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Submission Title: [Channel modeling for medical implanted communication systems by numerical simulation and measurement]

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Abstract: [Provide needs of channel modeling for medical implanted communication system]

Purpose: [To provide basic channel characteristics for the manufacture of medical implantable communication system]

Channel modeling for medical implanted communication systems by numerical simulation and measurement

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- Biological tissues
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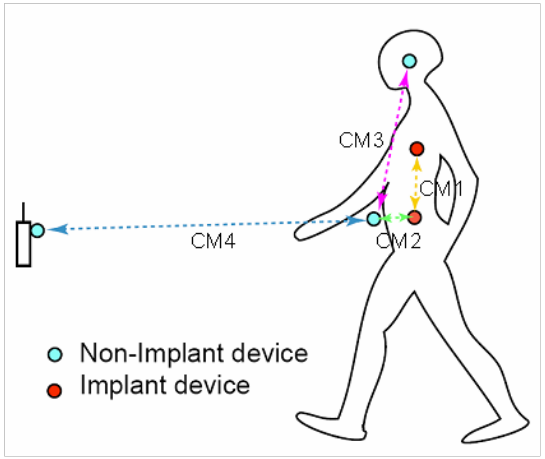
Channel models for BAN



Scenario	Description	Frequency Band	Channel Model
S1	Implant to Implant	402-405 MHz	CM1
S2	Implant to Body Surface	402-405 MHz	CM2
S3	Implant to External	402-405 MHz	CM2
S4	Body Surface to Body Surface (LOS)	TBD (f_1,… f_n)	CM3
S5	Body Surface to Body Surface (NLOS)	TBD (f_1,… f_n)	CM3
S6	Body Surface to External (LOS)	TBD (f_1,… f_n)	CM4
S7	Body Surface to External (NLOS)	TBD (f_1,… f_n)	CM4

Basic channel modeling parameters

- Path-loss

$$P_R = P_T G_T G_R e^{-2\alpha R}\left(\frac{\lambda}{4\pi R}\right)^2$$

✓ TX power : P_T

✓ Attenuation loss : $e^{-2\alpha R}$

✓ TX antenna gain : G_T

✓ Radiation loss : $\left(\frac{\lambda}{4\pi R}\right)^2$

✓ RX antenna gain : G_R

- Mean excess delay

$$\tau_m = \frac{\int_{-\infty}^{\infty} \tau P_h(0,\tau)\, d\tau}{\int_{-\infty}^{\infty} P_h(0,\tau)\, d\tau}$$

✓ Power delay profile : P_h

- rms delay spread

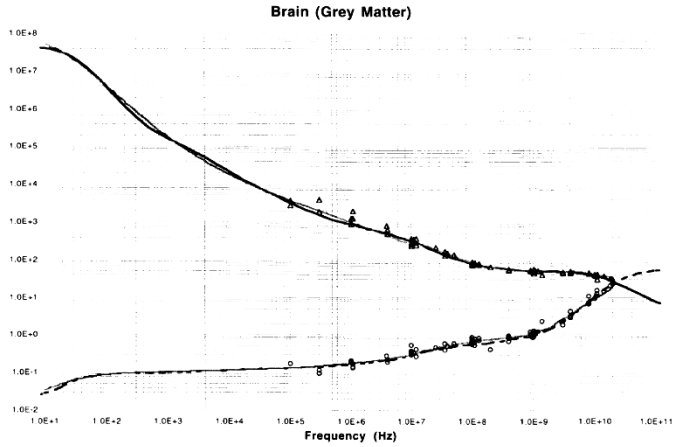
$$\tau_{RMS} = \sqrt{\frac{\int_{-\infty}^{\infty} (\tau - \tau_m)^2 P_h(0,\tau)\, d\tau}{\int_{-\infty}^{\infty} P_h(0,\tau)\, d\tau}}$$

