Human Body Blockage - Guidelines for TGad MAC development

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Abstract

This contribution presents results from a TUBS measurement campaign investigating the influence of moving humans on the 60 GHz channel. Together with the results from [1] and [2] this will be the base for guidelines concerning TGad beamforming algorithm and MAC layer development. These guidelines could be included to the channel model document [3].

Human induced shadowing events

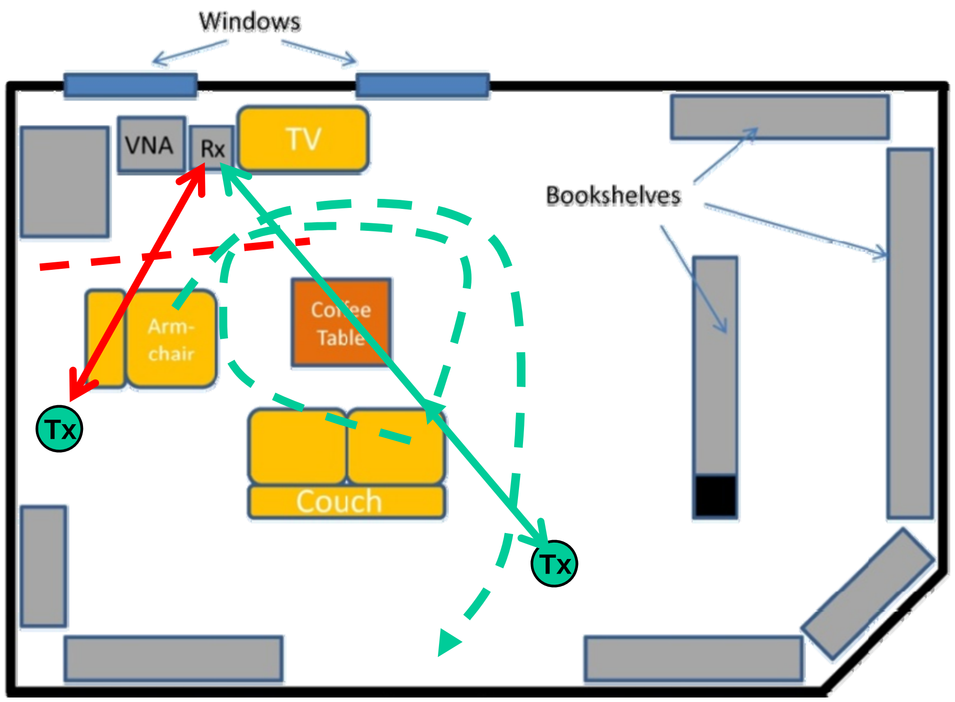
- **Statistics about human induced shadowing effects should be included in the channel model document**

- **Important quantities for beamforming and MAC development:**
  - How fast does the channel change?
  - How often does shadowing events occur?
  - How long is the shadowing event
  - What is the amplitude of a shadowing event?

- **These questions will be answered based on measurement results at TUBS and from [1]**

Dynamic Measurements

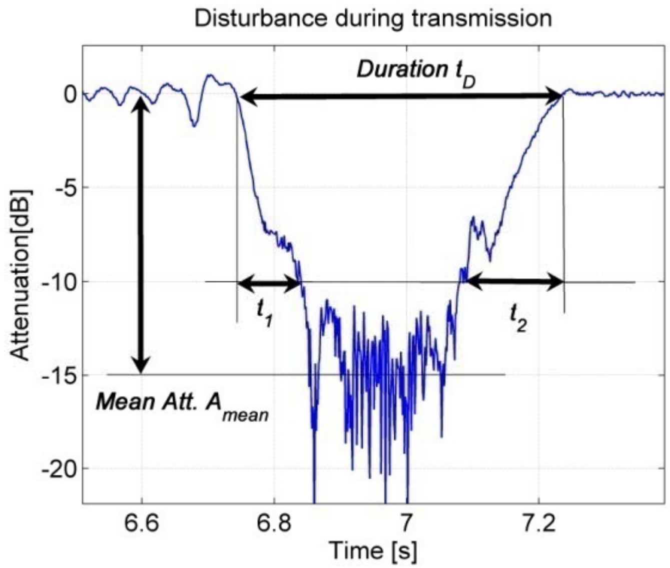
- **Living room scenario**
- **Single Person moving**
- **2 different Tx positions**
- **3 different walking paths**
- **Single Frequency: 67 GHz**
- **20 dBi Horn Antennas**




-15
-20
-25
-30
-35
-40
-45
-60
S21 [dB]
0
5
10
15
20
Time [s]

