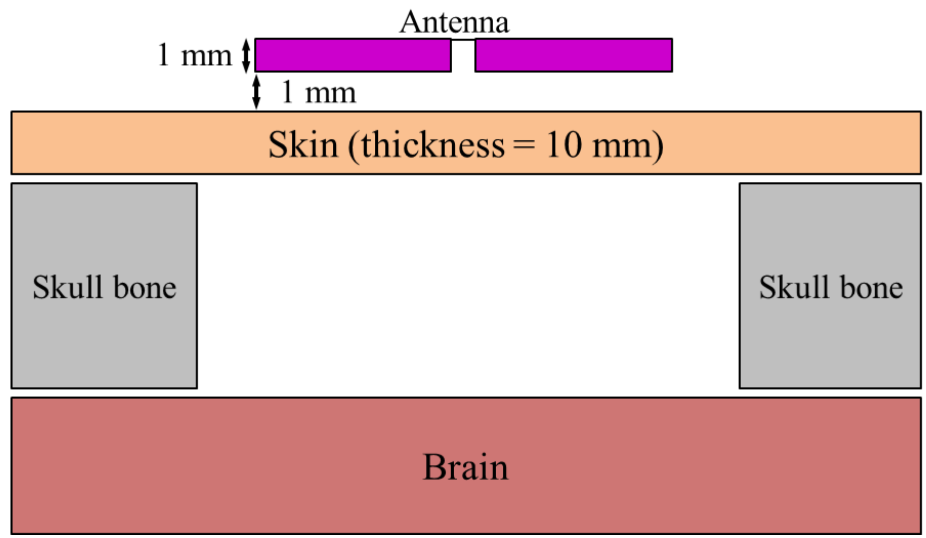


BMI: Brain Machine Interface

Simulation model for BMI case (Sideways antenna direction)







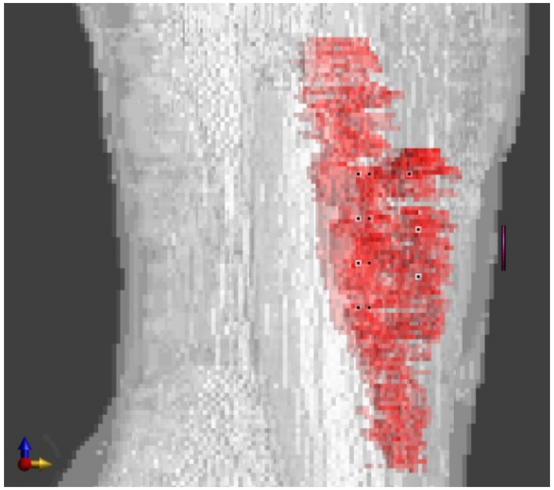
BMI: Brain Machine Interface

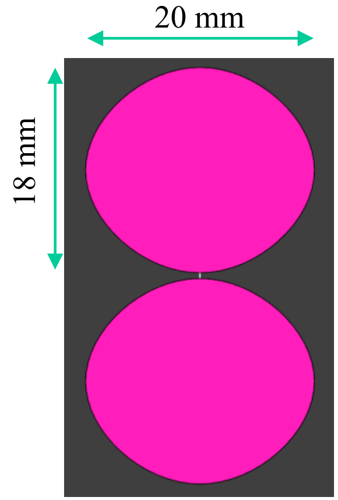
Summary of channel parameters

Antenna direction	Case	Receiving direction	Receiving antenna position														
			Whole head (d_0 = 10 mm)			Scalp (d_0 = 10 mm)			Arm (d_0 = 100 mm)			Torso (front) (d_0 = 100 mm)			Off-body (d_0 = 10 mm)		
			PL_0 [dB]	n	σ_s [dB]	PL_0 [dB]	n	σ_s [dB]	PL_0 [dB]	n	σ_s [dB]	PL_0 [dB]	n	σ_s [dB]	PL_0 [dB]	n	σ_s [dB]
Forward	BCI	X	24.84	3.84	9.52	27.13	3.36	10.18	23.70	9.76	0.74	69.31	3.85	3.02	48.47	1.45	9.63
		Y	3.78	6.80	7.27	11.44	5.32	6.96	102.62	0.57	8.15	50.24	2.76	0.65	19.13	2.67	2.72
		Z	3.73	6.03	9.31	17.58	3.31	7.52	104.27	0.59	4.98	27.52	8.61	1.98	22.81	2.69	7.55
	BMI	X	32.21	2.55	12.94	33.07	2.40	14.17	60.60	2.01	1.10	70.72	5.04	2.69	40.26	1.65	6.19
		Y	10.72	5.63	8.02	14.08	4.89	7.88	90.00	0.66	10.08	59.62	3.02	0.61	23.09	2.25	3.85
		Z	13.00	4.62	8.86	18.04	3.52	8.75	87.49	0.45	5.35	32.56	9.25	1.61	22.12	2.66	5.81
Sideways	BCI	X	20.37	3.80	7.47	10.97	5.63	6.89	51.42	3.14	1.13	16.68	10.59	2.42	0.05	4.95	2.66
		Y	19.60	4.96	7.59	25.39	3.86	7.31	80.65	1.99	11.42	67.02	3.72	1.80	34.94	2.74	5.65
		Z	13.36	4.54	7.09	19.77	3.34	7.03	76.35	1.85	5.12	62.07	6.87	2.61	44.11	0.56	5.84
	BMI	X	17.71	4.01	7.33	14.01	4.84	7.51	51.22	3.28	1.09	15.68	11.30	2.58	-3.03	5.25	4.76
		Y	26.20	4.19	12.94	33.17	2.65	12.88	78.08	2.63	12.69	56.25	4.89	1.52	45.33	1.24	6.31
		Z	20.14	4.09	8.89	23.42	3.39	9.35	77.09	1.87	5.07	36.17	10.07	1.61	42.50	0.80	4.96

