STQ Workshop

Reproducing Reverberation for the Receiving Path

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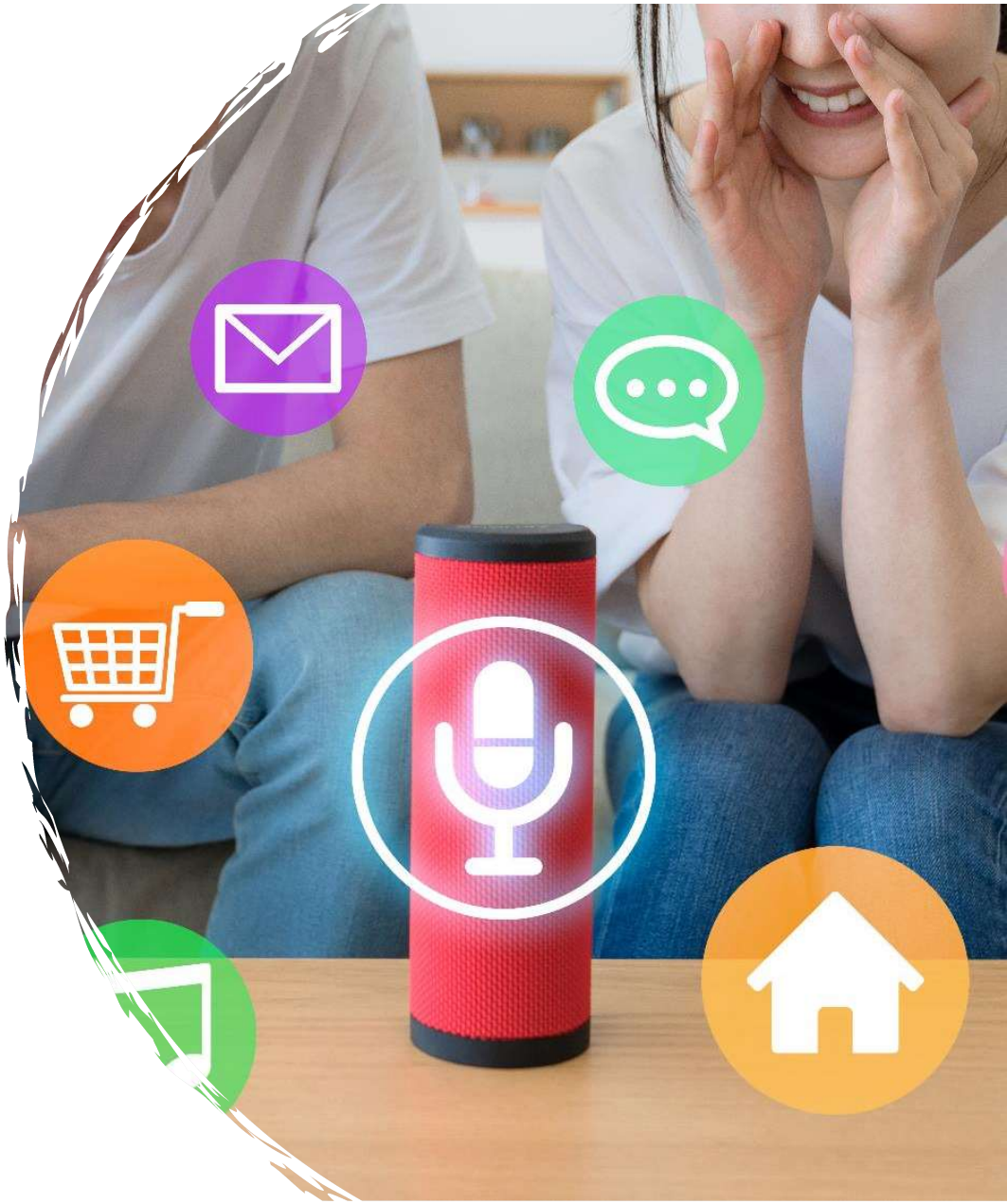


21/11/2022

Reproduction of Reverberation

- Reverberation impacts communication: Increased listening effort, echos, detrimental effect on the performance of signal enhancement algorithms
- Three relevant transfer paths:
  - Sending
  - Receiving
  - Echo

Reproduction of Reverberation

- Target
  - Realistic reverberation
  - Replicable in different reproduction rooms