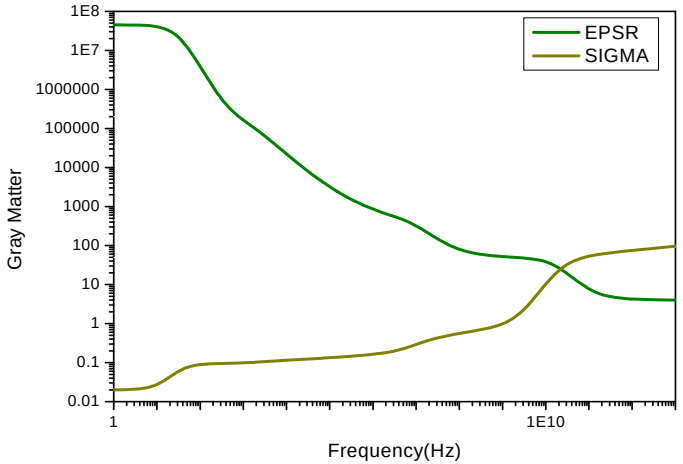
Biological tissues - FCC

1	bladder	16	fat(mean)	31	Skin(dry)
2	blood	17	Gall bladder	32	skin(wat)
3	bone canaliculus	18	gall Blad bile	33	small intenstine
4	bone cortical	19	gray matter	34	spleen
5	bone marrow Infiltrated	20	heart	35	stomach esop duodenum
6	bone marrow not Infiltr	21	kidney	36	tendon
7	breast fat	22	Lens_Cortex	37	testis prostate
8	cartilage	23	Lens_Nucleus	38	thyroid thymus
9	cerebellum	24	liver	39	tongue
10	cerebro_spinal_fluid	25	lung (inflated)	40	trachea
11	colon(Large intestilne)	26	Lung(Deflated)	41	uterus
12	cornea	27	muscle (parallel fiber)	42	vitreous_Humour
13	dura	28	muscle (transverse_fiber)	43	white matter
14	eye_tissue(sclera)	29	nerve (Spinal chord)		
15	fat	30	ovary		

- Website : http:// www.fcc.gov/fcc-bin/dielec.sh

Dispersive characteristics of biological tissues





The tissue parameters provided here are derived from the 4-Cole-Cole Analysis in "Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies" by Camelia Gabriel, Brooks Air Force Technical Report AL/OE-TR-1996-0037

$$\varepsilon_r(\omega) = \varepsilon_\infty + \sum_{n=1}^{4} \frac{\Delta\varepsilon_n}{1+(j\omega\tau_n)^{1-\alpha_n}} = \varepsilon_\infty + \chi(\omega)$$

4th Cole-Cole model

Methods for channel modeling

- Simulation
  - Model : Visible Human Project(VHP), Korean model
  - Numerical analysis : FDTD method
- Measurement
  - Phantom type: Liquid phantom, Mannequin
  - Time domain, Frequency domain

Parameters and scenarios for modeling

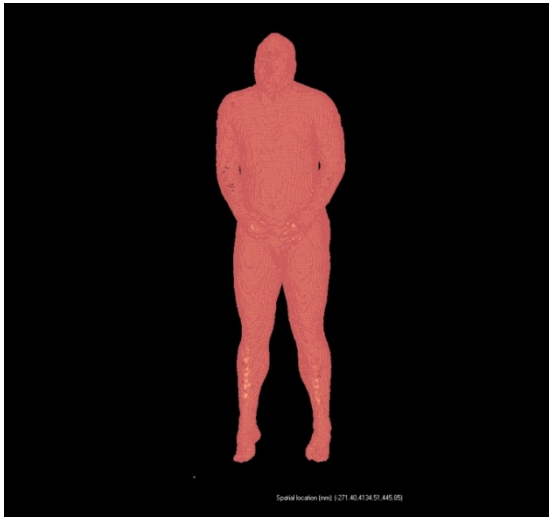
- Channel modeling parameters
  - Path loss
  - Mean excess delay
  - Excess rms delay spread
- Frequency band
  - 400 – 450 MHz (402 - 405 MHz)
- CM1(Implant to Implant)
  - TX /RX: gullet, stomach, belly, rectum, heart, liver (pancreas), kidney, joints
- CM2(Implant to Body Surface)
  - Implant: CM1 positions
  - Surface: waist, belly, neck, ear, wrist

Measurement scenario

- Liquid phantom will be used
- Measurement S21 using vector network analyzer
- Measurement environments
  - Office
  - Anechoic chamber

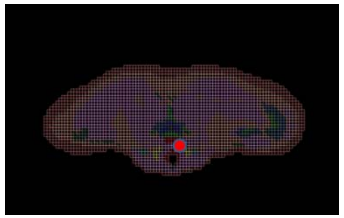
Preliminary simulation

- Visible Human Project model
  - Grid size : 135x86x396 cells
  - Maximum cell size : 5 mm
- XFDTD 6.4 (REMCOM co.)
  - Time domain analysis : Finite Difference Time Domain method



