

*Österreichische Akademie der Wissenschaften*  
*Institut für Schallforschung*



# **Schnelle Messung der Außenohr- übertragungsfunktionen mittels der Multiple Exponential Sweep Methode**

**Multiple Exponential Sweep Method for Fast Measurement of  
Head Related Transfer Functions**

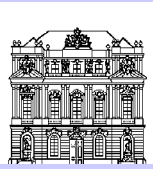
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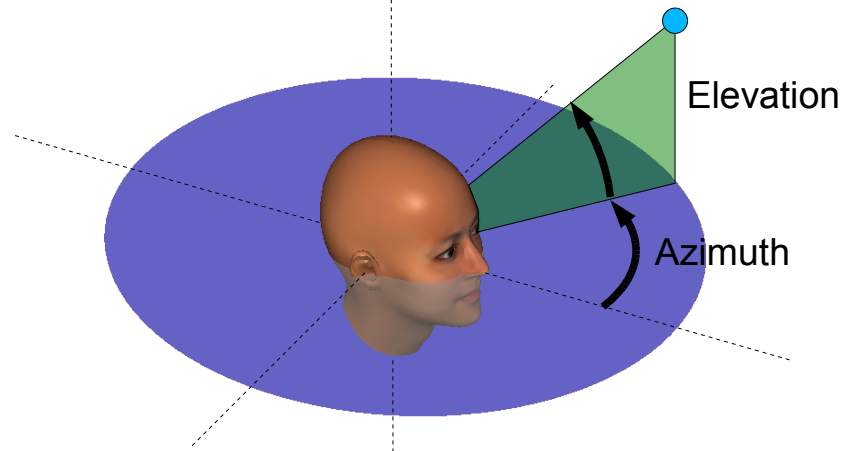
**AES-Meeting**

17.10.2006



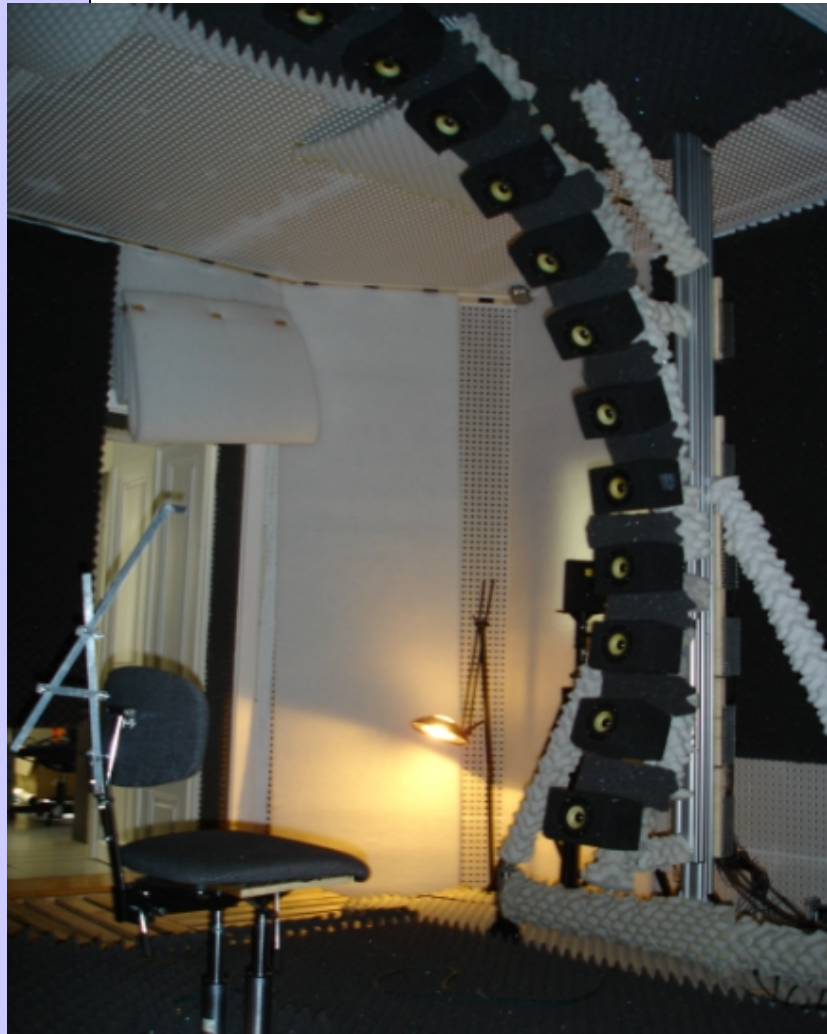
# Außenohrübertragungsfunktionen

- Head Related Transfer Functions (HRTF)
  - Beschreiben die Filterwirkung durch
    - Ohrmuschel
    - Kopf
    - Oberkörper
- in Abhängigkeit von der Schallquellenposition



