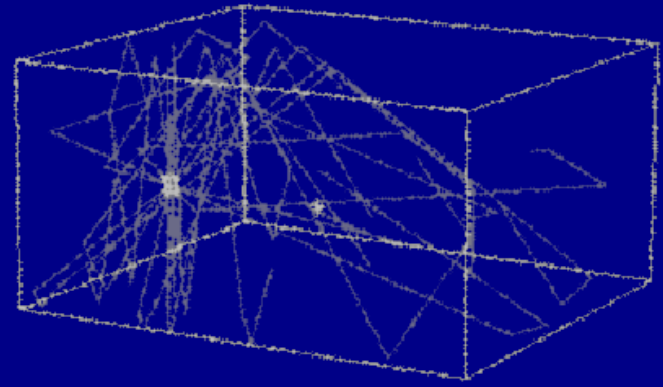


# Design, Measurement and Prediction of Sound Quality in Rooms



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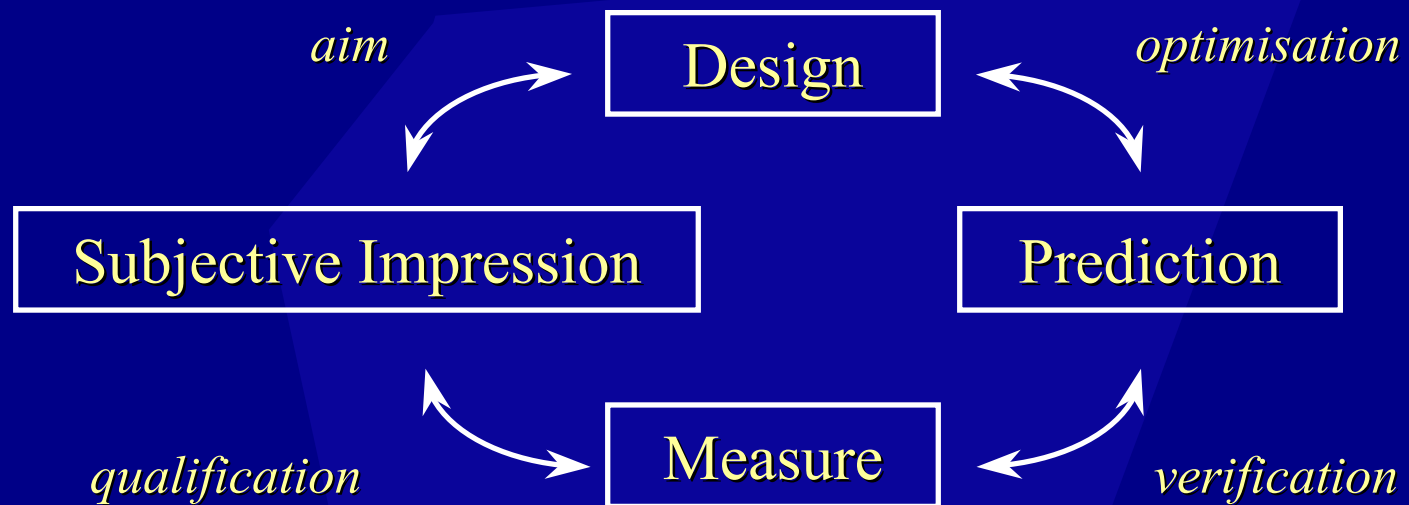
*Éva Borsiné-Arató*

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# Introduction



## Overview

- Subjective aspects - what phenomena do affect perceptual features...
- Objective aspects - how acoustical parameters describe subjective quality....
- Design - how to design for given acoustical parameters...

## Subjective aspects

Room shape and size

Surface properties

Source-Receiver type, position and properties

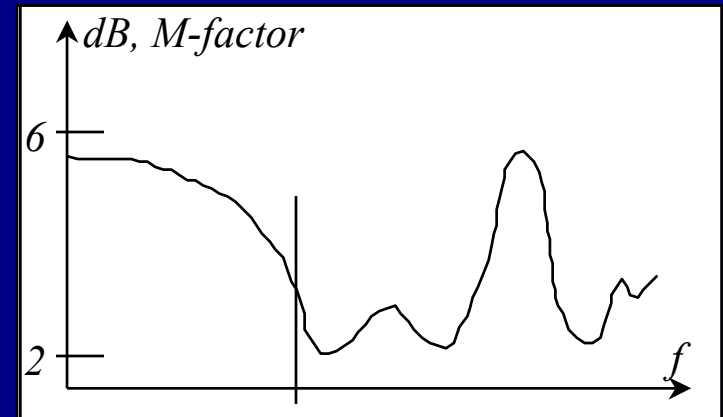
Direct sound

First reflections

Reverberation

Clarity  
... Definition  
Envelopment Spatial impression  
Timbre  
Sound colouring Transparency

