Modeling Coloration of Virtual Sound Sources in Listening Rooms

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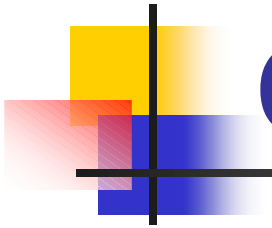
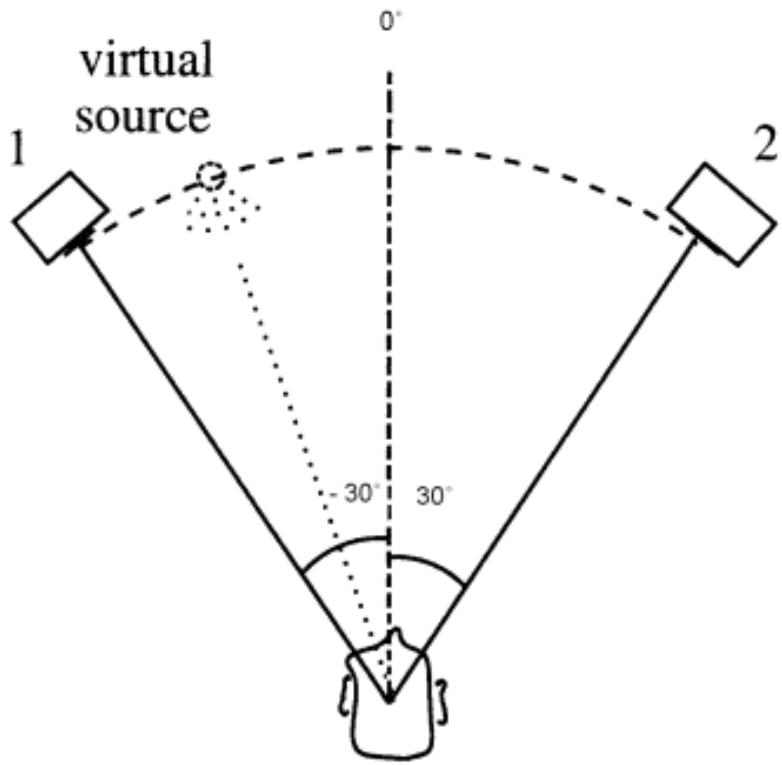


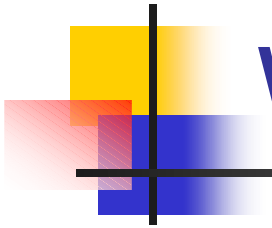
Outline

- Important to understand and evaluate quality of reproduced sound
- Coloration - frequently observed effect
- Aim:
  - To model coloration using a binaural auditory model in a listening room
- Focus: Amplitude panning

Virtual Source

- Example: stereophonic reproduction
- Position where the sound appears to come from
- Perceptual cues do not match any real source



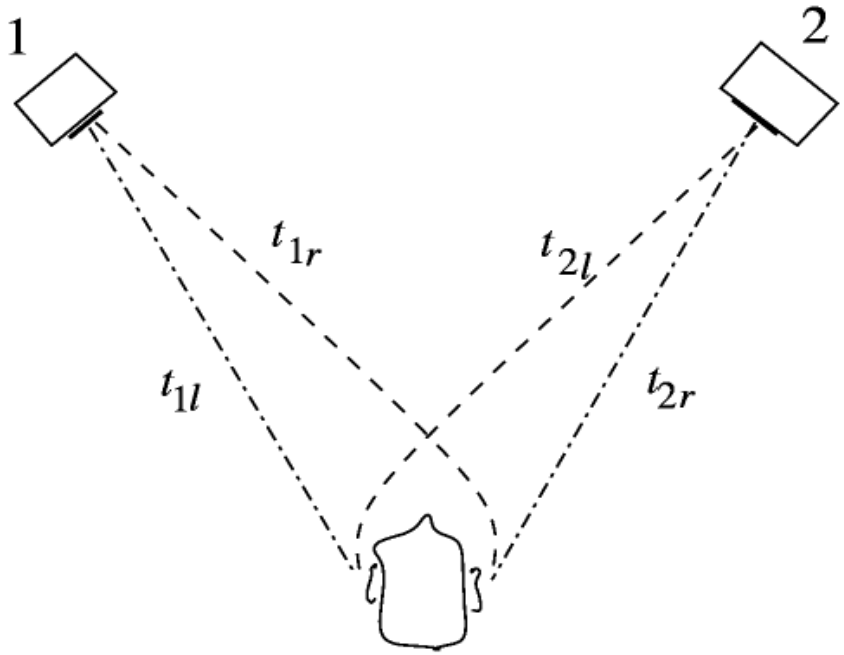


What Is Coloration?

