ACOUSTICS2008/2977

# Automotive tire/road sound quality

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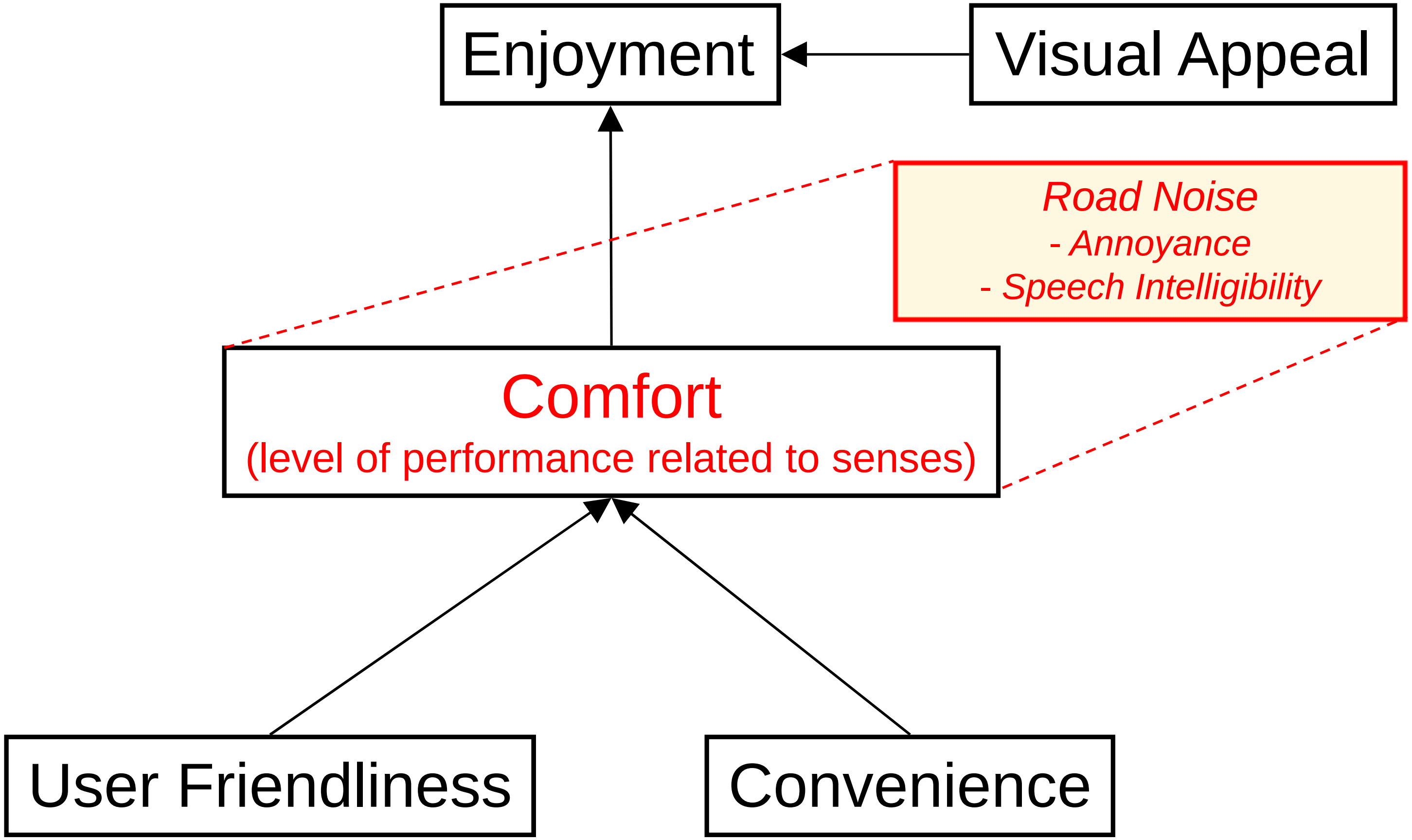
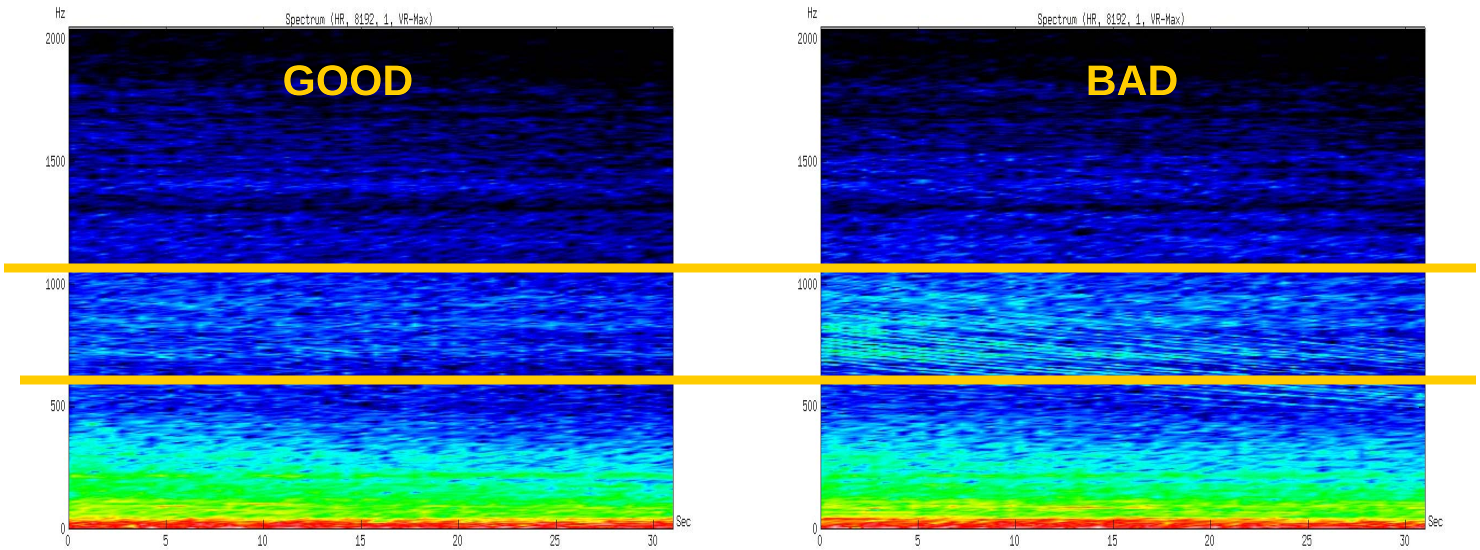
# Vehicle Harmony Elements

