Dynamic Channel Measurement for Body Area Network

Nov. 20, 2008 @ MCRG Tokyo Tech

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- Introduction of Body Area Network
- IEEE802.15.6 WG BAN
- Channel Model
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About Body Area Network

- Definition :
  - Short range wireless communication in the vicinity of, or inside, a human body
- Smaller area than PAN (Personal Area Network)
- Applications
  - Medical / Healthcare
  - Consumer Electrics (Entertainment, Fashion)

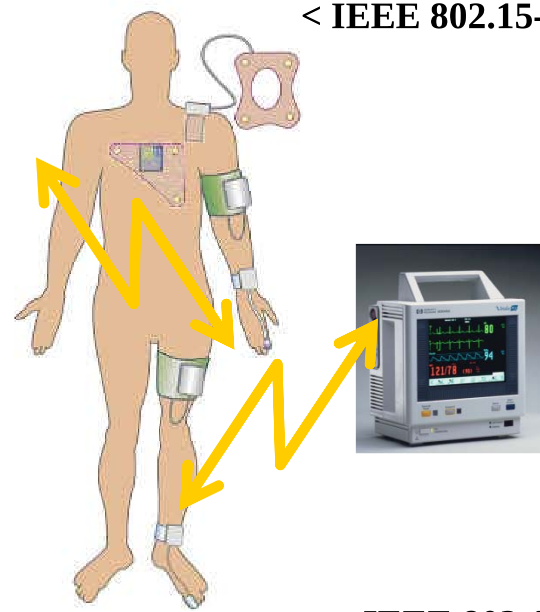
BAN Application

- Medical / Healthcare
  - Implantable medical devices
    - Cancer tracking, cardiac pacemakers / defibrillators, neurostimulators, drug pumps, glucose sensor, etc.
  - Swallowable devices: Pills for drug delivery and imaging
  - Wearable sensors: EEG, ECG, blood pressure, body temperature, …
  - Hearing aids, Wellness / Fitness sensors, Baby care
- Consumer Electrics (CE)
  - Wearable audio & Video stream
  - Remote control & I/O devices: Imaging

Medical Applications

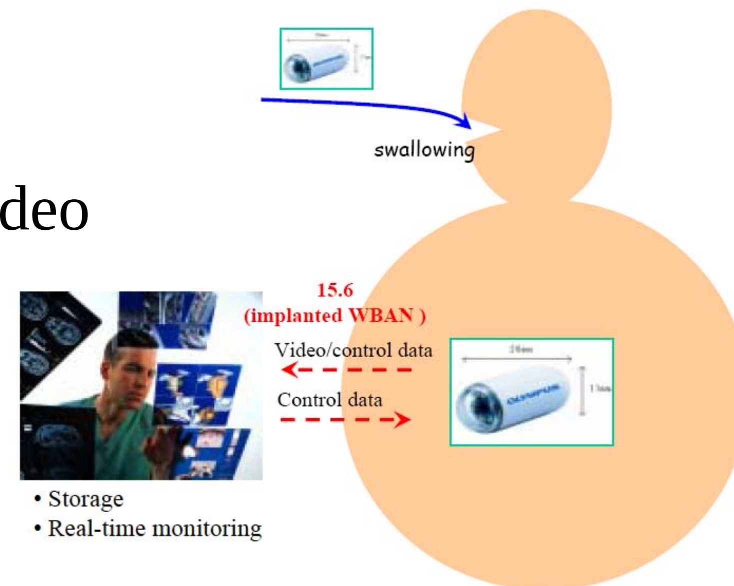
- Medical application
  - Vital patient data
  - Wireless sensors
  - Link with bedsite monitor
  - Count on 10 – 20 sensors
  - Total traffic / patient < 10 kbps

< IEEE 802.15-05-0694r0 >



- Capsule endoscope
  - Monitoring the digestive organs such as the small intestine by video or successive image data
  - Video data < 10 Mbps