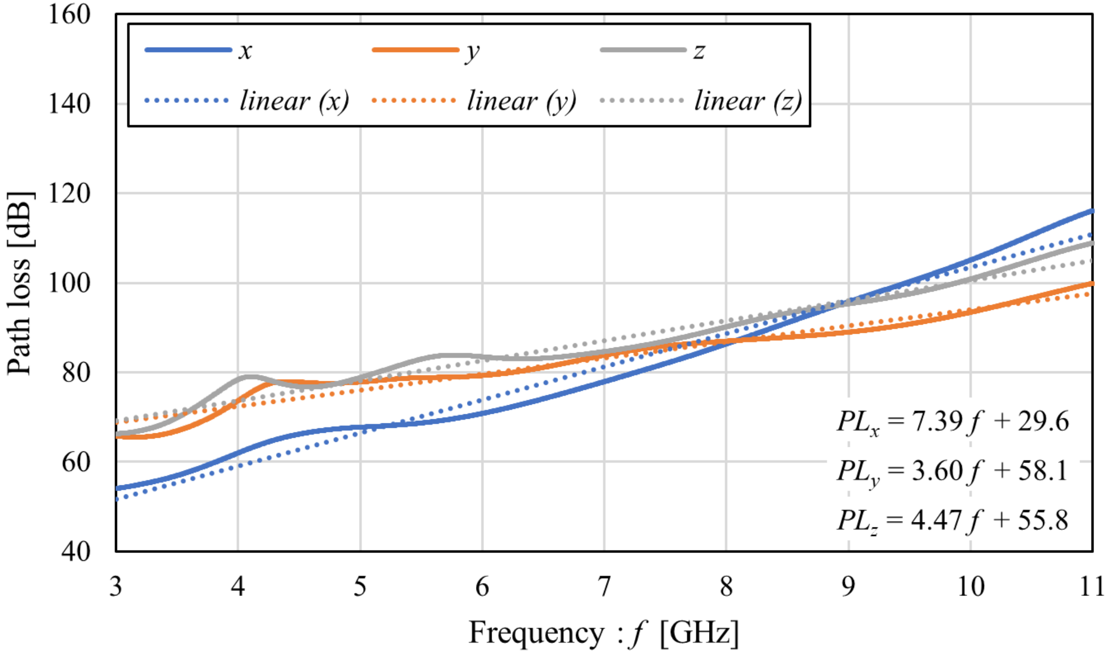
Path loss characteristics of implant (upper body) to on-body propagation

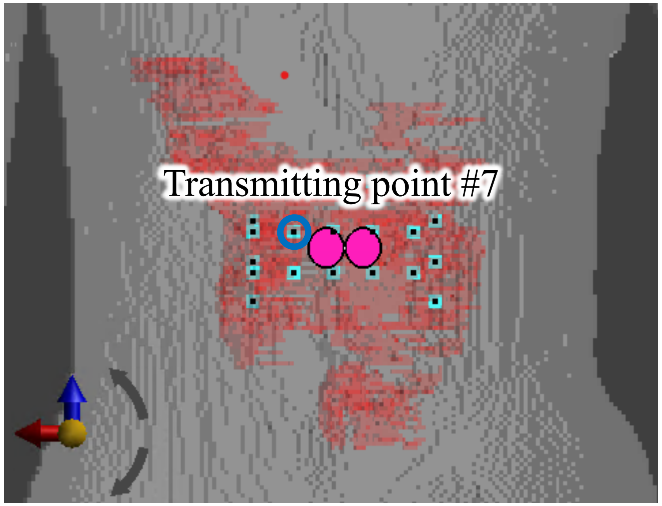
- Frequency band: 3.1-10.6 GHz
- Anatomical numerical male human body model developed by NICT, Japan
- Frequency-dependent FDTD method
- 23 transmitting points were chosen inside the small intestine
- Receiving antenna was put on the body surface with 1-mm spacing



