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

Submission Title: [Statistical Property of Dynamic BAN Channel Gain at 4.5GHz]
Date Submitted: [July 13, 2008]
Source: [Minseok Kim[1], Jun-ichi Takada[1,2], Lawrence Materum[1], Tomoshige Kan[1], Yuuki Terao[1], Yohei Konishi[1], Kenji Nakai[1], and Takahiro Aoyagi[1,2]]
Company [1: Tokyo Institute of Technology, 2: NICT]
Address [S6-4, 2-12-1, O-okayama, Meguro-ku, Tokyo 152-8550, JAPAN]
Voice:[+81 3 57343282], FAX: [+81 3 57343282], E-Mail:[takada@ide.titech.ac.jp]

Re: [Contribution to Channel modeling report]

Abstract: [The contribution provides the statistical property of dynamic ban channel gain.]

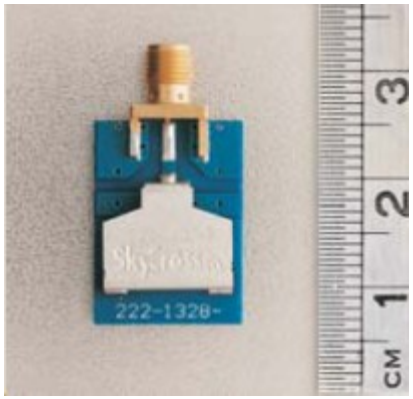
Purpose: [To provide information on body area network use cases, typical requirements, and to start the process on possibly starting a study group in 802.15 on this topic.]

Measurement Overview

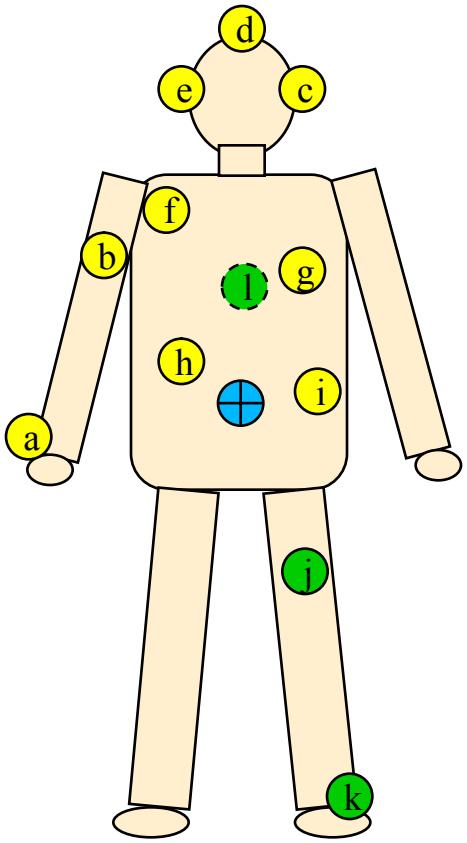
- Measurement of dynamic channel behavior
- RUSK-Fujitsu channel sounder
  - 4.5GHz, 120MHz
  - SISO measurement
- Posture / Motion : still, walking, stand up/seat down
- Estimate distribution parameters of random variable of path gain
- Fit distributions

Measurement Setup

- RUSK-Fujitsu channel sounder
  - 4.5GHz, BW=120MHz
  - SISO measurement
- Antenna
  - UWB SkyCross Antenna
  - 26.2 x 18.5 x 1.0 mm
  - 3.1 ~ 10 GHz



Sensor Positions



Tx	Navel

	Point	Distance from Tx [cm]
a	Right wrist	44 ~ 52.5
b	Right upper arm	36
d	Head	71
e	Right ear	65
f	Shoulder	31
g	Chest	23
h	Right rib	18.3
i	Left waist	14
j	Right thigh	34
k	Right ankle	81.5 ~ 94

Same positions as NICT static channel measurements.

Human specimen

Sample #1
(sex: male)

Height	171.5 cm
Bust	89.5 cm
Waist	76.5 cm

Motions

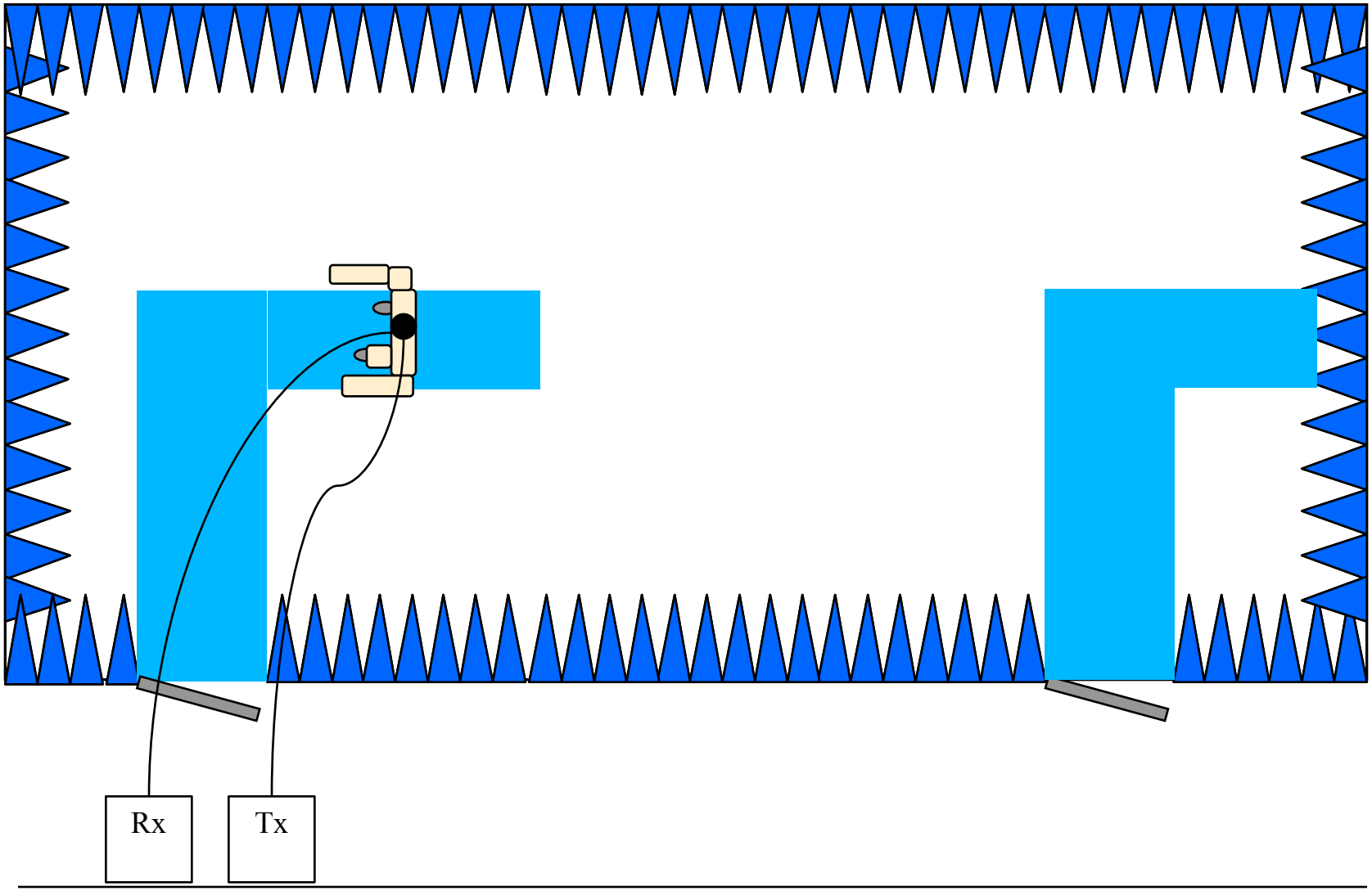
Walking

Stand up/ Seat down

Measurement Campaign

- Anechoic Chamber, Tokyo Institute of Technology
- Measurement Campaign
  - 12 Rx points => 10 Rx points except left ear and back
  - About 10,000 snapshots (10 seconds) at every Rx and every posture
  - 3 postures : still, walking, stand up/down
- Measured data
  - Frequency domain channel response
- Visual data: both movie and still