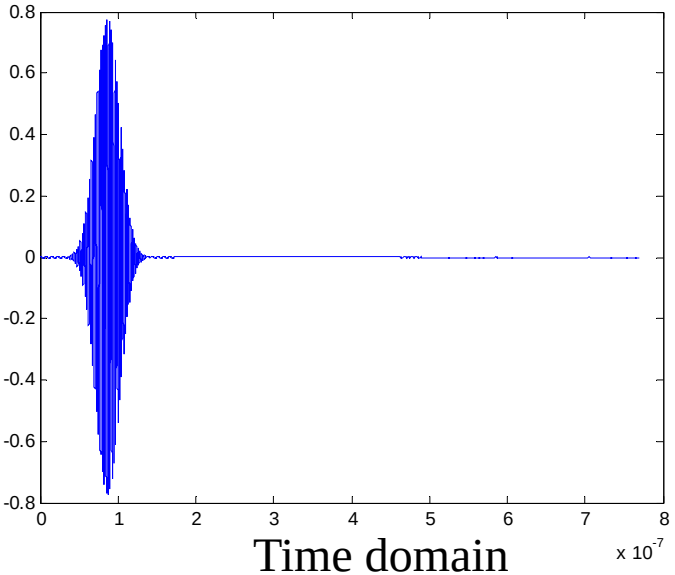
Simulation setup

Source position : neck(70, 50, 332)

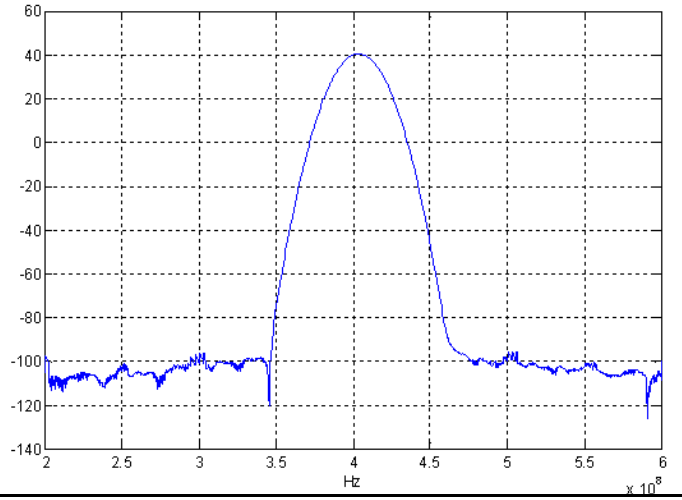


xy plane

xz plane

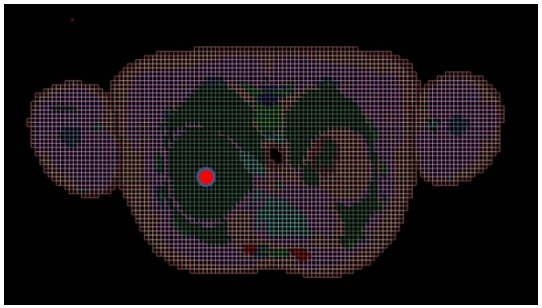


Time domain

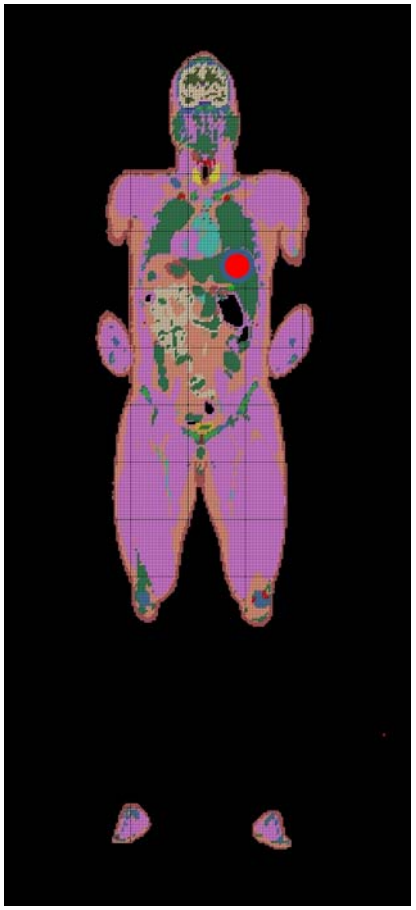


Simulation result(1/4)