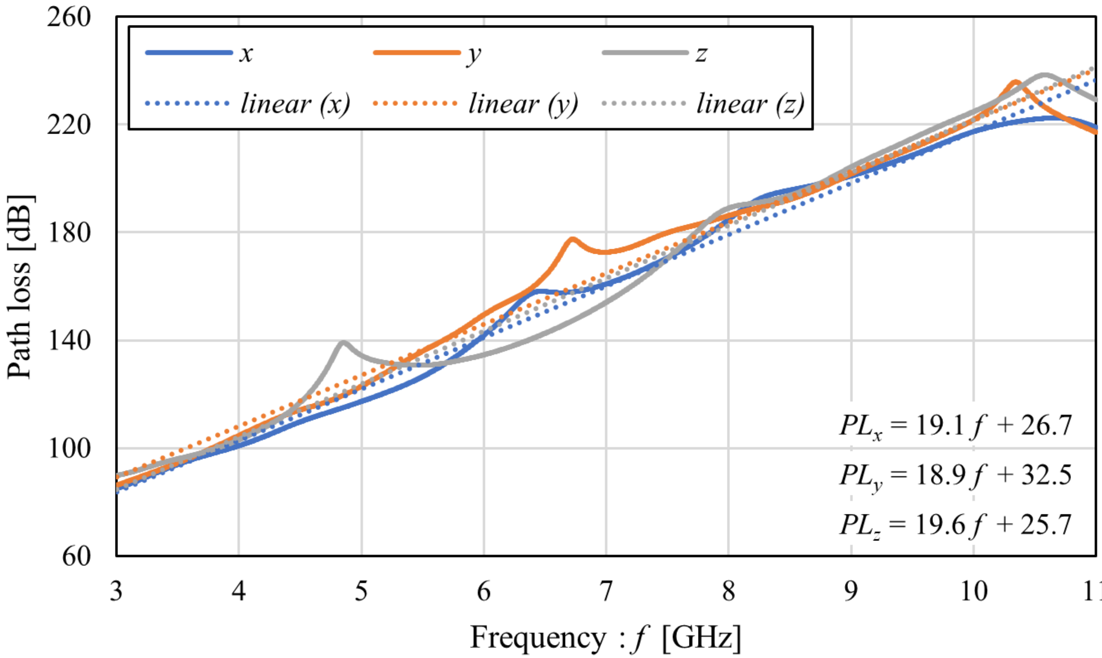


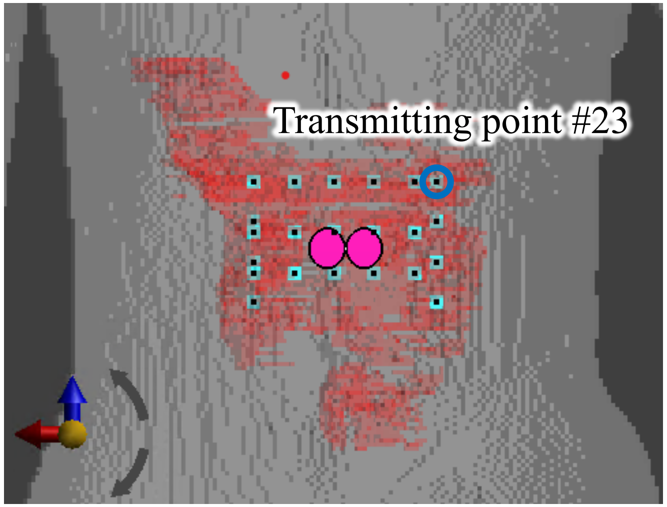
Path loss characteristics (#7)



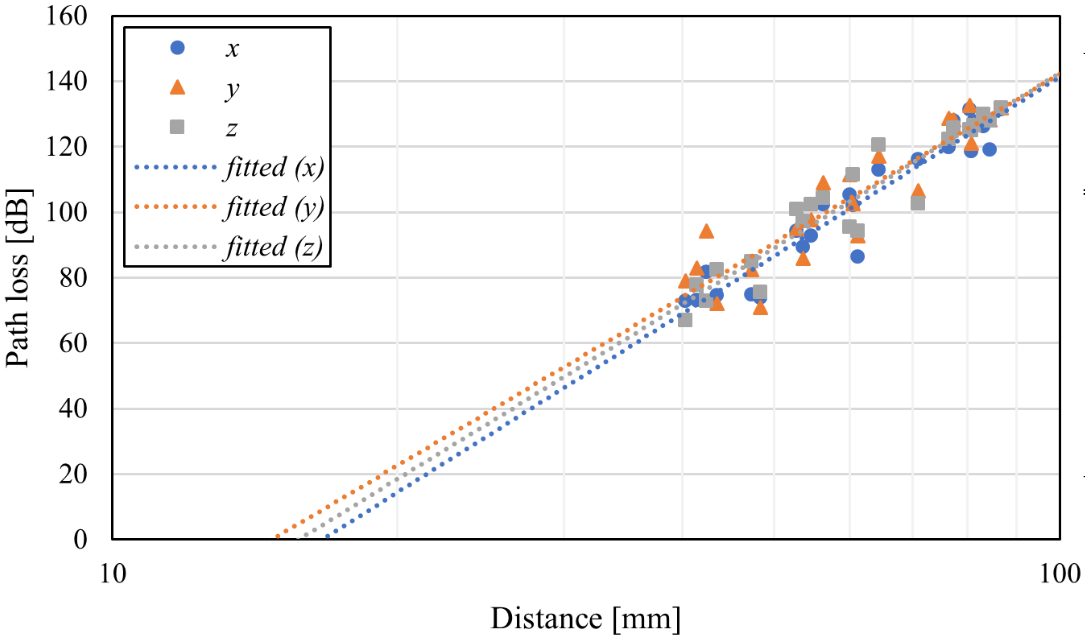


Path loss characteristics (#23)





