HARMAN/BECKER
AUTOMOTIVE SYSTEMS

Systems for Improvement of the Communication in Passenger Compartments

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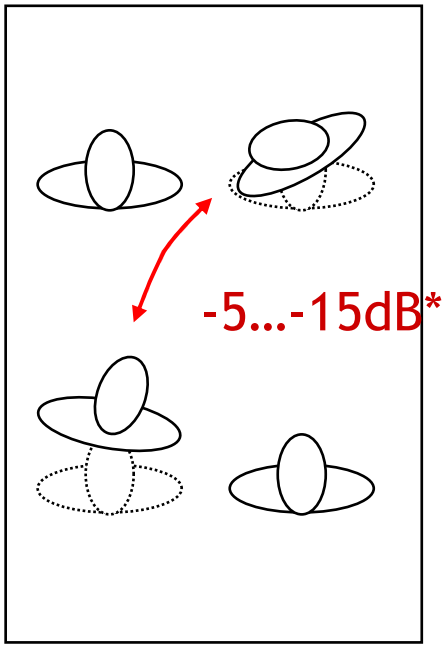
Passenger compartment



***Acoustic loss (referred to the ear of the driver)**

Current Situation:

- Communication between passengers is difficult, because of the acoustic loss (especially front to back
- Front passengers have to speak louder than normal – longer conversations will be tiring
- Driver turns around – road safety is reduced

Solution:

- Improve the speech quality and intelligibility by means of an intercom system

Application:

- Mid and high class automobiles, which are already equipped with the necessary audio and signal processing components
- Vans, etc. → systems with reduced quality

Configurations

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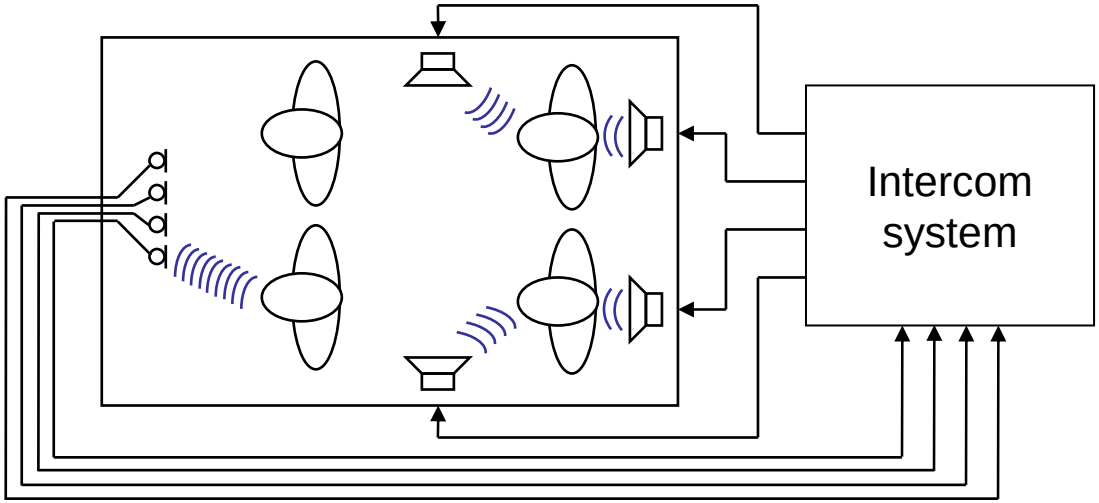
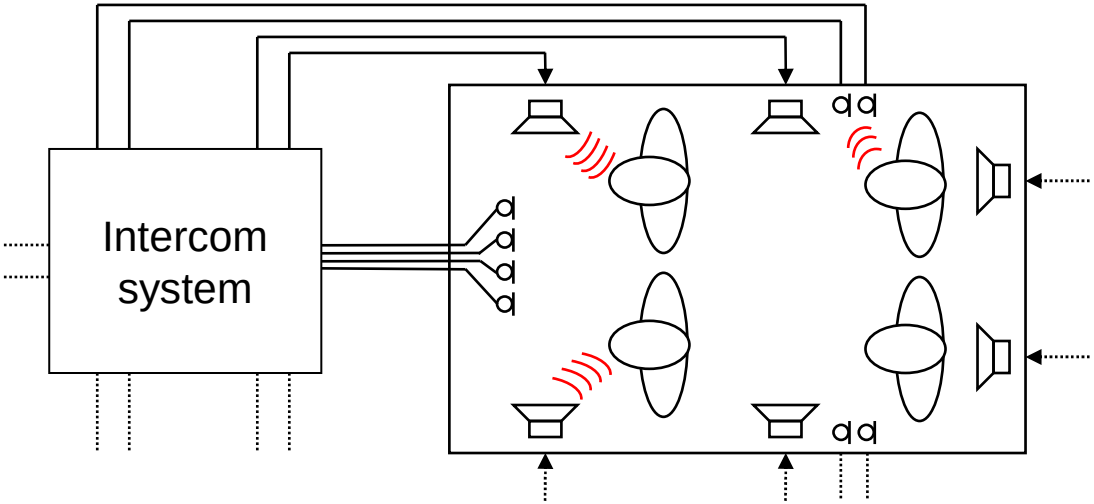
One-Way System

