Comb-Filter Free Audio Mixing Using STFT Magnitude Spectra And Phase Estimation

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Overview

- Audio Mixing and the Comb Filter Effect
- STFT Magnitude Mixing
- Phase Estimation
- Evaluation

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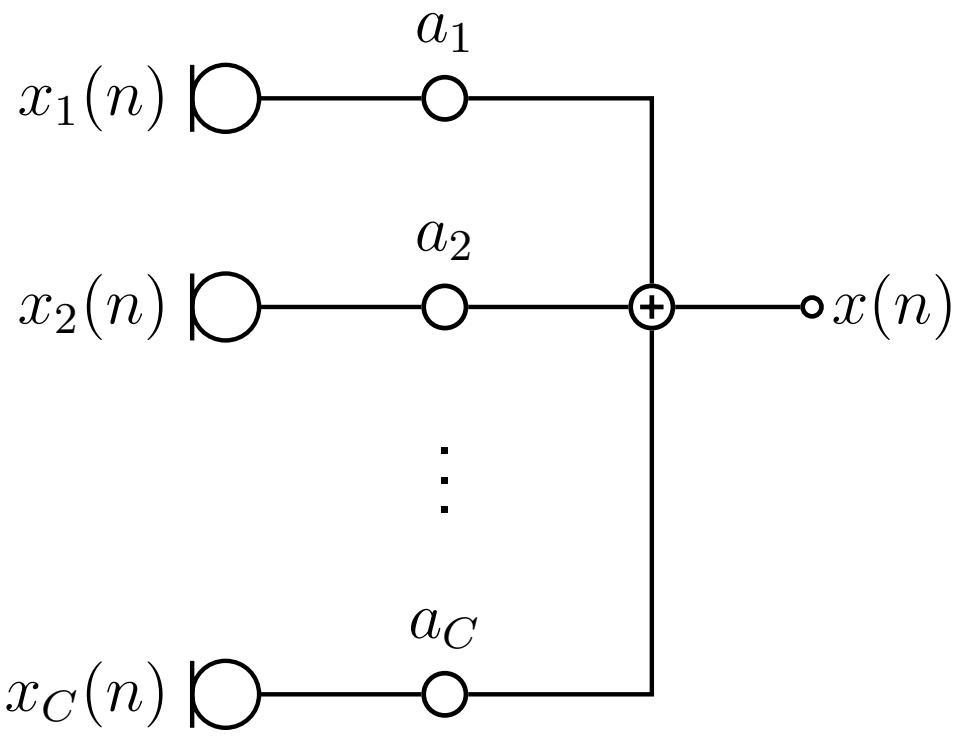
Audio Mixing

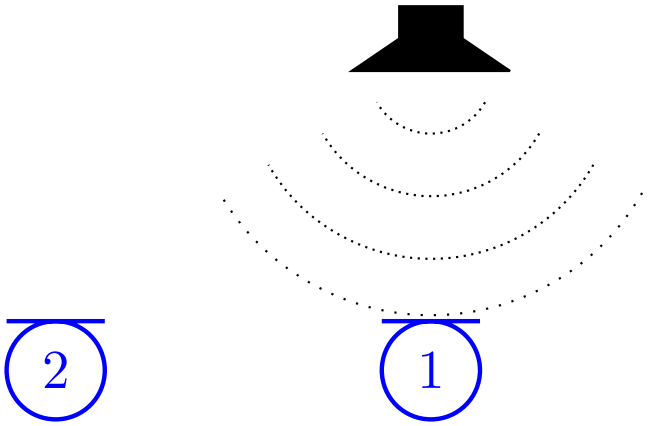


Audio mixing

output = linear combination of input

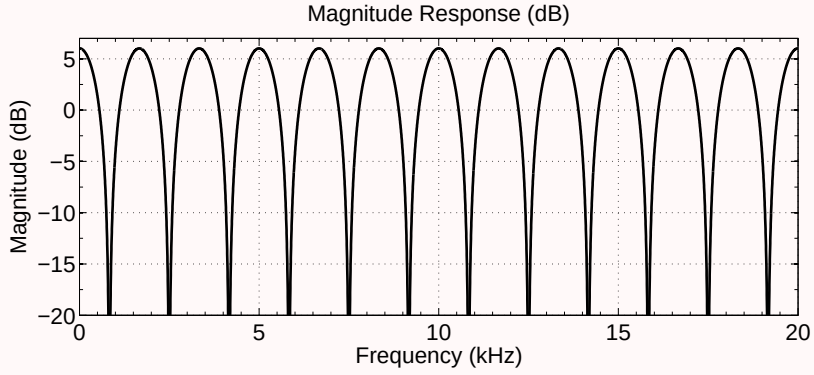
$$x(n) = \sum_{c=1}^{C} a_c x_c(n)$$

Comb Filter Distortions



- scenario: one source recorded with multiple mics
- delays between mics (wave propagation)
- mix = original + delayed version