## Objective aspects



Measurement of impulse responses (EDC)

Parameters characterising the response with an omni receiver

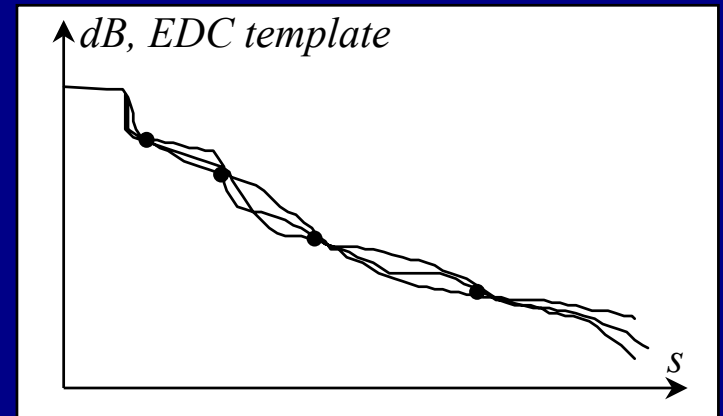
- absolute position of 1 point on EDC -  $RT_{60}$ ,  $C(t_e)$ ,  $D(t_e)$ , etc.
- relative position of 2 points on EDC - M-factor,  $EDT_{10}$ ,  $RT_{5-25}$ , etc.
- other -  $t_s$

Parameters from not omni receivers or more channels

- LEF, IACC, etc.

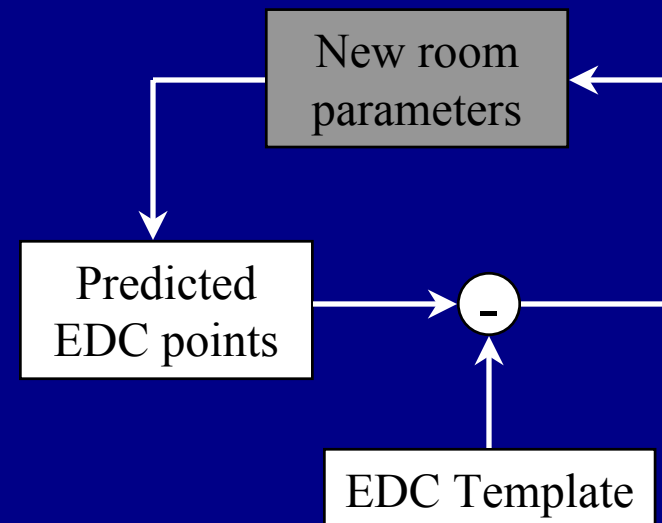
Frequency dependence!

# Design

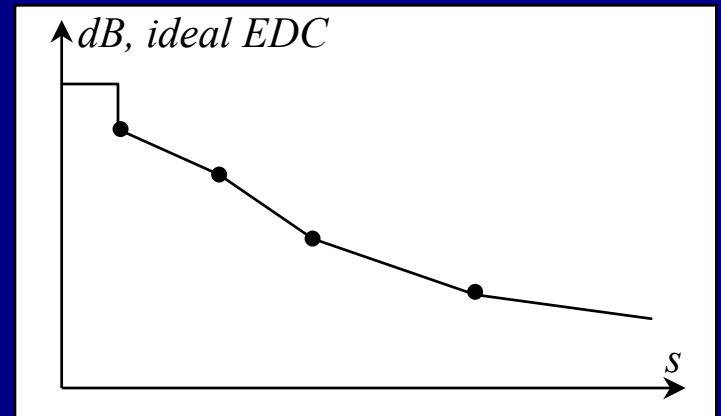


Several EDCs can match a given specification, the “EDC template”

