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# Modal Filter Reverberator

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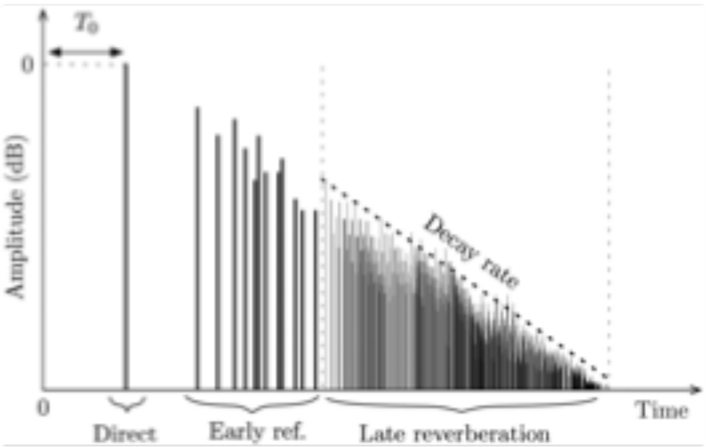
ELEC-E5630

ACOUSTICS AND AUDIO TECHNOLOGY SEMINAR 2016

# Contents

1. Idea
2. Architecture
3. Design
4. Practical Implementation and Sound Examples




Välimäki et al. 2012

# Modal Filter Reverb

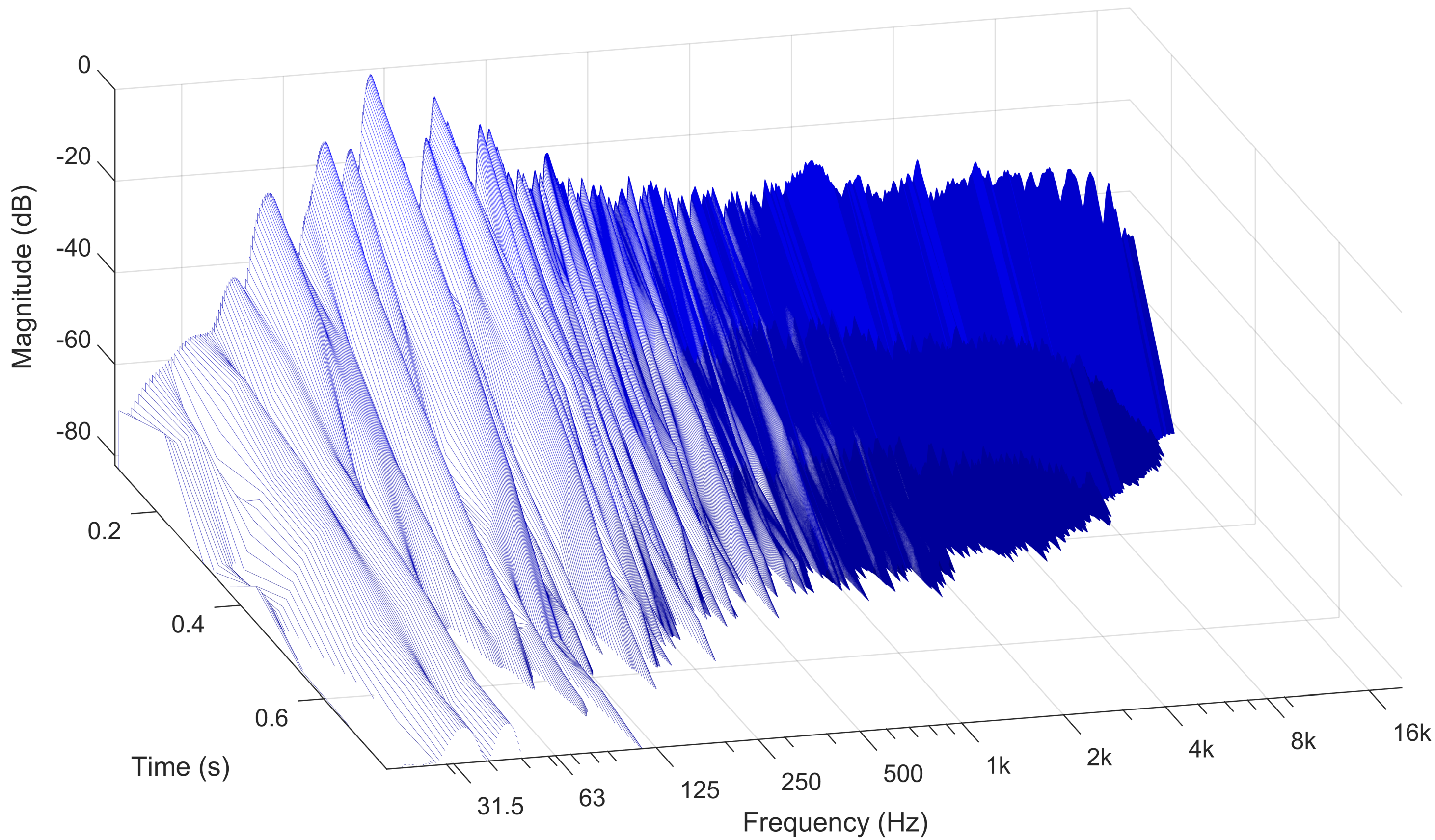
- New method for artificial reverberation.
- Idea first mentioned by Karjalainen and Järvinen in 2001.
- Fully developed algorithm by Abel, Coffin and Spratt