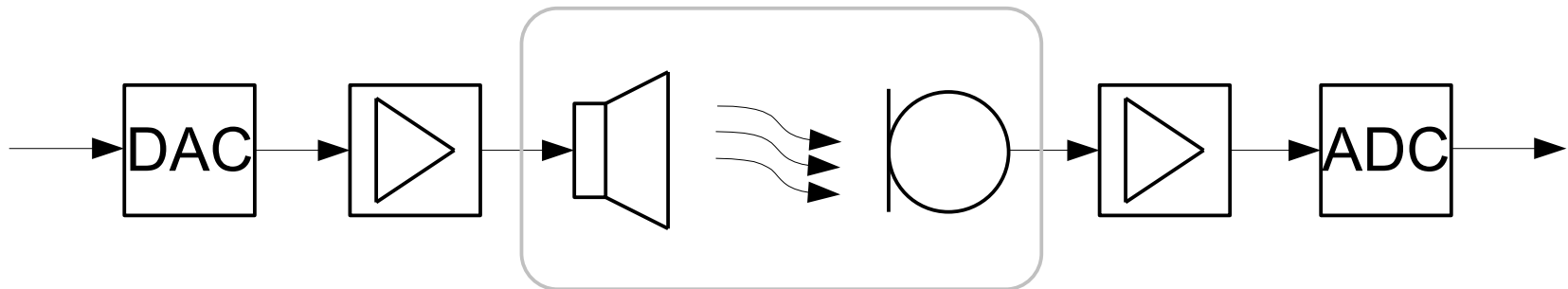


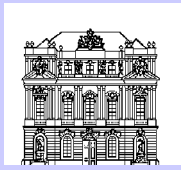
# Messung der HRTFs





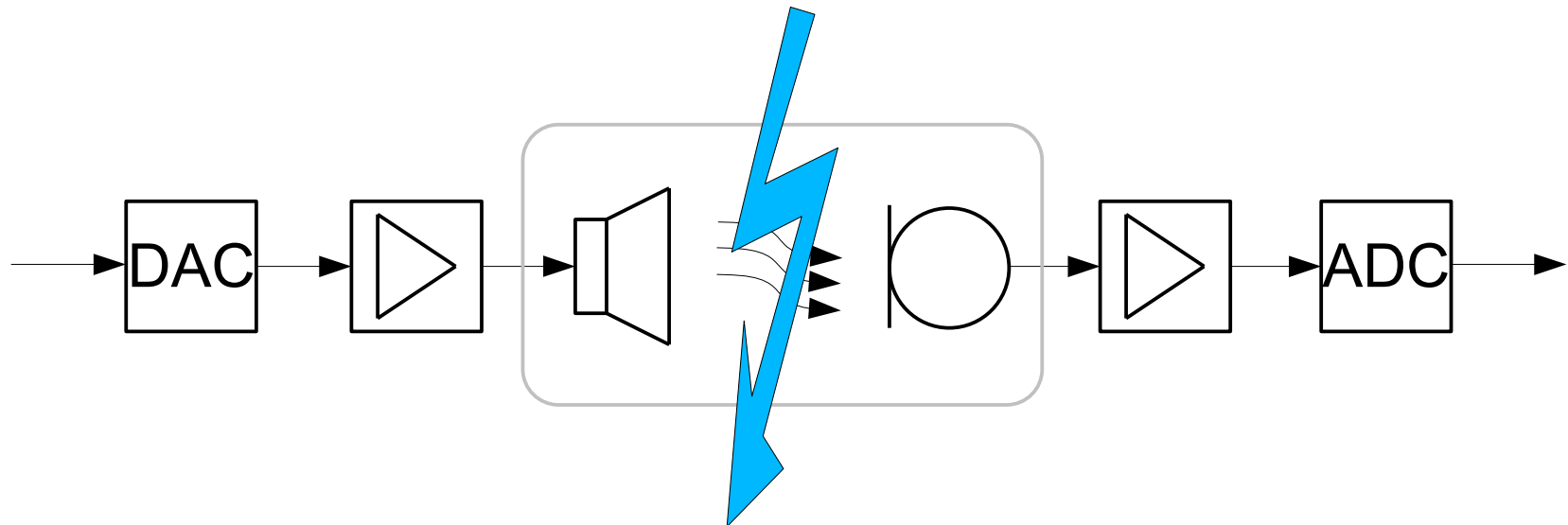
# Elektro-Akustische Signalkette





# Elektro-Akustische Signalkette

- Leicht nicht-lineares System
- HRTF: lineares System



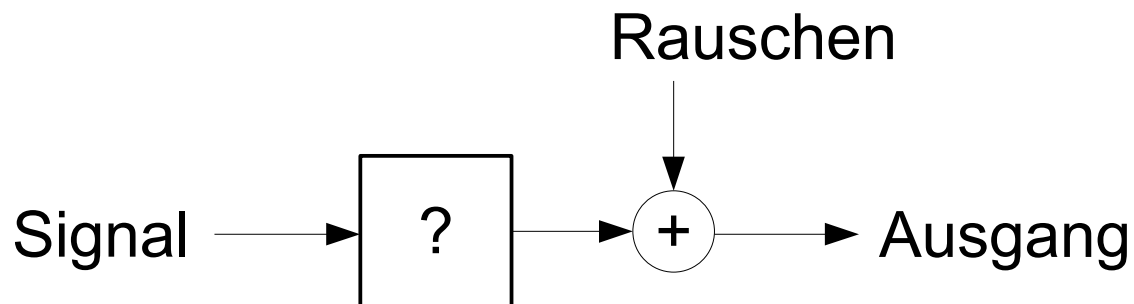
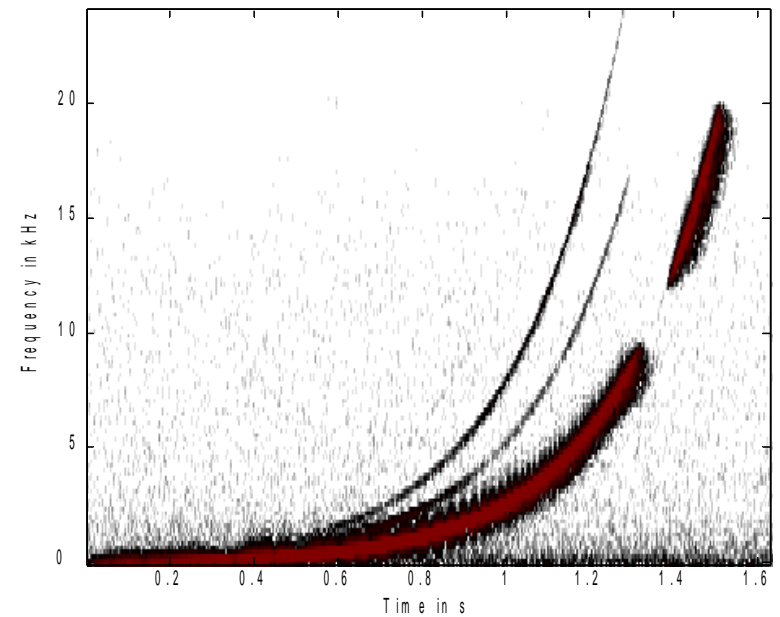
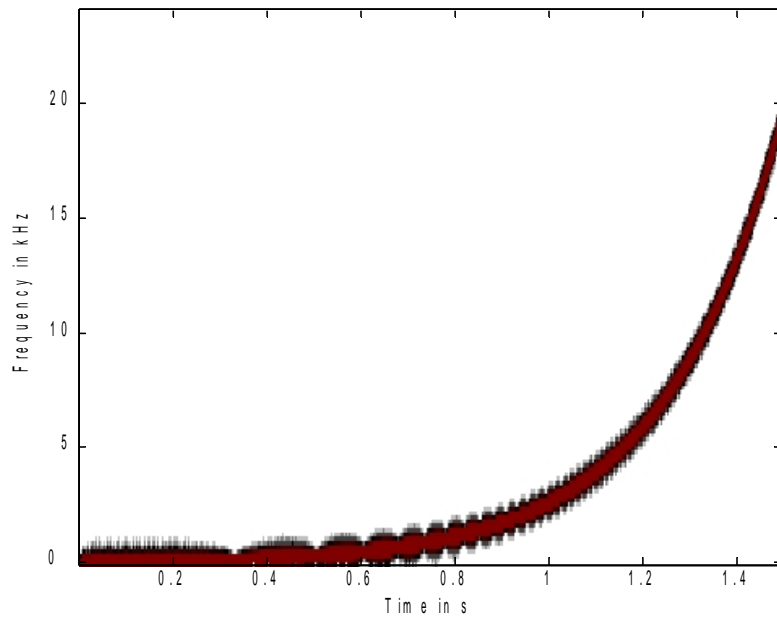


