COMMON-SLOPE MODELING OF LATE REVERBERATION

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Main results

- We propose a new **model for anisotropic and inhomogeneous late reverberation**.
- The model describes late reverberation as **linear combinations of exponential decays** called common slopes.
- Their **decay times are invariant across space and direction**, while their **amplitudes vary across both**.
- **Common decay times are determined** from a room impulse response set **via k-means clustering.**

1 Introduction

- The diffuse sound field model is often violated in practice, e.g. in coupled rooms or rooms with non-uniform absorption.
- In non-diffuse sound fields, late reverberation varies spatially (inhomogeneity) and directionally (anisotropy).
- Simple and heuristic models predict inhomogeneous late reverberation from room properties and the source-receiver configuration [1, 2, 3]. In contrast, the common-slope model is data-driven and purely descriptive.
- Inhomogeneity and anisotropy can be modeled as mode-amplitude variations, because mode decay times are independent of the source-receiver configuration. This property was demonstrated by Haneda et al. with their common-acoustical-pole and residue model [4]. The common-slope model adapts their idea by grouping individual modes and modeling them as exponential slopes.

2 The common-slope model

We propose the common-slope model, which is given by

$$d_\kappa(\mathbf{x},t) = N_{0,\mathbf{x}}\ \Psi_0(t) + \sum_{k=1}^{\kappa} A_{k,\mathbf{x}}\big[\Psi_k(t) - \Psi_k(L)\big], \tag{1}$$

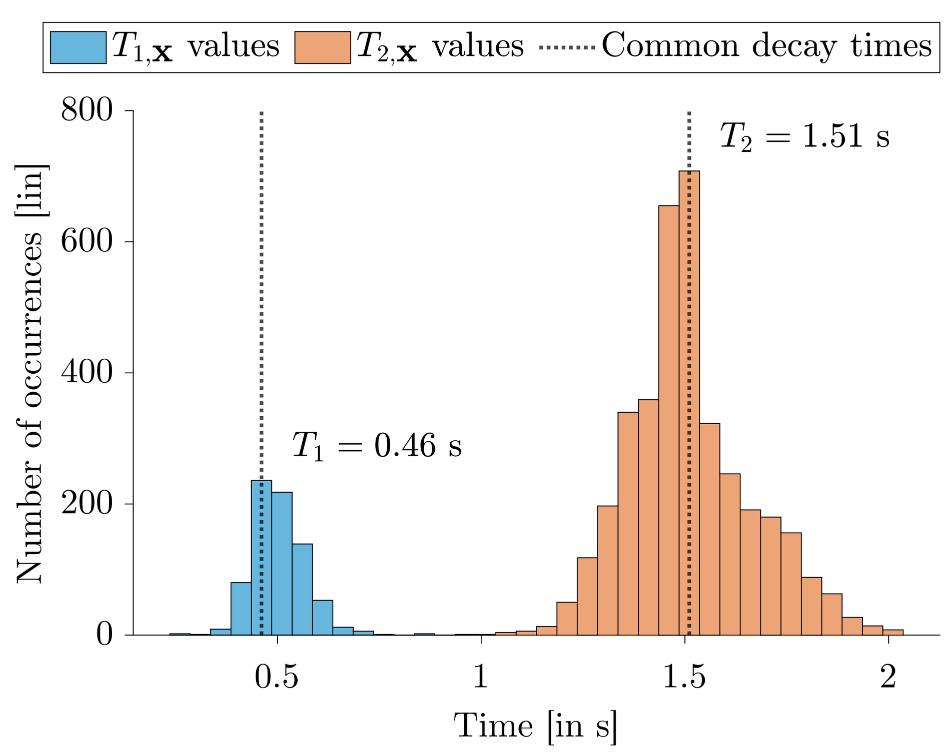
with the decay kernel

$$\Psi_k(t) = \begin{cases} L - t, & \text{if } k = 0 \\ \exp\left(\frac{-13.8\ t}{f_s\ T_k}\right), & \text{if } k > 0 \end{cases}, \tag{2}$$

where T_k and $A_{k,\mathbf{x}}$ are the decay times and amplitudes of the kth mode group, respectively, and $N_{0,\mathbf{x}}$ is the amplitude of the noise term. The model parameters can be determined from a measured energy decay $d(\mathbf{x},t)$ via a least-squares fit.