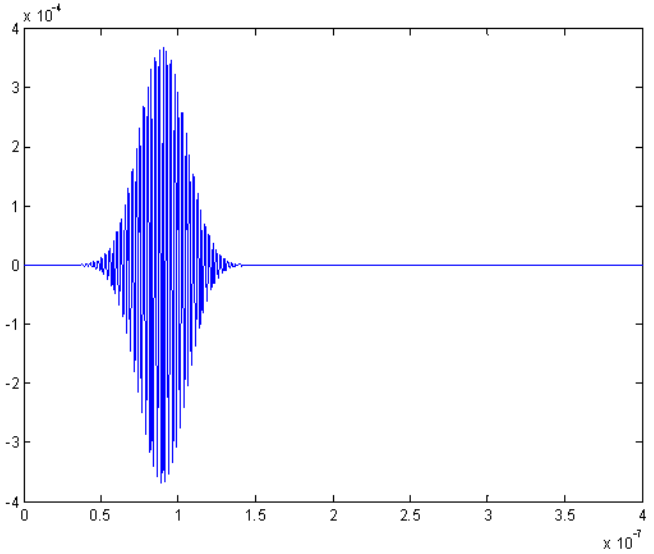
Calculation position : heart (52, 43, 290)



xy plane



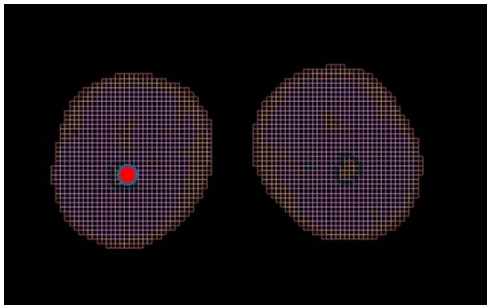
xz plane



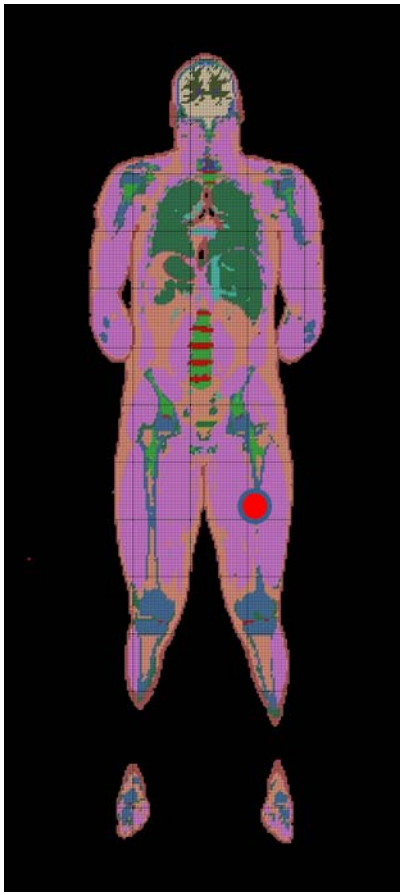
Time domain

Simulation result(2/4)

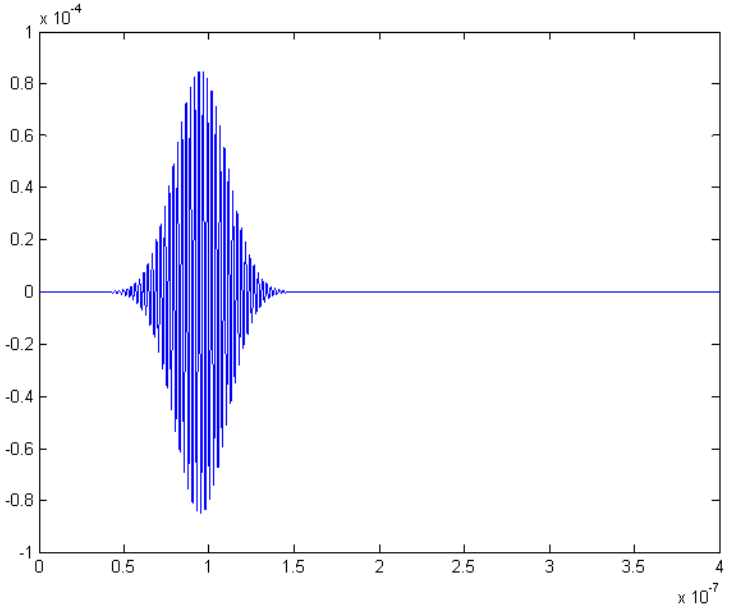
Calculation position : thigh(48, 52, 155)