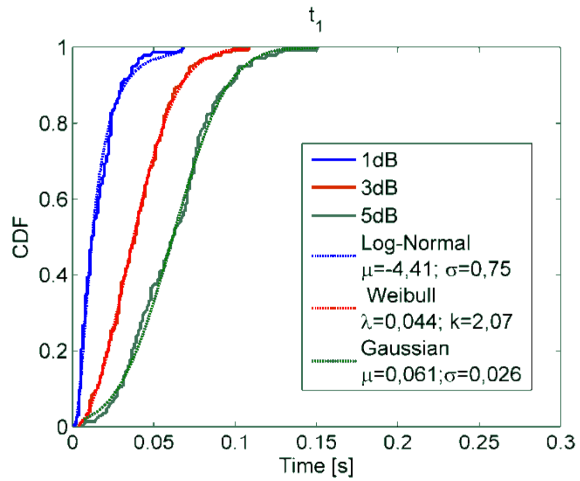
Definitions

- **The following parameters of a shadowing event have been statistically analyzed**
  - Decay time $\mathbf{t_1}$ (for a given threshold)
  - Rising time $\mathbf{t_2}$ (for a given threshold)
  - Duration $\mathbf{t_d}$
  - Mean Attenuation $\mathbf{A_{mean}}$ for the window ($t_d/3<t<2/3\ t_d$)
  - Max. Attenuation $\mathbf{A_{max}}$



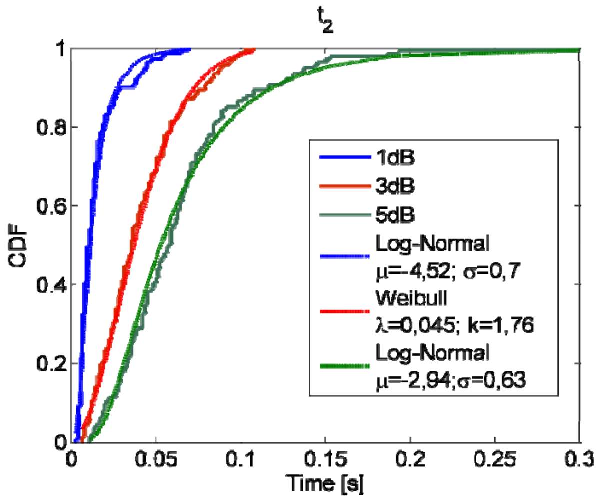
- **For all parameters fitted distributions are given, validated by Kolmogorov–Smirnov test**

Decay and Rising Time



- Decay time

Threshold	Mean Value	Standard deviation
1 dB	16 ms	14 ms
3 dB	39 ms	20 ms
5 dB	61 ms	26 ms
20 dB	230 ms	92 ms

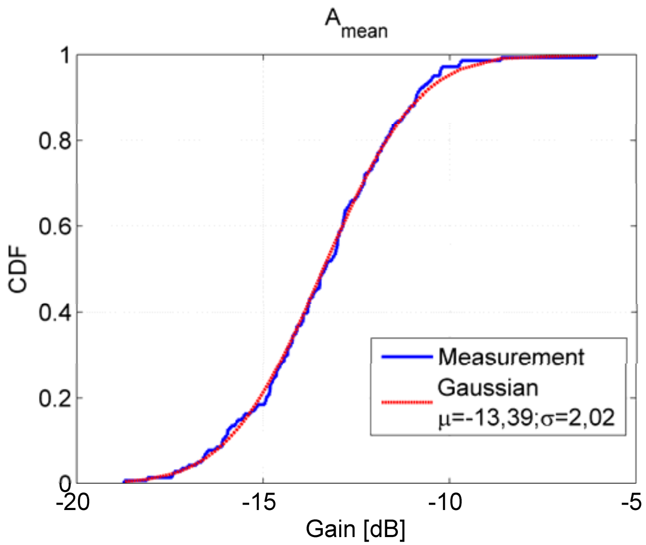


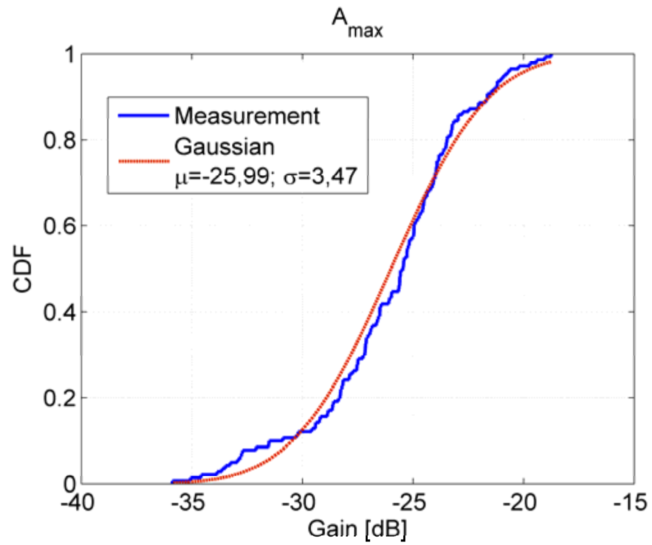
- Rising time

Threshold	Mean Value	Standard deviation
1 dB	14 ms	11 ms
3 dB	40 ms	23 ms
5 dB	65 ms	45 ms
20 dB	220 ms	100 ms

