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Submission Title: [Channel Modeling and Signaling of Medical Implanted Communication Systems]

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Abstract: [Channel Modeling and Signaling of Medical Implanted Communication Systems]

Purpose: [To provide an introduction to the Channel Modeling and Signaling of Medical Implanted Communication Systems]

Channel Modeling and Signaling of Medical Implanted Communication Systems

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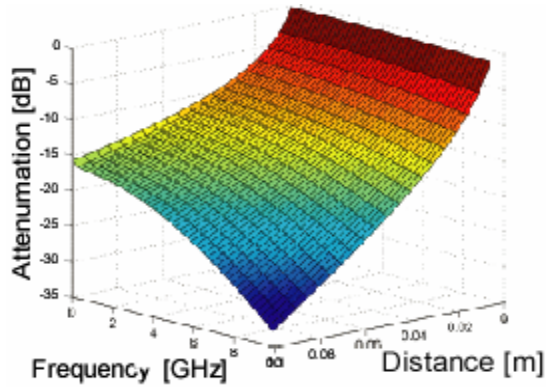
Outline

- Radio wave propagation in a human body
- Measurement result of radio wave propagation
- Channel modeling of radio wave propagation in the human body
- Summary

Radio Wave Propagation in a Body

- Attenuation
  - Human body : lossy media
  - Exponential attenuation with distance & frequency
  - Attenuation depending on tissues



- Wave distortion
  - Reflection on the boundary of body tissues
  - Differences of wave velocity in each tissues

Measurement Set up
(Experiments with pig)

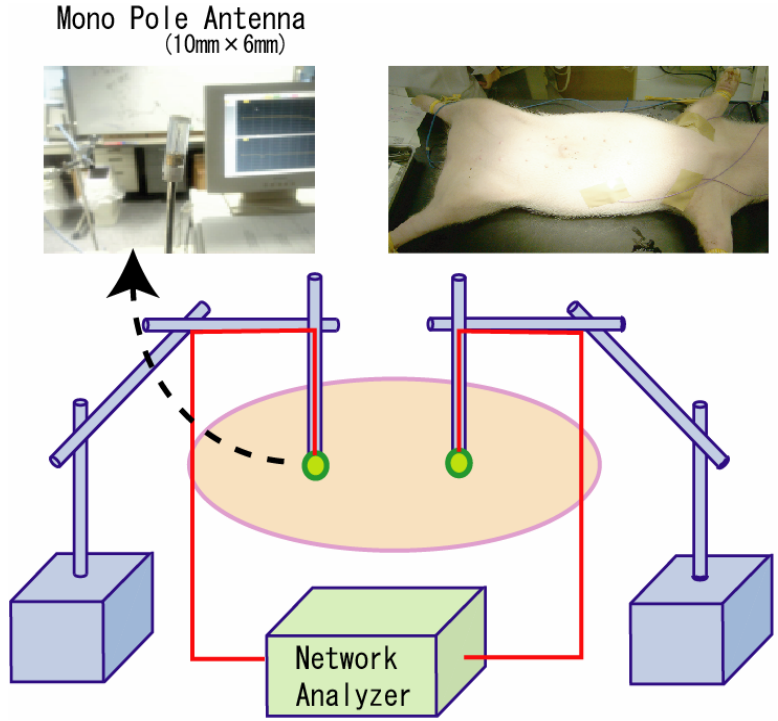
- Weight = 25kg

(as big as human's waist)