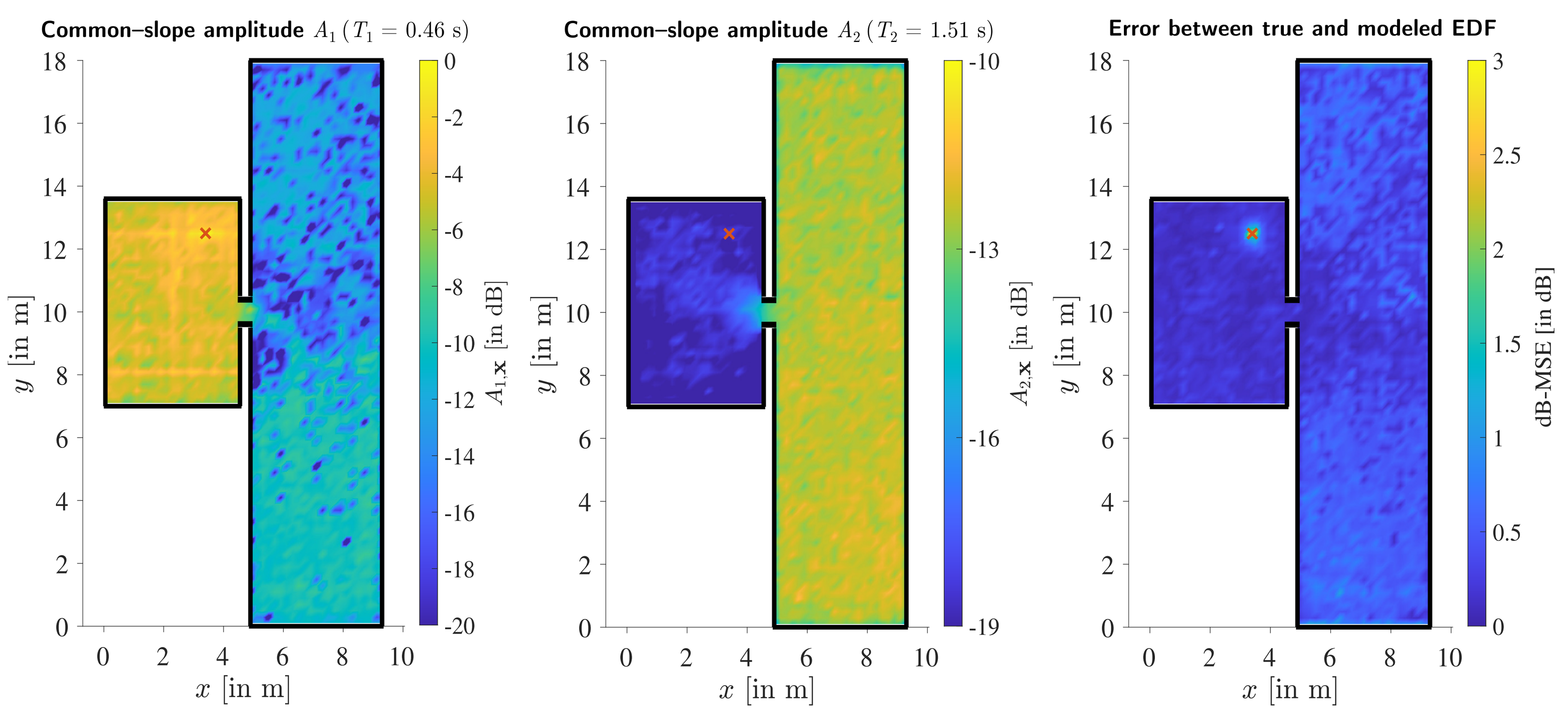
3 Determination of common decay times via k-means clustering

We compared different approaches for determining the common decay times T_k, with k-means clustering being the most general and robust.