xy plane



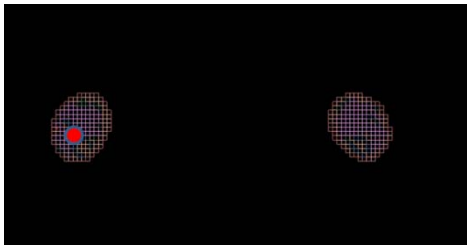
xz plane



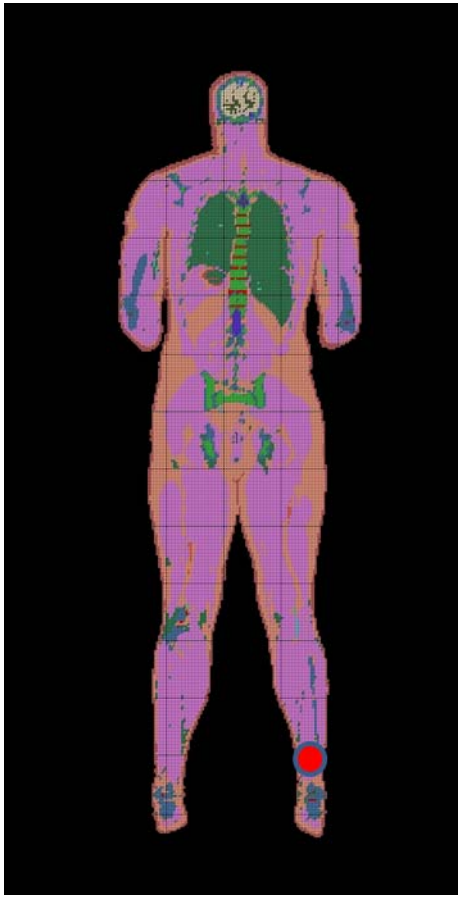
Time domain

Simulation result(3/4)

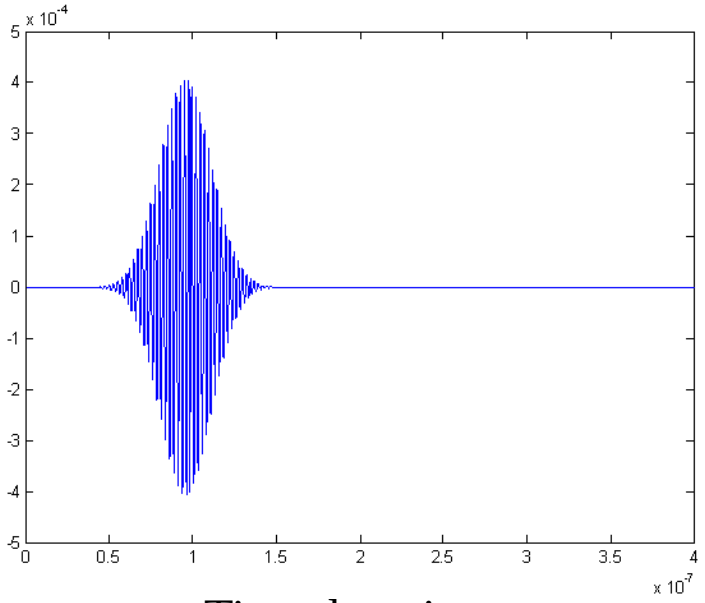
Calculation position : heel(35, 60, 56)