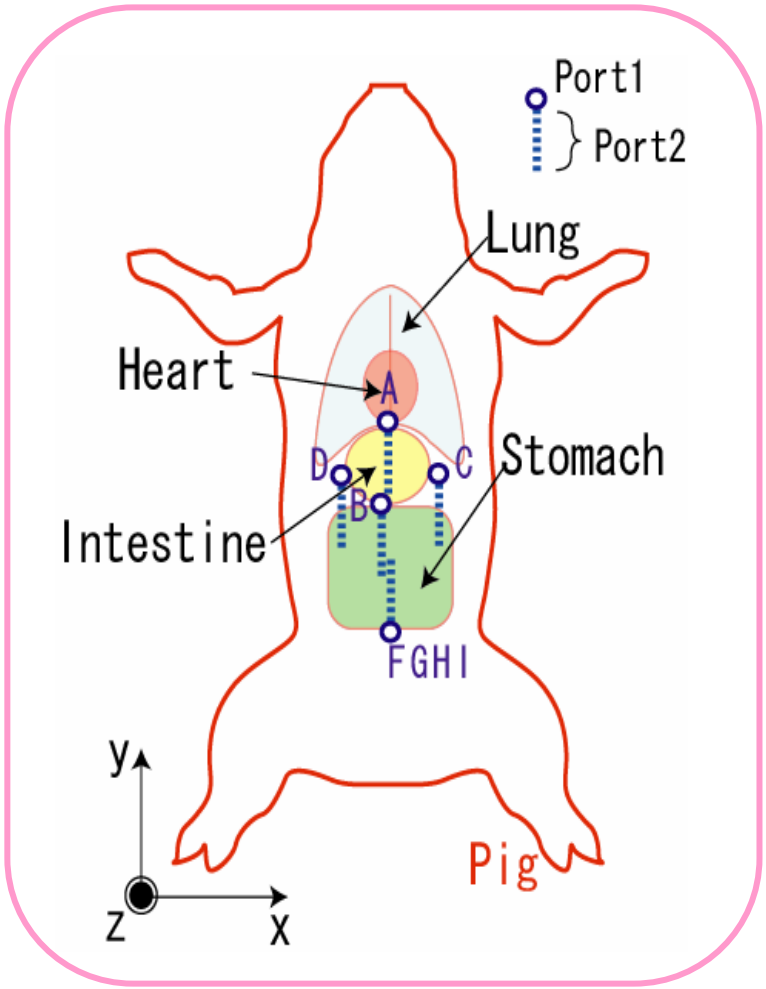
Cut Abdomen Skin of the Pig

- Insert of Antennas

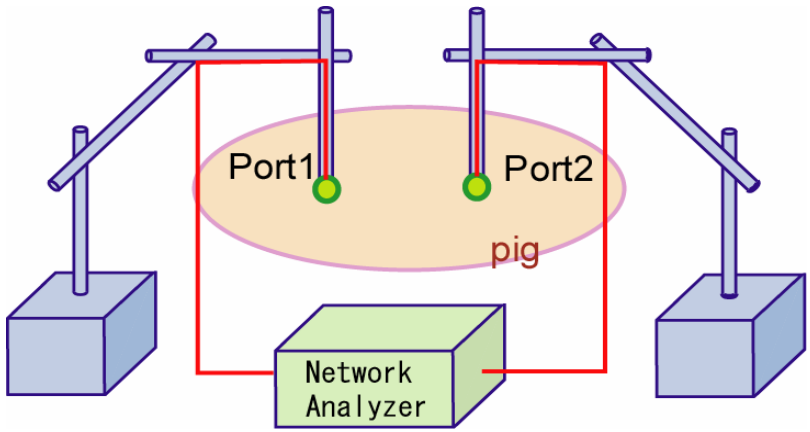
in co-polarized position



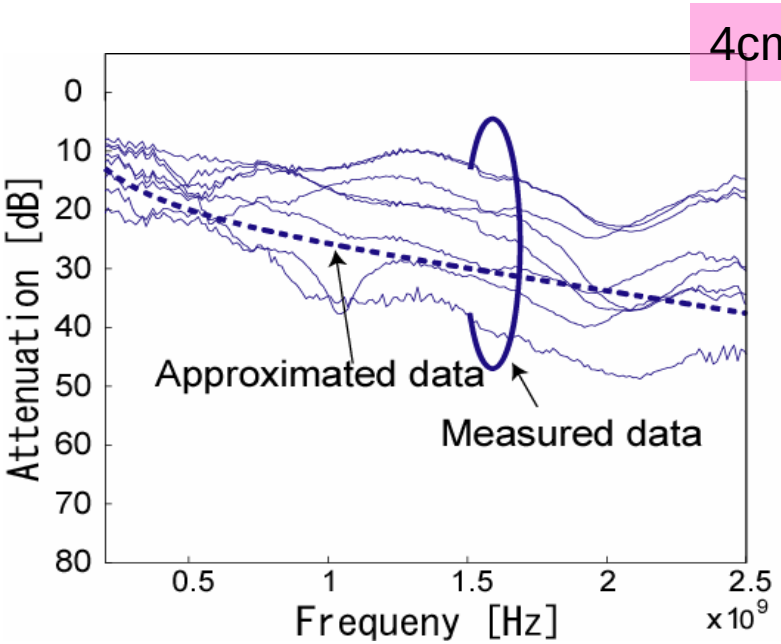
Position of Antennas



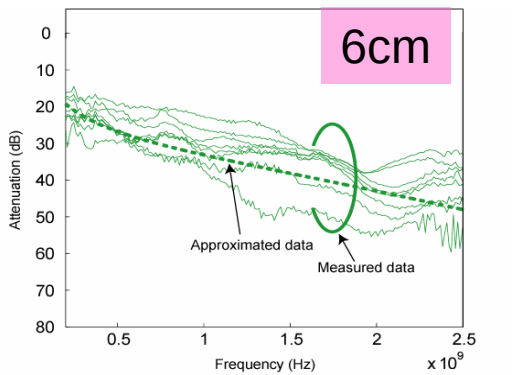
- Measurement along the Center line of the Body
  - Distance : 2～12cm
  - 8×6 = 48 points
  - Inserted Depth ≒ 10cm