Anechoic Chamber Setup



Distribution Functions

- Log-normal distribution

$$f(x \mid \mu, \sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

μ : location

σ : scale

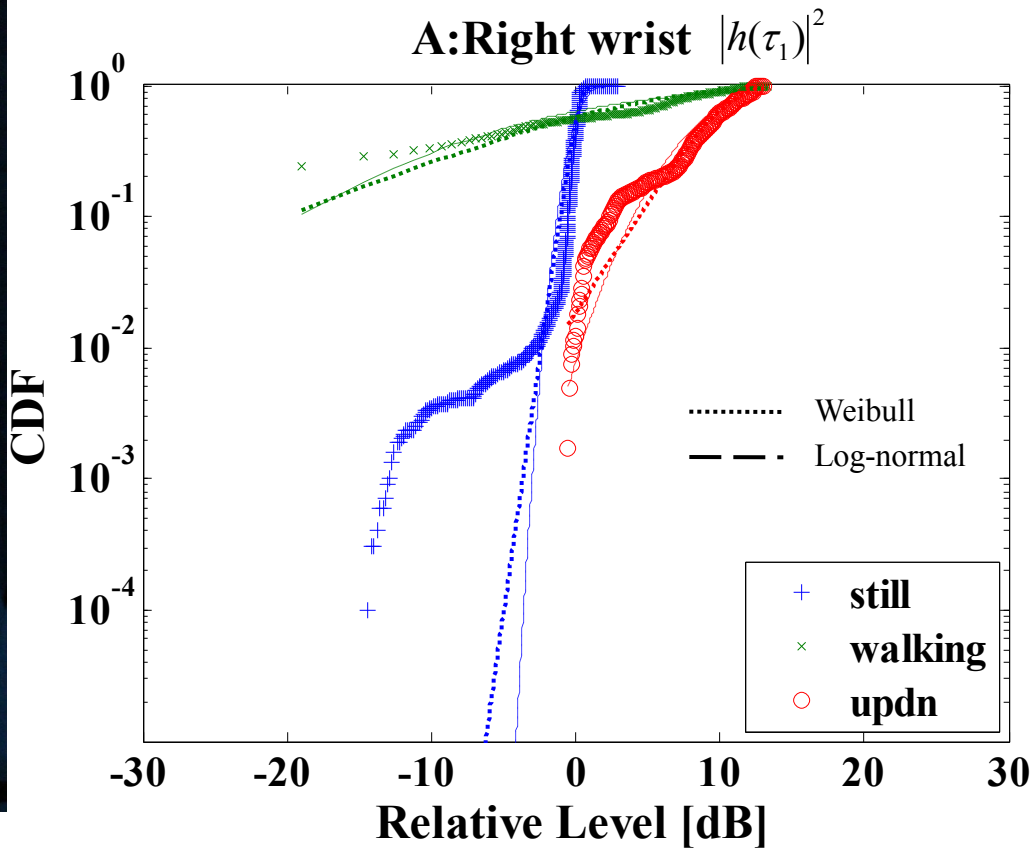
- Weibull distribution

$$f(x \mid a, b) = b a^{-b} x^{b-1} e^{-\left(\frac{x}{a}\right)^b} I_{0,\infty}(x)$$