# Methoden zur Systemidentifikation

- Periodische Impulsanregung
- 2-Kanal-FFT
- Binäre Pseudozufallsfolgen
  - Maximum Length Sequences (MLS)
  - Golay Codes
- Frequenzsweeps:
  - linear (time delay spectrometry)
  - exponentiell

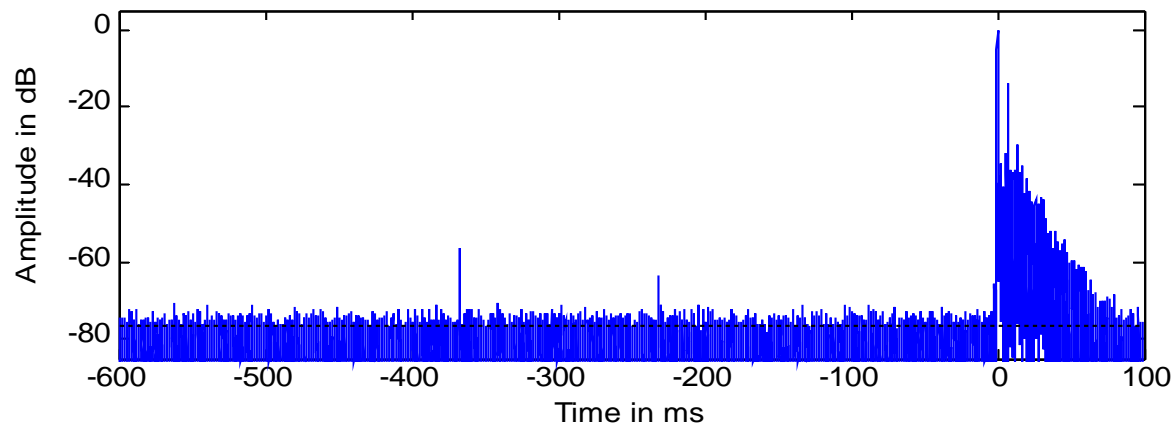
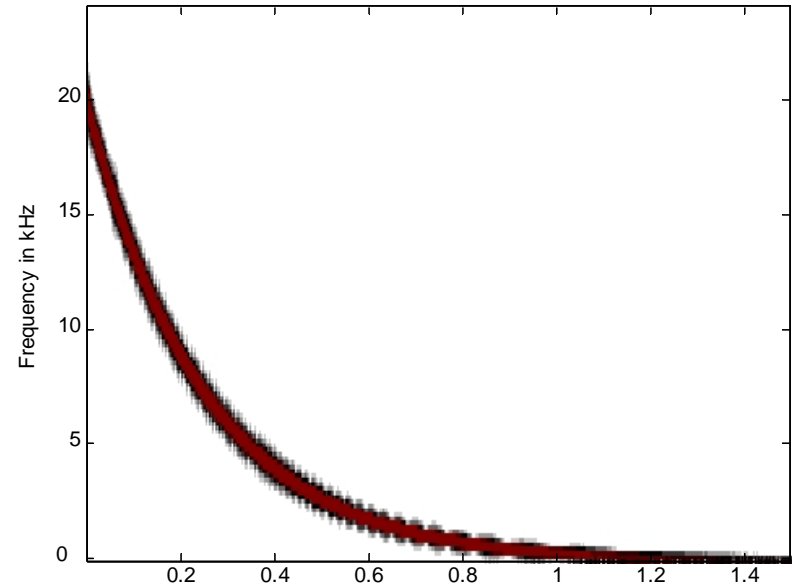
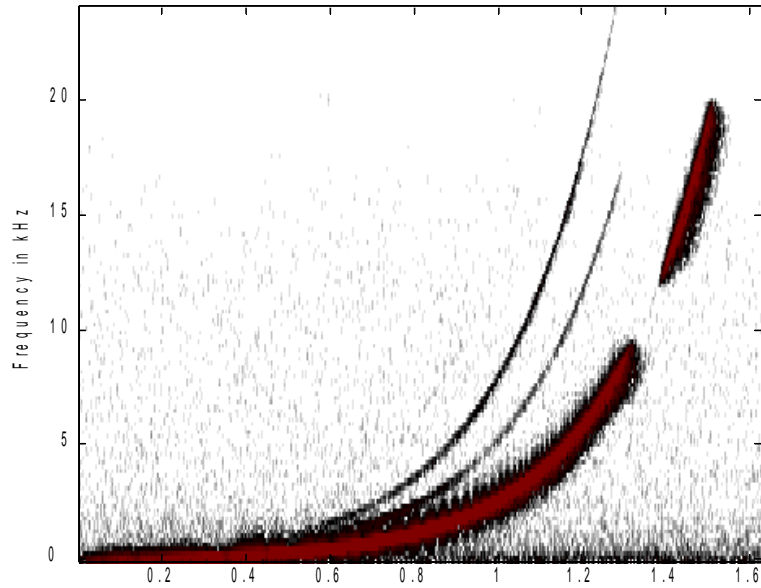