The common design method is to optimise for an EDC template by tuning the room parameters

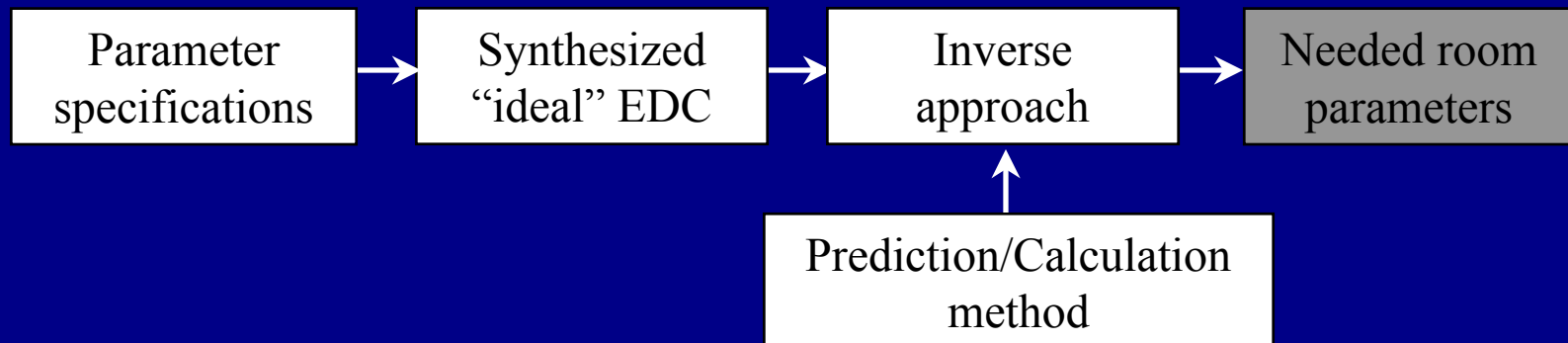


## Design II.



The optimum is hard to find, more straightforward method is needed... inverse methods

Using a required EDC (e.g. “ideal EDC”)





## Inverse approach

$$\begin{aligned}(1 - \alpha_1)^{m_{1,1}} \cdot (1 - \alpha_2)^{m_{1,2}} \dots (1 - \alpha_N)^{m_{1,N}} &= A_1 \\ \vdots \\ (1 - \alpha_1)^{m_{K,1}} \cdot (1 - \alpha_2)^{m_{K,2}} \dots (1 - \alpha_N)^{m_{K,N}} &= A_K\end{aligned}$$

### Assumptions:

The prediction method is accurate enough, errors are mainly due to parameter errors...

Choosing geometrical methods, the echograms

### The inverse method:

- 1st step: EDC fitting (echogram timings) to get echo amplitudes
- 2nd step: Solving the equation system (tracing data) to get model parameters

## Application example - comparing rooms

What “valid” parameter values can a given room offer?

Assumptions:

- source and receiver are omnidirectional
- plane surfaces, no focusing phenomena

... then the room is valid at given parameter values only if the direct sound has the highest amplitude.

Using only the EDC fitting procedure

Results are theoretical (any absorption anywhere?)...