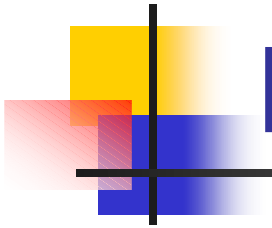
- Spectral distortion
- Virtual sources: variation in *timbre* of the virtual source w.r.t. a reference real source.
- Timbre mainly depends on
  - Spectral envelope
  - Variation of the spectrum with time

Why is there coloration?

- Arrival time difference *at each ear* from the two loudspeakers
- Comb filter effect

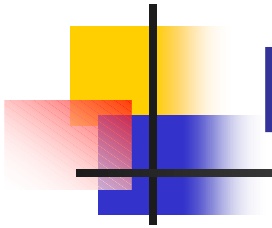


Part 2
Some Related Aspects of Timbre



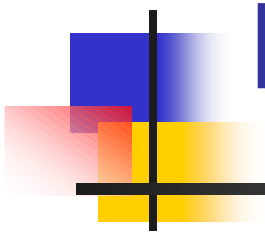
Loudness summation

- Zurek studied echo suppression
- Echo is more detectable when it is diotic
- Conclusion:
  - Binaural *summation* of spectral representations from both ears: resultant combination spectrum is less deeply modulated than each ear spectrum



Effect of reverberation

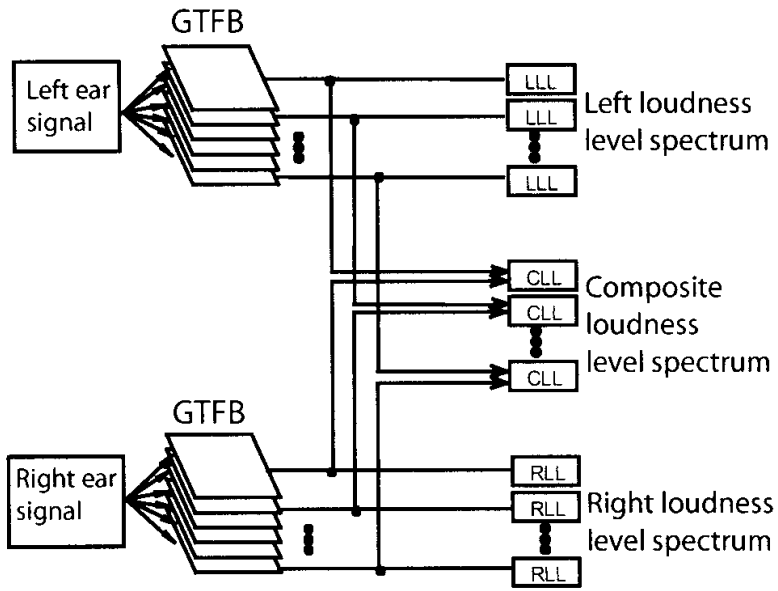
- Bech found that
  - As reverberation increases, contribution of an echo to the perception of timbre decreases
  - Detection threshold of the echo increases with reverberation
  - This implies that coloration effects should be reduced in a room