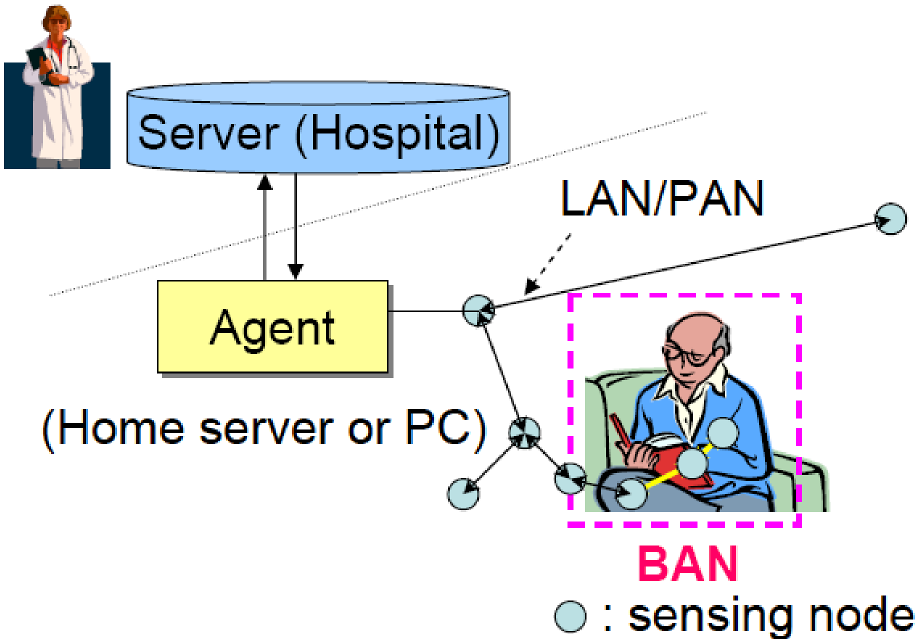
< IEEE 802.15-08-154 >

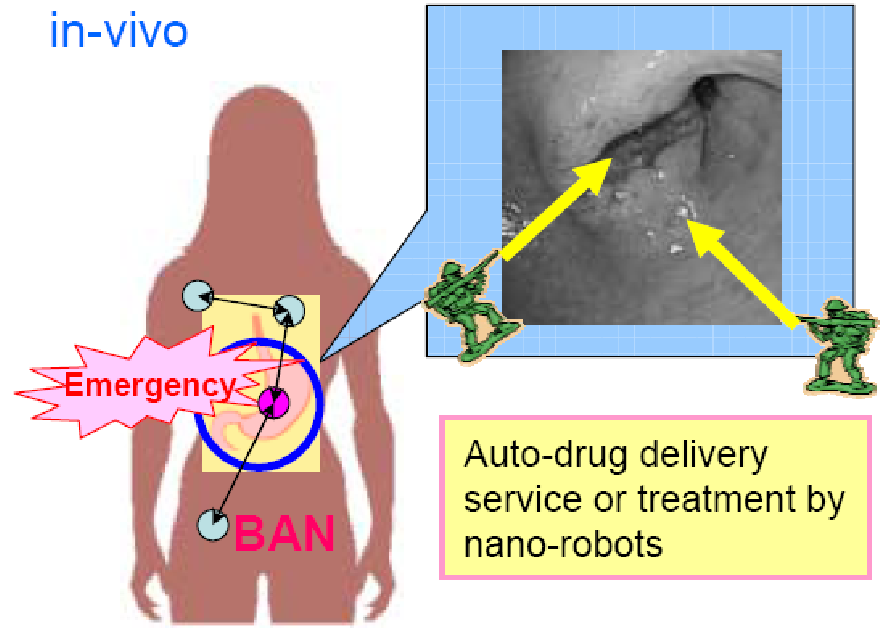


Healthcare Applications

< IEEE 802.15-06-012 >

- Health monitoring / alarm





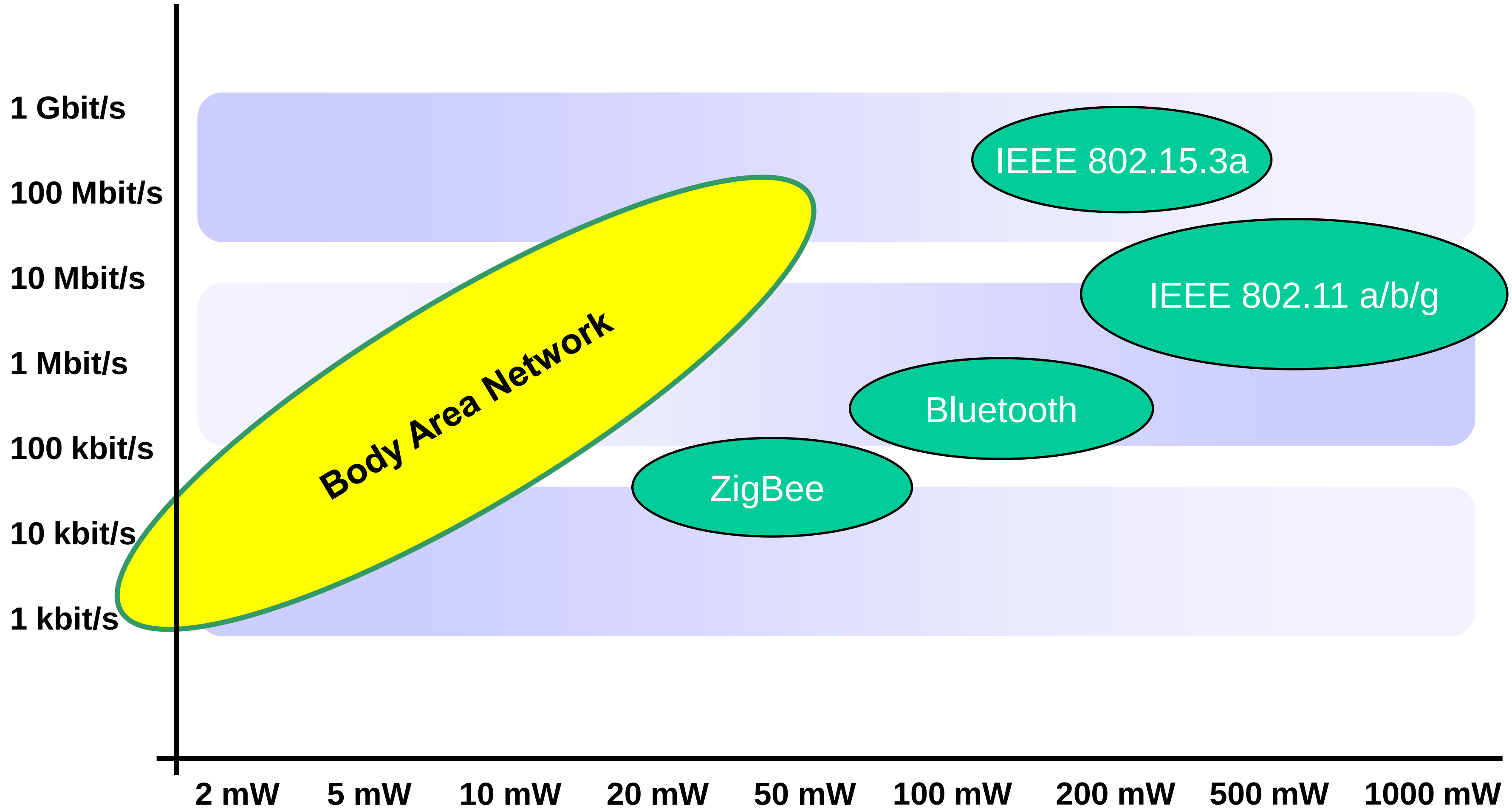
Consumer Electrics

- Non medical applications
- Wearable computer : Network for peripherals
- Fashion with wearable electronic devices
  - Wearable Technology
  - 20% of garments have electronic devices inside within next 10 years : Wearable Era is coming
  - BAN will play a big role connecting them wirelessly