## Results

### Figure (A)

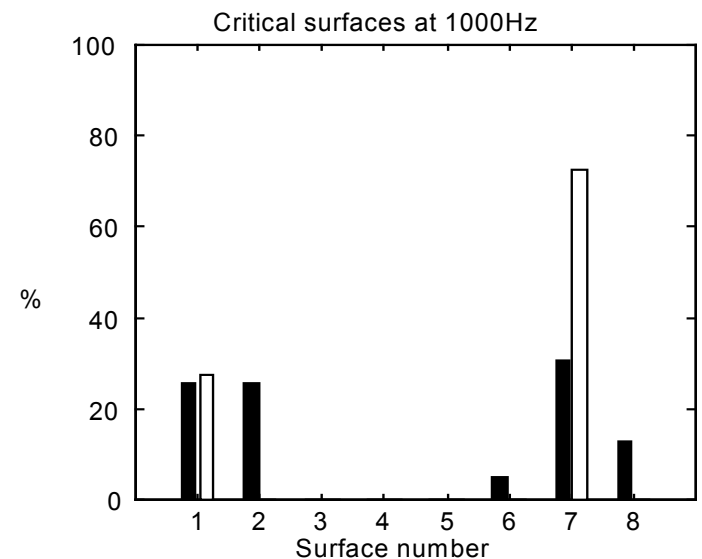
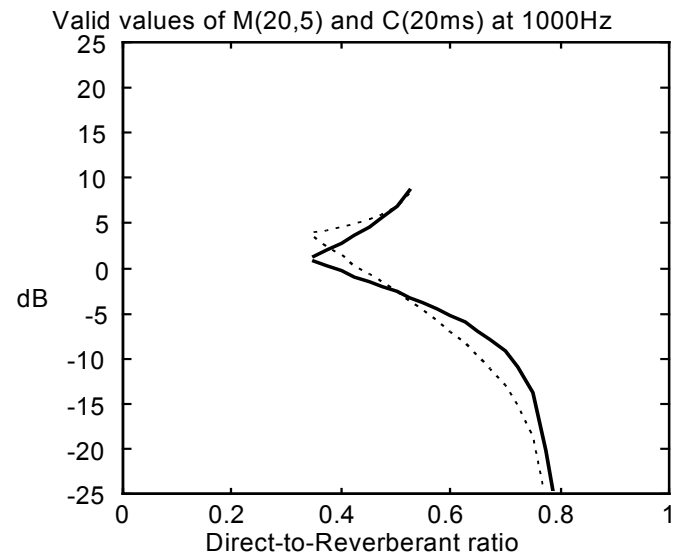
possible max. and min. values.

$C_{20ms}$  and M-factor as the function of the