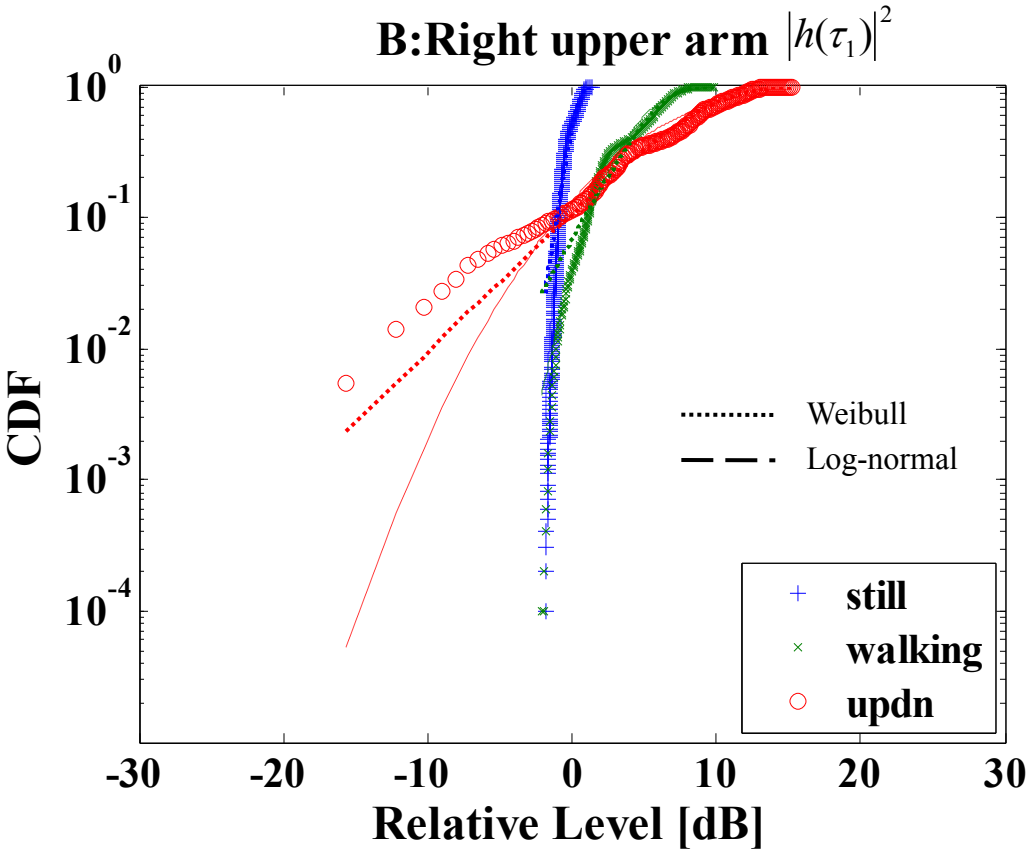
a : scale

b : shape

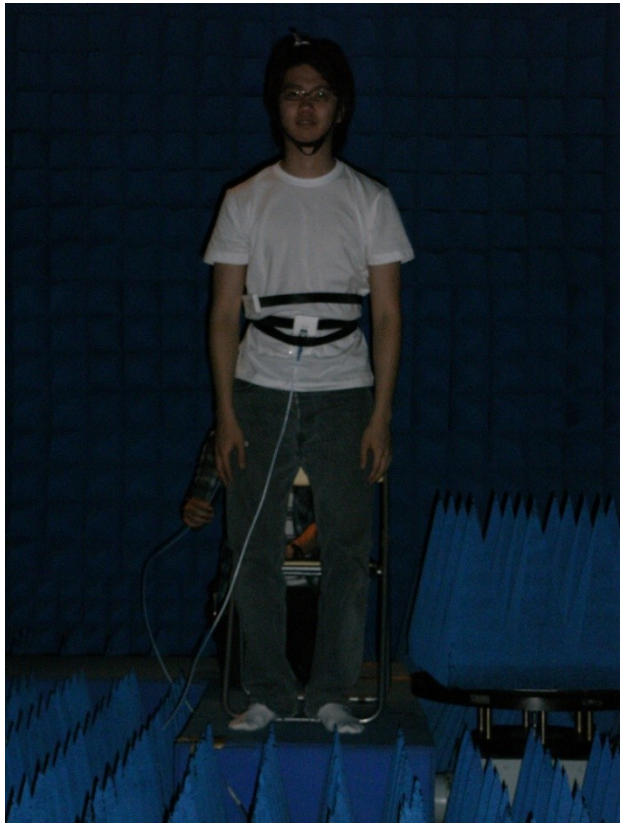
A: Right wrist (S1A)

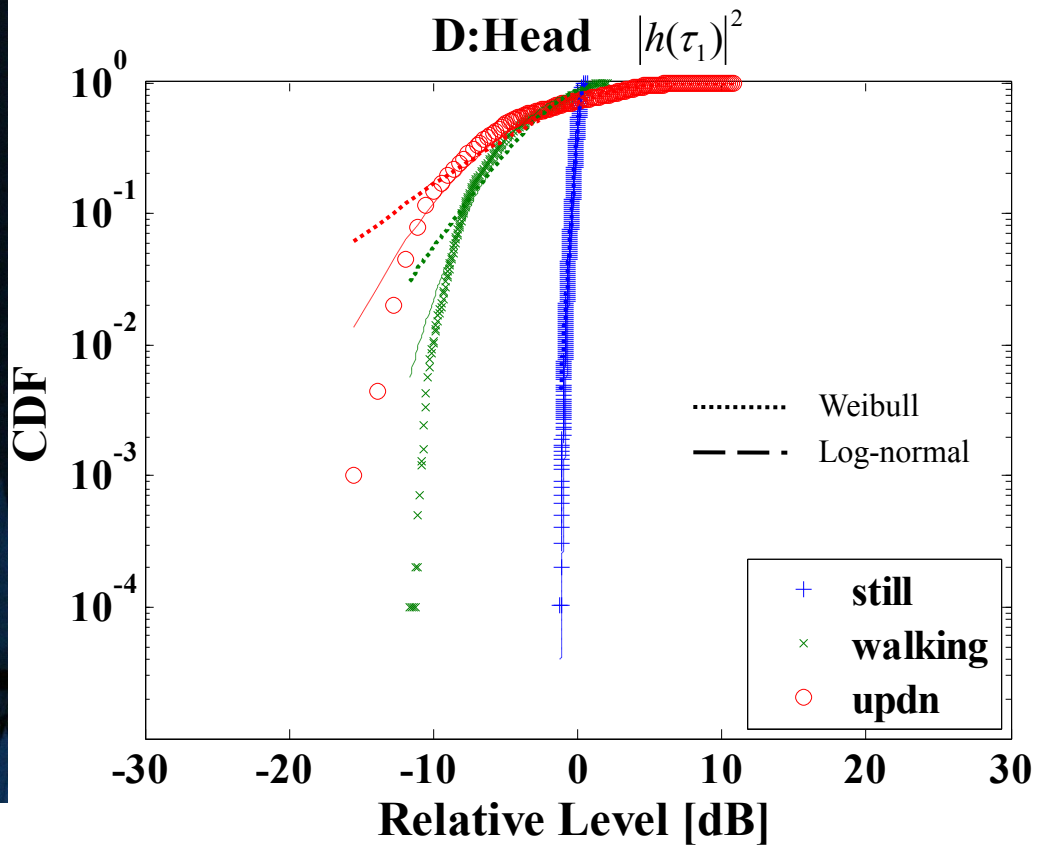


B: Right Upper Arm (S1B)

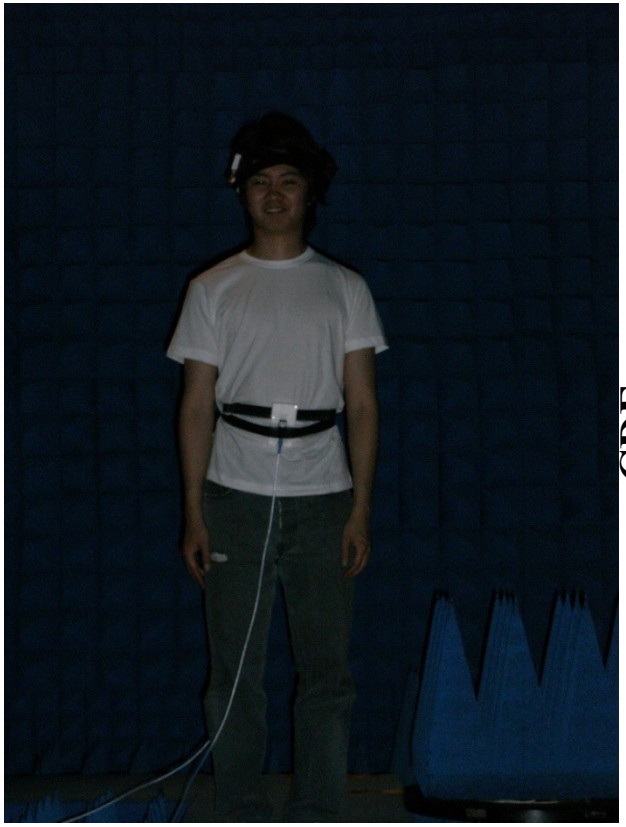


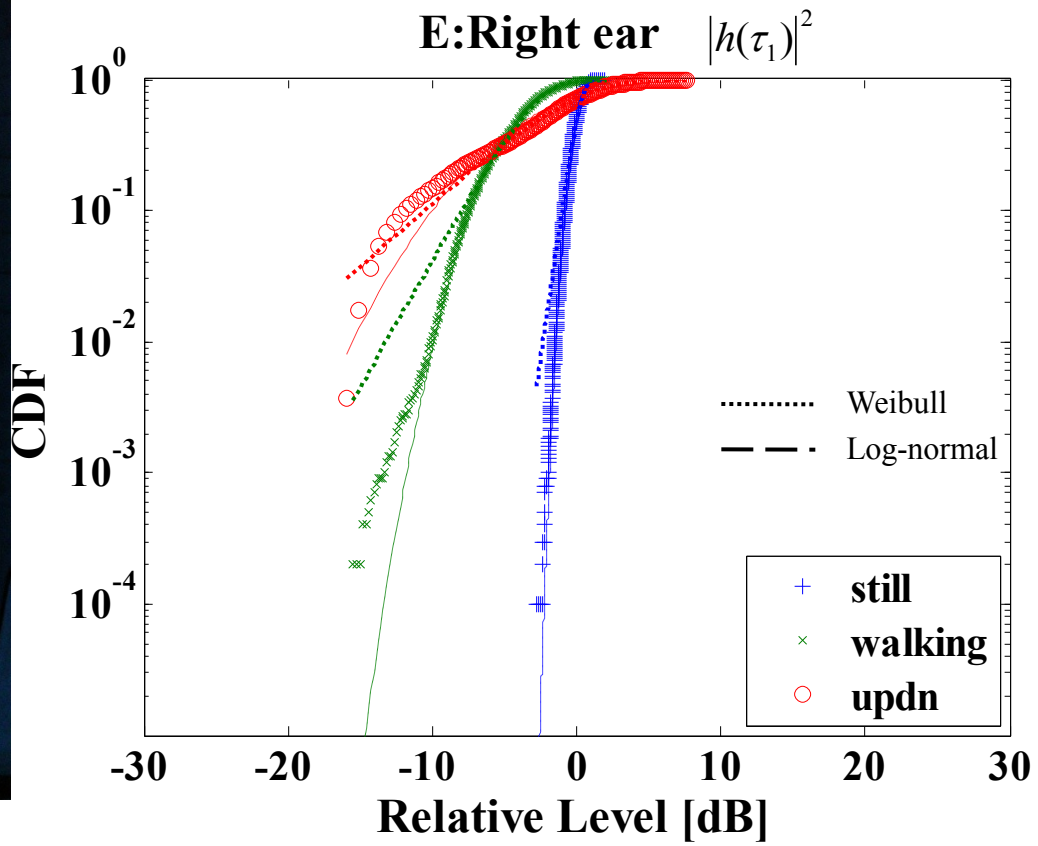
D: Head (S1D)