# Anregung mit einem exponentiellen Sweep





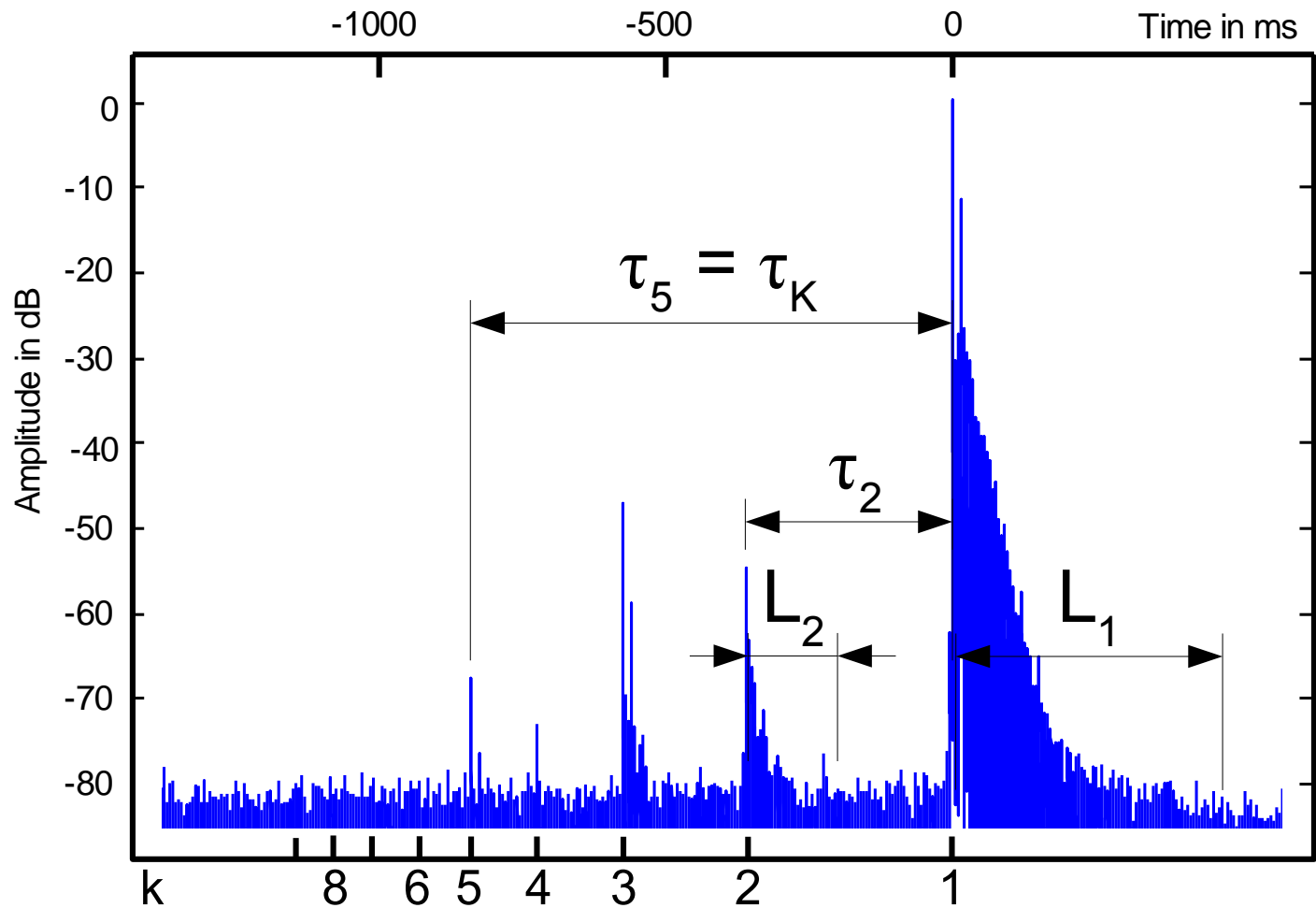
# Faltung mit dem inversen Sweep





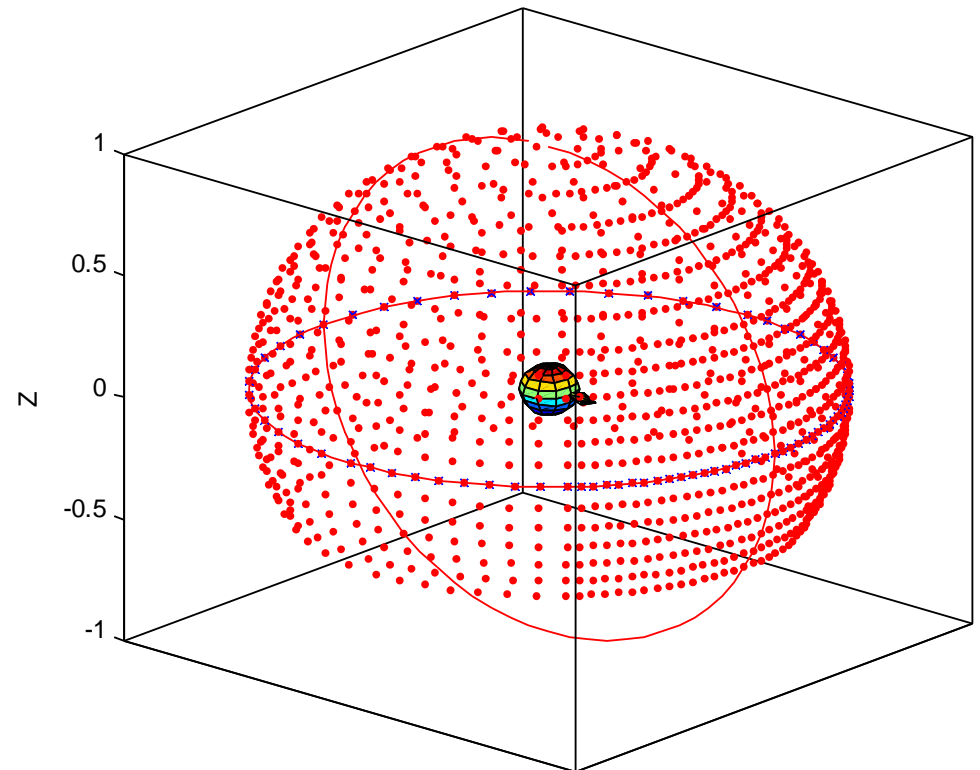
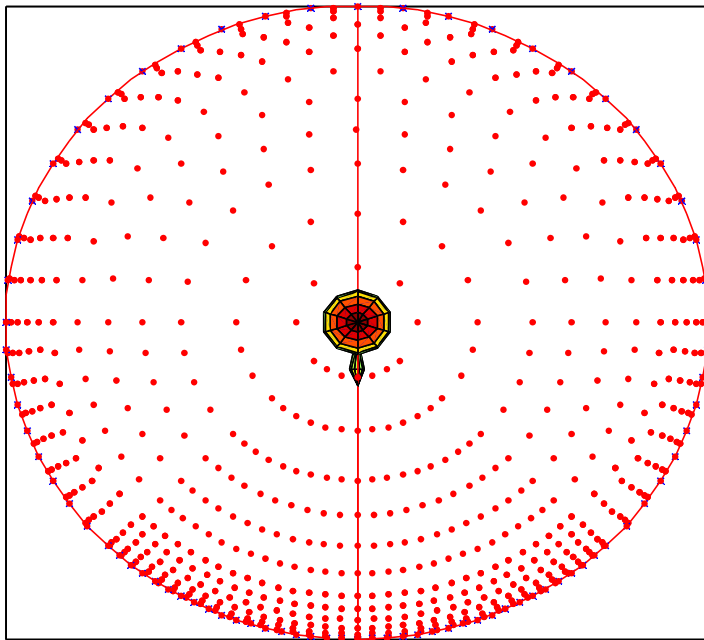