direct-to-reverberant ratio.

### Figure (B)

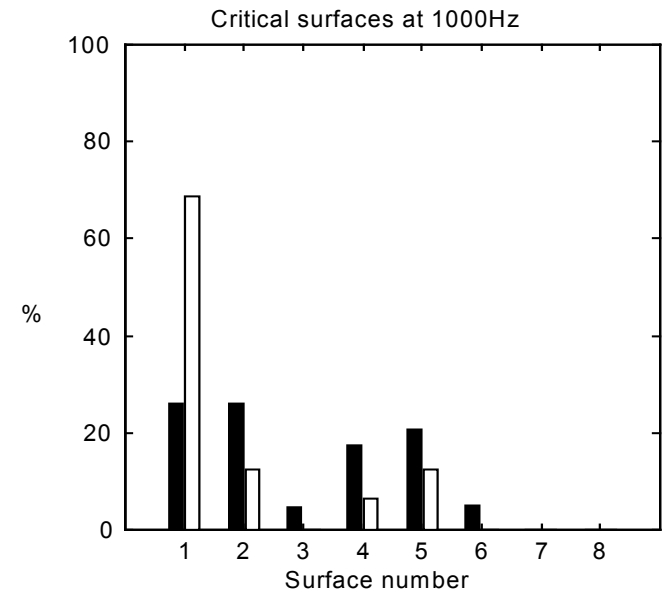
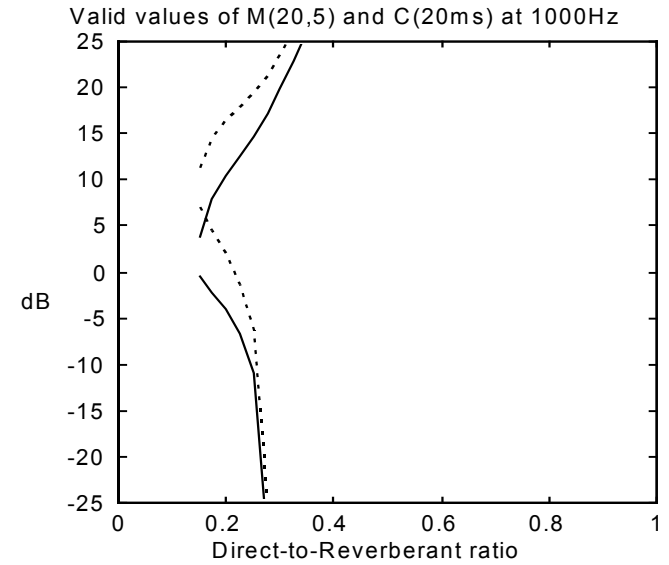
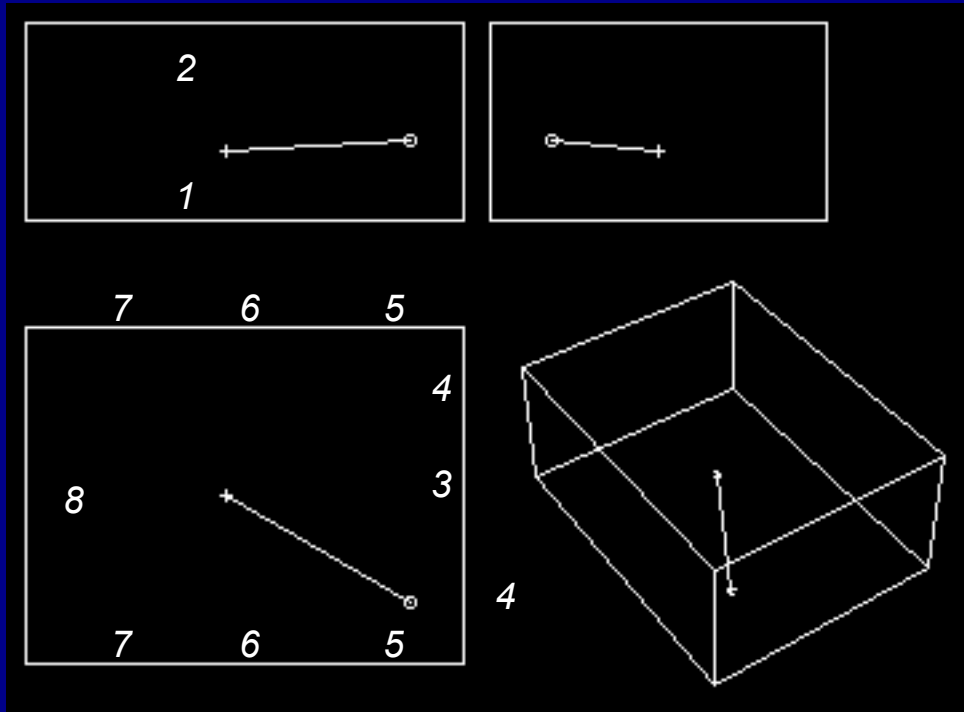
critical surfaces.