xy plane



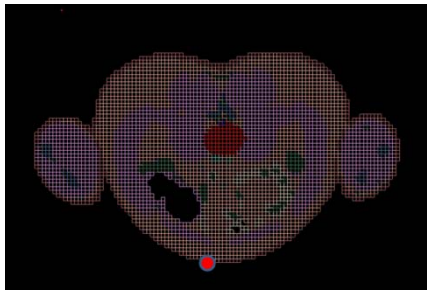
xz plane



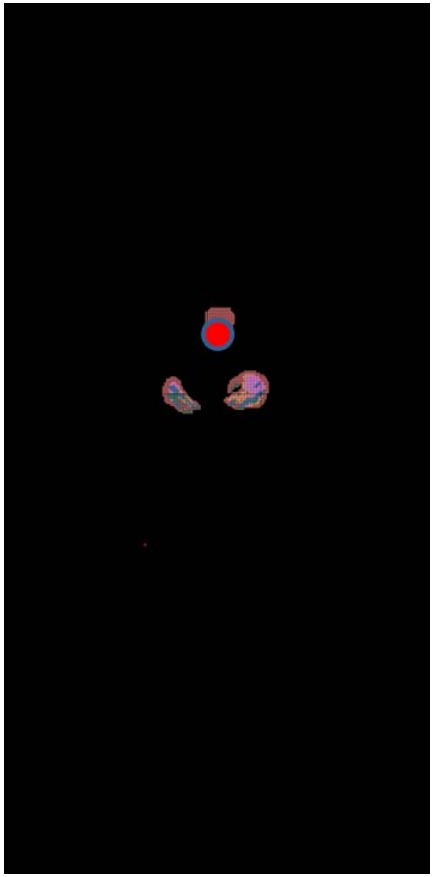
Time domain

Simulation result(4/4)

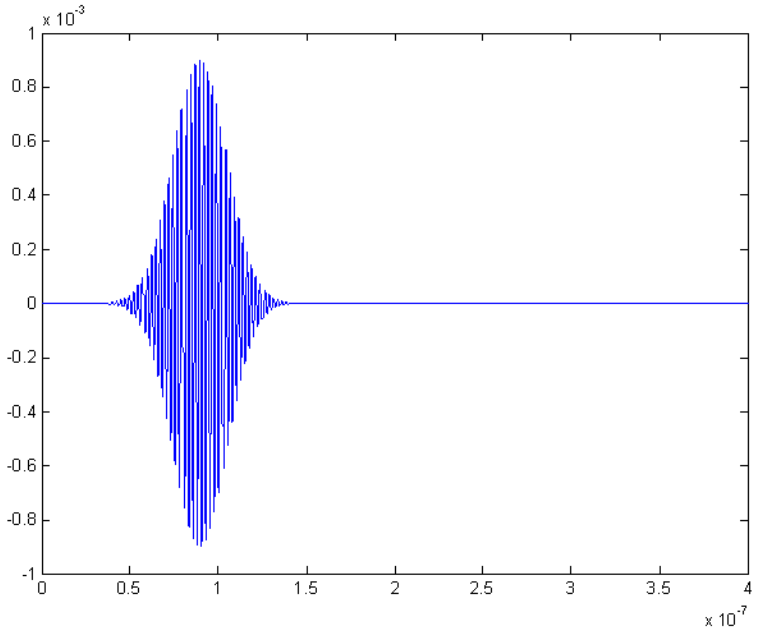
Calculation position : belly (69, 18, 248)



xy plane



xz plane



Time domain

Channel parameter values

Source position : neck (70, 50, 332)

Position	Distance [m]	Mean excess delay [nsec]	Excess rms delay spread [nsec]	Path loss [dB]
(52,43,290)	0.23	4.20	0.06	55.59
(70,25,246)	0.45	3.71	0.05	62.25
(106,33,235)	0.52	10.78	0.54	70.50
(36,33,235)	0.52	5.95	0.14	70.35
(72,44,235)	0.49	5.13	0.11	72.71
(48,52,155)	0.89	8.32	0.15	77.45
(94,52,155)	0.89	10.53	0.22	78.47
(103,60,56)	1.39	8.63	0.13	68.85
(35,60,56)	1.39	8.71	0.12	67.35
(69,18,248)	0.45	3.25	0.06	61.12

Channel parameter values

Source position : heart (70, 25, 246)

Position	Distance [m]	Mean excess delay [nsec]	Excess rms delay spread [nsec]	Path loss [dB]
(52,43,290)	0.25	3.41	0.08	68.18
(106,33,235)	0.19	3.61	0.06	53.67
(36,33,235)	0.18	3.67	0.06	52.60
(72,44,235)	0.11	0.39	0.05	48.76
(48,52,155)	0.49	4.48	0.04	80.36
(94,52,155)	0.49	4.31	0.05	79.27
(103,60,56)	0.98	5.06	0.12	72.64
(35,60,56)	0.98	5.12	0.12	73.00
(69,18,248)	0.04	0	0.04	26.24

Conclusions

- ISSUES
  - Human body (model) is different for age, sex, race, etc.
  - Accurate channel modeling as well as health risk assessment need to be studied.

- Future schedule
  - Simulation and channel modeling for BAN : May 2008
  - Fabrication of physical phantom : June 2008
  - Measurement and analysis for BAN : August 2008