Magnitude response vs frequency



Listening example

- original ♫
- comb filter (1 ms delay) ♫

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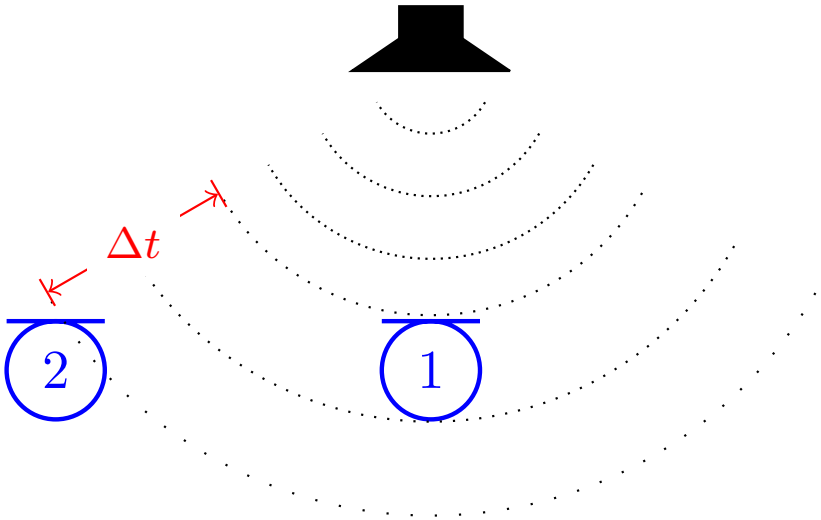
Comb Filter Distortions



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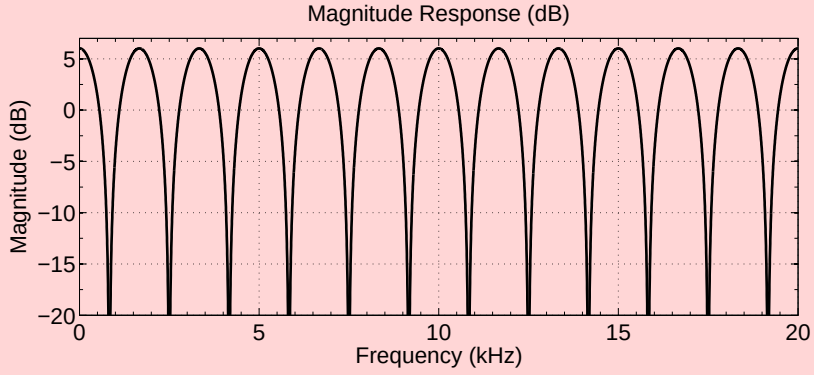

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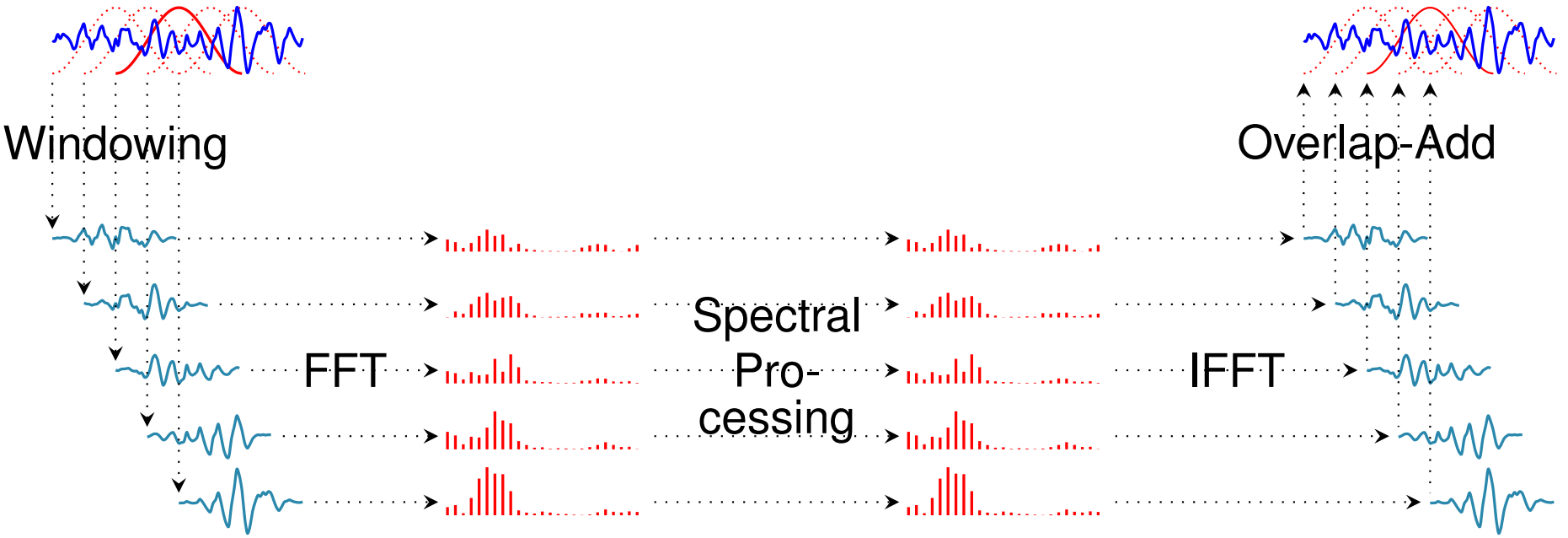
Review of STFT Processing