Distance characteristics

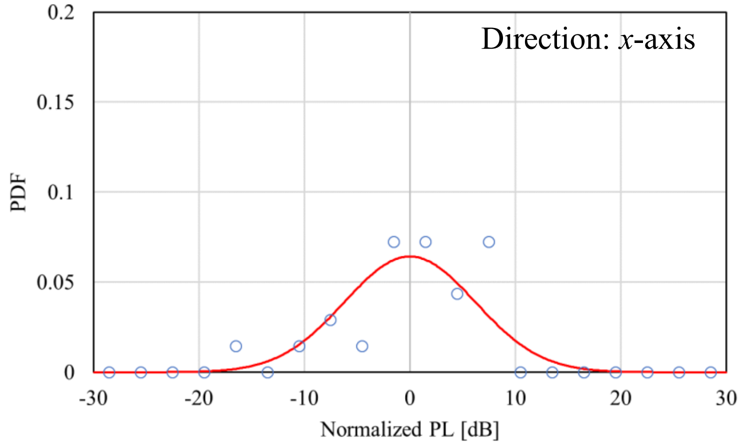


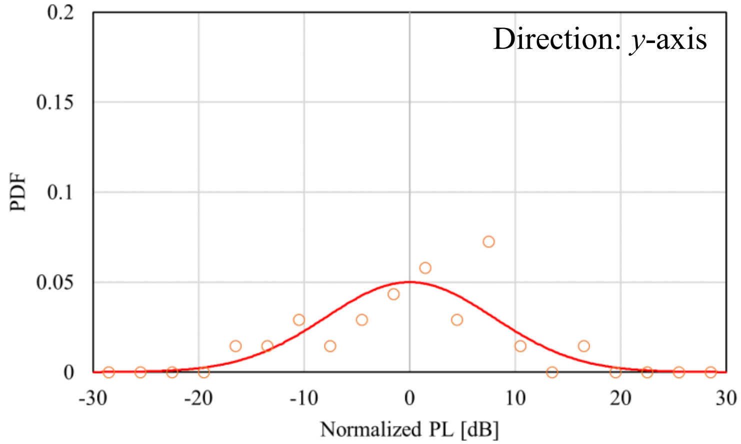
$d_0 = 10$ mm

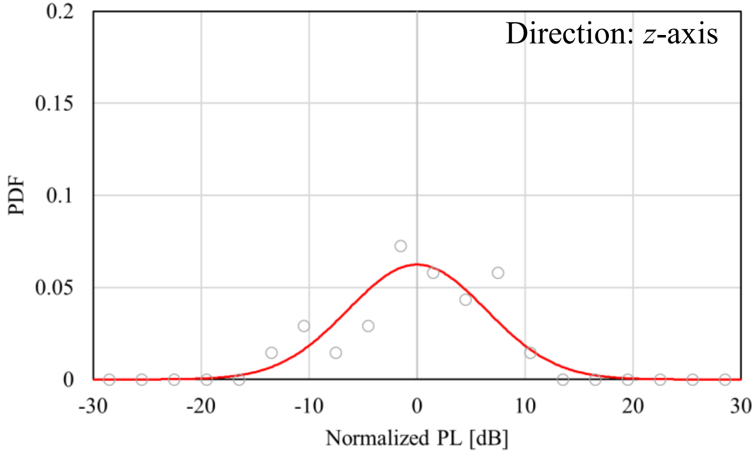
Transmitting components	PL_0 [dB]	n	σ_s [dB]
x	69.05	18.14	6.21
y	74.10	17.09	7.98
z	71.92	17.74	6.40

$$PL_{\mathrm{dB}} = PL_{0,\mathrm{dB}} + 10n \log_{10}\left[\frac{d}{d_0}\right]$$

Shadow fading characteristics

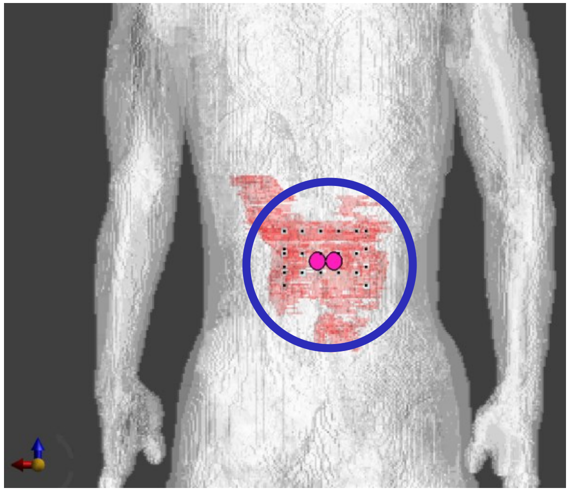




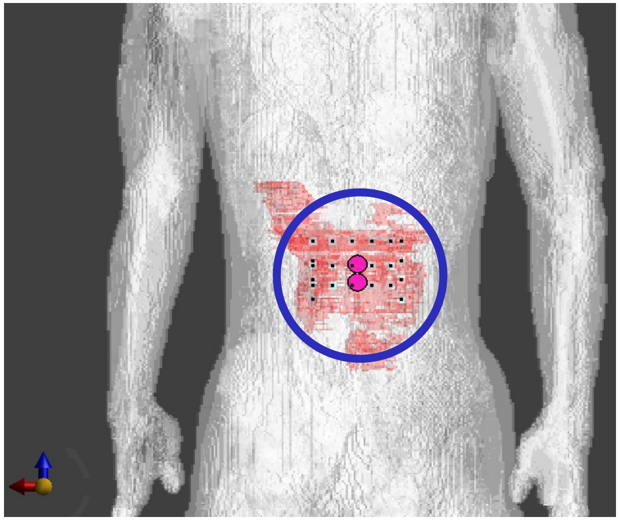


Path loss characteristics with another receiving antenna direction

- Frequency band: 3.1-10.6 GHz
- Anatomical numerical male human body model developed by NICT, Japan
- Frequency-dependent FDTD method
- 23 transmitting points were chosen inside the small intestine
- Receiving antenna was put on the body surface with 1-mm spacing