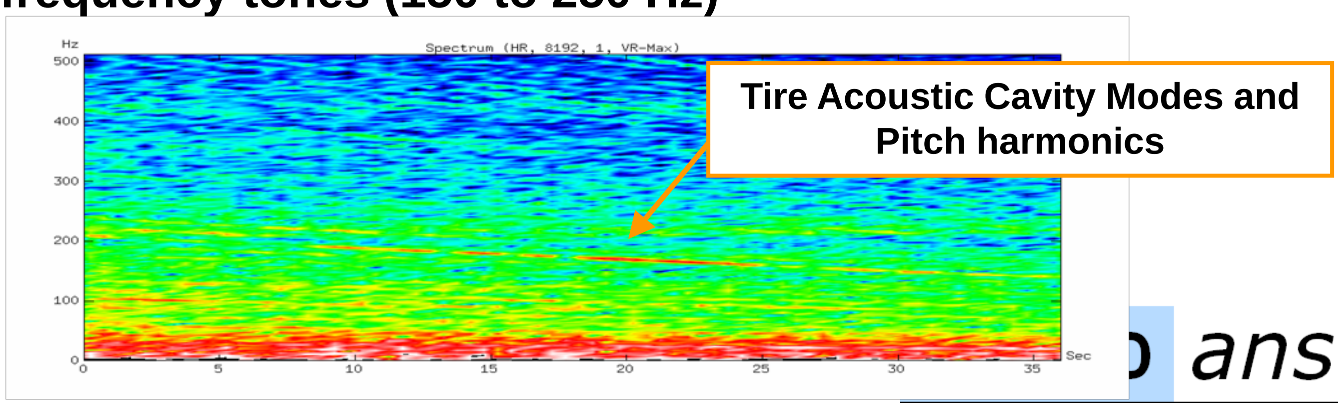


# PERCEPTION of ROAD NOISE

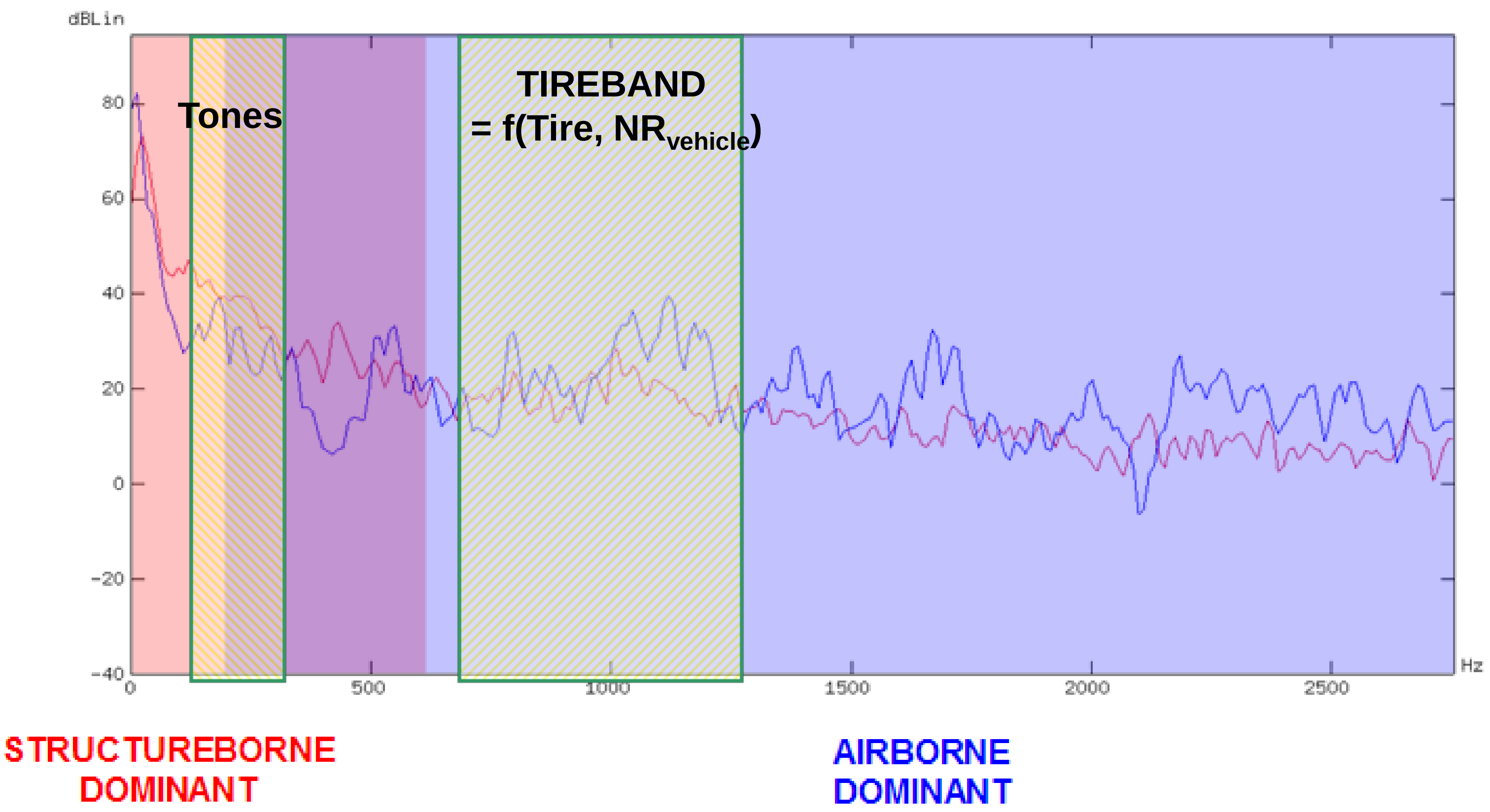
## 1) 600 to 1200 Hz range (Tire band)