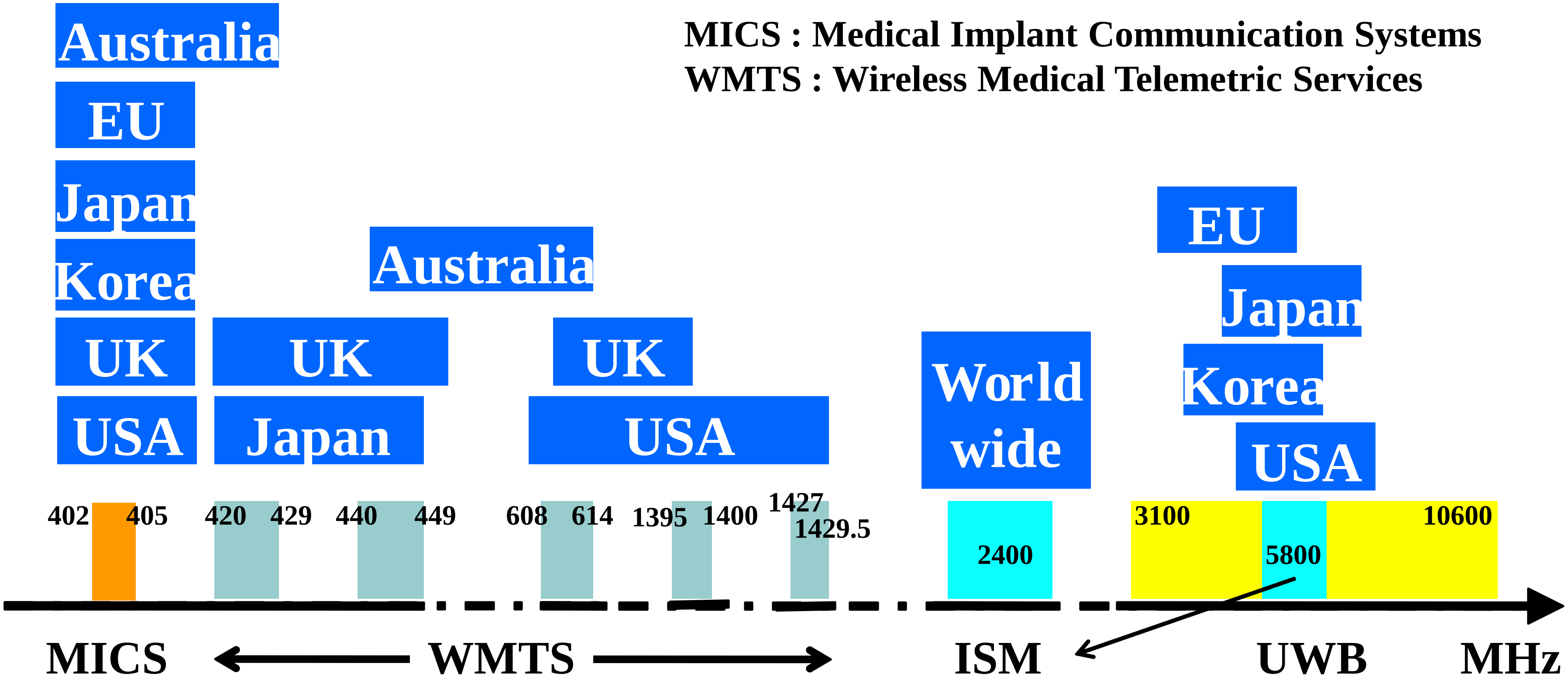
Target Positioning

Average power consumption, sustained data rate

< IEEE 802.15-05-0694r0 >



Candidate Frequency Bands
(0034-06-0006)



IEEE 802.15.6 (1)

- Standardization for short range, wireless communication in the vicinity of, or inside, a human body
- Started at Nov. 2007 as IEEE802.15.6 TG BAN
- Finish : End of 2009
- Steering members
  - Chair : Authur Astrin (US)
  - Vice chair : Huanbang Li (Japan, NICT)
  - Secretary : Bin Zhen (Japan, NICT)
- Responders : NICT, Philips, ETRI, Samsung, NICTA, IMEC NL, KORPA, Hitachi, Fujitsu, LG, etc
- Frequency : existing ISM, approved bands for medical uses (MICS, WMTS), and UWB

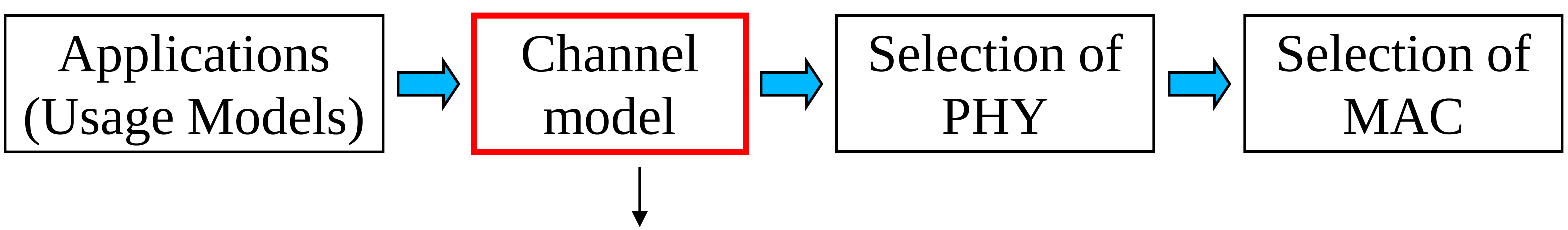
IEEE 802.15.6 (2)

- Overall Requirements
  - Self recoverable from link & node failure
  - Support for Quality of Services (QoS)
  - Very low power consumption
  - Data rates
    - Some tens of kbps (in most cases)
    - up to 10 Mbps
  - Coexistence between BANs and other technologies
  - SAR (specific absorption rate) should satisfy relevant regulatory requirement

Channel Model

- Useful for link budget calculation
  - Propagation path loss
- Usage scenarios
- Transmission simulation at PHY, MAC layer
  - Monte Carlo simulation of dynamic channel impulse responses

< Standardization Process >



TG6 Channel Model Document has been reviewed and approved
(Nov. 13, 2008)