# Ergebnis der Entfaltung





# HRTF-Messung: 1550 Positionen



1550 Positionen á 1.5 Sekunden: 41 Minuten



# Optimierung der Messdauer

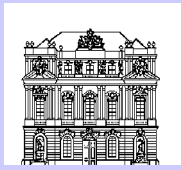
Verzahnung

+

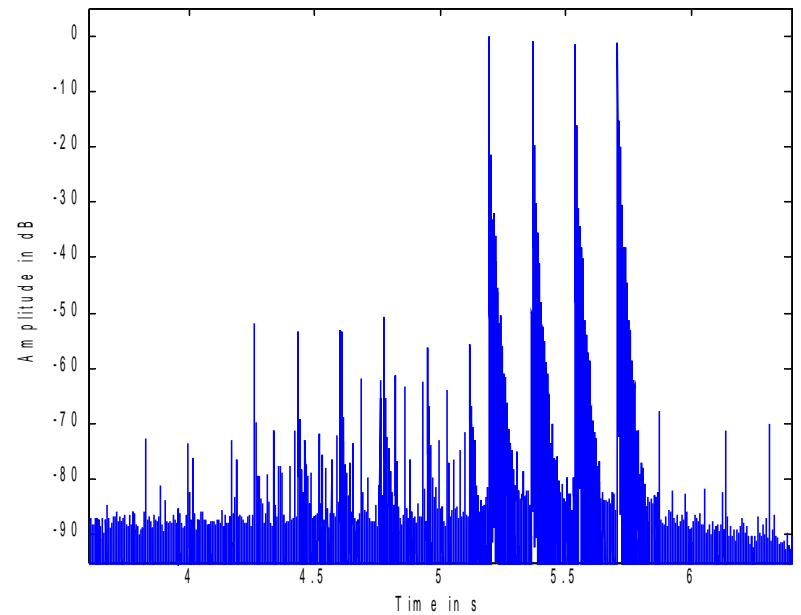
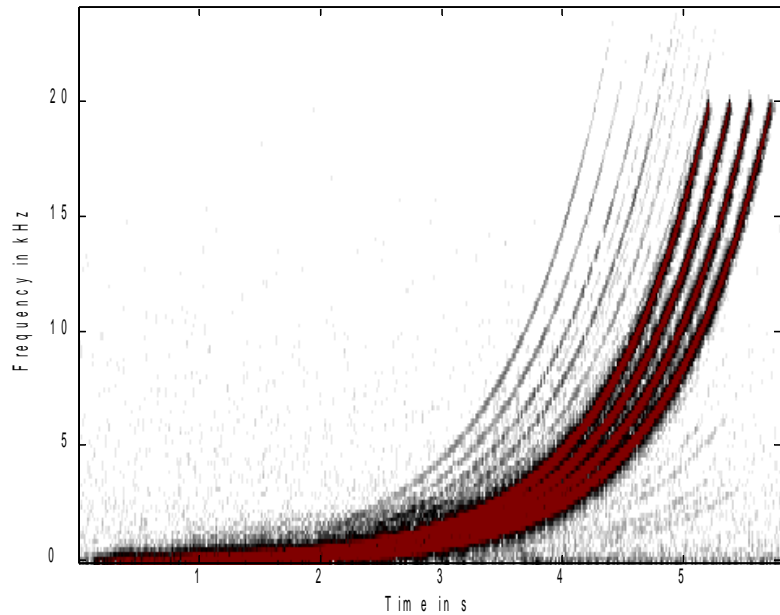
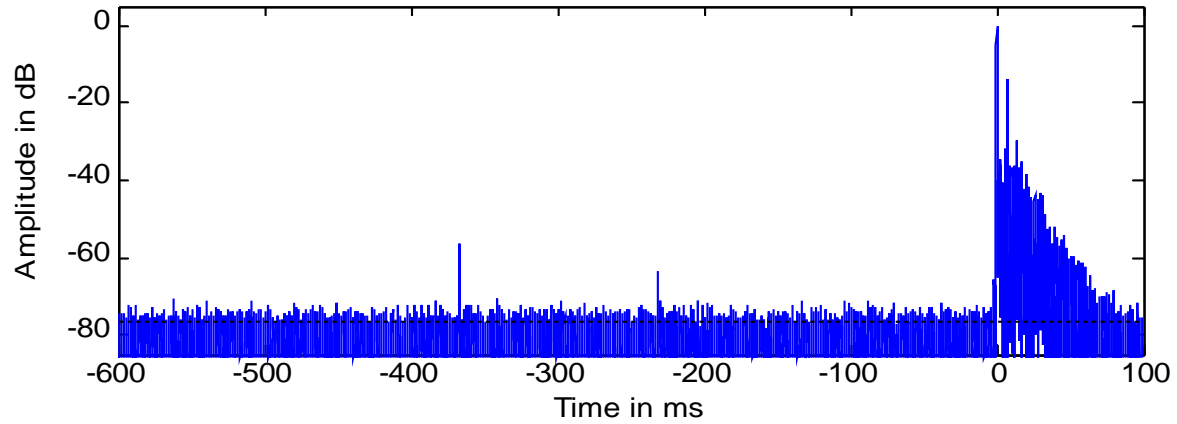
Überlappung

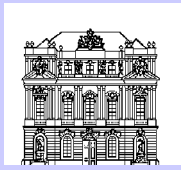
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Multiple Exponential Sweep Methode  
**(MESM)**