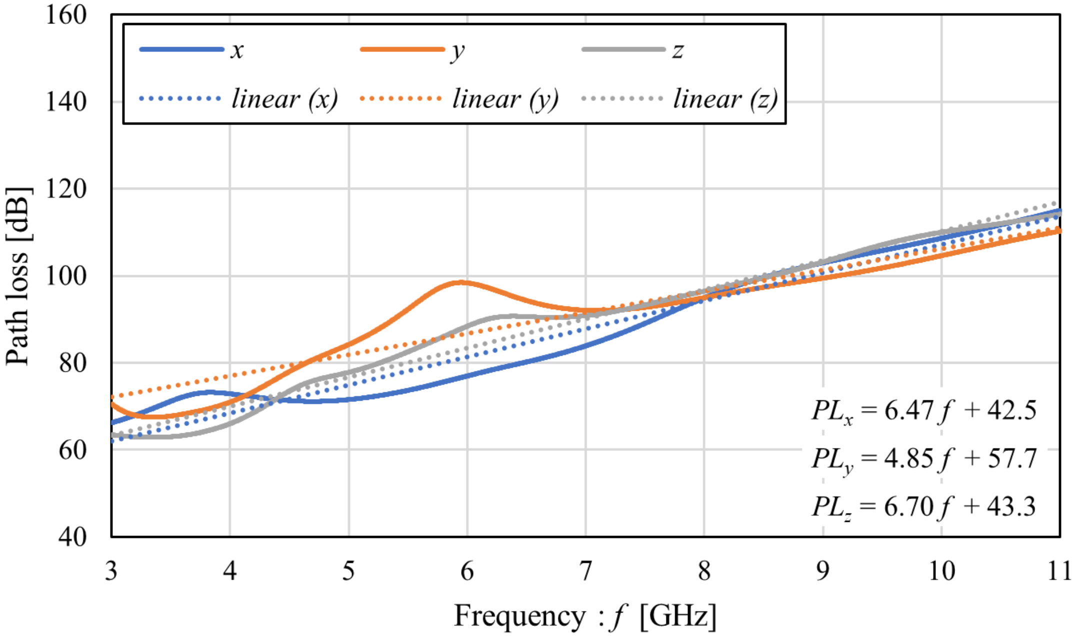


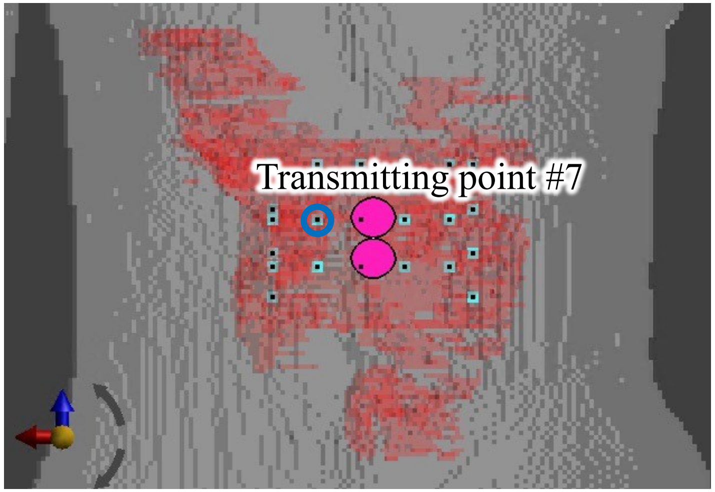
Horizontal arrangement



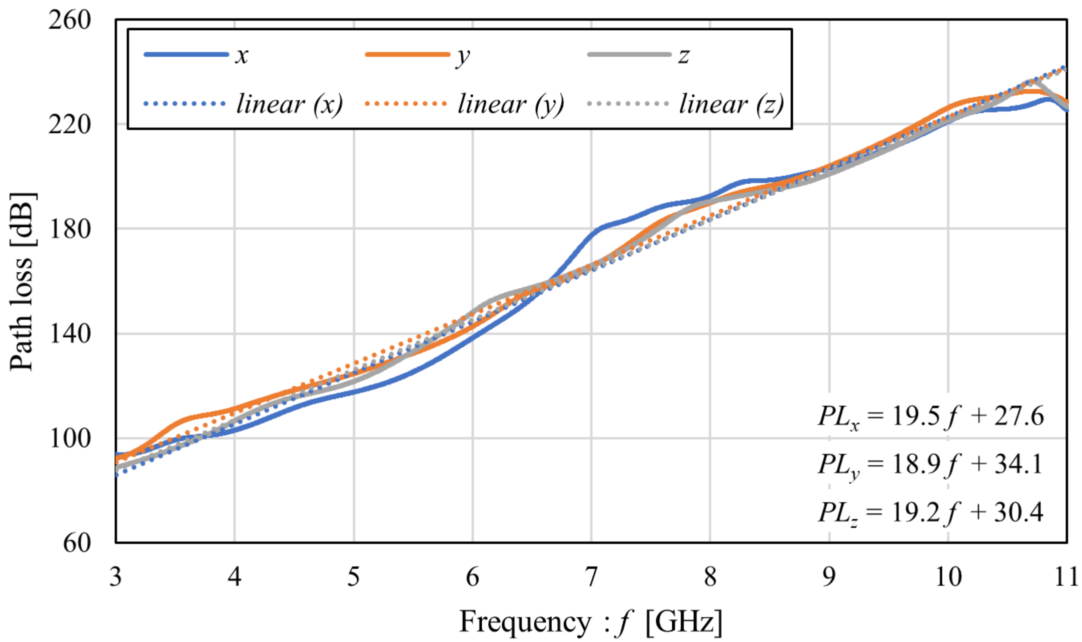
Vertical arrangement

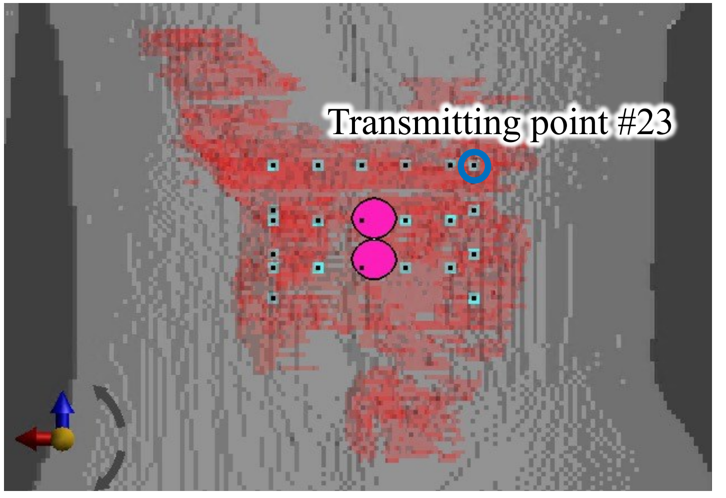
Path loss characteristics with vertical arrangement (#7)