Attenuation

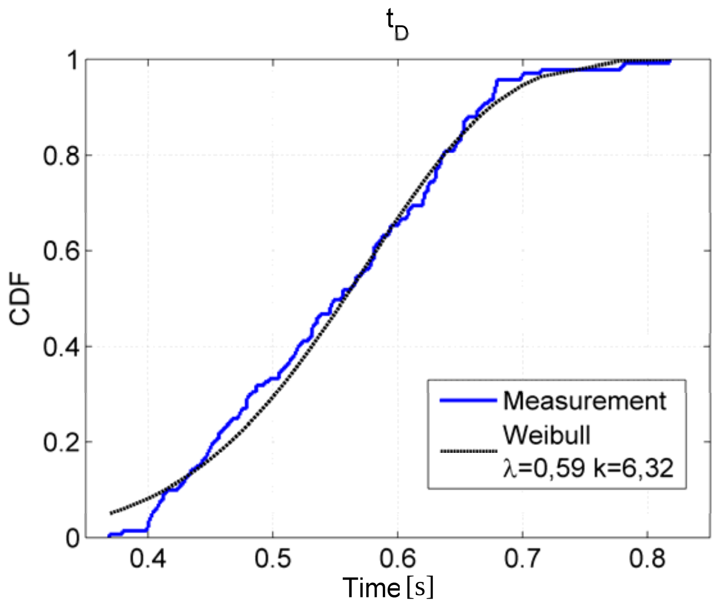
- Mean and max. attenuation fitted by gaussian distribution (parameters : see figures)
- Measured A_{mean} values lie between -18 dB and -6 dB
- Measured A_{max} values lie between -36 dB and -18 dB





Duration

- **Parameter t_d fitted by Weibull distribution**
  - Mean value: 560 ms
  - Standard deviation: 100ms
- **Measured t_d values lie between 370 ms and 820 ms**



Conclusion

- **Full parameter set to model shadowing events compiled**

- **Rising Time**
  - Mean value: 16 ms, 39 ms, 61 ms , 230 ms (1 dB, 3 dB, 5 dB, 20 dB threshold) (TUBS)
  - Can be short („worst case“: <30ms) [1]

- **Attenuation**
  - Mean value: 13.4 dB, Max. value 26 dB (TUBS)
  - Mean value >15 dB for directive antennas (horn, 22.4 dBi) [1]
  - Mean value <15 dB for 3 dBi patch antennas [1]

- **Inter-arrival time between two successive shadowing events**
  - Not investigated @ TUBS
  - Spreads from 2 s up to 20 minutes depending on human activity [1]

- **Duration**
  - Mean Value: 550 ms for 0 dB threshold (TUBS)
  - 300 to 450 ms for 10 dB threshold [1]
  - 100 to 300 ms for 20 dB threshold [1]

- **Further investigation will be carried out based on dynamic channel simulations [2]**

Guidelines for Beamforming development

The investigations show that human movement can lead to a drop of signal level and hence SNR up to more than 20 dB. The time between two successive shadowing events is widespread and ranges from 2 s to 20 min.

The investigations have also shown that the drop of signal level happens in the order of *tens of milliseconds*. In average the signal decreases by 20 dB in 230 ms, whereas it takes 16 (61) ms for a drop of 1 (5) dB. In 90% of the cases the signal decrease took at least 4 ms for a 1 dB, 27 ms for a 5 dB and 101 ms for a 20 dB threshold.

In case a shadowing event happens, beamforming should be applied to find alternative transmission paths. This has to happen faster than the stated time values to assure QoS.

Appendix - Distribution functions

- **Gaussian:**

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

- **Log-Normal**

$$f_X(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}, \quad x > 0$$

- **Weibull**

$$f(x;\lambda,k) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

References

- **[1]** ***M. Jacob, T. Kürner:*** **Influence of moving people on the 60 GHz channel –a literature study, IEEE 802.11-09/0744r0, July 2009**
- **[2]** ***M. Jacob et al.:*** **Modeling the human induced 60 GHz channel dynamics, IEEE 802.11-09/1170r0, November 2009**
- **[3]** ***A. Maltsev et al.:*** **Channel Models for 60 GHZ WLAN Systems, IEEE802.11-09/0334r3, July 2009**