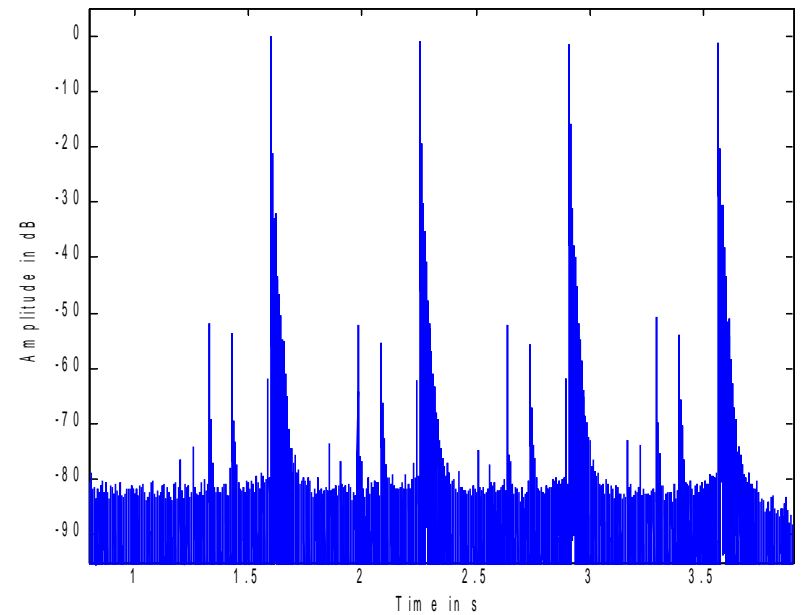
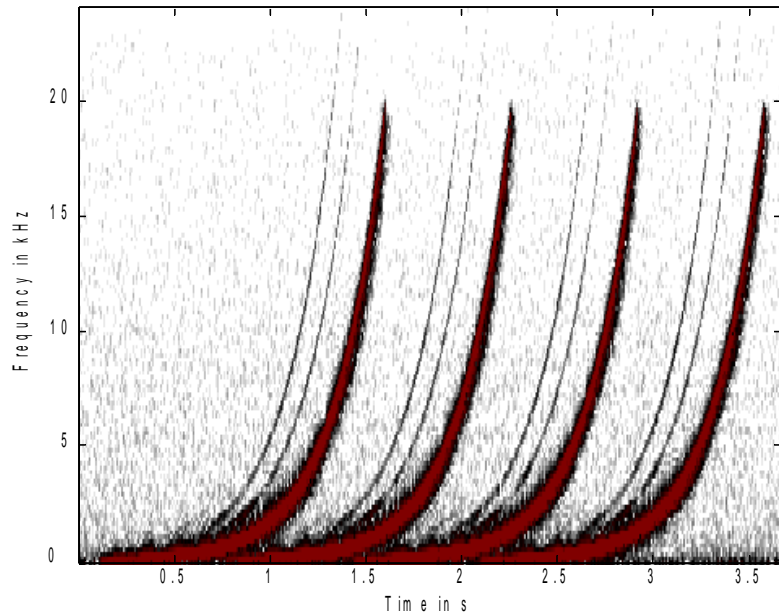
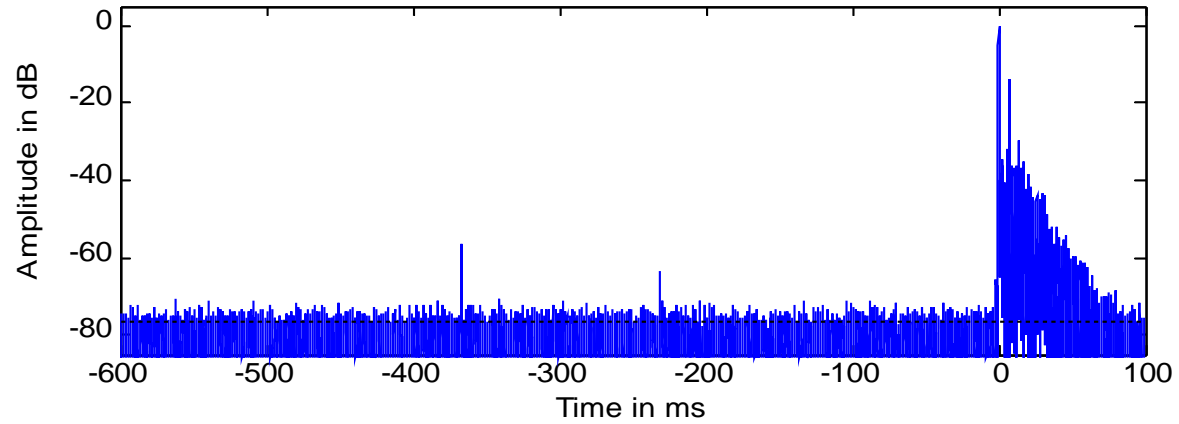


# Verzahnung





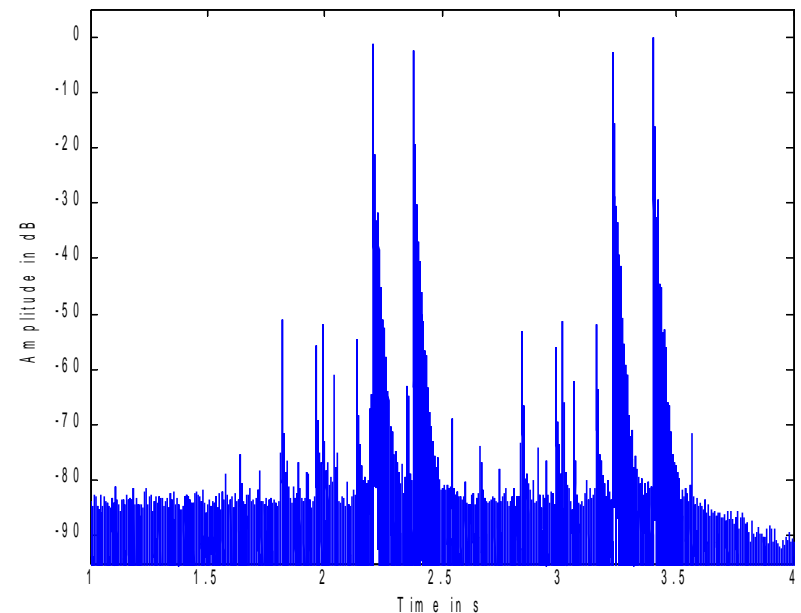
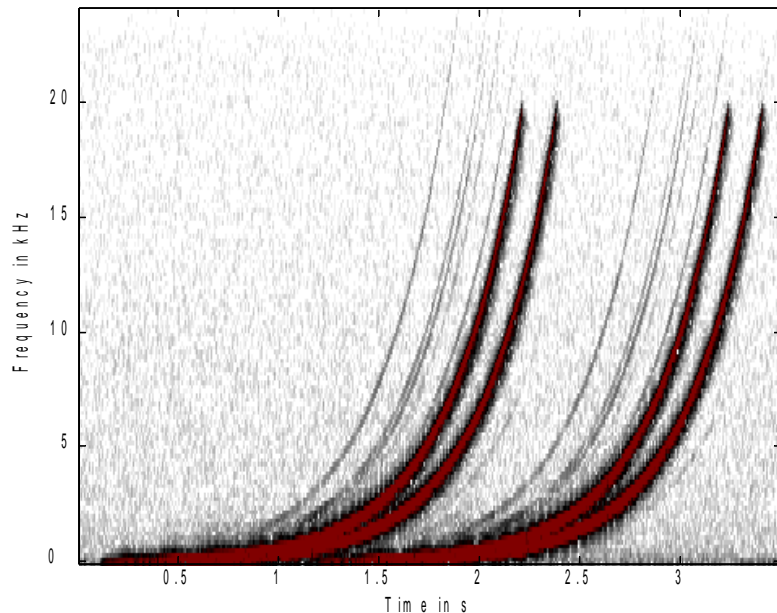
# Überlappung