  - Monopole antenna for Tx&Rx

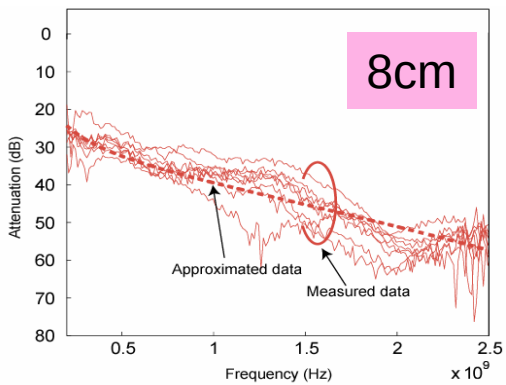


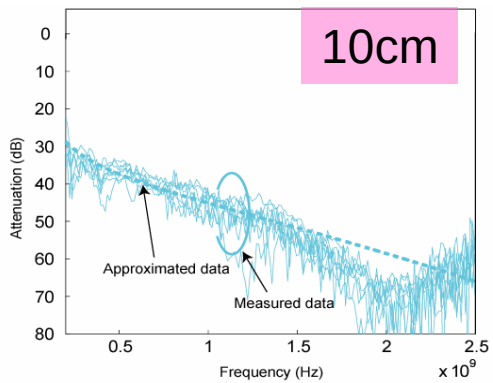
Result (Frequency-domain)



- The gradient of approximated data gets sharper as the distance between antennas is increased
- High-frequency component attenuated significantly.
- Stochastic dispersion of data







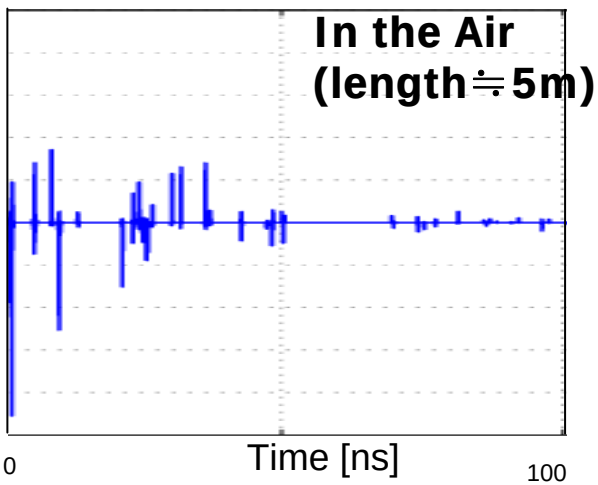
Result (Time Domain)