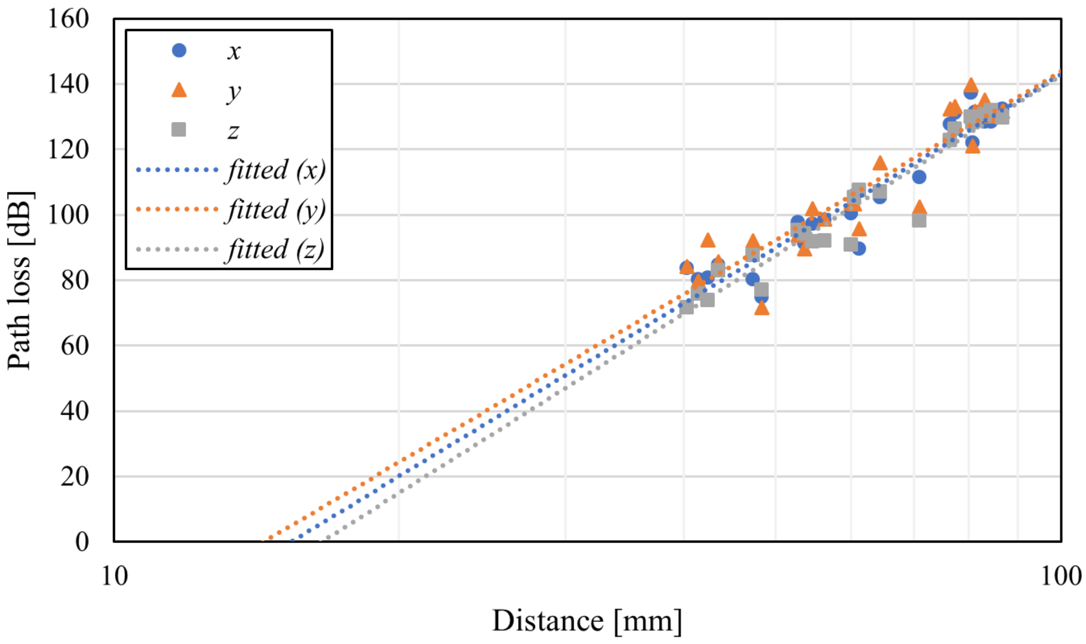


Path loss characteristics with vertical arrangement (#23)





Distance characteristics (vertical arrangement)

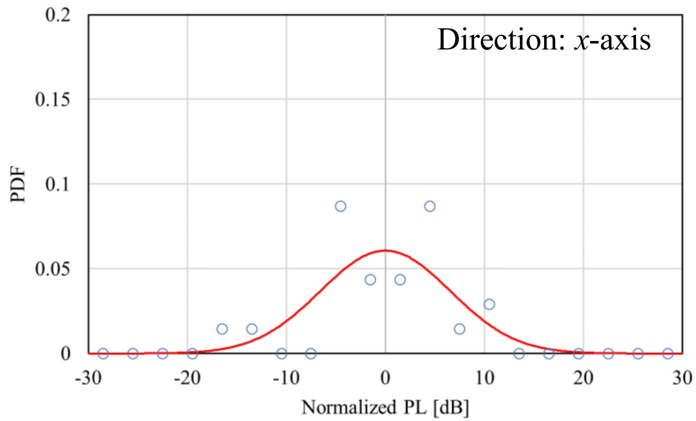


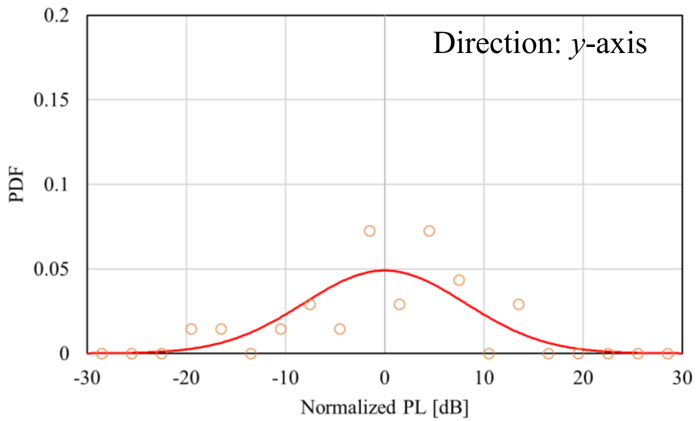
$d_0 = 10$ mm

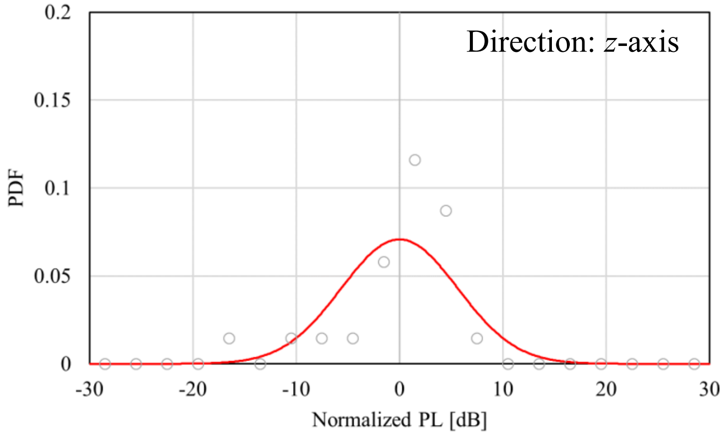
Transmitting components	PL_0 [dB]	n	σ_s [dB]
x	72.95	17.56	6.57
y	75.79	17.07	8.14
z	69.90	18.26	5.64

$$PL_{\mathrm{dB}} = PL_{0,\mathrm{dB}} + 10n \log_{10}\left[\frac{d}{d_0}\right]$$