# MESM

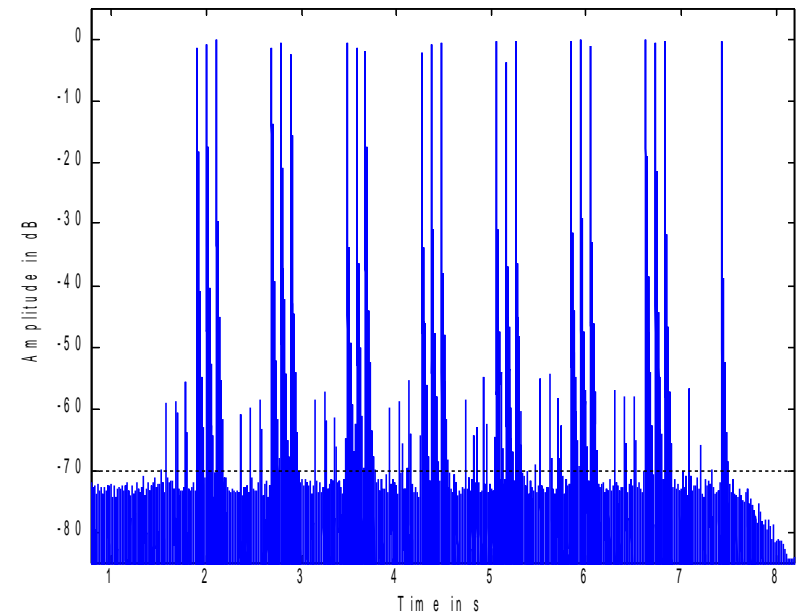
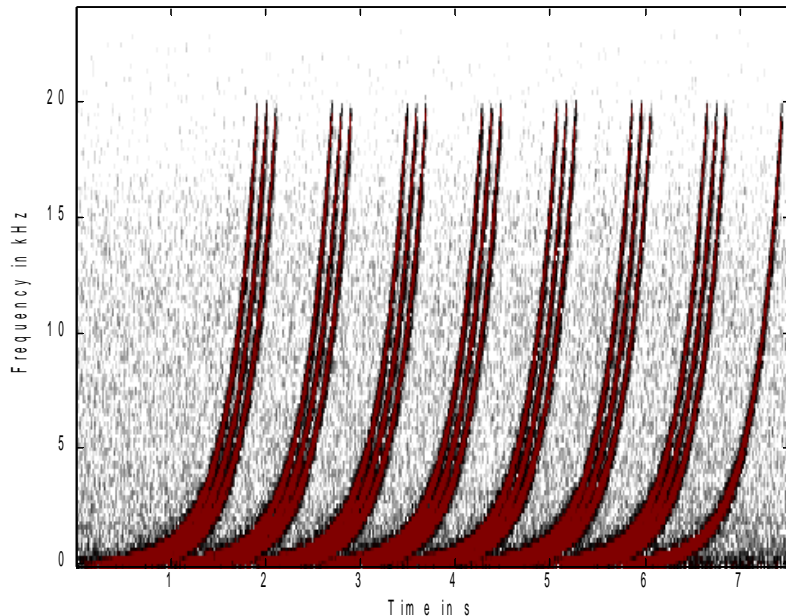
- Optimierung der Zeitpunkte der Anregung
- Notwendige Parameter aus der Referenzmessung
- Erfassung nur linearer Teile des Systems





# MESM und HRTF-Messung

- 22 Elevationen
- 7 Gruppen á 3 verzahnte Sweeps + 1 Sweep
- Messdauer: 7.1 statt 35.2 s





# HRTF-Messung

- 1550 Positionen
- 144 horizontale Positionen
  - Maximum: 22 Elevationen
  - Durchschnittlich: 11 Elevationen
- Messdauer: 10 Minuten
  - ohne MESM: 41 Minuten
- Zeitgewinn: **Faktor 4!**