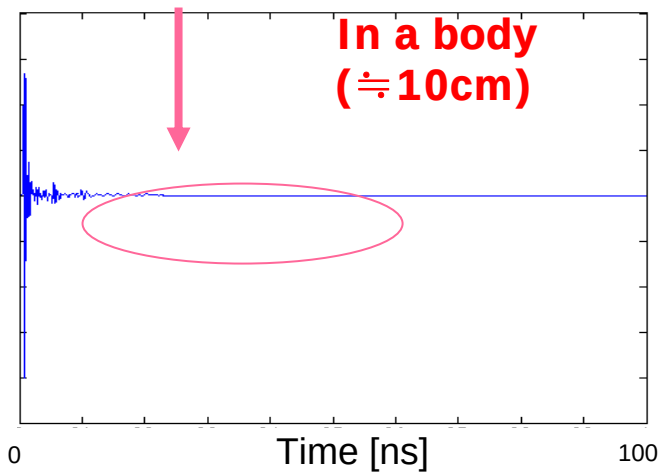
Multipath : Negligible effect

- Delayed waves : Small power

⇒ Channel model without a large delay spread

Attenuated significantly

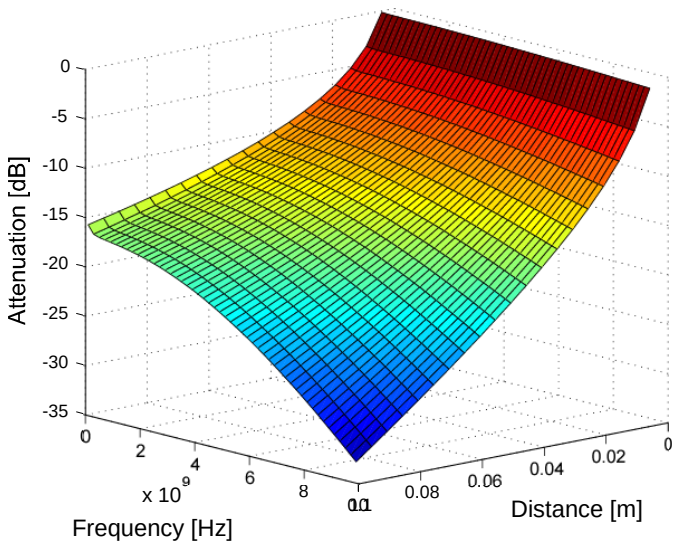




Channel Model

$$H(f,d) = \sqrt{\frac{1}{2} PL_0 \left(\frac{d}{d_0}\right)^{-n} \left(\frac{f}{f_c}\right)^{-2(\kappa+1)}} \; e^{-(\alpha(f)+j\beta(f))d} \; Av(f)$$

frequency distance



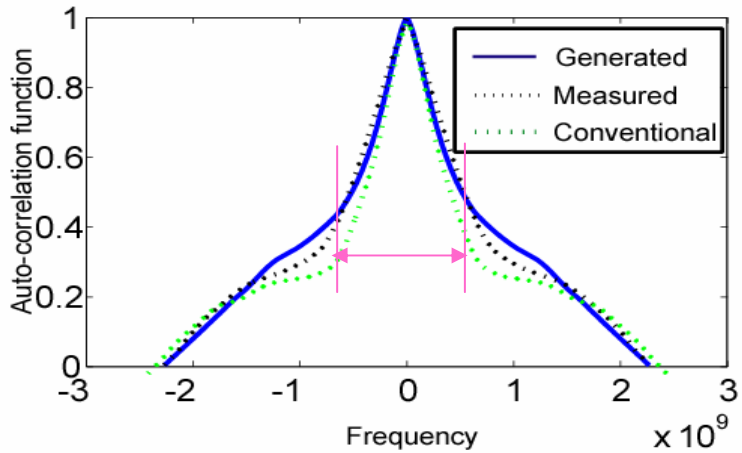
General distance decay (depending on frequency)