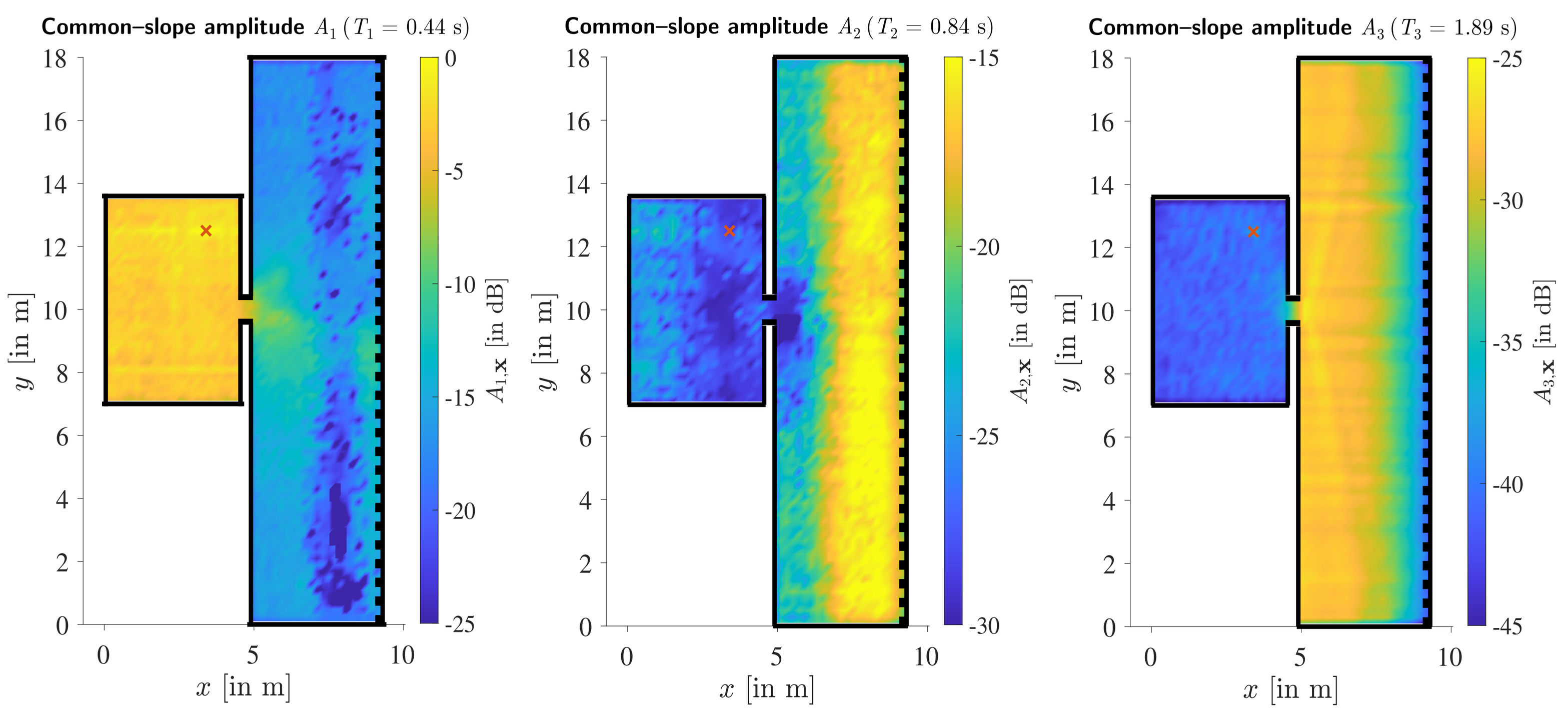


4 Evaluation in coupled rooms

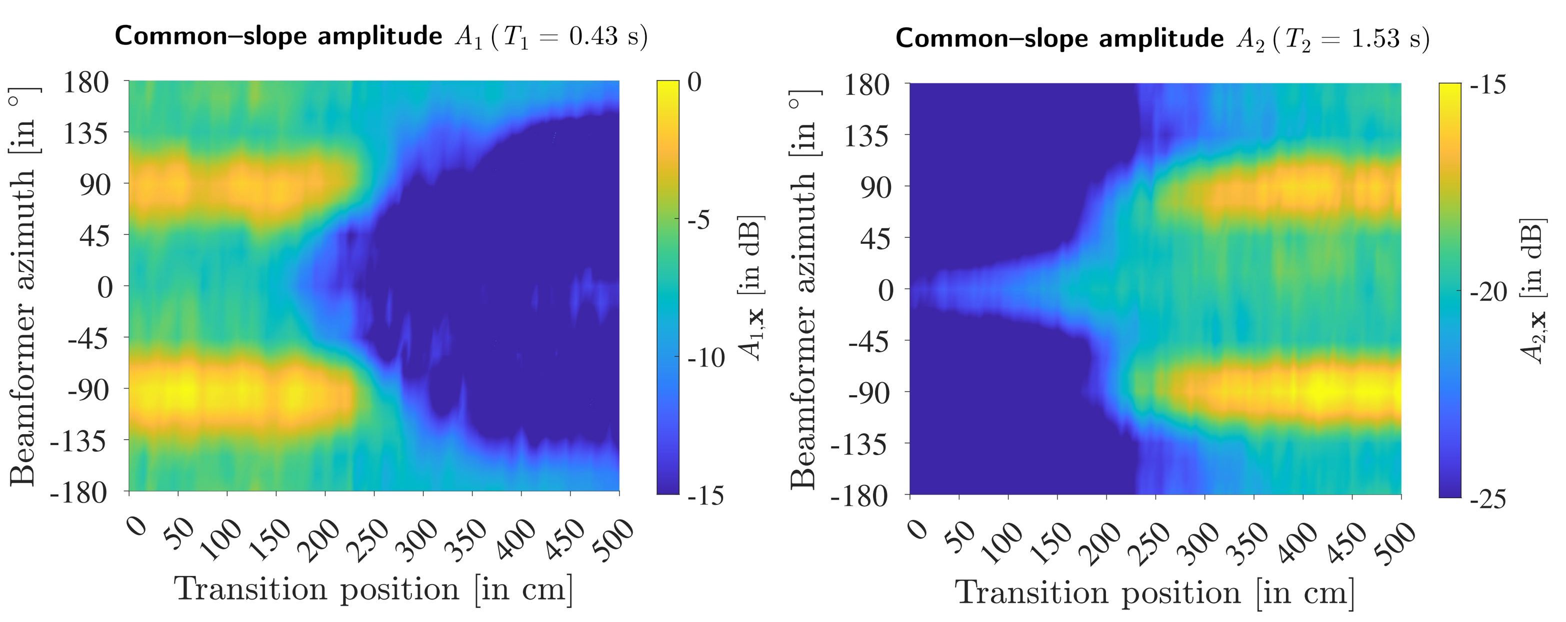
The common-slope amplitude maps illustrate the late reverberation cross-fade when transitioning between rooms. The error between true and modeled EDFs is small across the entire scene.



The inhomogeneity increases for non-uniform absorption. In the scenario depicted below, the right wall is highly absorptive.



The late reverberation anisotropy becomes evident when beamforming into different directions and plotting the corresponding common-slope amplitudes.



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