FFT coefficients are complex

- $C = |C| \cdot e^{j\varphi}$ with $|C|$ = magnitude, φ = phase
- reconstruction requires magnitude **and** phase information

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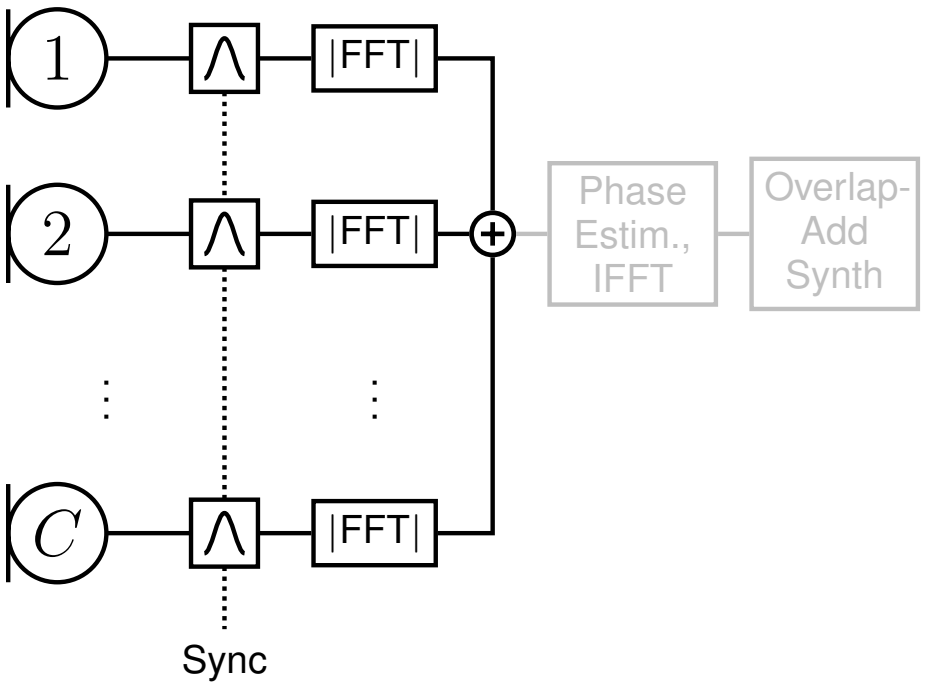
STFT Magnitude Spectrum Mixing



Advantage

magnitude-only mixing $\Longrightarrow$
no phase cancellations $\Longrightarrow$
no comb filter effect

Disadvantage

magnitude-only mixing $\Longrightarrow$
phase information missing

Listening example

overlap-add on magnitude-only spectrum IFFT: ♫

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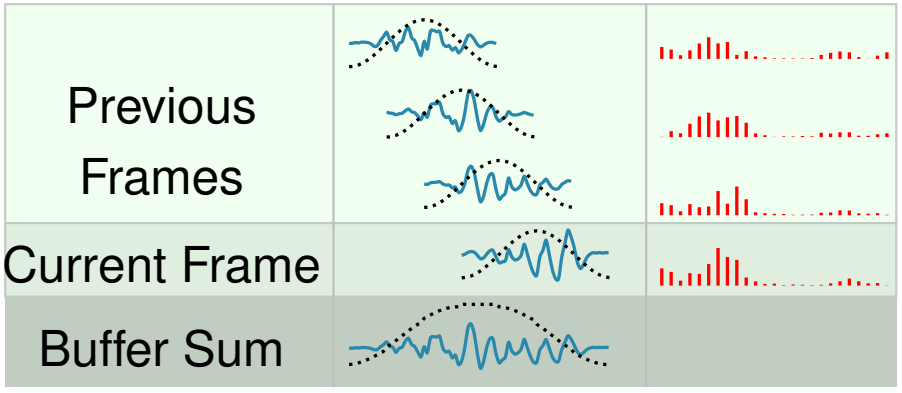
Review: Phase Estimation with RTISI