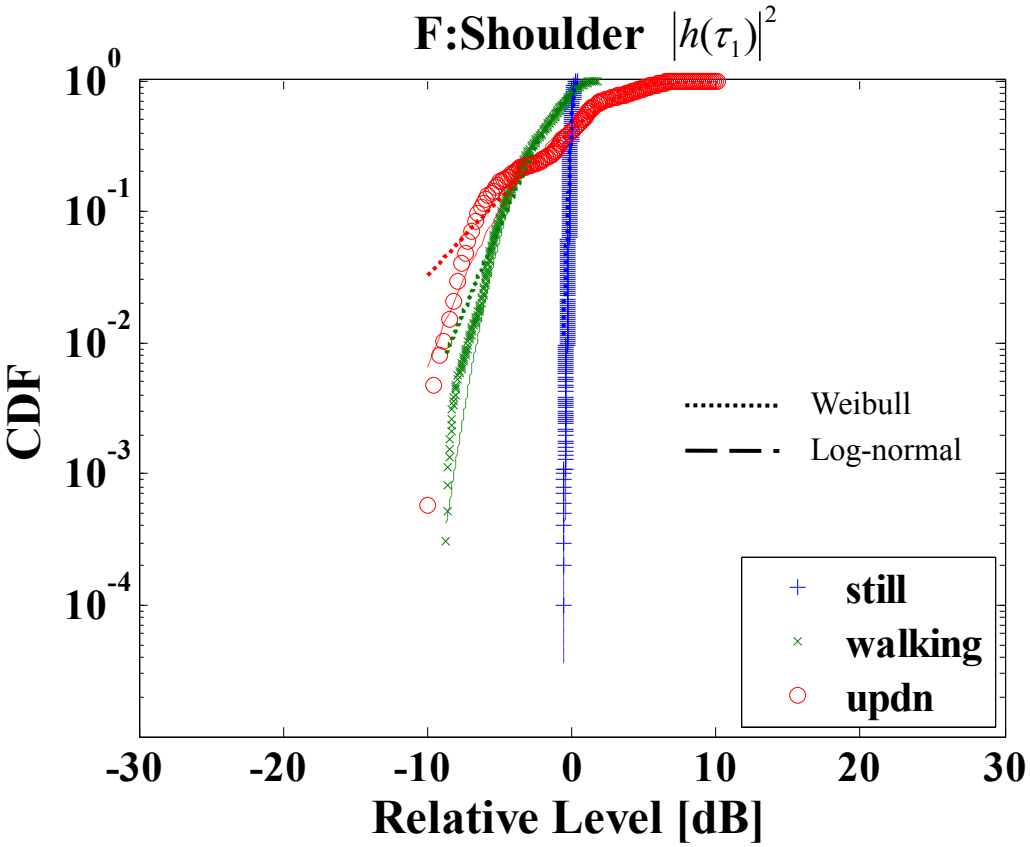

D:Head $|h(\tau_1)|^2$
CDF
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
-30
-20
-10
0
10
20
30
Relative Level [dB]
Weibull
Log-normal
still
walking
updn

E: Right Ear (S1E)