Consideration in BAN Channel

- Mutual interactions between body and antenna
  - Distortion of directivity (Null appearance)
  - Loss due to body (Absorption, impedance mismatch, distance dependent)
  - Polarization rotation due to installation
  - Antenna miniaturization
  - SAR (Specific Absorption Rate) limitation
- Difficult to separate antenna effect from measured channel response

Dynamic Channel Measurement

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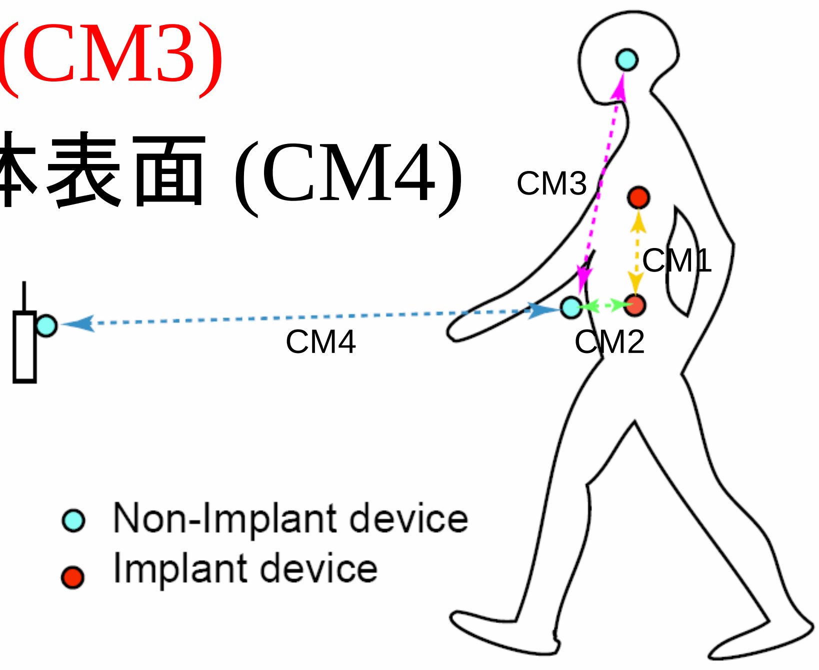
背景

- 人体周りの近距離通信における高まる関心
- IEEE802.15.6 BANにて標準化が行われている
- 医療ヘルスケア用ウェアラブルデバイス
- デバイス設計のためには，人体における伝搬チャネルについて理解が必要
- 既存の測定は静的な環境での評価
- 人体の動作を考慮した動的（準静的）なチャネルモデルが必要

BANチャネルの分類

- インプラントBAN
  - 人体内部⇔人体内部 (CM1)
  - 人体表面⇔人体内部 (CM2)
- ウェアラブルBAN
  - 人体表面⇔人体表面 (CM3)
  - アクセスポイント⇔人体表面 (CM4)

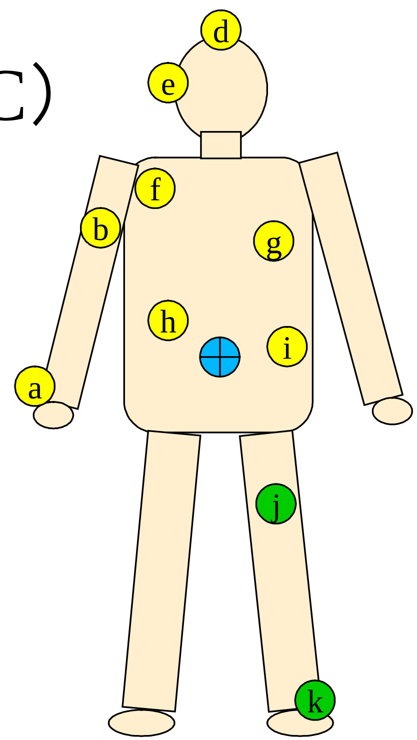


測定の概要(1)

- 人体表面におけるチャネル:人体の動きによるフェージング
- 準静的な変動, パスゲイン分布
- BANにおける候補周波数:
  MICS (402~405MHz), active RFID (950MHz)
  ISM(2.4GHz), UWB-LB(3~5GHz)
  ⇒　今回は4.5GHz帯における測定
- 動的な測定が可能なチャネルサウンダーを利用(f=4.5GHz, BW:120MHz)
- 人体サンプルを利用

測定の概要(2)

- 暗室測定⇒人体周りの外部散乱物の影響はない
- 主に人体の動きによる伝搬距離変動と遮へいの影響を確率的にモデル化
  - 静止状態時:呼吸など思わぬ動き(A)
  - 歩き動作時:(A)＋歩き動作(B)
  - 立ち座り動作時: (A)＋立ち座り動作(C)
- 測定方法
  - 送信点固定(臍付近), 受信点10ヶ所
  - 動作：静止, 徒歩, 立ち座りの繰り返し
  - 約1万スナプショット(約10秒分)