Part 3
Modeling Coloration

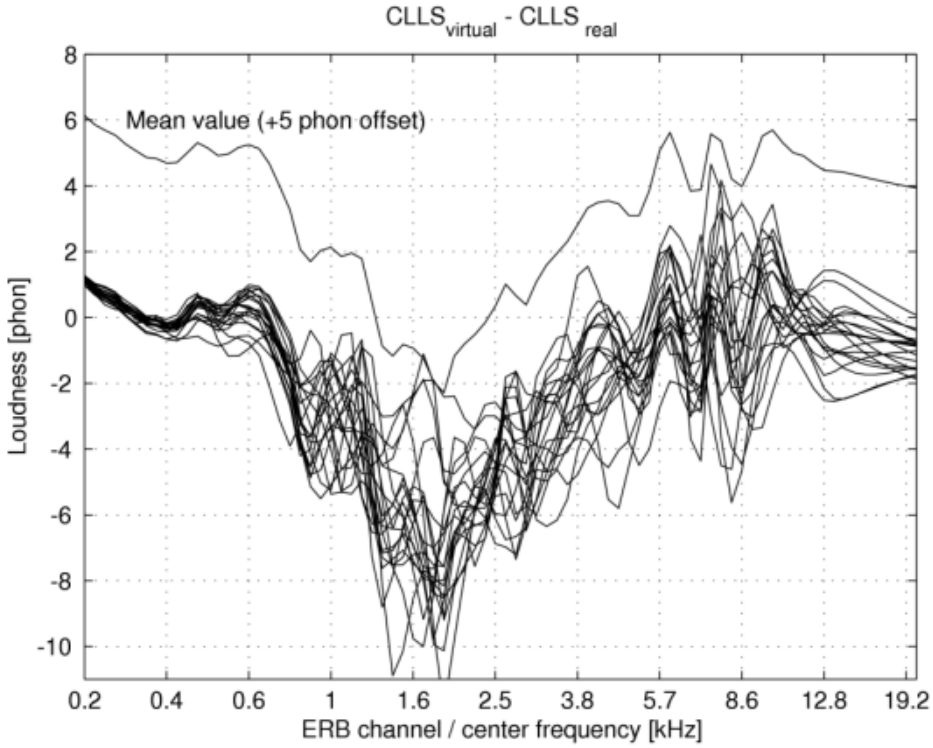
Auditory model used

- HUTear 2.0 package
- Calculates Composite Loudness Level spectrum (CLL spectrum)

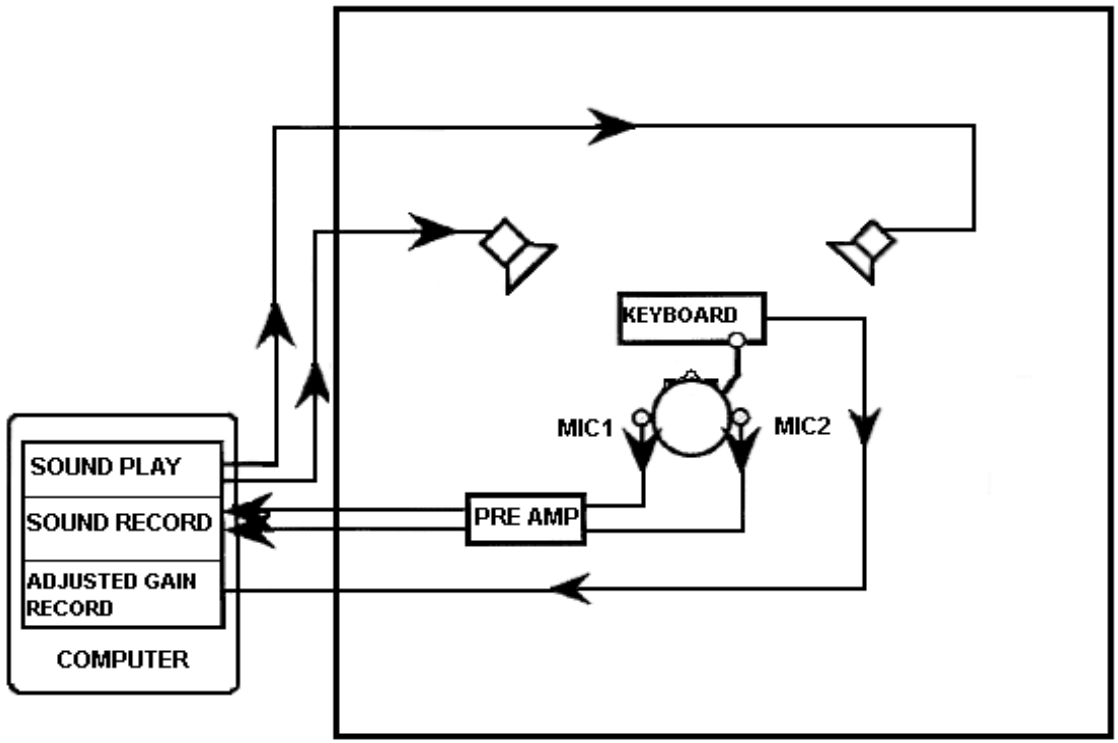


Simulated Anechoic Coloration

- Simulation with the auditory model
- Coloration is defined as CLL(virtual) – CLL (real)
- Output: loudness level across frequencies



Listening Test Setup



Listening Test Procedure

- Real source (30 degrees) followed by Virtual source
- Subjects adjusted loudness of frequency bands of the virtual source
- Set of gain adjustment parameters obtained from the listener's responses