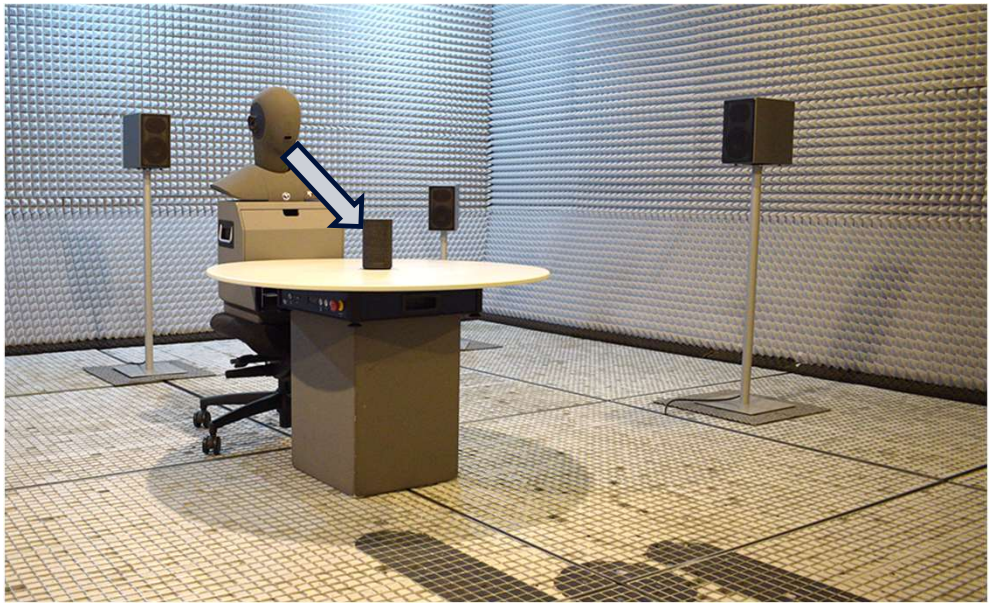
- Application scenarios
  - Development and testing of hands-free devices
    - Conference phones
    - Smart speakers

Overview

- Motivation
- Reproducing Reverberation for the sending path
- Similarities and Differences between the cases
- Experimental results
- Conclusion

Reproduction System – Sending Direction from ETSI TS 103 557

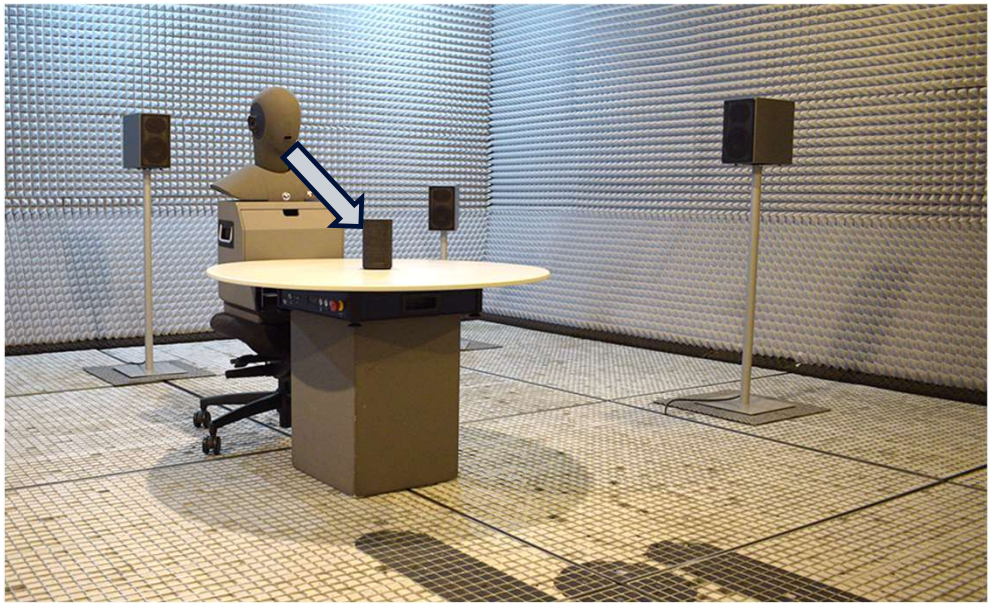
- Established approach
  - Measure impulse responses in reverberant environments
  - Separation of reverberant impulse responses
  - Set up reproduction system
    - Direct sound
      - Artificial mouth
    - Reverberation
      - Equalized loudspeaker system from ETSI TS 103 224
  - Carry out reproduction