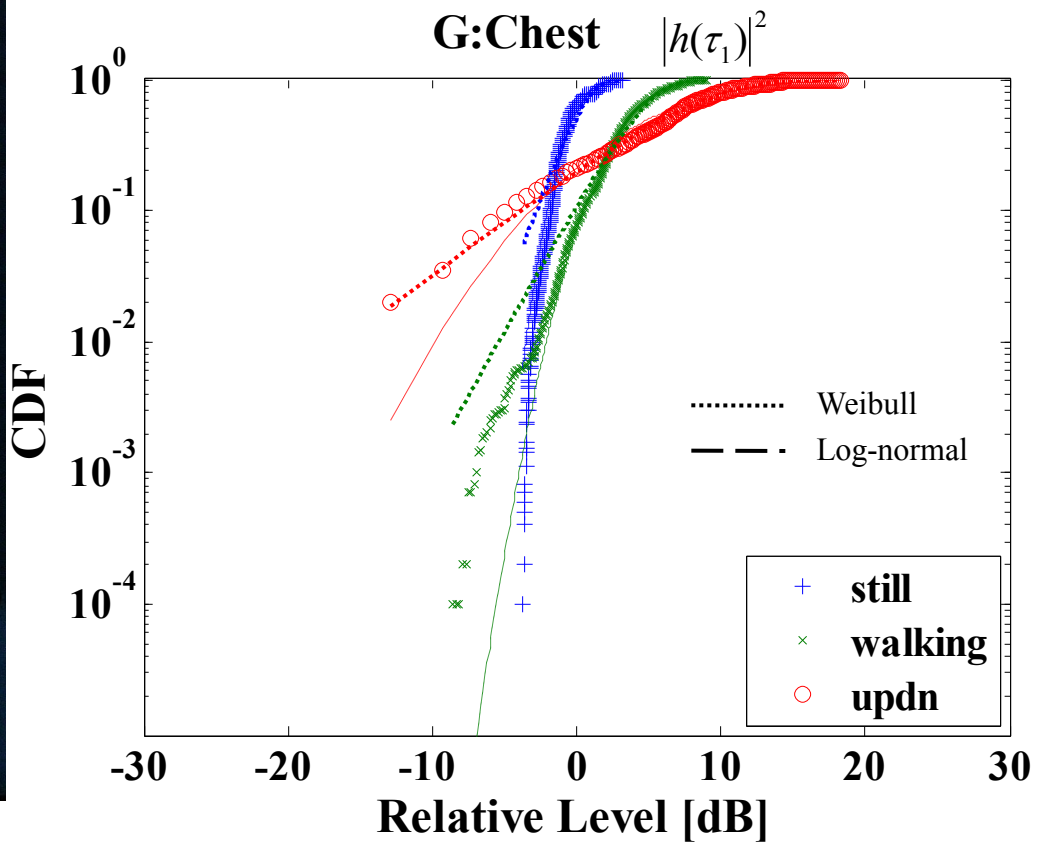




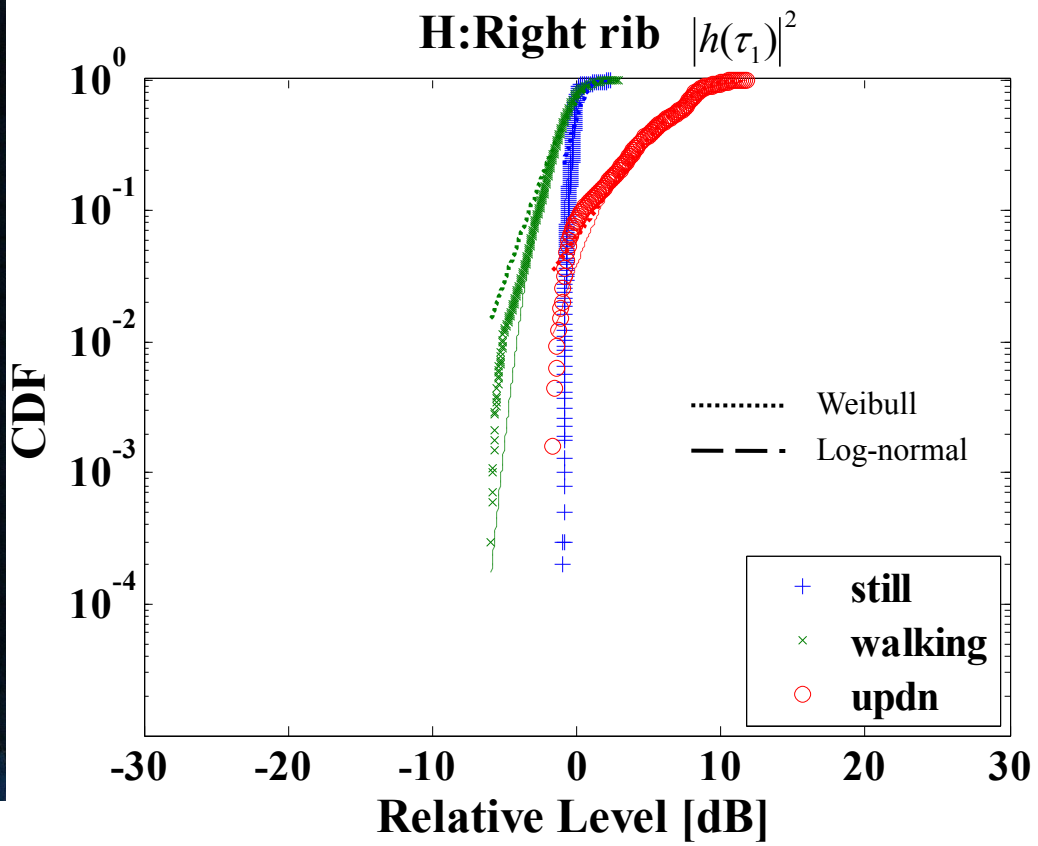
F: Shoulder (S1F)



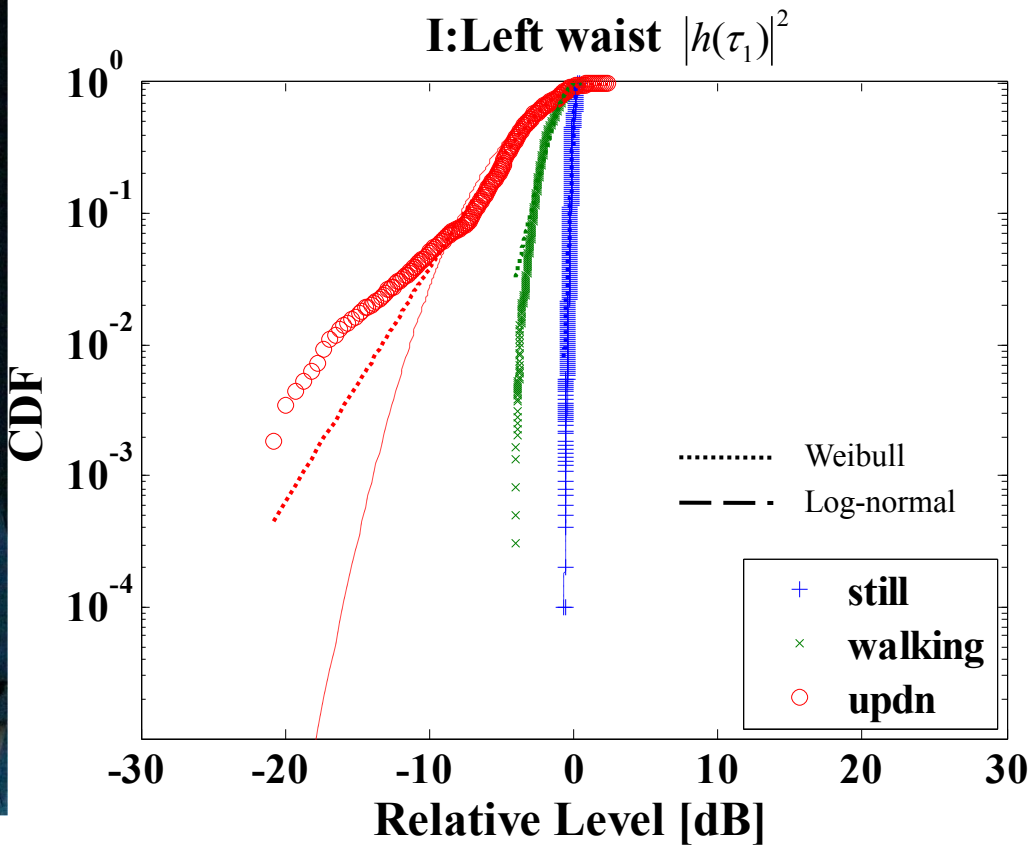
G: Chest (S1G)


G:Chest
$|h(\tau_1)|^2$
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

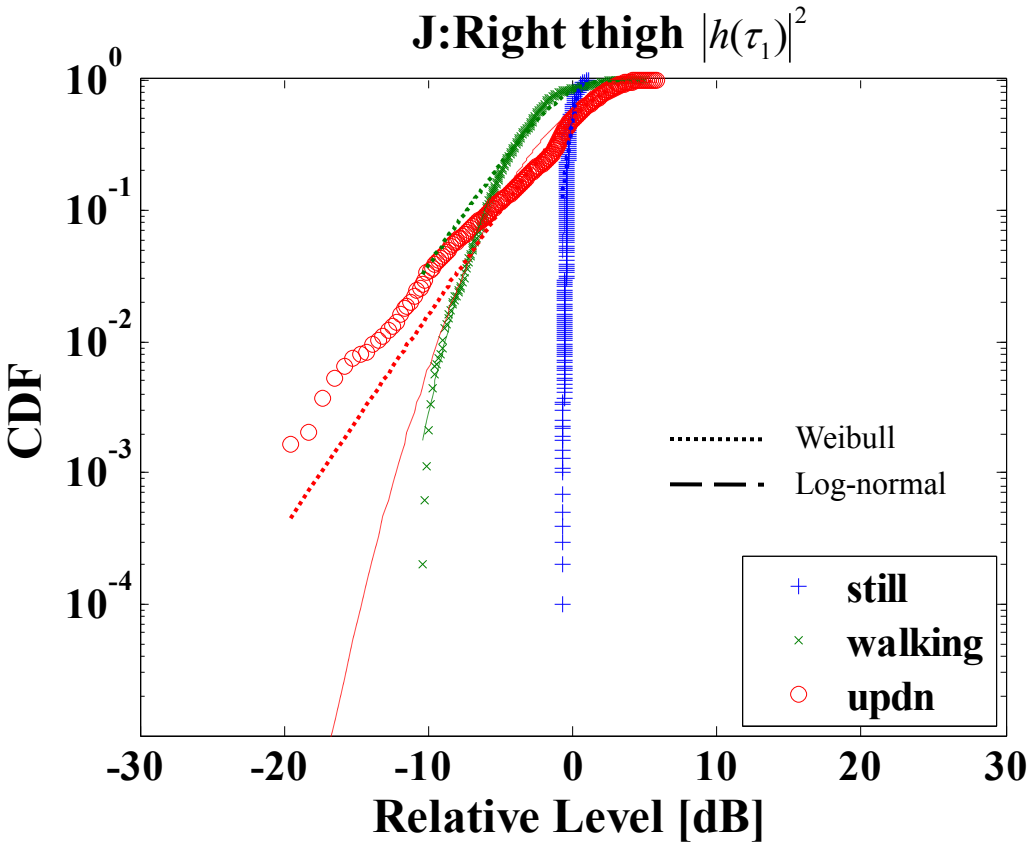
H: Right Rib (S1H)