Shadow fading characteristics (vertical arrangement)

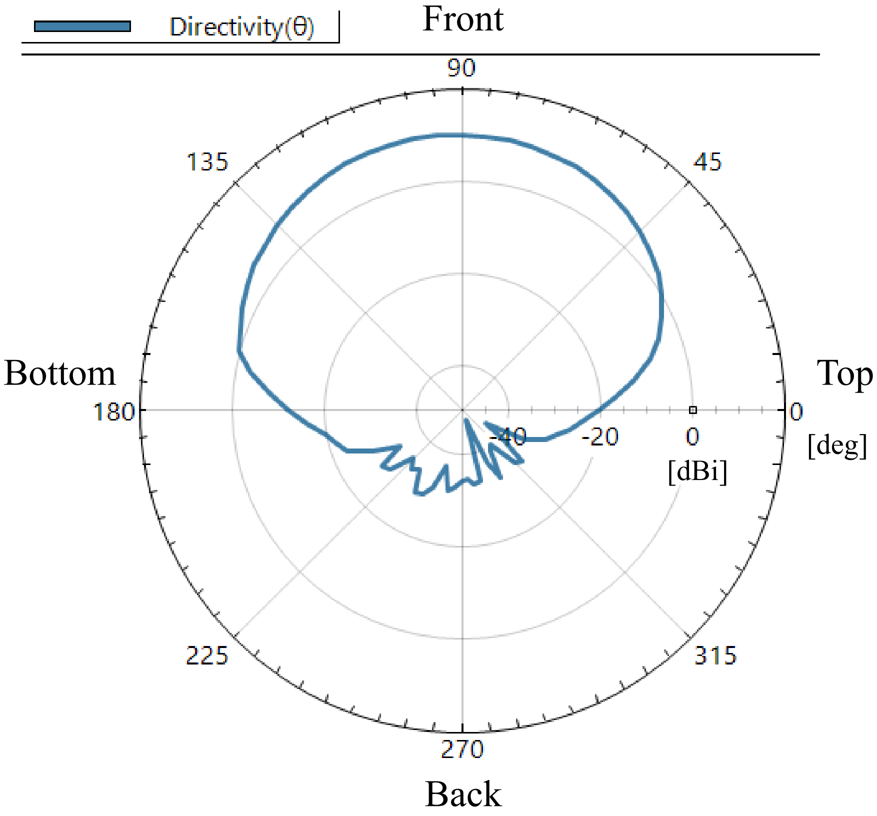




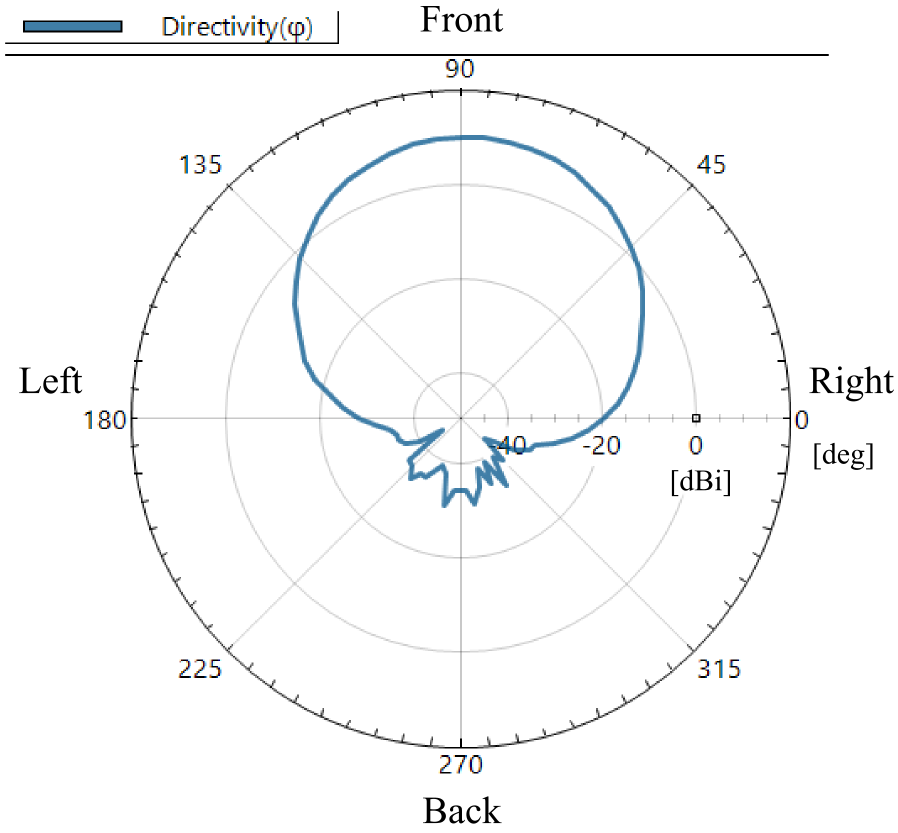


Antenna direction (On-body)

Antenna direction (On-body)