Reproduction System – Receiving Direction

- Entire setup very similar

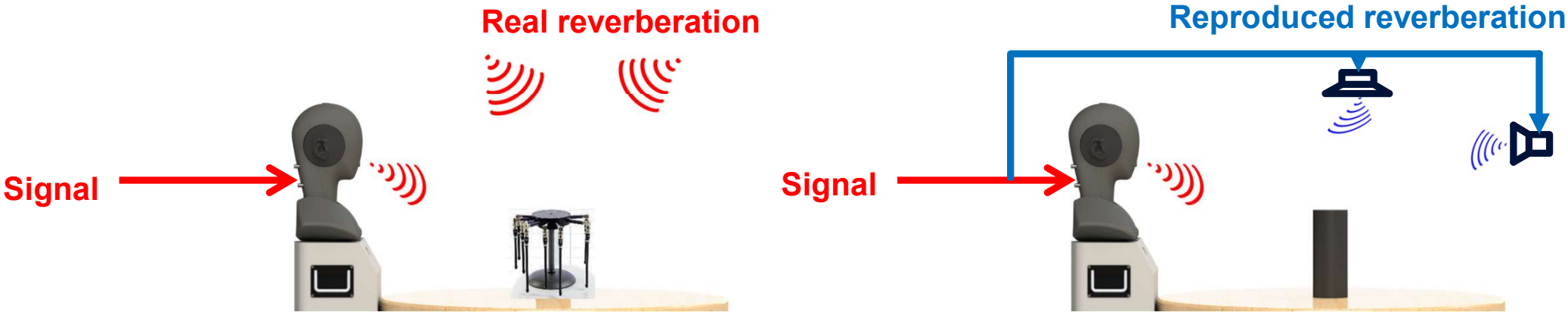
- Different transfer path
  - From: Loudspeaker(s) of the device under test
  - To: Ears of the head-and-torso-simulator (HATS)



- Impact of this change?

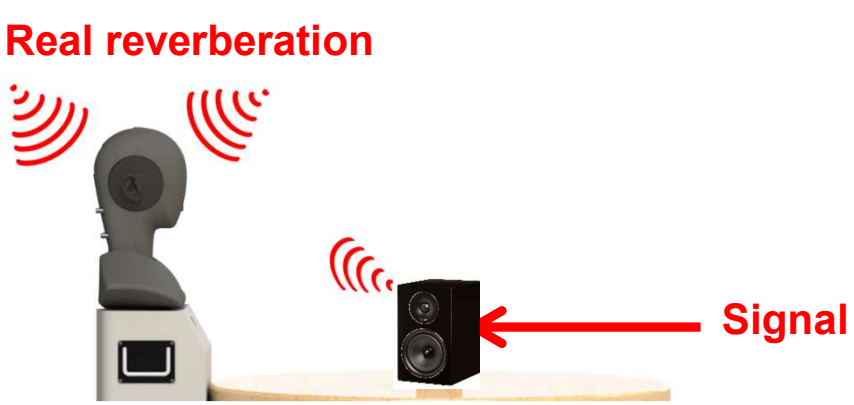
Sending Direction vs. Receiving Direction

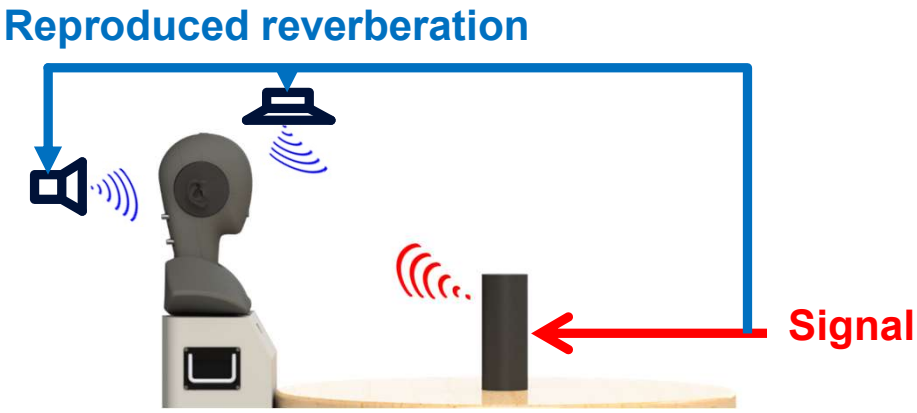
- Important difference
  - Sound source for recording impulse responses and reproducing direct path component
    - Sending direction: identical (mouth of HATS)