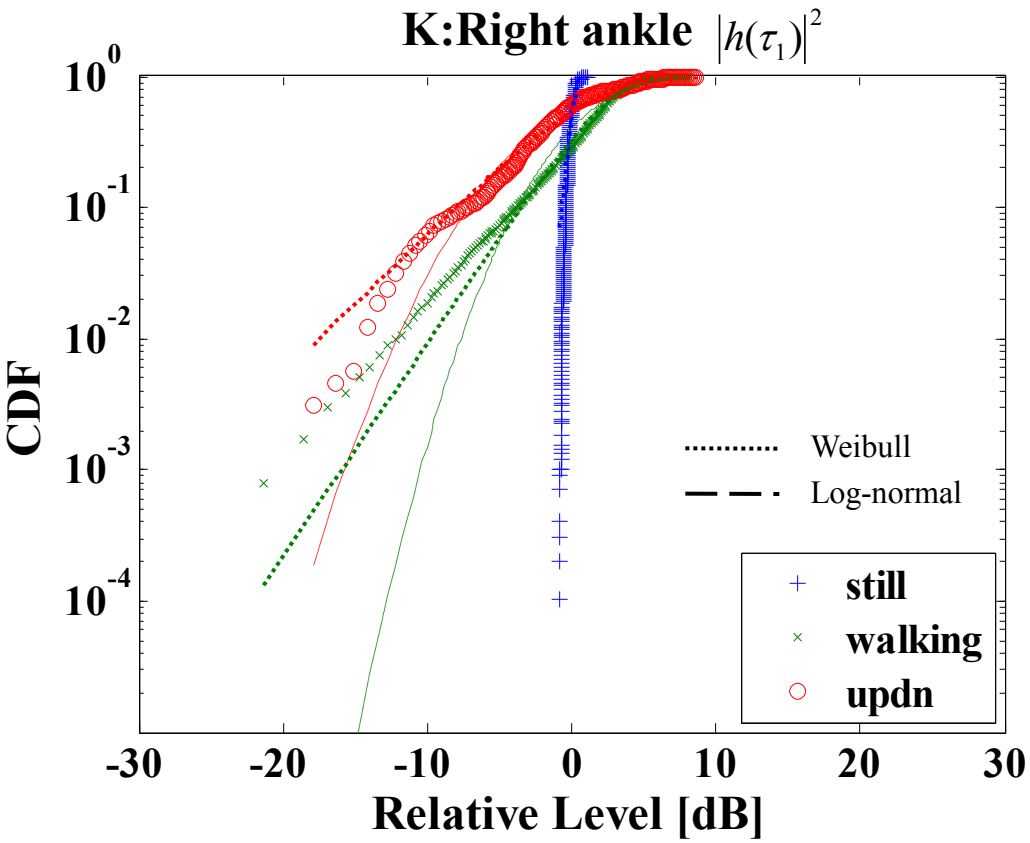
I: Left waist (S1I)



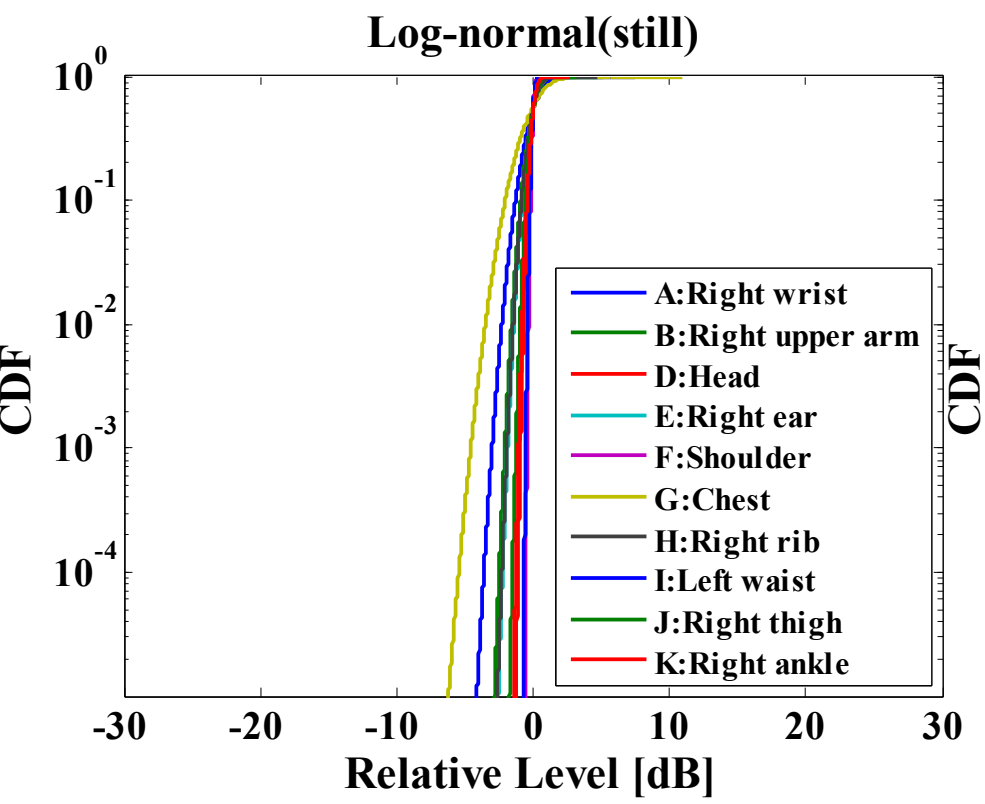
J: Right Thigh (S1J)