published in 2014.

# Modal Decomposition

- Describe the acoustics of a space using modal analysis:
  - Resonant modes create narrow-band peaks and dips in the frequency response.
  - Ringing in the time domain.
  - Variation in both depending on location.
- Total response is the sum of all modes (assuming LTI).

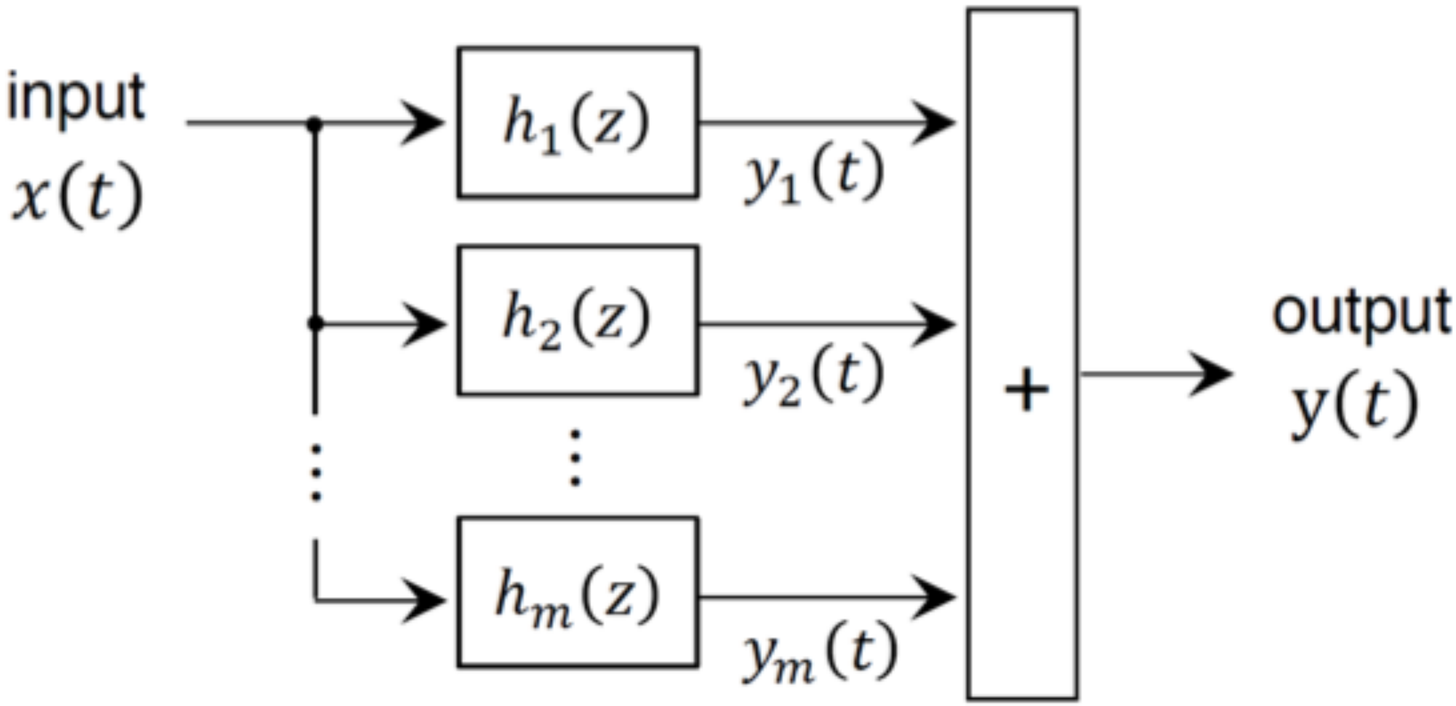
# Modal Decomposition



# Architecture

- Simulate modes using a parallel filter structure:
  - Each mode is modeled with a resonant filter.
  - Match filter resonance frequency and damping to mode frequency and decay time.
- Any acoustic space or object can be modeled accurately with a sufficient number of modeled modes.