Statistical indication of how often a given surface limits the maximal or the minimal value.



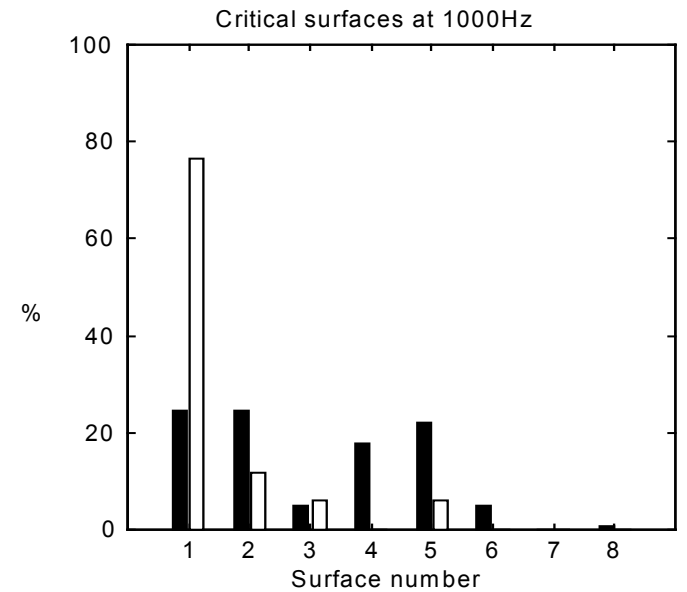
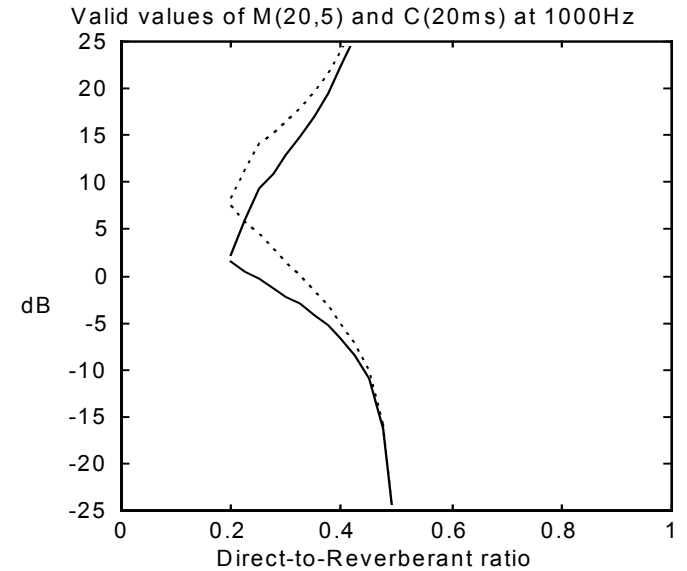
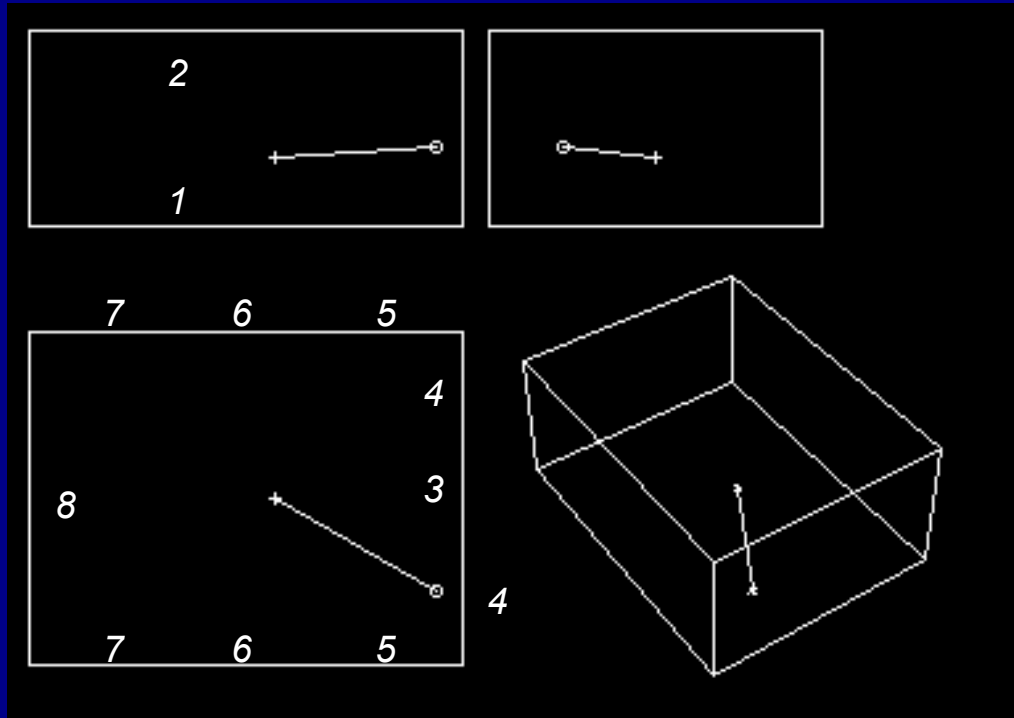
# Results - case 1