Sending Direction vs. Receiving Direction

- Important difference
  - Sound source for recording impulse responses and reproducing direct path component
    - Sending direction: identical (mouth of HATS)
    - Receiving direction: measurement loudspeaker for recording impulse responses, DUT loudspeaker(s) for reproducing reverberation





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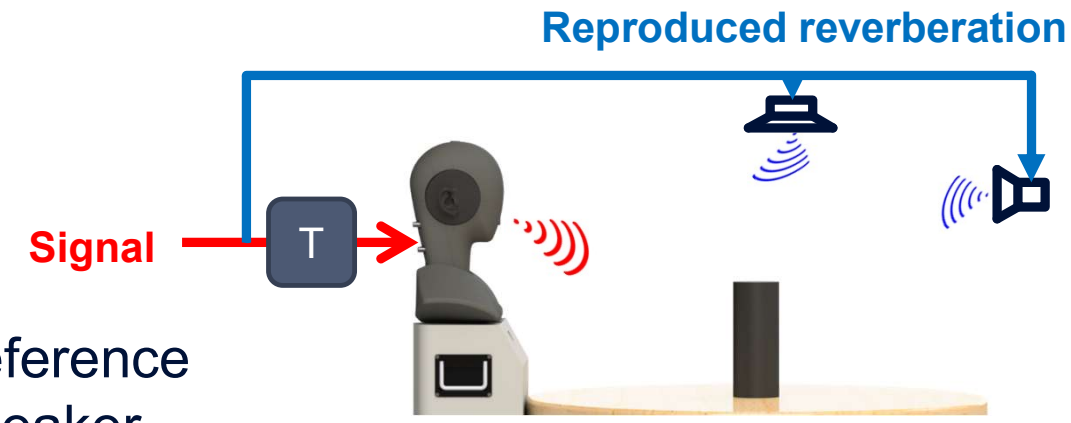
- Different sound sources
  - Different directivity
  - Different frequency response
  - Possibly: time-variant (adaptive) signal processing

Setting up the Reproduction System

- Sending direction



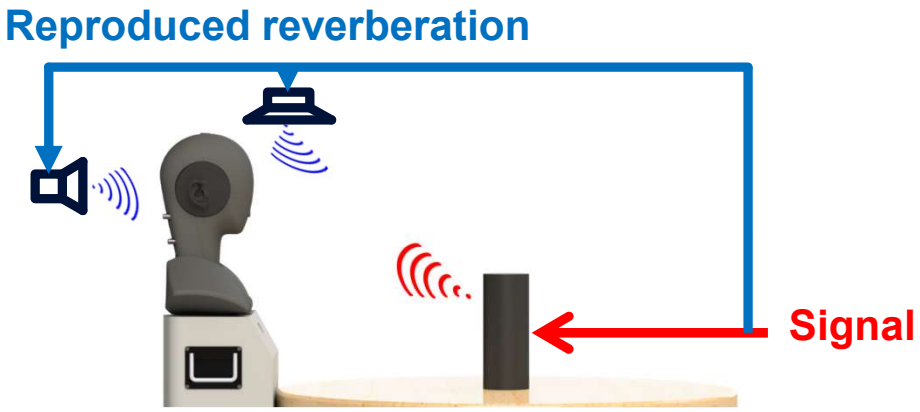
- Procedure
  - Play signal (only HATS)
  - Reproduce direct sound from reference scenario (only equalized loudspeaker system)
  - Compare the recordings
    - Compensate for differences in delays and levels
    - Usually: significantly delay mouth signal