RTISI = Real-Time Iterative Spectrogram Inversion (Zhu, Beauregard, Wyse, IEEE ASLP, 2007)



- consecutive frames stored in consecutive rows
- row content:
  - recent estimation of time domain signal
  - STFT magnitude spectrum (given by mixer)

Characterization of algorithm

- estimation of the **last** buffer row (time domain).
- iterative combination of
  - the magnitude stored in the row
  - the phase from the buffer sum FFT
- result IFFT is windowed and written back

Improvement

look-ahead extension

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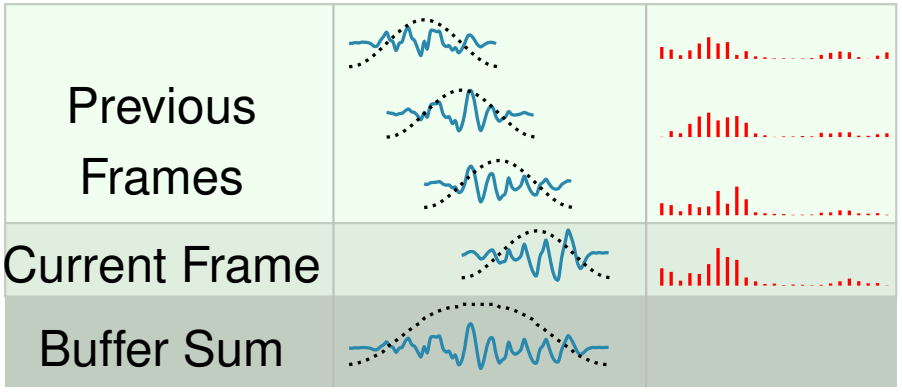
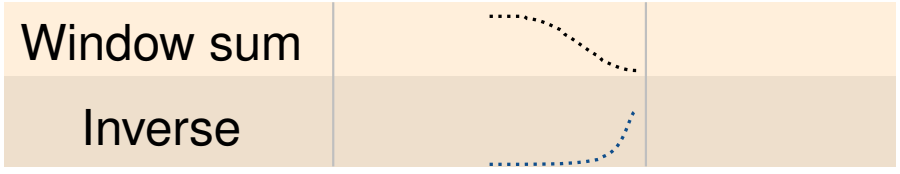
Window Sum Compensation



Window sum error

- buffer sum implicitly windowed with window sum (dotted line)
- mismatch analysis window
- FFT does not match given spectrograms even with correct signal



Compensation

- applying the window sum inverse to the buffer sum
- re-windowing the buffer sum with the Hamming window

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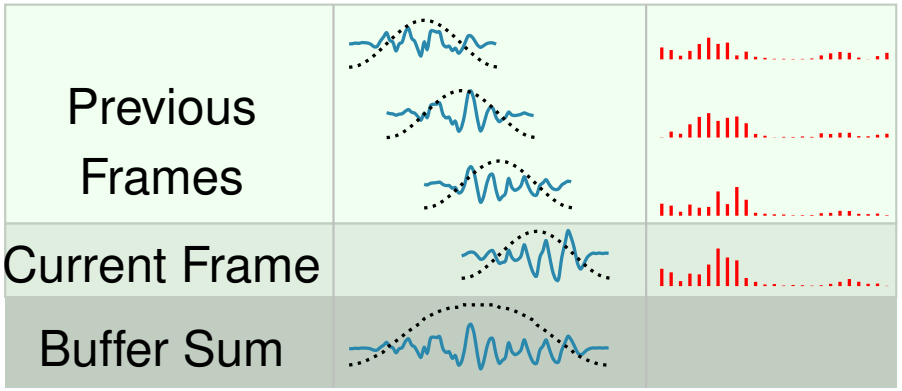
RTISI Initialization for Mixing



Initialization

- iterative algorithm → approaching a local minimum
- result depending on the initial buffer values
- good initialization heuristic: **time domain mix**

Comb-Filter effect removal

comb filter effects are removed **automatically** (combination with the comb-filter-free magnitude spectrum).