## 2) Low-frequency tones (150 to 250 Hz)



# Road Noise Contributions

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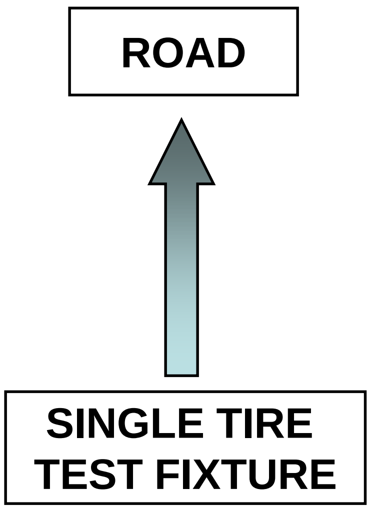
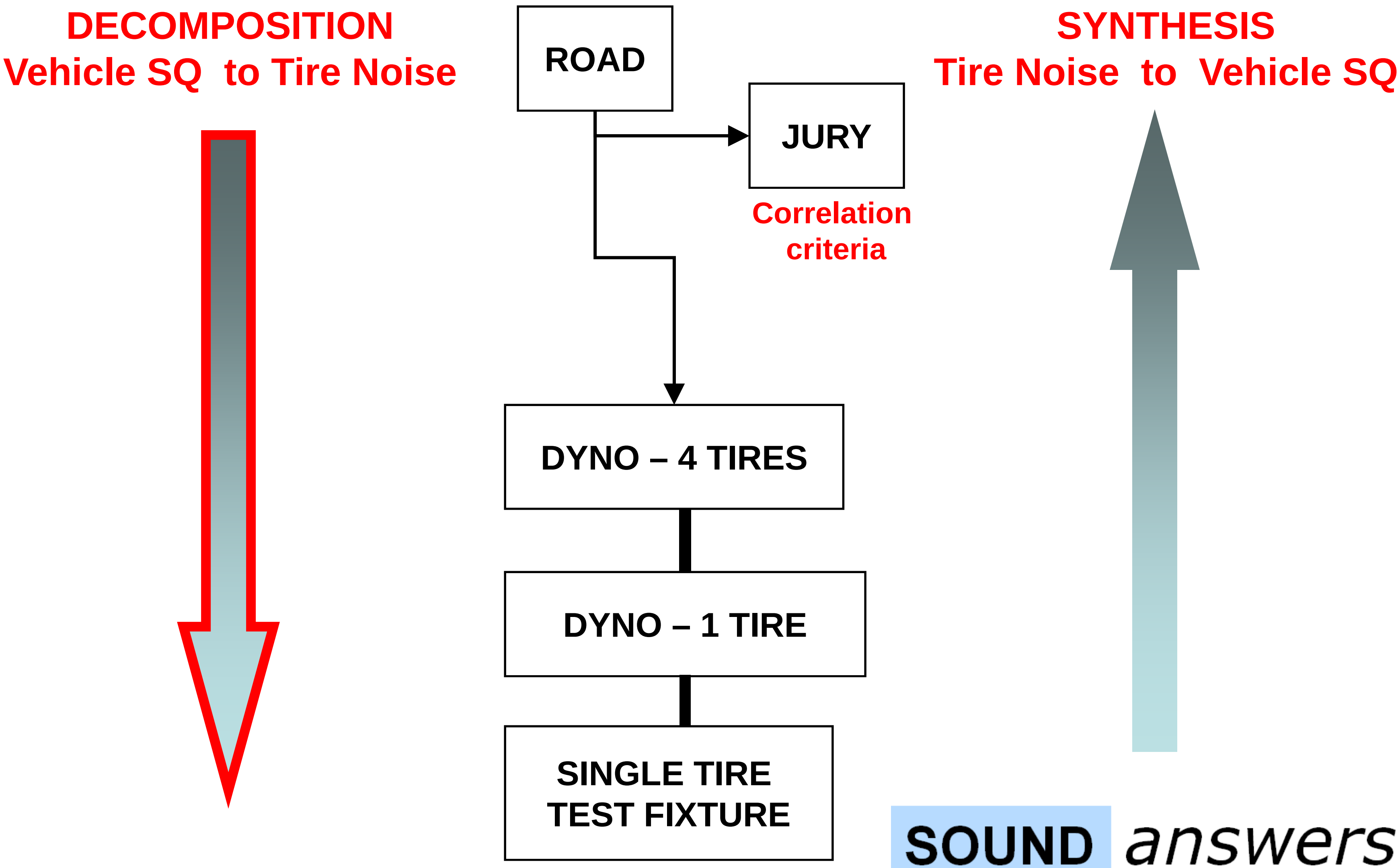
# The perspective of the Aftermarket Tire Manufacturer