Changing of attenuation & phase characteristics based on tissues

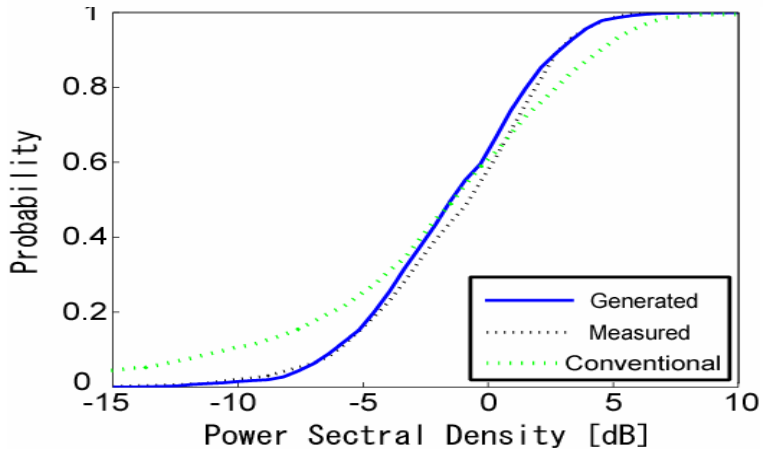
Stochastic dispersion (Expression by using the Zero-Pole model)

Evaluation of Statistical Characteristic in Frequency Domain

- Correlation function of frequency responses
  - Correlation bandwidth = Bc
    - Generated model : 508[MHz]
    - Measured model : 508[MHz]
    - Conventional model : 498[MHz]



- Cumulative distribution function (CDF) of electric power spectrum density
  - CDF according to various tissues with the constant distance such as 2-12 cm



A statistical characteristic is reproduced in the frequency domain.

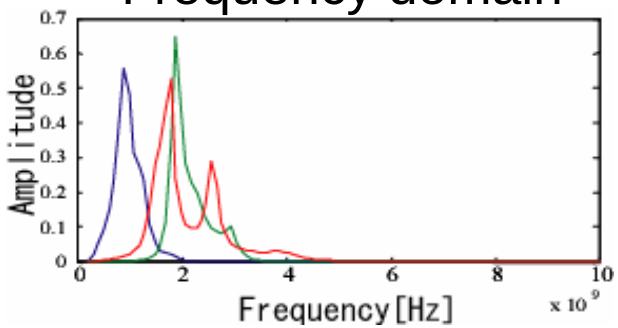
Conventional is generated stochastically in time domain as well as existing model