- 2-4 microphones
- 2-4 loudspeakers





Two-Way System

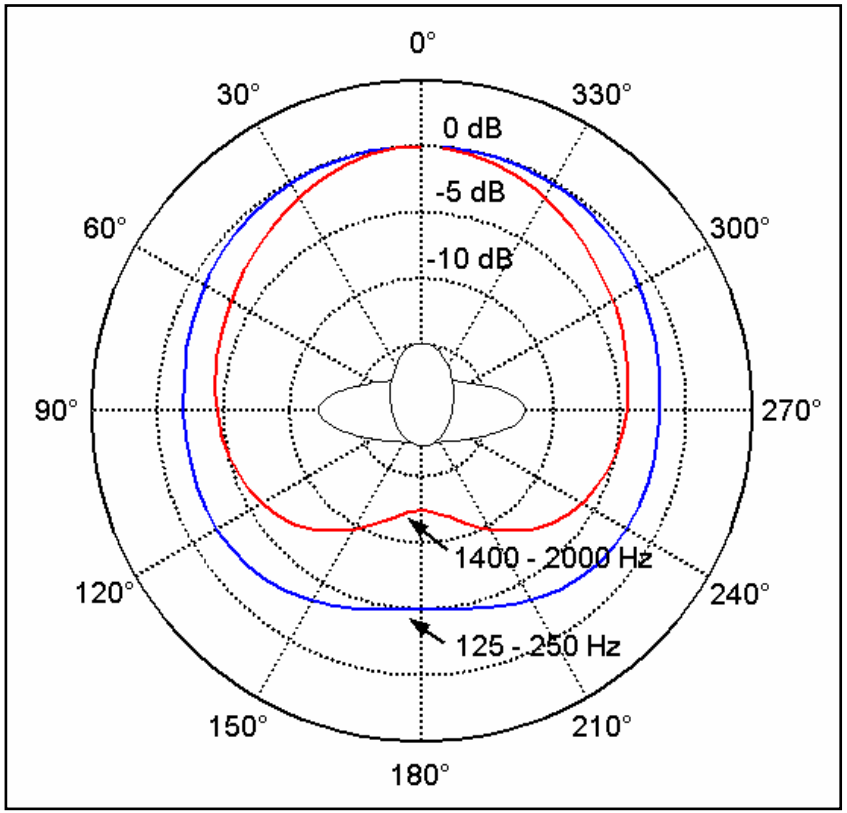
- 4-8 microphones
- 6-8 loudspeakers

Directionality of the Human Mouth

- A human mouth does not emit sound with equal intensity in all directions
- The lower the frequency the less developed is the reduction of sound intensity by the mouth

Consequences:

- It is more important to support front-to-rear communication
- It might be sufficient to install only „one-way“ intercom systems



average directionality of the human mouth

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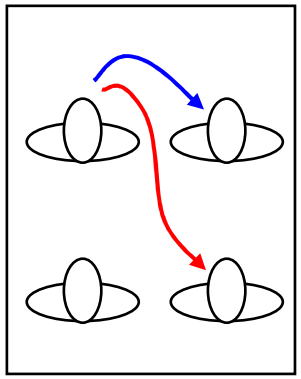
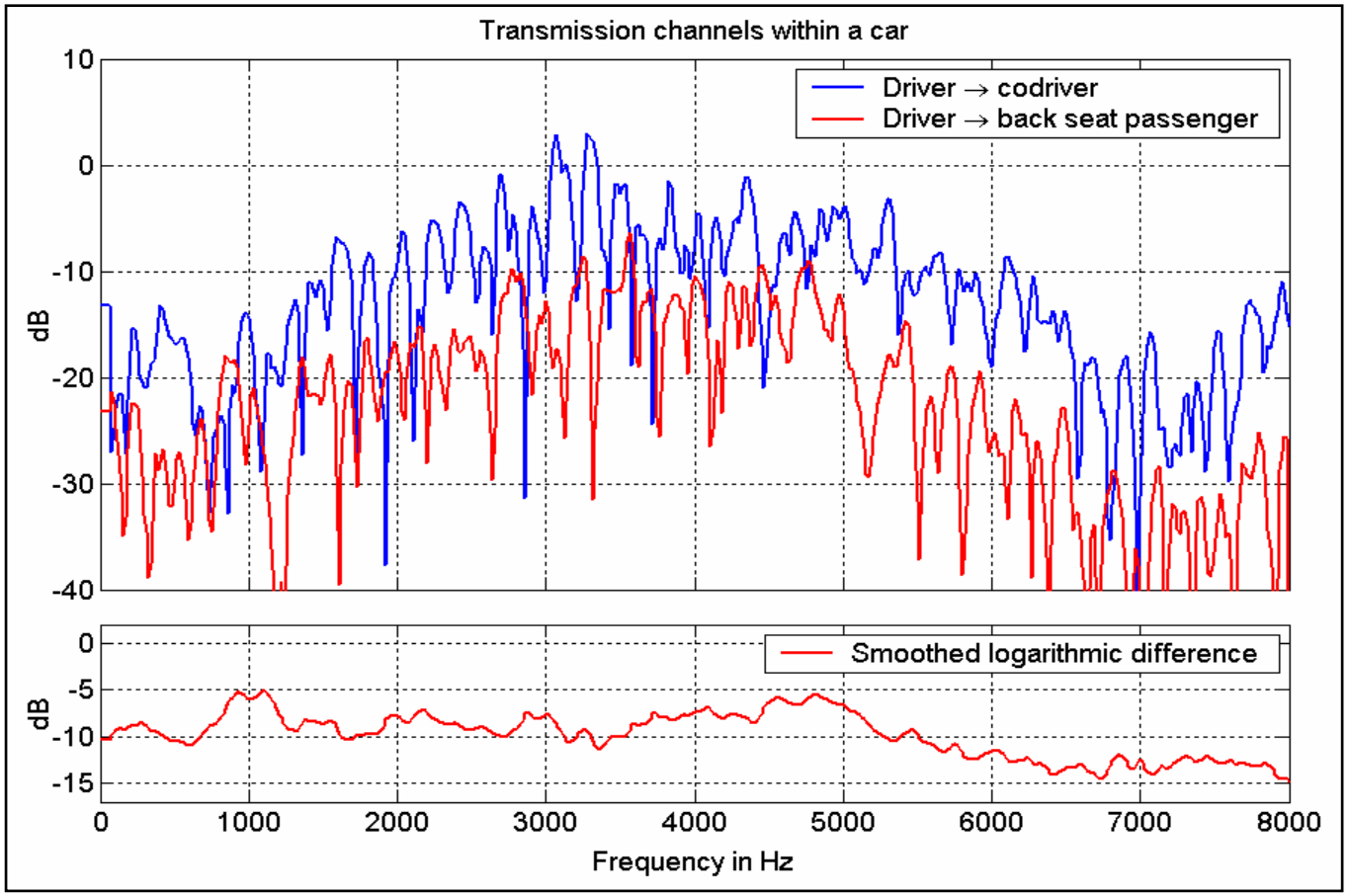
Transfer functions