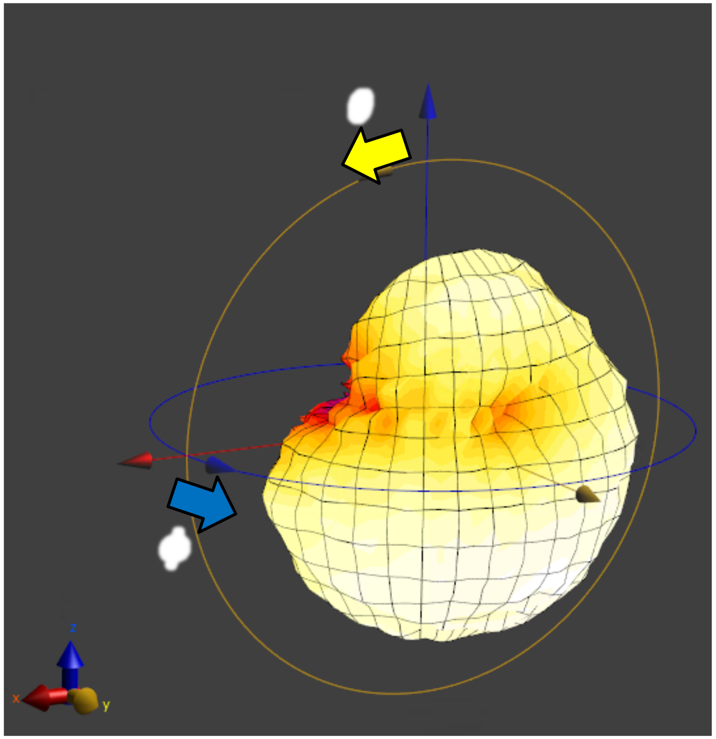


Horizontal plane ($\theta = 90°$)



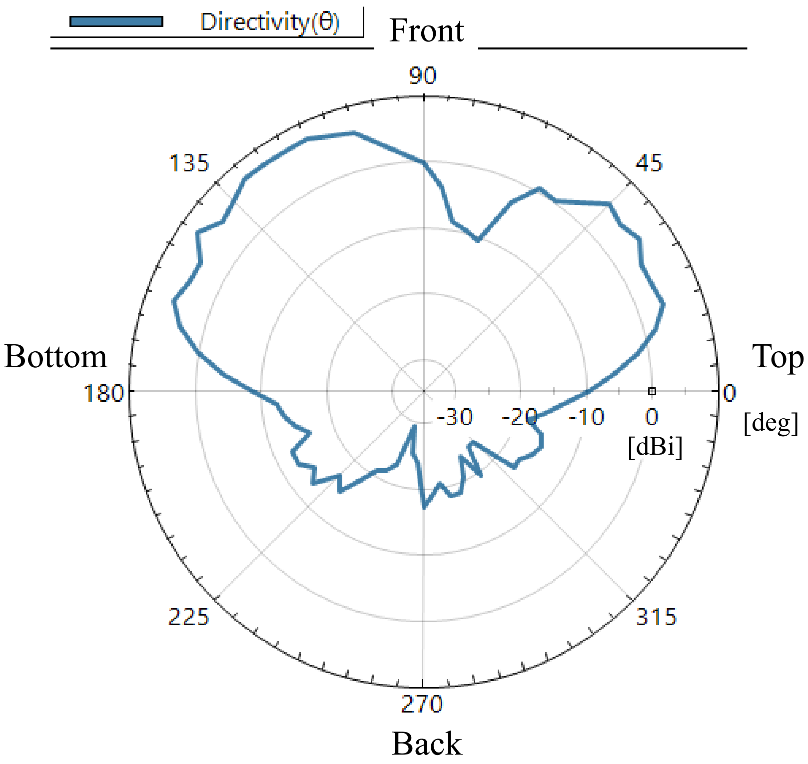
Vertical plane ($\phi = 90°$)

Antenna direction (In-body)

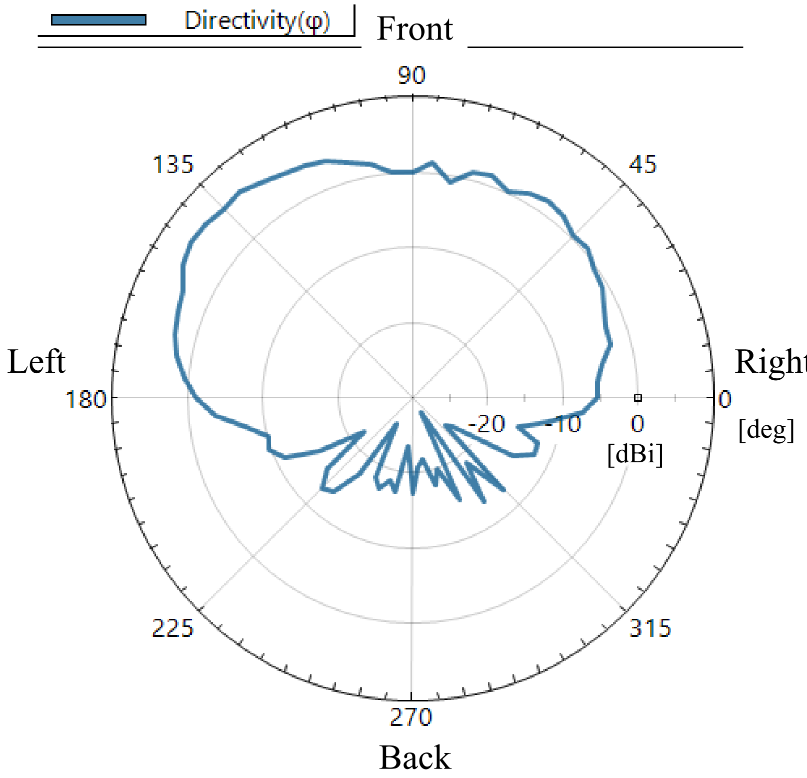


The antenna was put inside the small intestine

Antenna direction (In-body)



Horizontal plane ($\theta = 90°$)



Vertical plane ($\phi = 90°$)

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