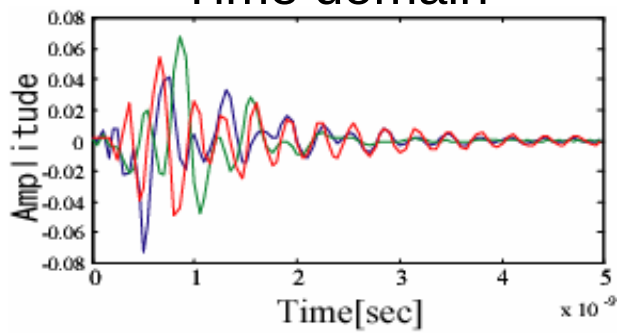
Generated Channel Model

Frequency domain

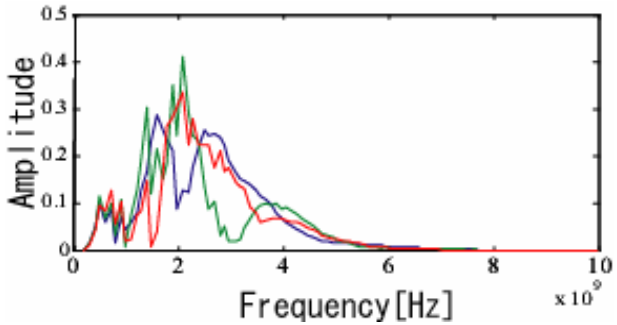
Time domain

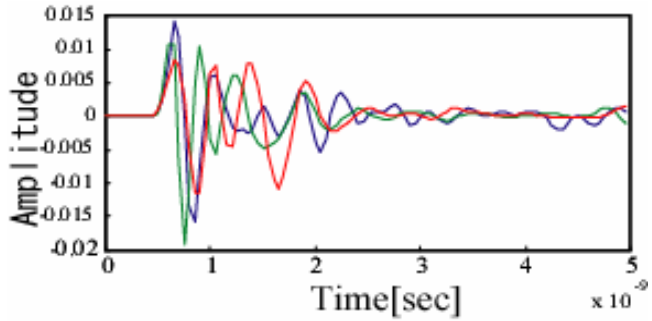
Generated model





Measured data



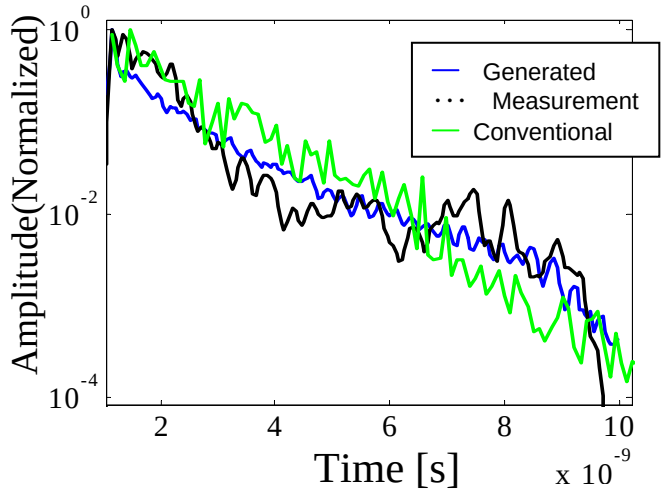


- **Evaluation of statistical characteristics**
  - **Changing in frequency domain ⇒ Correlation Function & CDF**
  - **Changing in time domain ⇒ Delay Profile & CDF**

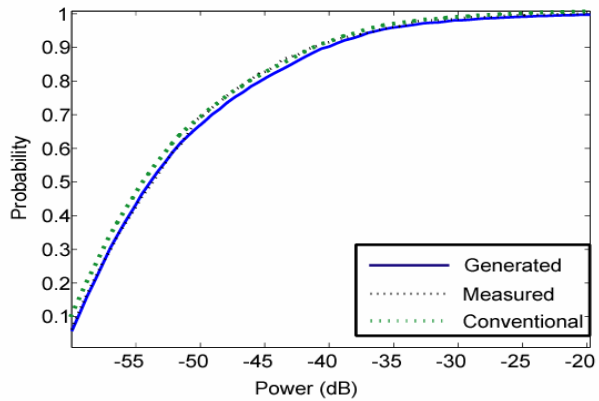
Evaluation of Statistical Characteristic in Time Domain

- Delay profile of power
  - Calculated delay attenuation rate
    - Measured model: 7.5 [dB/ns]
    - Generated model: 8.1 [dB/ns]

  Although generated model is derived to match its frequency characteristics into measured one, its time characteristics is also very close to measured one.



- Cumulative distribution function of received power
  - CDF according to various tissues with the constant distance such as 2-12 cm



A statistical characteristic is reproduced in both time domain & frequency domain.

Summary

- Attenuation in the body is more severe than in the air
- Human tissue：Conductor; Becoming an absorber of radio wave
- High frequency component is absorbed and attenuated significantly
- The degree of attenuation (FD)
  - depends on each tissues.
  - The data of frequency response has stochastic dispersion.
- Multi paths have negligible effect (TD)
- The new Channel Model Introduce a stochastic dispersive factor due to distribution of various tissues, expressing dispersion of channel in frequency domain
- Experimental Measurement derives a stochastic dispersive factor

Reference;

Kazunari Tai, Hiroki Harada, Ryuji Kohno "Channel Modeling and Signaling of Medical Implanted Communication Systems and a Step to Medical ICT," 16th IST Mobile & wireless communication Summit, June 1-4, 2007, Special session on medical ICT.