- Mouth reference point (driver) → Left ear of the front passenger
- Mouth reference point (driver) → Left ear of the passenger behind the front passenger





Acoustic loss referred to the left ear of the front passenger:
5 – 15 dB

System Requirements

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- The speech signal of the driver and the front passenger should be reproduced with high quality and with a minimum system delay by the rear loudspeakers (rear → front vice versa).
- The passengers should not be aware of the system.
- Speaker localization should be preserved by the system.
- System stability has to be guaranteed.
- The in-car communication system has to be realized on existing hardware (e.g. hands-free-system/ speech-dialog-system).

Problems in a Real System

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- At medium to large output gain the acoustic situations starts becoming „diffuse“, i.e. spatial localization is not possible any more.
- At large output gain visual and acoustic sensation do not fit any more (driver is visually located in front of the rear passengers but acoustically behind the rear passengers) – very irritating for a few people.
- At very large output gains the system will become instable (without signal processing).
- In case of too large system delay the signals sound reverberant („bathroom atmosphere“) and the speaking passengers will be aware of their own echo.

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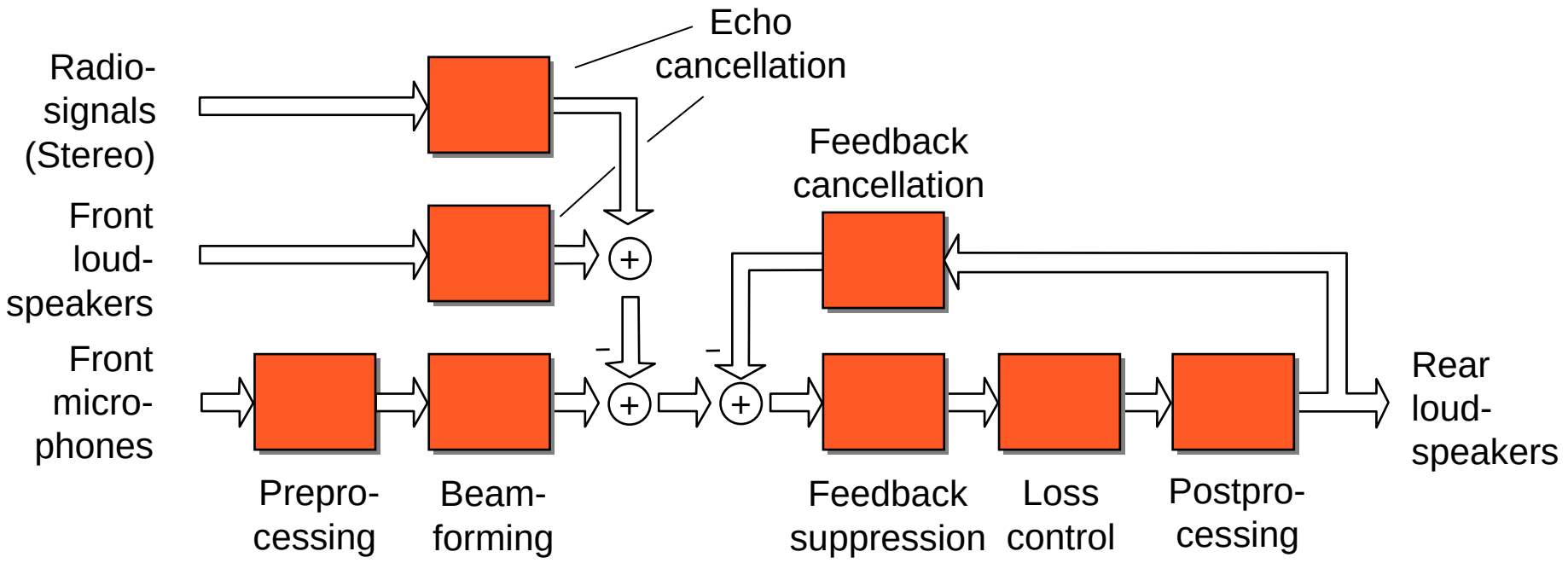
Algorithmic Structure for Direction Front → Rear:



Problems and Challenges:

- Stability
- System delay
- Correlation of excitation and distortion

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Subjective Evaluation Methods

- Speech Quality Tests (Comparative Mean Opinion Score Tests CMOS)
- Speech Intelligibility Tests (Diagnostic and Modified Rhyme Tests DRT/ MRT)

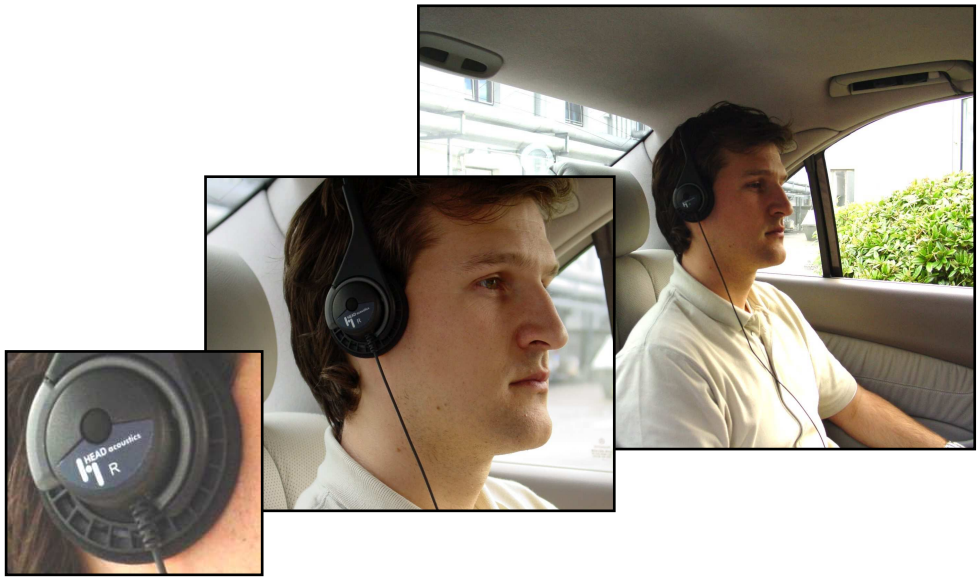
Objective Evaluation Methods

- System Gain
- Frequency Response Evaluation
- Impulse Response Evaluation

Subjective Evaluation

- Prerecorded speech examples with different Lombard levels were played back via an artificial mouth

- Binaural recordings were made by means of a HEAD acoustics NoiseBook on the seat behind the driver