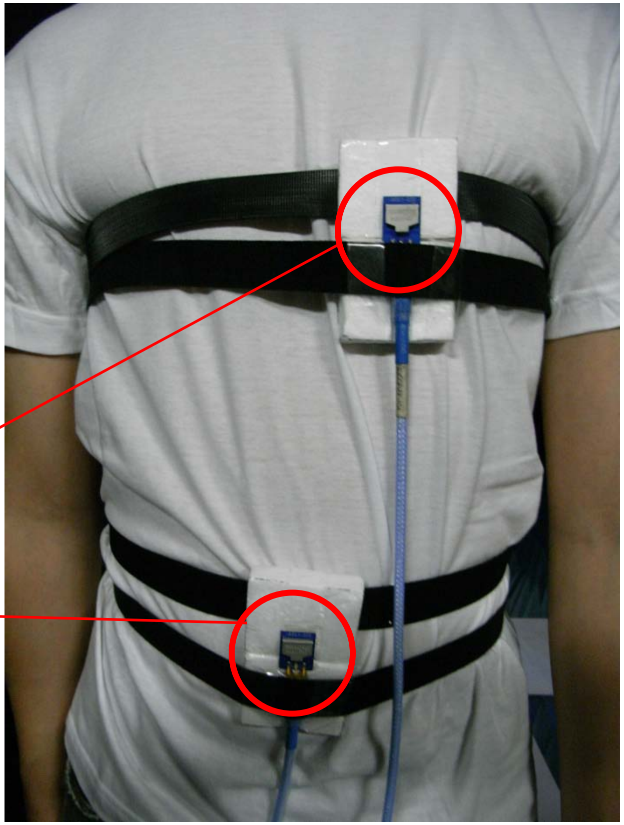


人体サンプルとアンテナ

- 人体サンプル（男性）

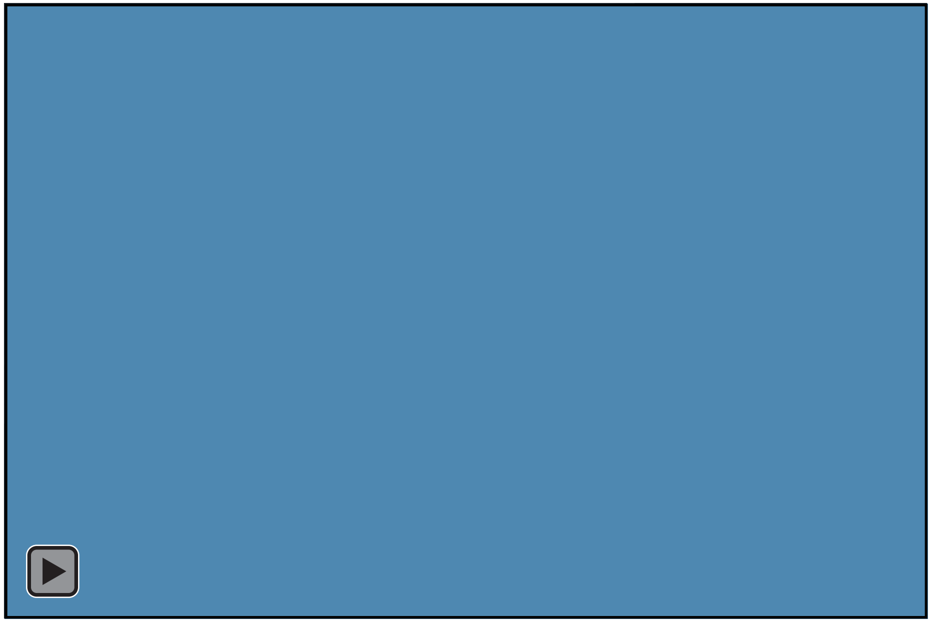
Height	171.5 cm
Bust	89.5 cm
Waist	76.5 cm

- アンテナ
  - UWB SkyCross
  - 3.1~10 GHz
  - アンテナと人体の相互作用による変化：アンテナを伝搬路から分離することは困難→ チャネルの一部として考える

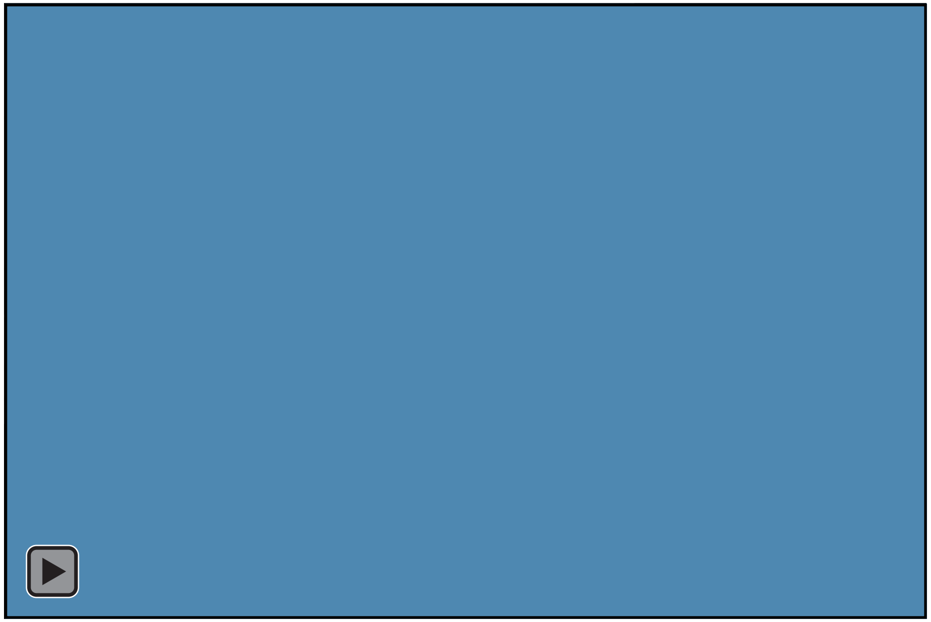


Motions

Walking



Stand up/ Seat down



確率分布モデル

- 正規(Normal)分布
- 対数正規(Log-normal)分布

$$f(x \mid \mu, \sigma) = \frac{10/\ln 10}{x\sigma\sqrt{2\pi}} e^{-\frac{(10\log_{10} x - \mu)^2}{2\sigma^2}}$$