Setting up the Reproduction System

- Receiving direction

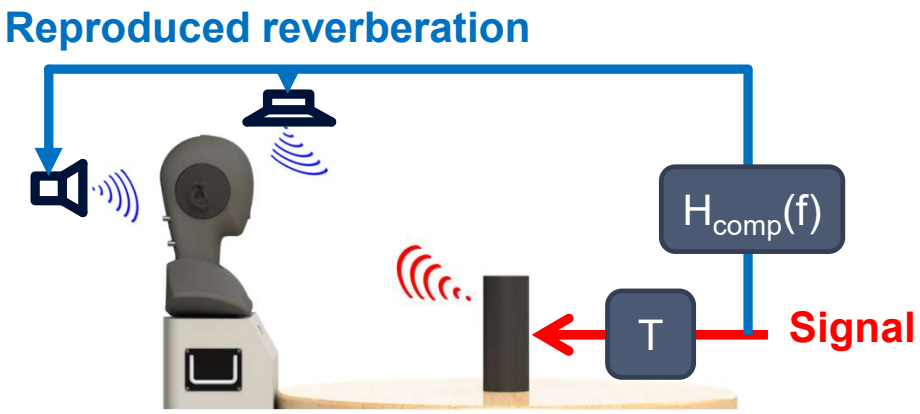
- Procedure
  - Play signal (only DUT)
  - Reproduce direct sound from reference scenario (only equalized loudspeaker system)
  - Compare the recordings
    - Compensate for differences

    ➔ How?



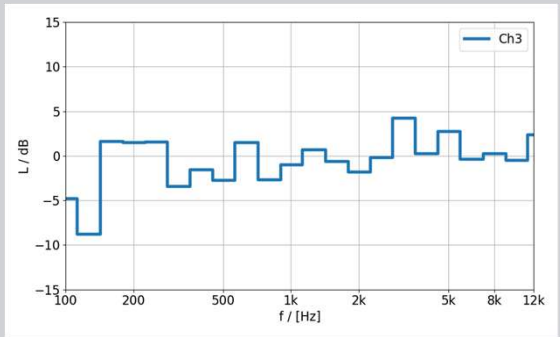
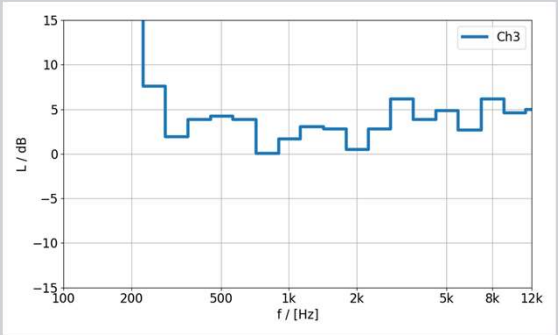
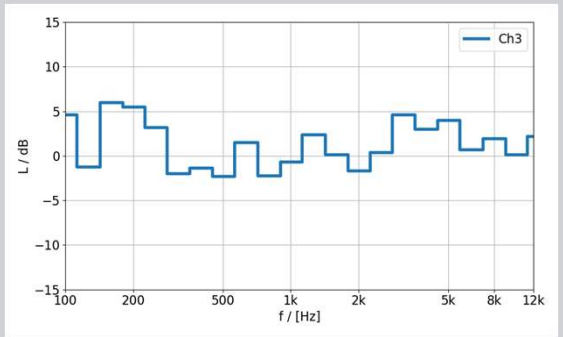
Compensation Filter Approach

- Delay compensation
- Calculate compensation filter
  - $H_{comp}(f) = \frac{H_{DUT,d}(f)}{H_{Ref,d}(f)}$
- Target:
  - Match spectrum of reverberation to frequency response of DUT
- Implementation details under investigation
  - Frequency resolution
  - Averaging over multiple microphones
  - Possibly adaptive



Experimental results

- Two analyses
  - Difference between transfer function in reverberant environment and transfer function in reproduced reverberation
  - Reverberation time in reproduced reverberation
    - True reverberation time in reverberant environment: 653 ms

Reproduction method	Only DUT	DUT + Reverberation (without compensation filter)	DUT + Reverberation (with compensation filter)
Transfer function difference			
Reverberation time	108 ms	700 ms	571 ms

→ Clear improvement by compensation filter

Conclusions and Outlook

- System setup for reproducing reverberation in the receiving path
- Many similarities between sending and receiving direction
- Important differences due to different sound sources for measuring impulse responses and reproducing reverberation
- Compensation filter for alleviating the impact of different frequency responses
  - First experimental results

- Impact of directivity and time-variant DUT signal processing?
- Applicability for echo path?

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