Driving Scenarios

- 0km/h beside motorway
- 130km/h on motorway

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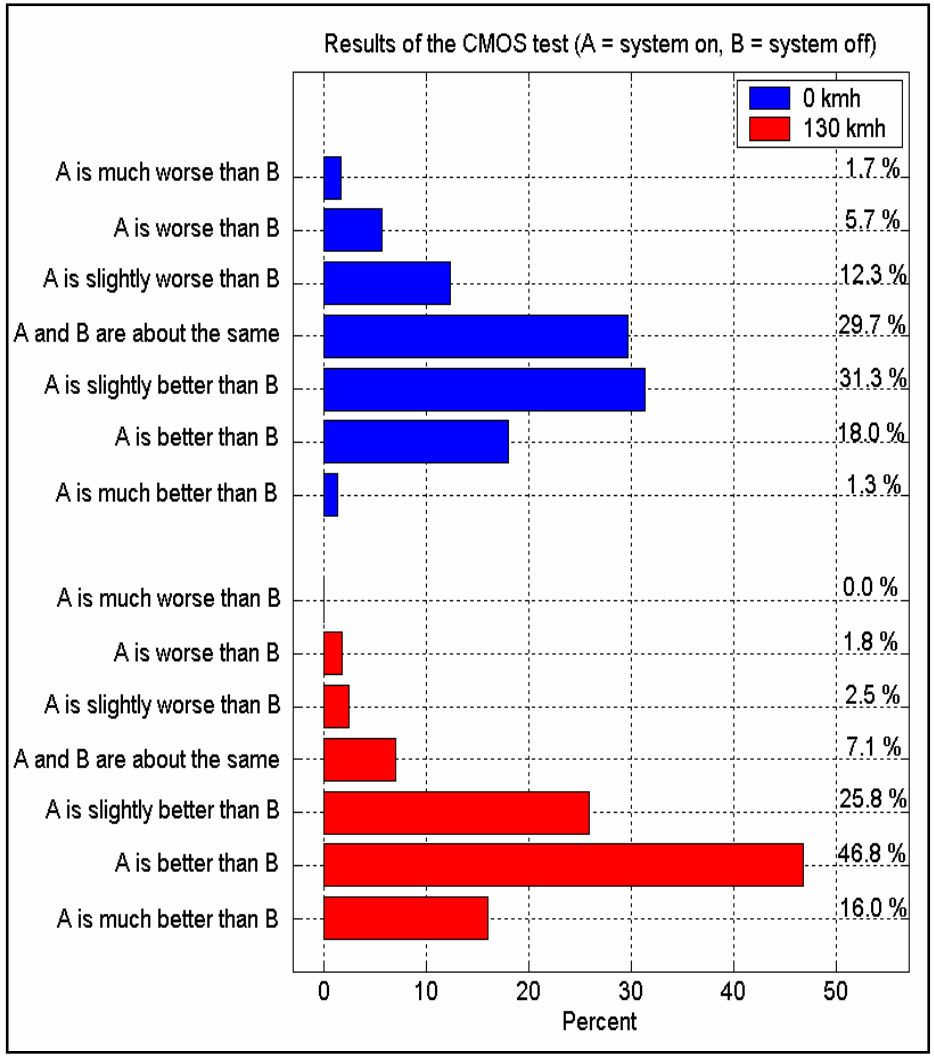
Results of the Comparison Mean Opinion Score (CMOS) Test (25 signal pairs for each driving situation / 15 listeners per scenario):

0 km/h, vehicle parked close to a motorway:

- 19.7 % prefer the system to be switched off
- 29.7 % have no preference
- 50.6 % prefer an activated system

130 km/h, motorway:

- 4.3 % prefer the system to be switched off
- 7.1 % have no preference
- 88.6 % prefer an activated system



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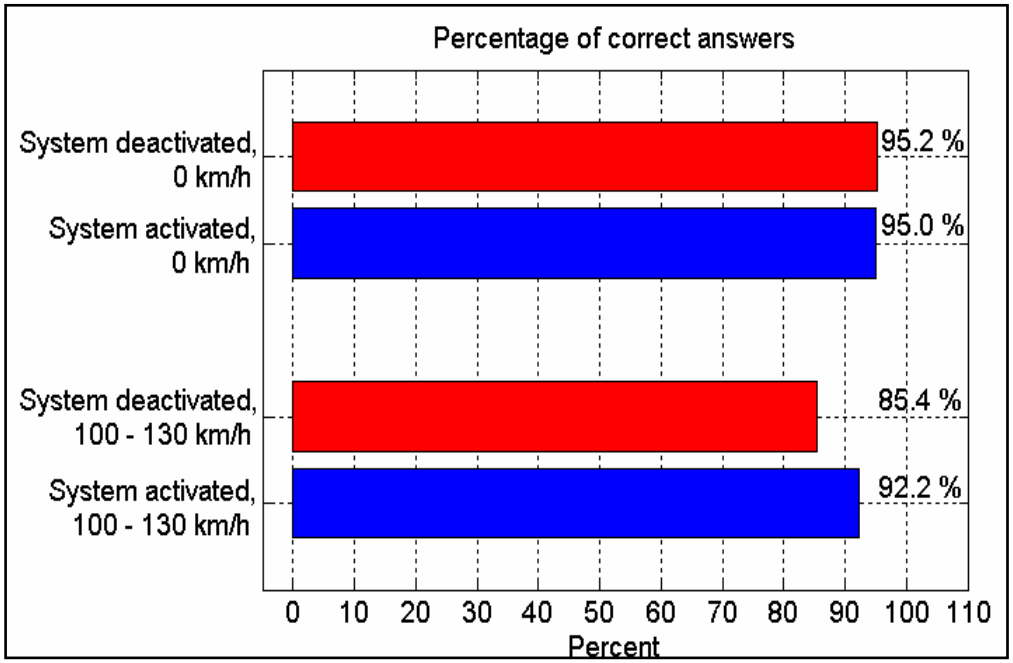
Results of Modified Rhyme Tests (MRT) (48 utterances were presented to each listener per driving situation):