μ : location

σ : scale

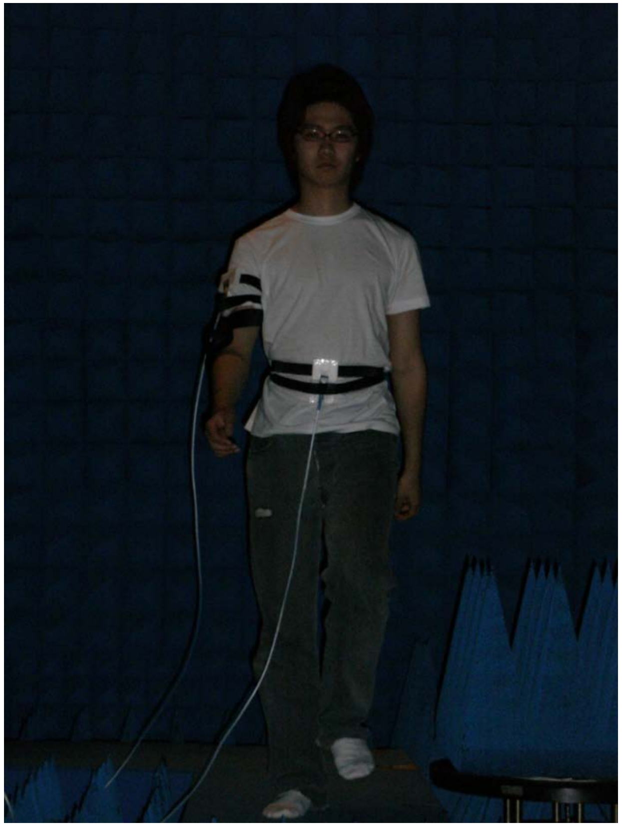
- ワイブール(Weibull)分布
  ⇒多様な分布系が表現可能

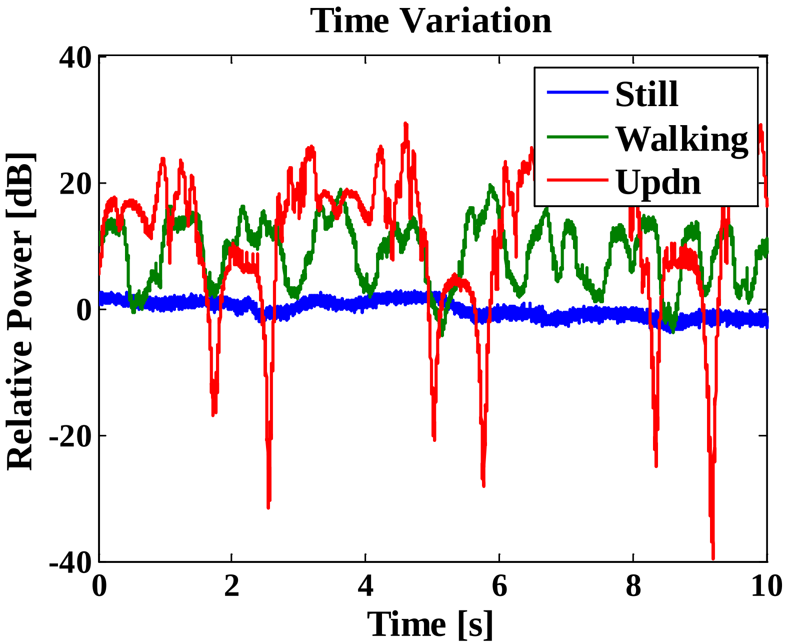
$$f(x \mid a, b) = \frac{b}{a}\left(\frac{x}{a}\right)^{b-1} e^{-\left(\frac{x}{a}\right)^b}$$

a : scale

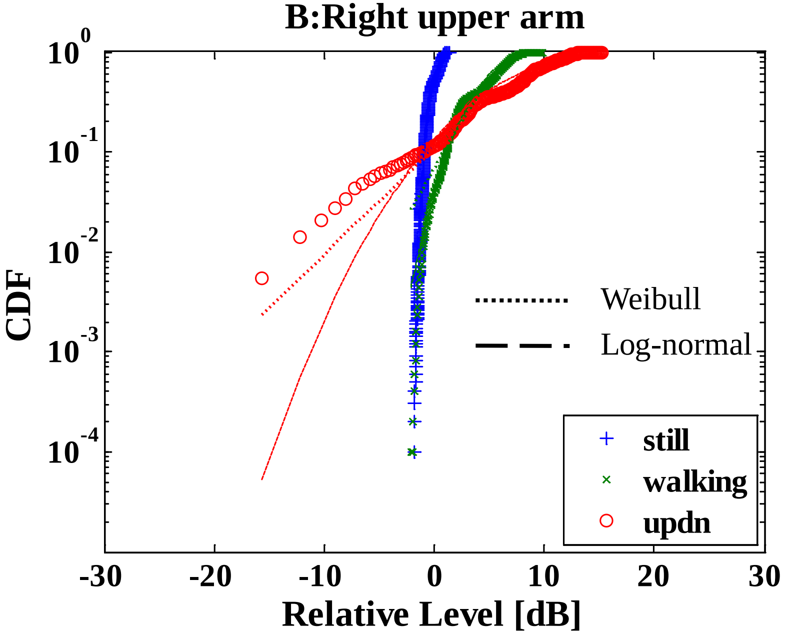
b : shape

測定結果(B: 右腕)