- **Background**
  - Current component test does not correlate to on-road SQ evaluation of tire noise (detectability/annoyance)
  - Vehicle not always available to tire OEM
- **Need**
  - Improved tire-only test that can be used to predict  on-the-road SQ rating of set of tires
- **Solution**

**SYNTHESIS**
**Tire-to-vehicle**
**(vehicle class-specific)**



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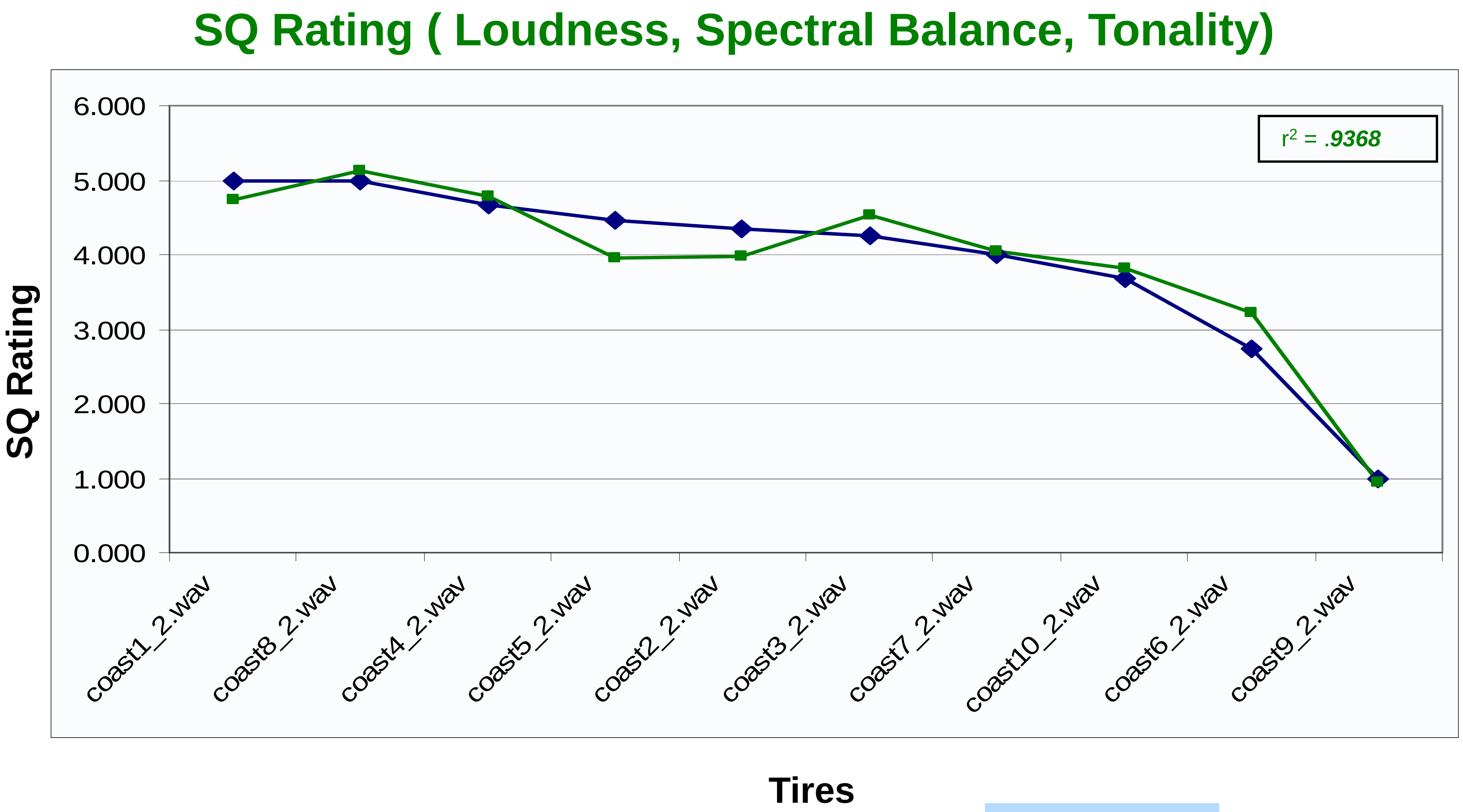
# ROAD NOISE ANNOYANCE/DETECTABILITY METRIC