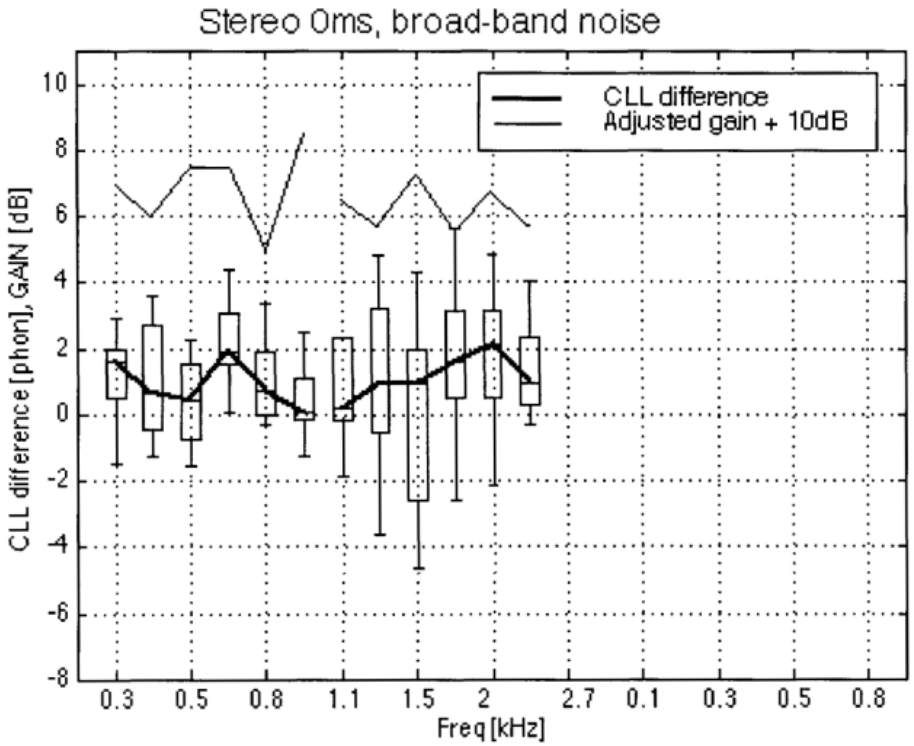
Listening Test Procedure

- Tests for 0 ms and 2 ms delay between the loudspeaker channels
- Broadband test signals: 6 Barks wide.

- If model predicts coloration accurately, CLL difference plot should be zero.

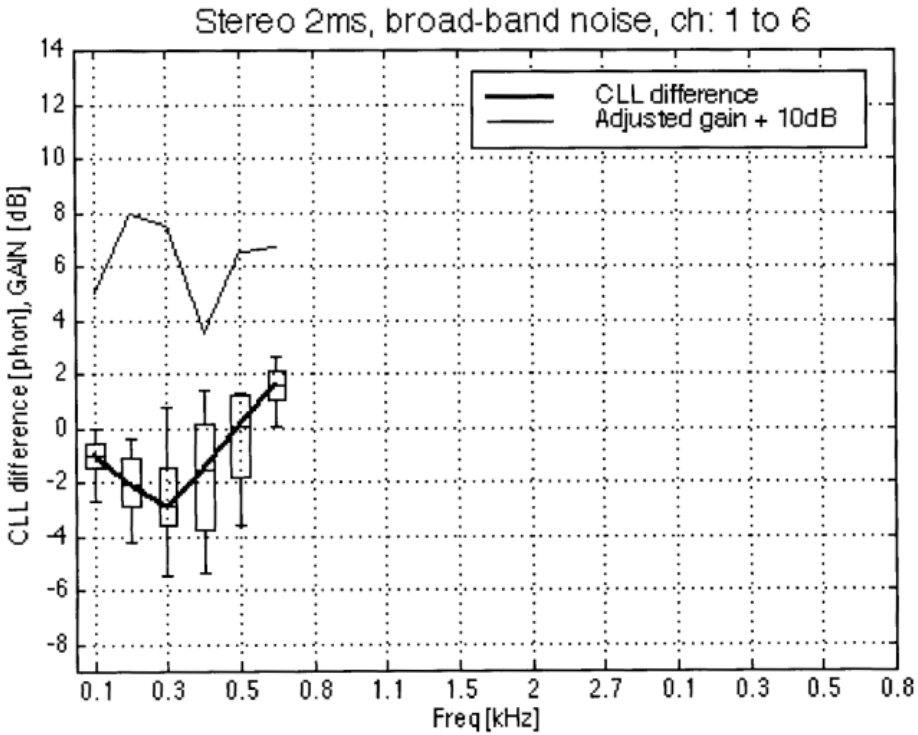
Test Results (no delay)

- CLL difference plot never exceeds +-1 phon : Good result!
- Slight positive offset probably due to test procedure



Test Results (2ms delay)

- Dip in CLL difference plot at 300 Hz: Model fails!
- Dip is not as deep as in the anechoic case
- Virtual source perceived as being louder than the model predicted
- Indicative of some binaural interaction besides summation



Conclusions

- Loudness summation is sufficient for the purpose of modeling coloration of amplitude panned virtual sources in the sweet spot.
- The model works well in a listening room. (Previous study has shown the same for anechoic conditions)
- The model fails only in cases when a time delay is introduced between the channels.
- Results suggest some binaural interaction besides summation. The nature of this mechanism is unknown.

Thank you!