# Architecture



# Architecture

- Interactive and individual control of each mode.
- Not all modes need to be modeled for perceptually good results:
  - Typically 1000 to 2000 modeled modes is sufficient.
  - A too low mode density leads to metallic sound and tonality.
  - Small memory requirement.
- Easy to design and specify desired reverberation parameters, or accurately model the reverberation of a real space.

# Design

- **Behavioral:** fit parameters to system measurements.
- **Analytical:** derive parameters from system physics.
- **Perceptual:** select parameters according to desired

equalization and reverberation time.

# Implementation

- Each mode response is made of:
  - Frequency $\omega_m$, damping $\alpha_m$, and complex amplitude (amplitude and phase) $\gamma_m$.

$$h_m(n) = \gamma_m e^{(j\omega_m - \alpha_m)n}$$

- Implemented as a phasor filter (complex first-order update)

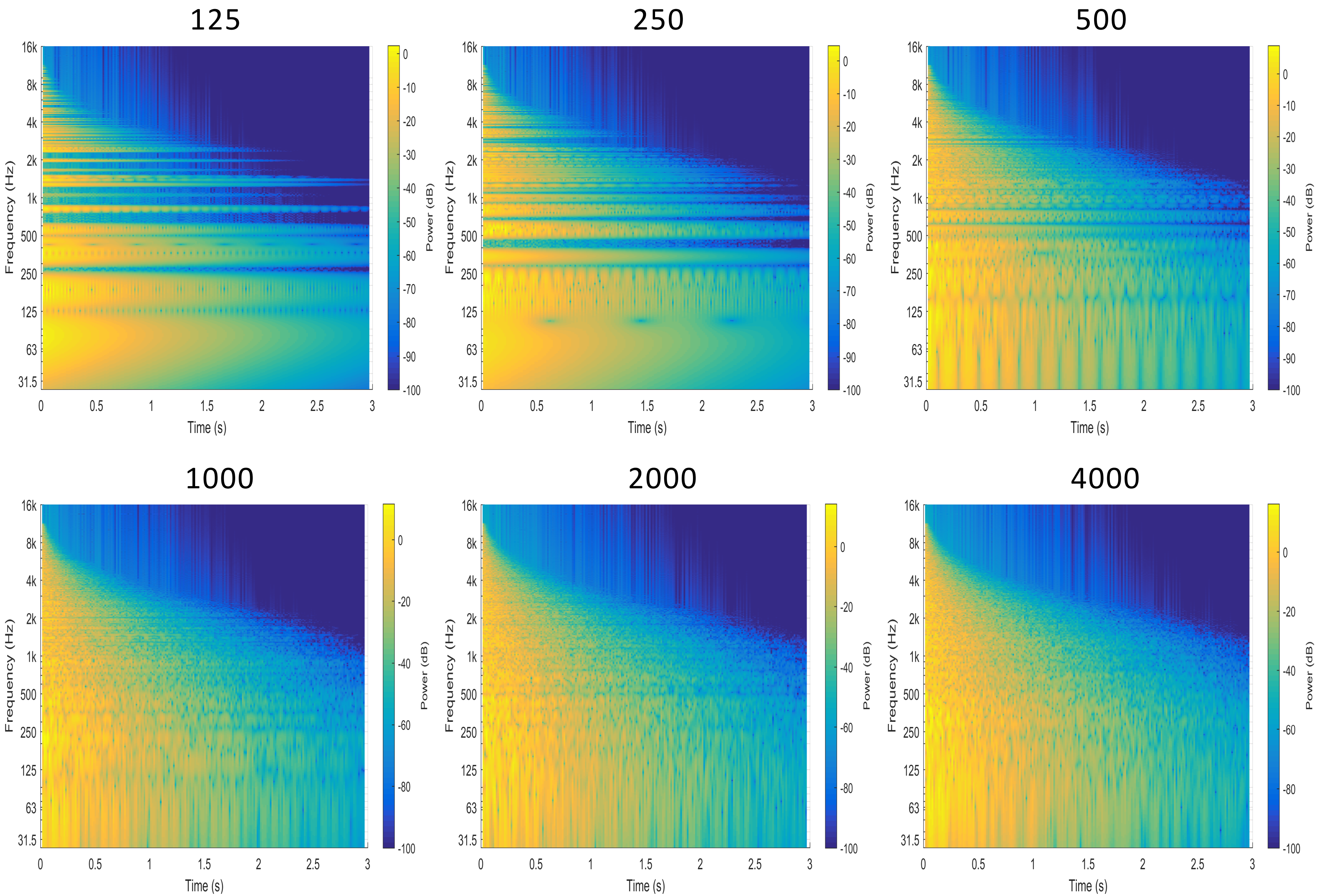
$$y_m(n) = \gamma_m x(n) + e^{(j\omega_m - \alpha_m)} \gamma_m(n-1)$$