$R^2$

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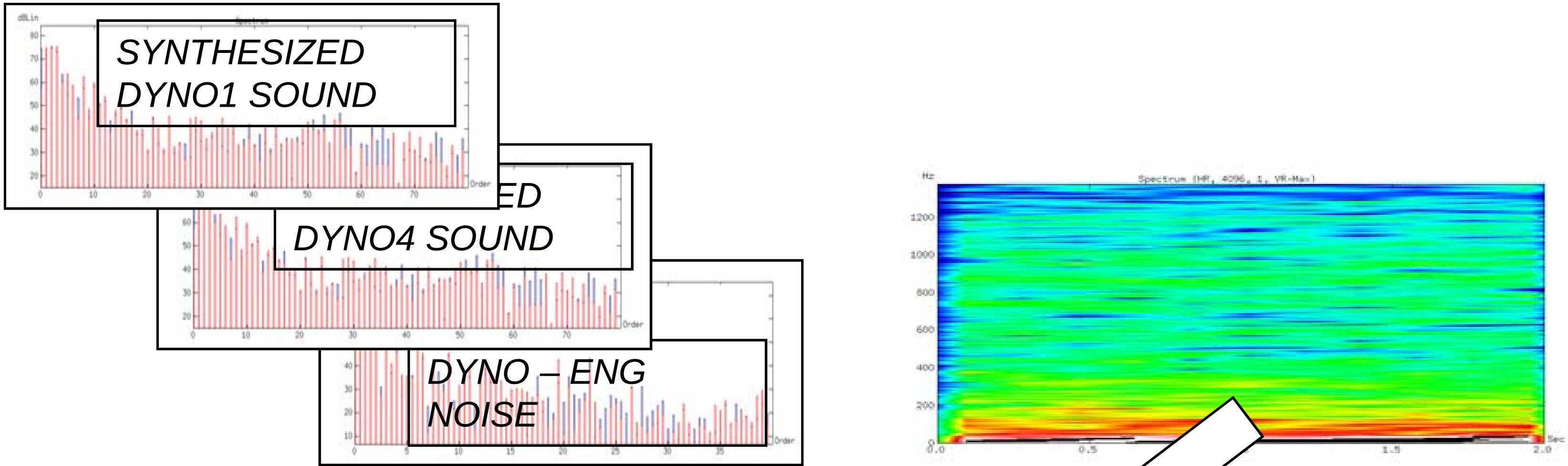
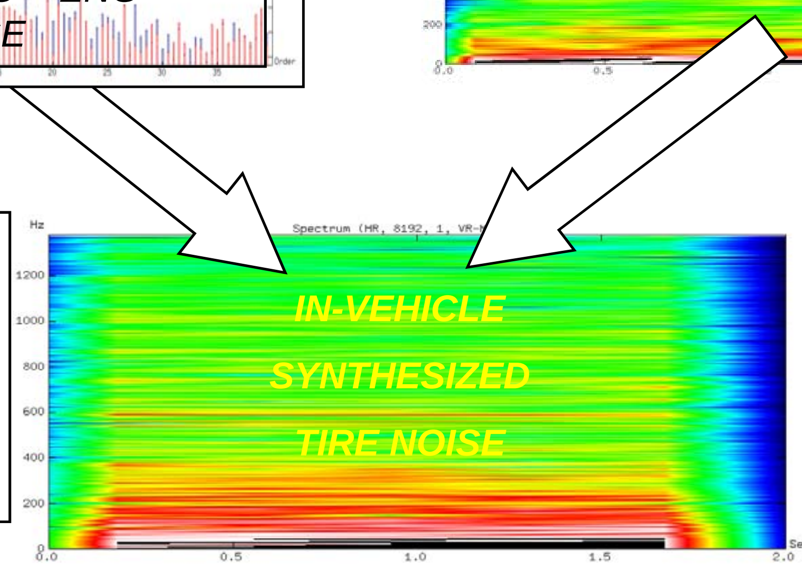
# DYNO TO ROAD SYNTHESIS