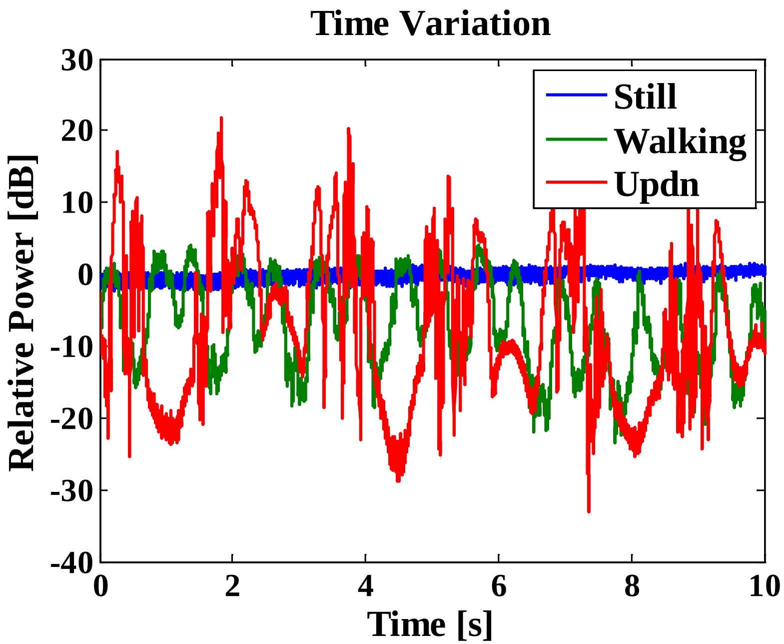


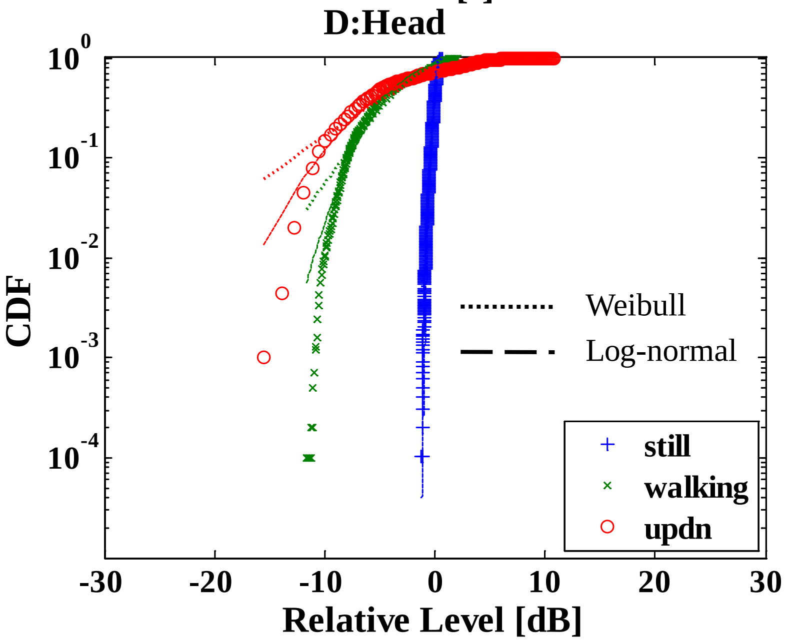
Time Variation
Still
Walking
Updn
Relative Power [dB]
Time [s]
40
20
0
-20
-40
0
2
4
6
8
10



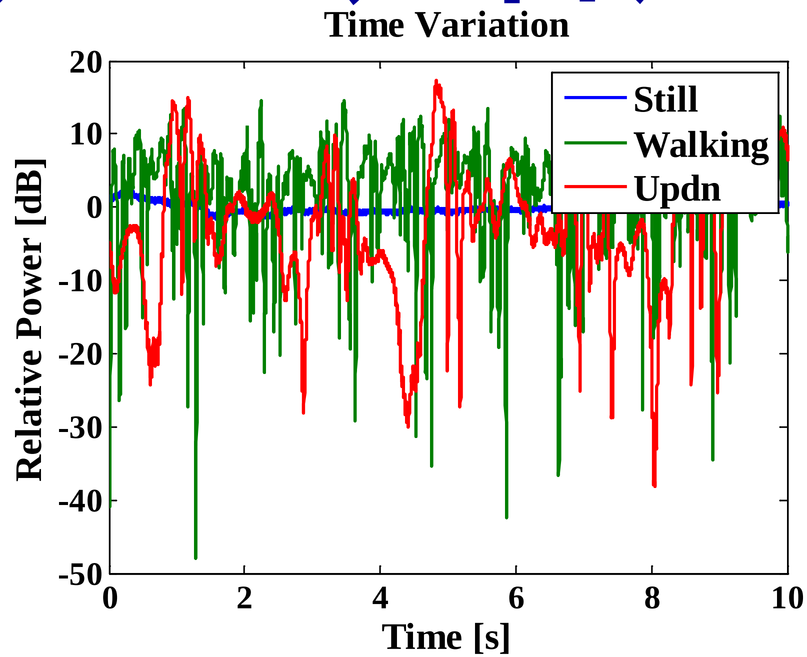
B:Right upper arm
CDF
Relative Level [dB]
Weibull
Log-normal
still
walking
updn
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
-30
-20
-10
0
10
20
30

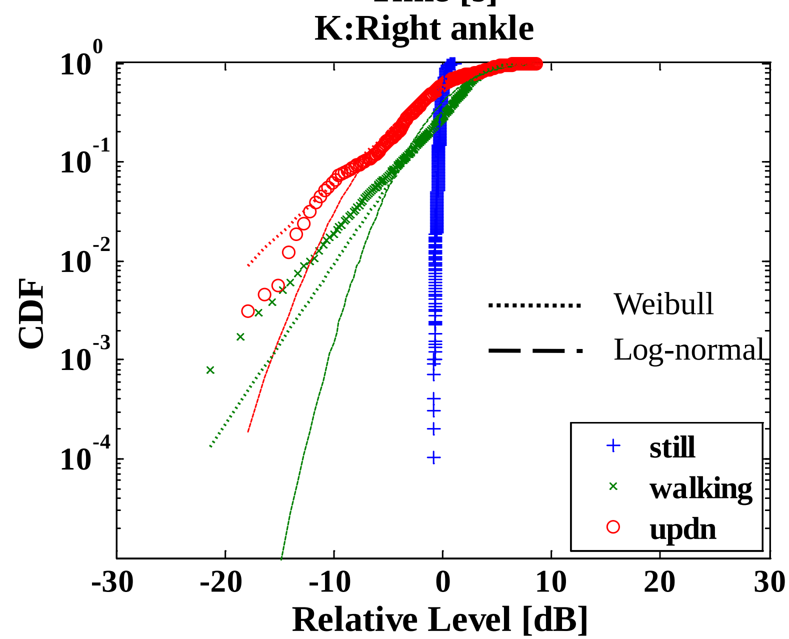
測定結果(D: 頭)


Time Variation
Relative Power [dB]
30
20
10
0
-10
-20
-30
-40
0
2
4
6
8
10
Time [s]
Still
Walking
Updn


D:Head
CDF
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
-30
-20
-10
0
10
20
30
Relative Level [dB]
Weibull
Log-normal
still
walking
updn

測定結果(K: 右足首)


Time Variation
Still
Walking
Updn
Relative Power [dB]
Time [s]


K:Right ankle
Weibull
Log-normal
still
walking
updn
CDF
Relative Level [dB]