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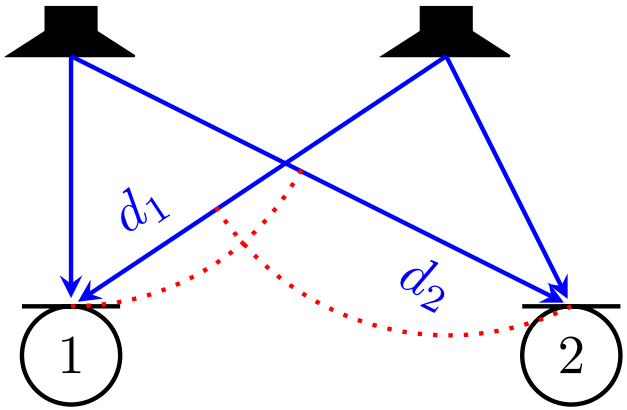
Listening Examples



Recording simulation

- two instruments, two microphones
- delay differences d_1, d_2 between long and short distances

Listening examples

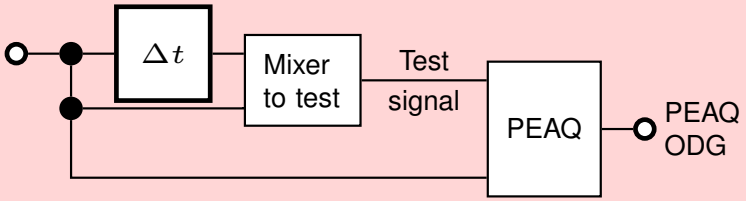
- Sources:
  - english horn
  - glockenspiel
- Delays:
  - d_1 (english horn) = 1 ms
  - d_2 (glockenspiel) = 0.3 ms
- reference = delay-free time-domain mix ♫
- time-domain mix with delays ♫
- rtisi mix with delays ♫

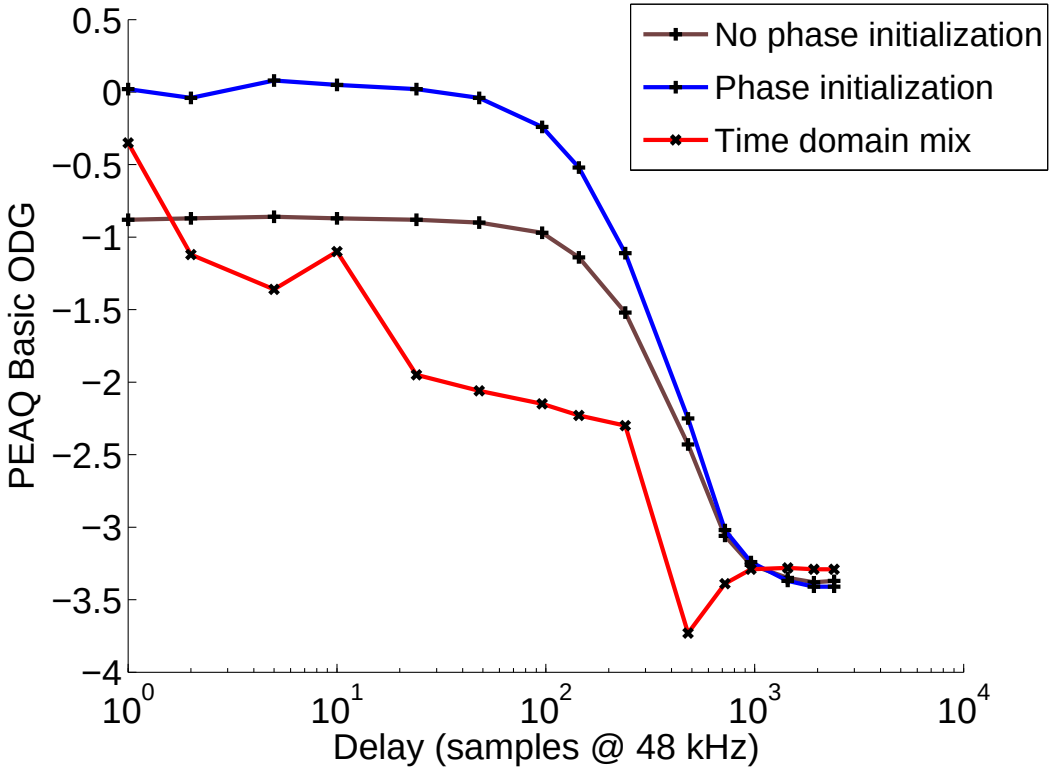
Evaluation with PEAQ

Source

- only single source
- german hip hop music, 15 s
- mono

Setup





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Thank you for your attention!