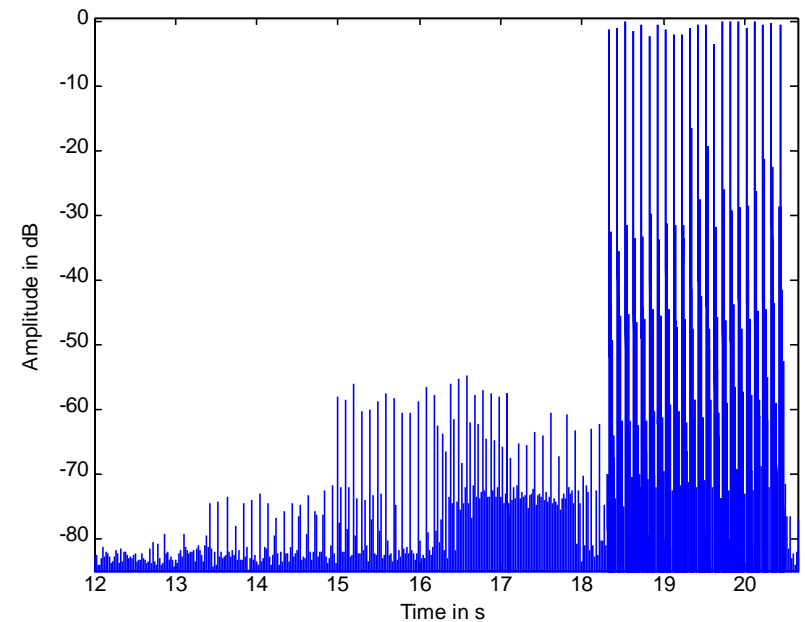
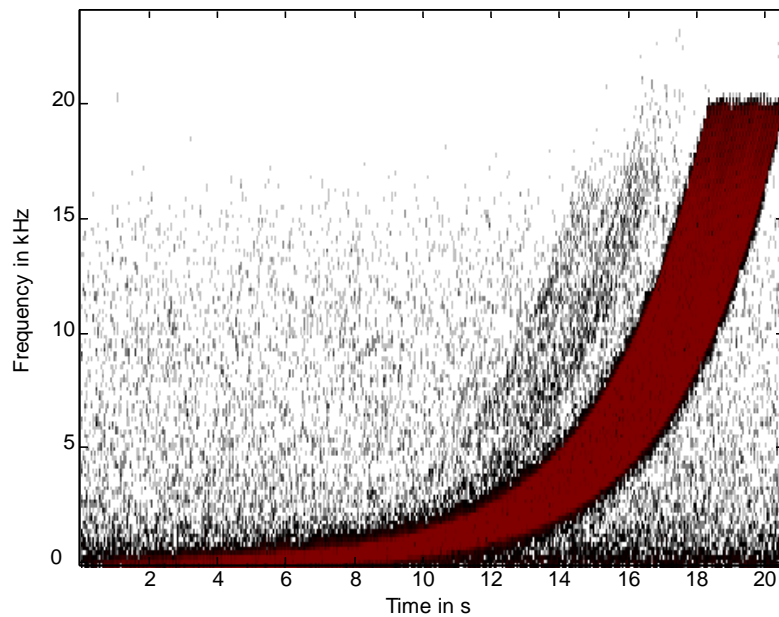
# Optimierungen mit MESM

- Optimierung der Messdauer:
  - Dauer des Sweeps nicht verändern
  - MESM anwenden
  - kürzere Messdauer
- Optimierung des Signalrauschabstandes (SNR):
  - Möglichst lange Sweeps verwenden
  - Erhöhung der SNR
  - Durch MESM keine Verlängerung der Messdauer



# SNR-Optimierung mit MESM

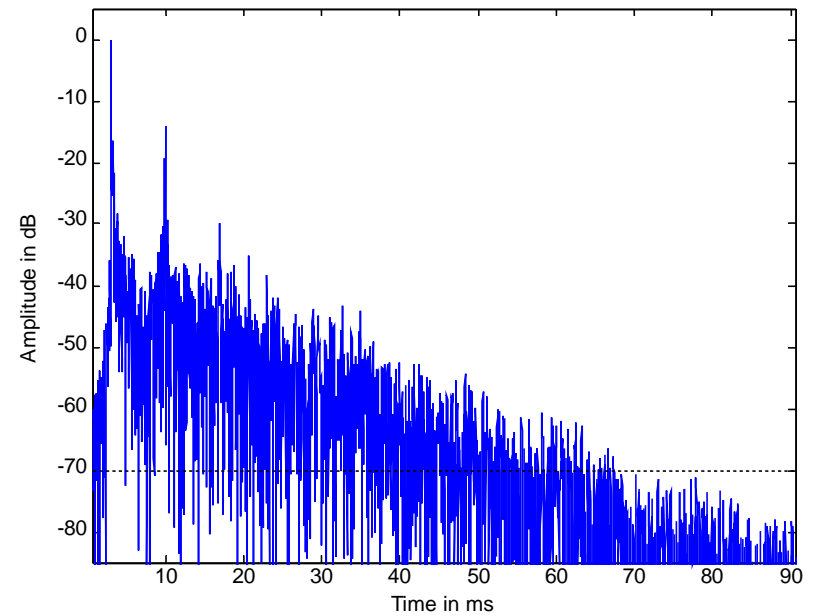
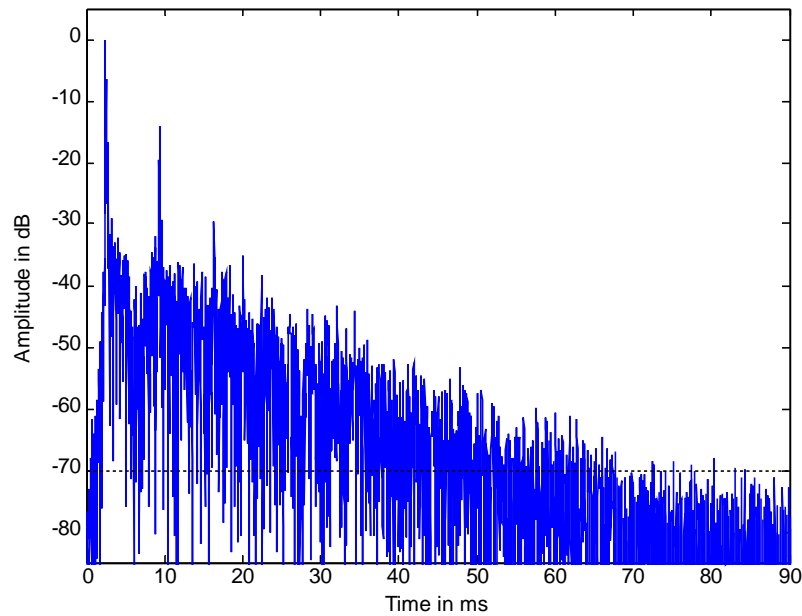
- 22 Sweeps á 33 s (statt 1.5 s)
- Messdauer: 35.2 s (gleich wie ohne MESM)

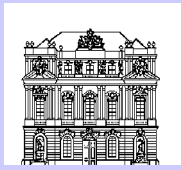




# SNR-Optimierung mit MESM

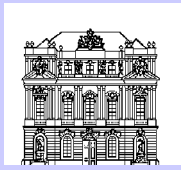
- SNR-Gewinn: 13.4 dB





# Multiple Exponential Sweep Methode

- Systemidentifikation leicht nicht-linearer Systeme
- Quasi-simultane Anregung multipler Systeme
- Optimierung in 2 Richtungen:
  - möglichst kurze Messdauer
  - möglichst hoher Signalrauschabstand
- HRTF-Messung als Anwendung:
  - Messdauer: 10 statt 41 Minuten (1550 Positionen)
- Weitere Optimierungen möglich:
  - Höhere SNR: Gabor multiplifier



# Danke!

PMajdak, equlized, 256 samples