確率分布パラメタ（1）

μ/ σ [dB] (-LogL)		Log-normal fitting		
		Still	walking	updn
A	Right wrist	-0.0652 / 0.9531 (-1114.1)	-3.9908 / 11.7727 (14948)	8.4456 / 3.4836 (31047)
B	Right upper arm	-0.0491 / 0.6544 (-4800.9)	4.4491 / 2.4972 (18735)	6.3009 / 5.6692 (31093)
D	Head	-0.0100 / 0.2969 (-12476)	-3.5392 / 3.2052 (2983.8)	-3.6932 / 5.3385 (7601)
E	Right ear	-0.0400 / 0.5921 (-5815.6)	-4.1465 / 2.4654 (-1005.5)	-3.3130 / 5.2458 (8384.1)
F	Shoulder	-0.0024 / 0.1453 (-19806)	-1.8011 / 2.0549 (2507.8)	0.2165 / 4.1023 (14537)

a / b (-LogL)		Weibull fitting		
		Still	walking	updn
A	Right wrist	1.0478 / 7.7411 (-5770.3)	1.4690 / 0.4510 (14629)	10.0006 / 1.7319 (29786)
B	Right upper arm	1.0655 / 7.3618 (-4529.3)	3.6759 / 2.0325 (18625)	7.5368 / 1.0787 (29631)
D	Head	1.0297 / 17.9473 (-13029)	0.6360 / 1.5519 (3061.7)	0.8015 / 0.8228 (8458.3)
E	Right ear	1.0594 / 7.7870 (-5394.6)	0.5071 / 1.9516 (-840.12)	0.8224 / 1.0055 (7959.7)
F	Shoulder	1.0165 / 29.8877 (-18940)	0.8237 / 2.6536 (1913.3)	1.6534 / 1.2203 (14452)

The value of each position is computed with the normalized $|h(\tau_1)|^2$ by mean value of still data

確率分布パラメタ（2）

μ/ σ [dB] (-LogL)		Log-normal fitting		
		Still	walking	updn
G	Chest	-0.2359 / 1.4019 (2315)	3.6360 / 2.4688 (16779)	5.0788 / 6.4077 (29907)
H	Right rib	-0.0470 / 0.6043 (-5657.3)	-0.8883 / 1.3994 (818.79)	5.7033 / 3.2101 (24051)
I	Left waist	-0.0035 / 0.1742 (-17942)	-1.4965 / 0.9770 (-4109.5)	-3.5588 / 3.3466 (3337.8)
J	Right thigh	-0.0191/ 0.4017 (-9717)	-2.6924 / 2.6453 (2970.7)	-0.5995 / 3.7712 (11098)
K	Right ankle	-0.0131/ 0.3352 (-11251)	0.9424 / 3.7030 (14861)	-1.1303 / 4.7167 (12357)

a / b (-LogL)		Weibull fitting		
		Still	walking	updn
G	Chest	1.1203 / 2.9913 (3487.2)	3.0419 / 1.9575 (16909)	6.3808 / 0.8247 (29393)
H	Right rib	1.0742 / 4.9107 (-1979.2)	0.9539 / 3.2009 (1357.2)	5.2709 / 1.6440 (23654)
I	Left waist	1.0190 / 28.9055 (-17946)	0.7915 / 4.9572 (-3903.2)	0.6117 / 1.7907 (1823.7)
J	Right thigh	1.0464 / 9.6410 (-7951.2)	0.7325 / 1.6297 (3867.9)	1.2626 / 1.6251 (9539.3)
K	Right ankle	1.0379 / 11.8572 (-9813.1)	1.7880 / 1.6227 (13323)	1.2867 / 1.0759 (12124)

The value of each position is computed with the normalized $|h(\tau_1)|^2$ by mean value of still data

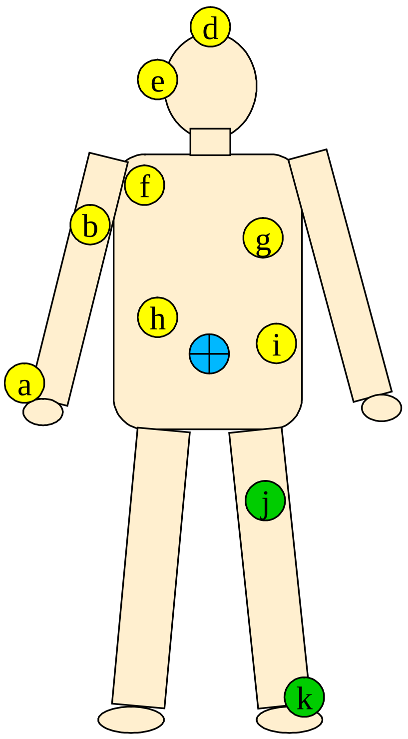
確率分布のまとめ

負の対数尤度(−LogL)の比較による判断

		Still	walking	updn
A	Right wrist	Normal	Weibull	Weibull
B	Right upper arm	Log-normal	Weibull	Weibull
D	Head	Weibull	Log-normal	Log-normal
E	Right ear	Normal	Log-normal	Weibull
F	Shoulder	Log-normal	Weibull	Weibull
G	Chest	Log-normal	Log-normal	Weibull
H	Right rib	Log-normal	Log-normal	Weibull
I	Left waist	Normal	Log-normal	Weibull
J	Right thigh	Log-normal	Log-normal	Weibull
K	Right ankle	Log-normal	Weibull	Weibull

まとめ

- パスゲイン測定による確率分布モデル
- 静止状態では正規/対数正規分布で表現できる
- 動作の小さい場合: 対数正規分布
  - 徒歩: D, E, G, H, I, J
  - 立ち座り: D
- 動作の大きい場合: Weibull分布
  - 徒歩: A, B, F, K
  - 立ち座り: A, B, E, F, G, H, I, J, K



今後の課題

- 静止状態(静的)で非自発的な動作の確率モデルの厳密的な検討が必要
- 人体によるバラツキ⇒人体サンプルを増やして測定
- 周波数依存性:今回は4.5GHz帯
- 人体動作とレベル変動の物理的メカニズムの究明(動画利用) ⇒ 物理現象に基づくモデル化が可能
- 測定法の工夫:アンテナ・ケーブルの影響