8m x 6m x 3,5m



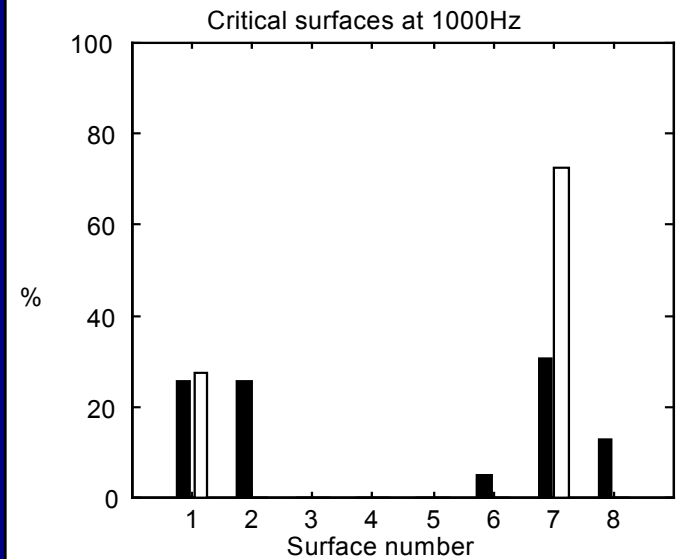
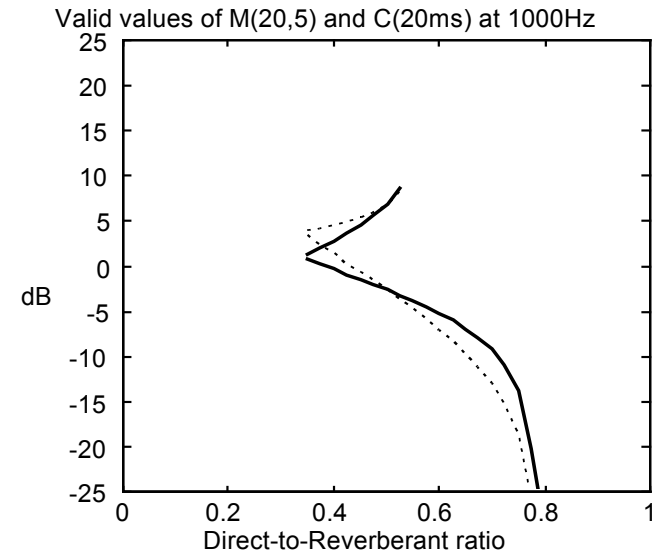
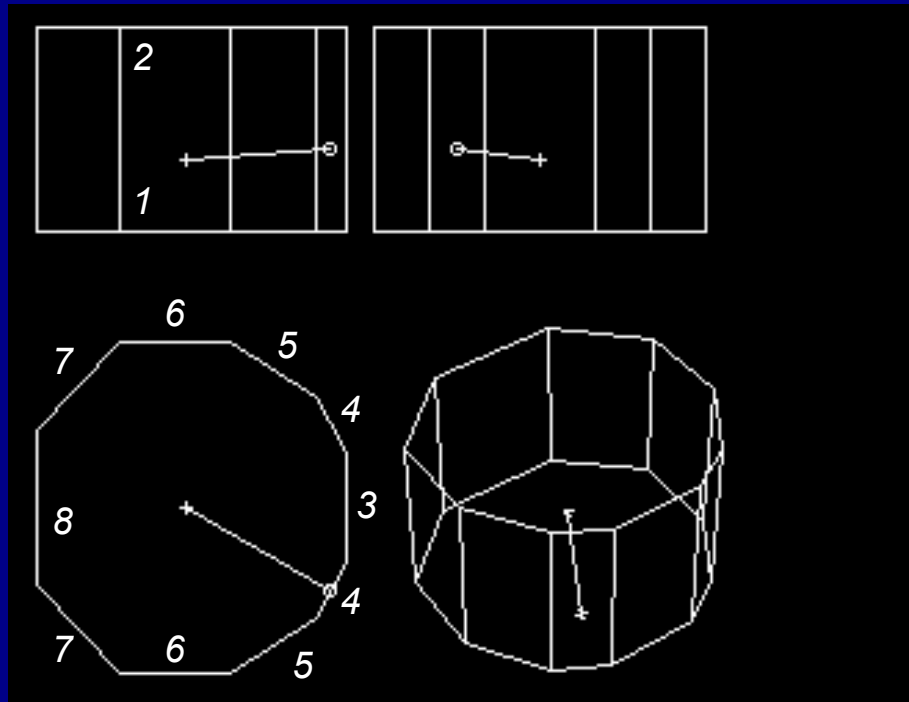
# Results - case 1b