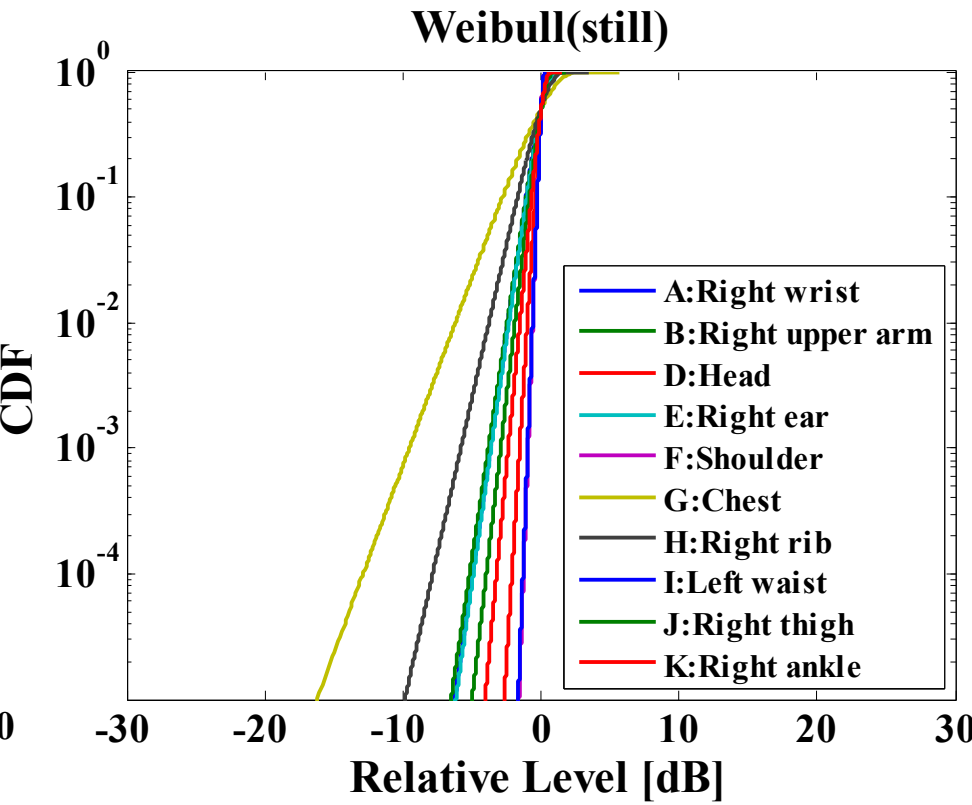


K: Right Ankle (S1K)

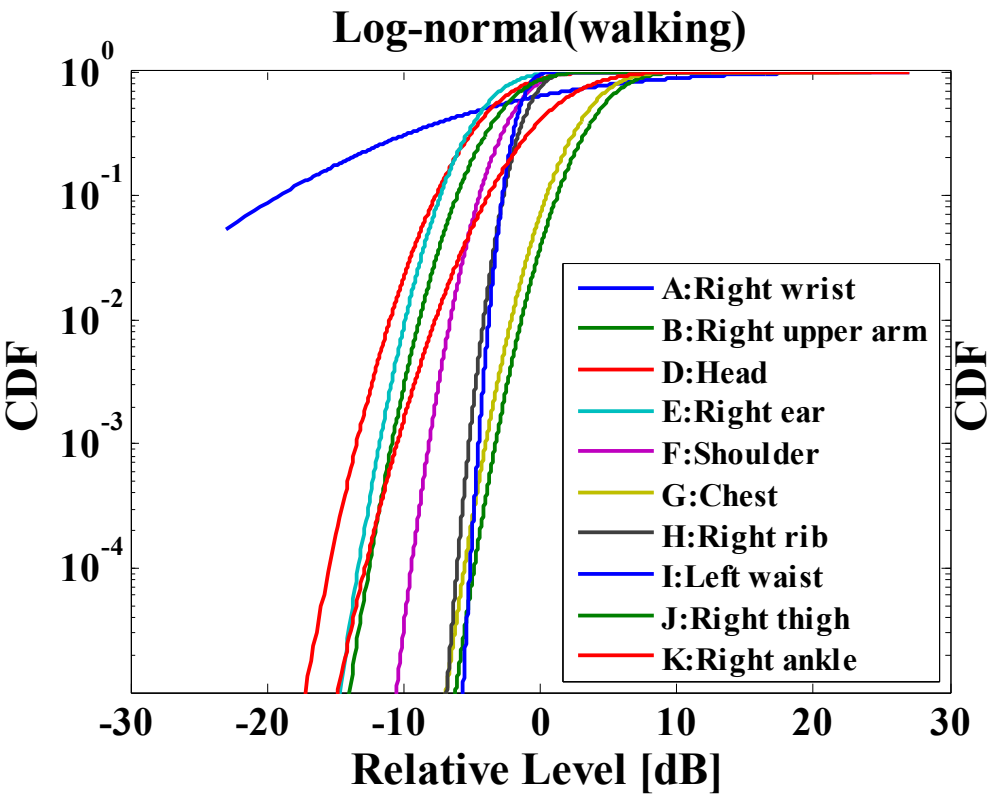


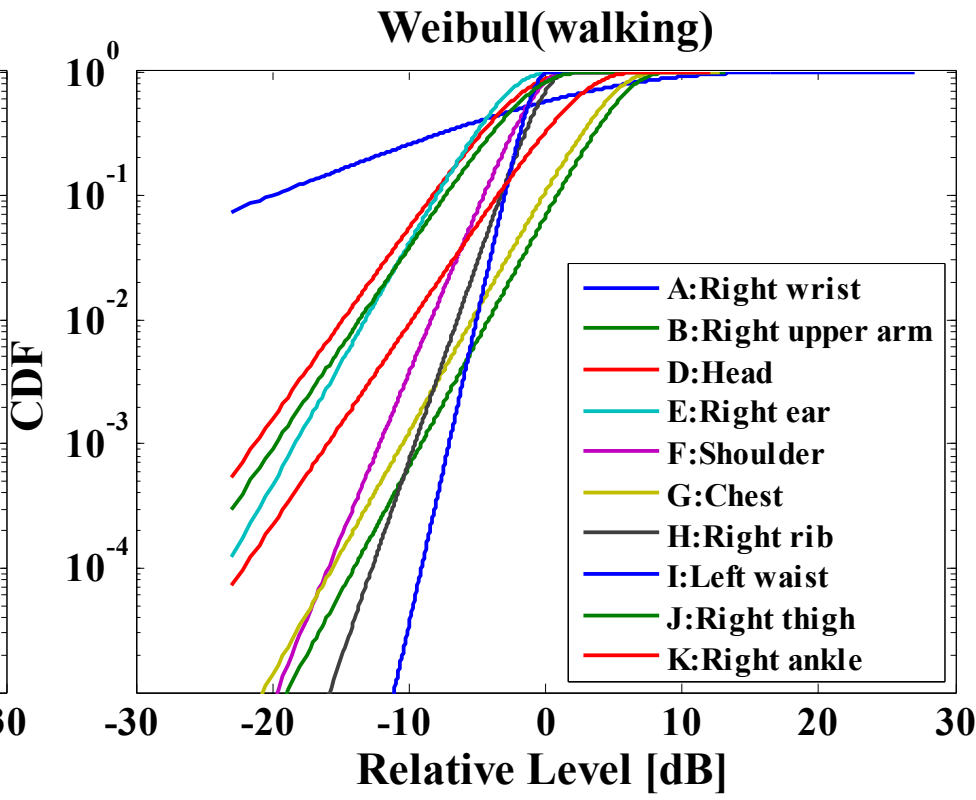
Distribution Fitting (still)