# Implementation

- Examine the effect of mode count:
  - Same reverberation using 125, 250, 500, 1000, 2000 and 4000 modes.
  - Divide modes exponentially to octave bands from 63 Hz to 8 kHz.
  - Random phases from 0 to $2\pi$.

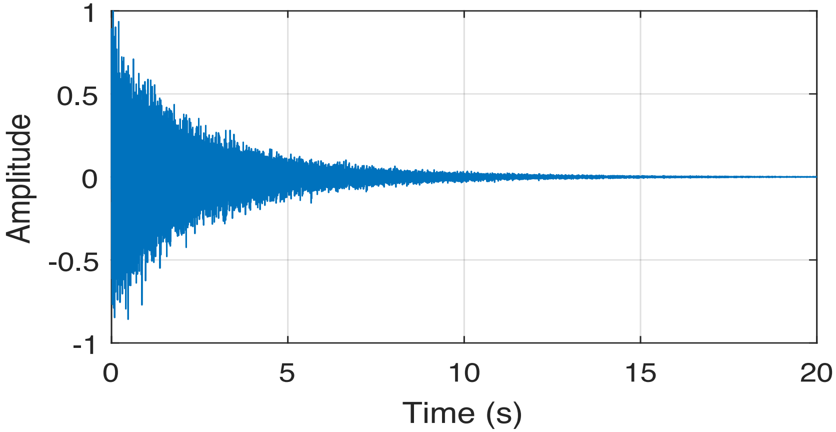
- Vocal and drum beat sound samples:

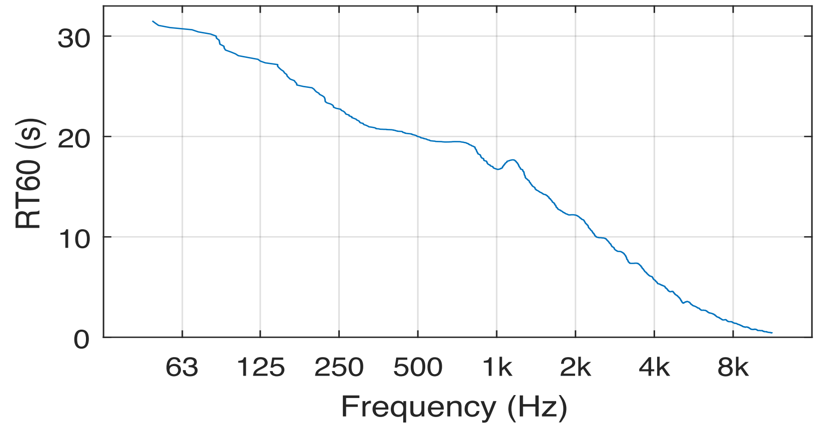
vocal: drum beat:

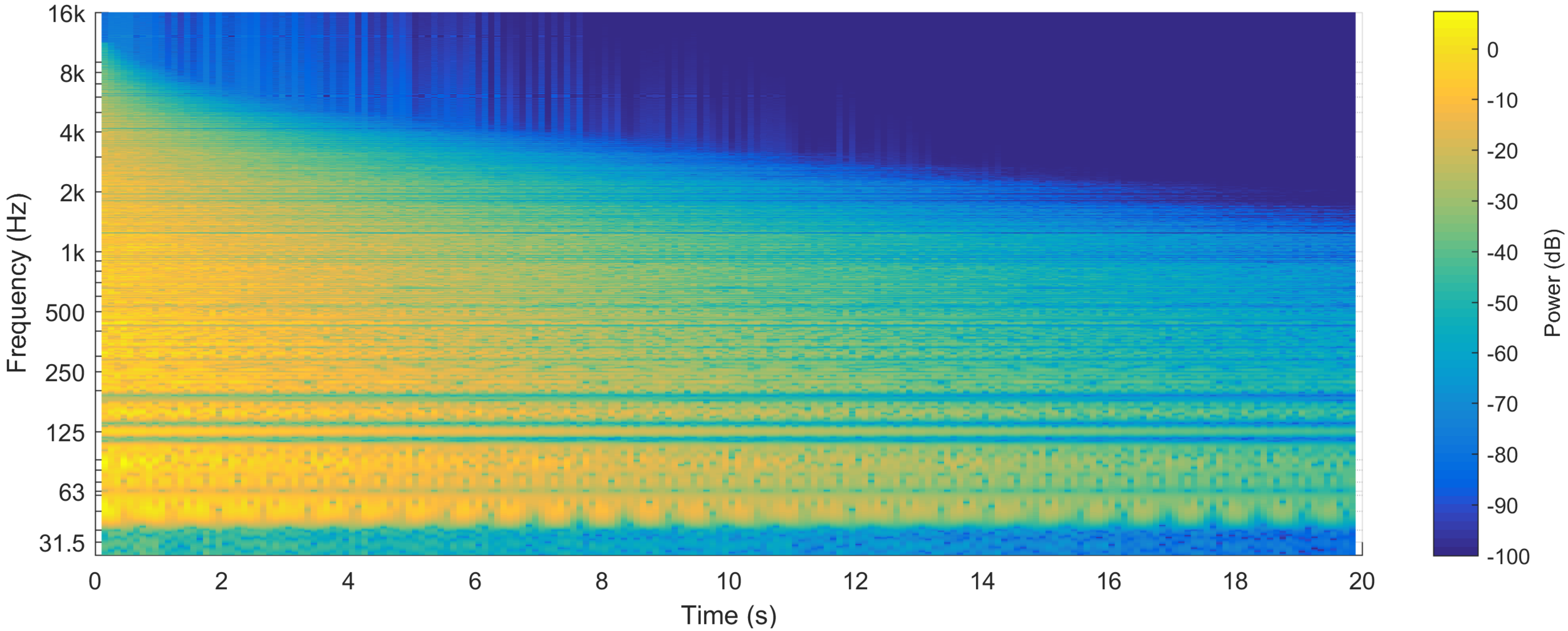

125
250
500
1000
2000
4000
Frequency (Hz)
Time (s)
Power (dB)
16k
8k
4k
2k
1k
500
250
125
63
31.5
0
0.5
1
1.5
2
2.5
3

# Implementation

- Computational complexity does not depend on reverberation time.
  - Synthesize a very long reverberation (approx. 25 s).


Amplitude
1
0.5
0
-0.5
-1
0
5
10
15
20
Time (s)


RT60 (s)
30
20
10
0
63
125
250
500
1k
2k
4k
8k
Frequency (Hz)


Frequency (Hz)
16k
8k
4k
2k
1k
500
250
125
63
31.5
0
2
4
6
8
10
12
14
16
18
20
Time (s)
Power (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100

# Conclusion

- Implement the acoustic modes of a space or object as a parallel filter structure.
  - Any acoustic space can be accurately modeled.
  - Can be used for synthesizing high quality artificial reverberation.
  - Separate control of each mode.
- Desired reverberation time and equalization easy to design.

# References


- M. Karjalainen and H. Järveläinen, “More about this reverberation science: Perceptually good late reverberation,” in *Proc. Audio Engineering Society Convention 111*, Audio Engineering Society, 2001.
- J. S. Abel, S. Coffin, and K. Spratt, “A modal architecture for artificial reverberation with application to room acoustics modeling,” in *Proc. Audio Engineering Society Convention 137, Los Angeles, CA, USA*, Audio Engineering Society, Oct 2014.
- T. Paatero and M. Karjalainen, “New digital filter techniques for room response modeling,” in *Audio Engineering Society Conference: 21st International Conference: Architectural Acoustics and Sound Reinforcement*, Audio Engineering Society, 2002.
- V. Välimäki, J. Parker, L. Savioja, J. O. Smith, and J. Abel, “More than 50 years of artificial reverberation,” in *Proc. Audio Engineering Society Conference: 60th International Conference: DREAMS (Dereverberation and Reverberation of Audio, Music, and Speech),* Jan 2016.

# Questions

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