0 km/h, vehicle parked close to a motorway:

- No significant difference (95.2 % system off versus 95.0 % system on)
- Due to the automatic gain adjustment the intercom system operates with only very small gain at these noise levels

130 km/h, motorway:

- Significant improvement of the MRT error rate
- Nearly 50 % error reduction (85.4 % correct answers increased to 92.2 % correct answers)



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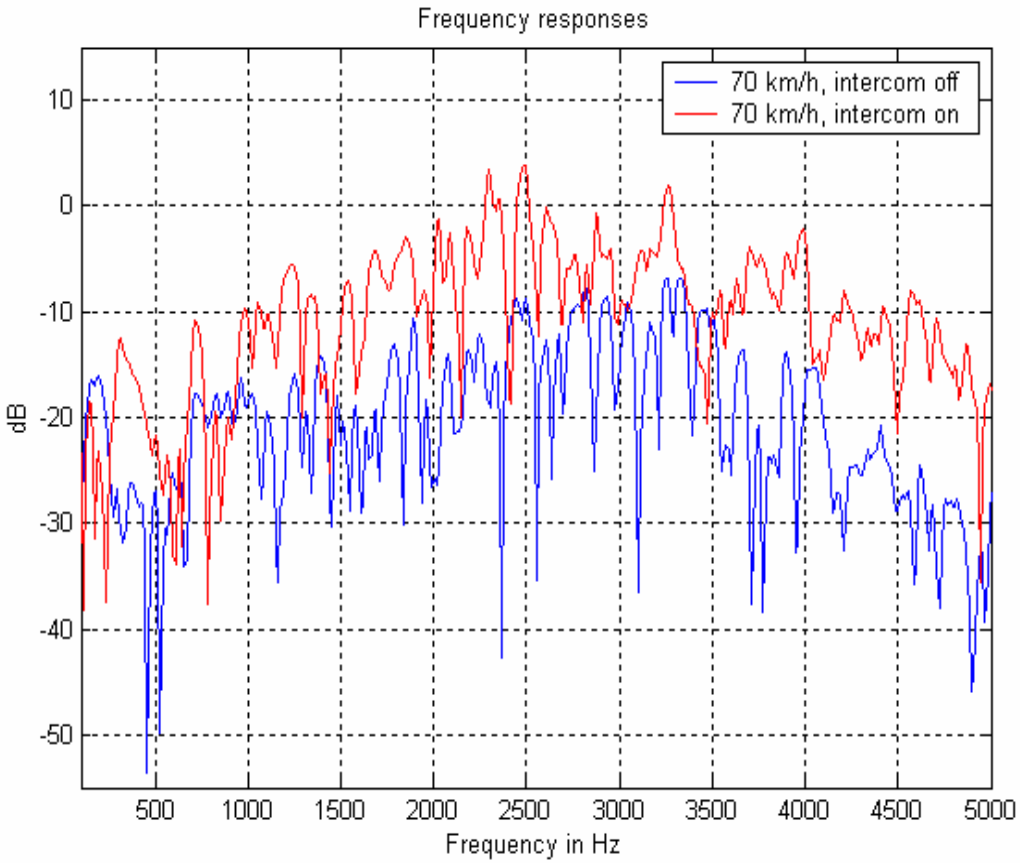
Measuring of the frequency response with deactivated and activated intercom using two artificial heads:

- Evaluation of system gain in dependence of the frequency
- Measurement should be performed at different driving speeds
- Requires the possibility to activate and deactivate the intercom system



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Detection of audible echoes by means of the measured frequency response between MRP and ear of the driver

- Speaking person might be annoyed by listening to echo components
- The later the echoes arrive the more annoying they are
- Audible echoes can be detected by comparing the slope of the impulse response with predefined thresholds