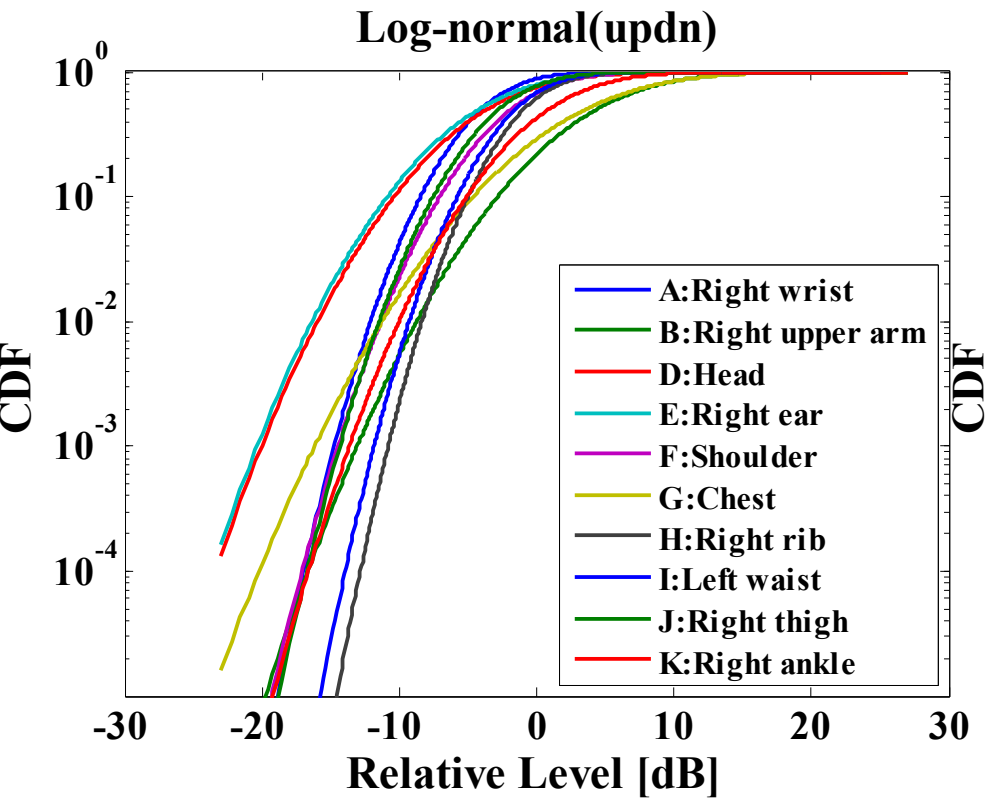


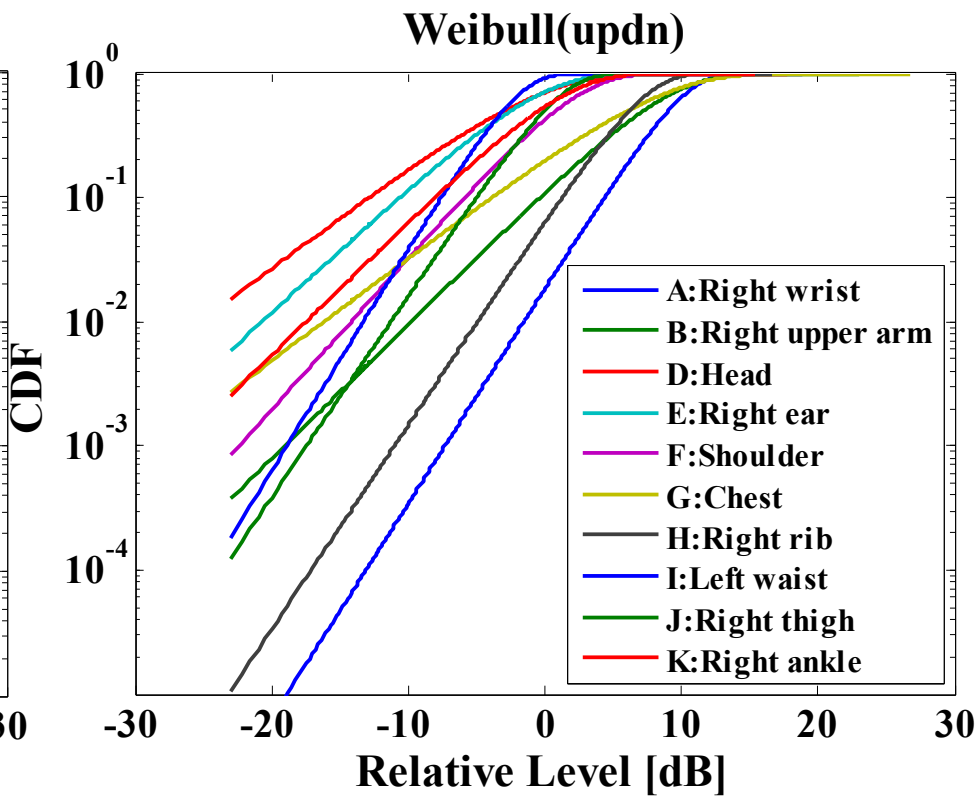
Distribution Fitting (walking)





Distribution Fitting (updn)





Summary of Distribution Fitting (1)

μ/ σ (-LogL)		Log-normal fitting		
		Still	**walking**	**updn**
A	Right wrist	-0.0150 / 0.2195 (-1114.1)	-0.9189 / 2.7108 (14948)	1.9447 / 0.8021 (31047)
B	Right upper arm	-0.0113 / 0.1507 (-4800.9)	1.0245 / 0.5750 (18735)	1.4508 / 1.3054 (31093)
D	Head	-0.0023 / 0.0684 (-12476)	-0.8149 / 0.7380 (2983.8)	-0.8504 / 1.2292 (7601)
E	Right ear	-0.0092 / 0.1363 (-5815.6)	-0.9548 / 0.5677 (-1005.5)	-0.7628 / 1.2079 (8384.1)
F	Shoulder	-0.0006 / 0.0335 (-19806)	-0.4147 / 0.4732 (2507.8)	0.0498 / 0.9446 (14537)

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

Summary of Distribution Fitting (2)

μ/ σ (-LogL)		Log-normal fitting		
		Still	**walking**	**updn**
G	Chest	-0.0543 / 0.3228 (2315)	0.8372 / 0.5685 (16779)	1.1694 / 1.4754 (29907)
H	Right rib	-0.0108 / 0.1391 (-5657.3)	-0.2045 / 0.3222 (818.79)	1.3132 / 0.7391 (24051)
I	Left waist	-0.0008 / 0.0401 (-17942)	-0.3446 / 0.2250 (-4109.5)	-0.8194 / 0.7706 (3337.8)
J	Right thigh	-0.0044 / 0.0925 (-9717)	-0.6199 / 0.6091 (2970.7)	-0.1381 / 0.8683 (11098)
K	Right ankle	-0.0030 / 0.0772 (-11251)	0.2170 / 0.8526 (14861)	-0.2603 / 1.0861 (12357)

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

Summary of Distribution Fitting (3)

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

Summary of Distribution Fitting (4)

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

Best Fit Distributions

		Still	walking	updn
A	Right wrist	Normal	Weibull	Weibull
B	Right upper arm	Log-normal	Weibull	Weibull
D	Head	Normal	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

Summary

- Normal / Log-normal distribution can express well the still conditions
- Log-normal distribution shows good match in cases of small movements
  - walking : D, E, G, H, I and J
  - updn: D
- Weibull distribution shows the best fit in cases of large movements
  - walking : A, B, F and K
  - updn: A,B,E,F,G,H,I,J and K