8mx6mx3,5m



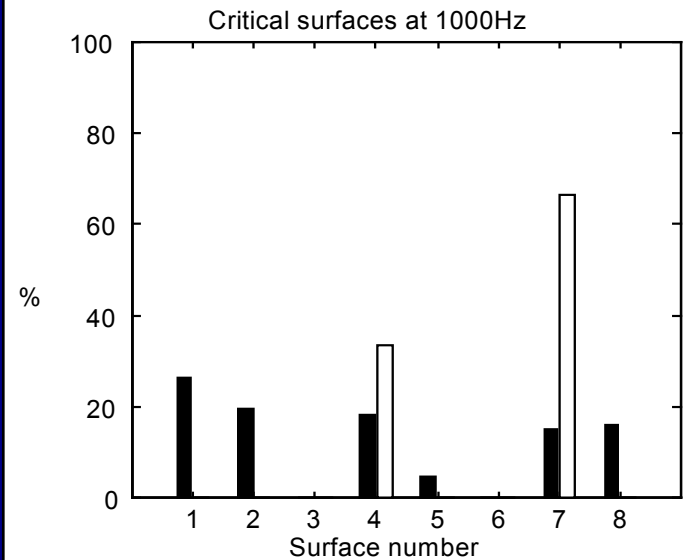
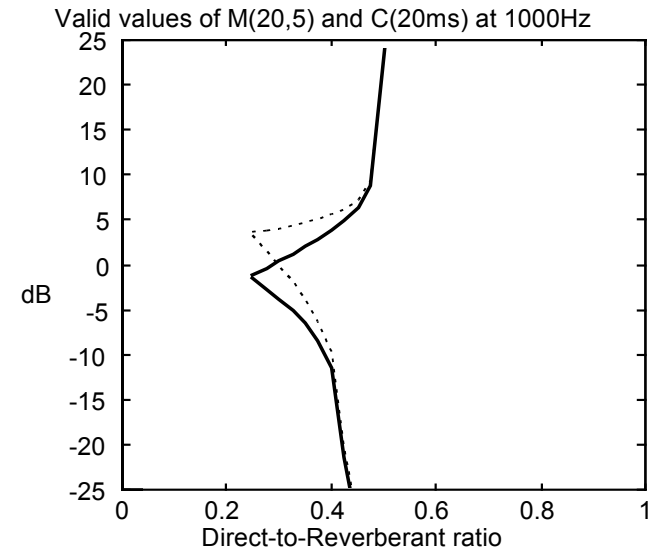
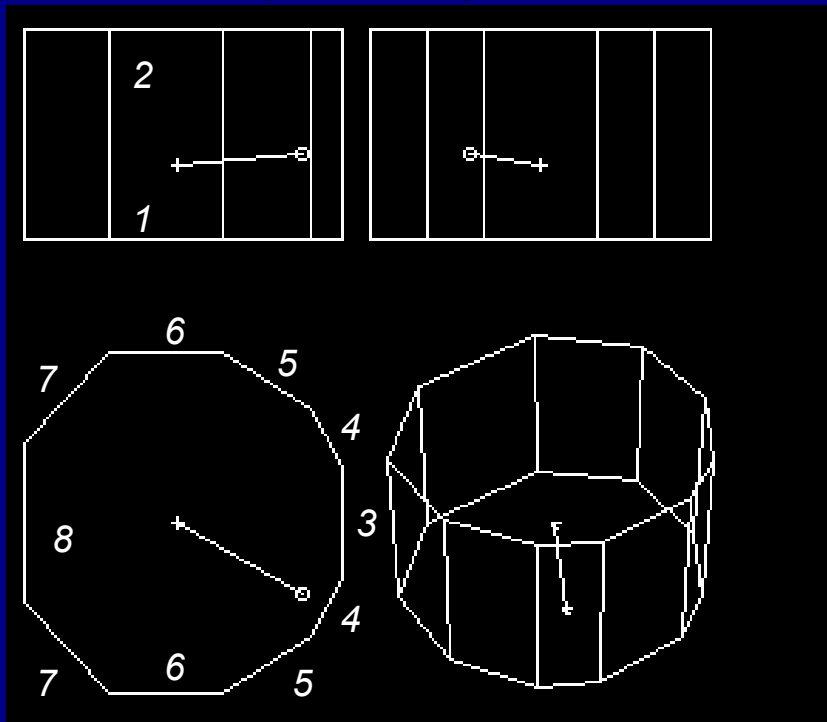
# Results - case 2

5,6m x 6m x 3,5m



# Results - case 2b

5,6mx6mx3,5m



## Summary

Uniform handling of measurement, prediction and design is needed.

With the inverse method the straightforward design and an analytical evaluation is possible.

By using the simple EDC fitting procedure an objective comparison between different room situations was presented.

A thorough and accepted parameter set is still needed to characterise the behaviour of rooms...