**The final step in the synthesis process is to add in the original parts produced during decomposition**

# The perspective of the Vehicle Manufacturer

- **Background**
  - Vehicle not competitive for Road noise
- **Need**
  - Reduce in-vehicle contribution from tire inputs
  - Improve speech intelligibility between front and rear seats
- **Solution**
  - Developed countermeasures for road noise
  - Developed separate targets for:
    - road noise
    - speech transmission in lab (using Loudness inputs to RASTI calculation)

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# Forms of Speech Corruption

- **Masking**

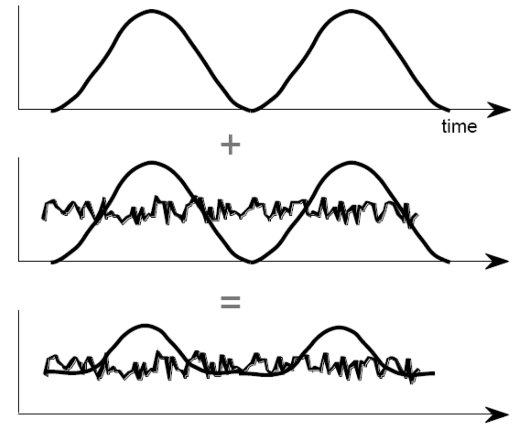
**Noise from all external sources (tires, powertrain, wind) coming to the cabin interior from all paths (structure- and airborne)**

*Tests on the road*

*Original modulation*

*Corruption by background noise*

*Resulting lower modulation at listener*




- **Reverberation**

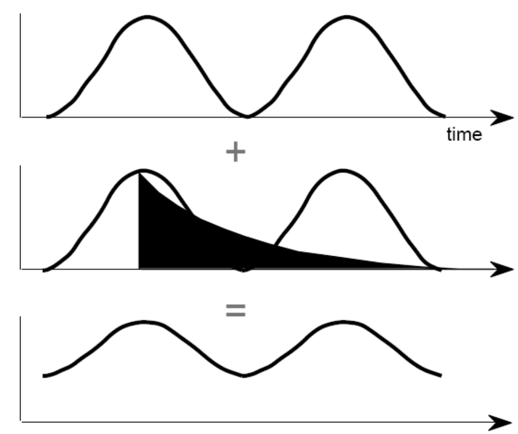
**Depends on the absorption of the interior acoustic package**

*Tests in the lab following RASTI procedure*

*Original modulation*

*Corruption by reverberation*

*Resulting lower modulation at listener*

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# Measures of Speech Intelligibility

- Articulation Index (AI)
  - uses third-octave band levels (from 160 to 6300 Hz) of background noise spectrum, each weighed by a factor which is minimum at the extremes of the frequency range and maximum at 1600Hz m ***-> depends on background noise only***
- Speech Transmission Index (STI) and Room Acoustics Transmission Index (RASTI)
  - Speech is simulated by a repeatable, synthesized signal which has the same characteristics of speech with regard to intelligibility (i.e., frequency content between 125 Hz and 8kHz and amplitude modulation between 1 and 16 Hz) and measures the loss of modulation from source to receiver ***-> depends on boundary conditions only***

# Speech Intelligibility Investigation

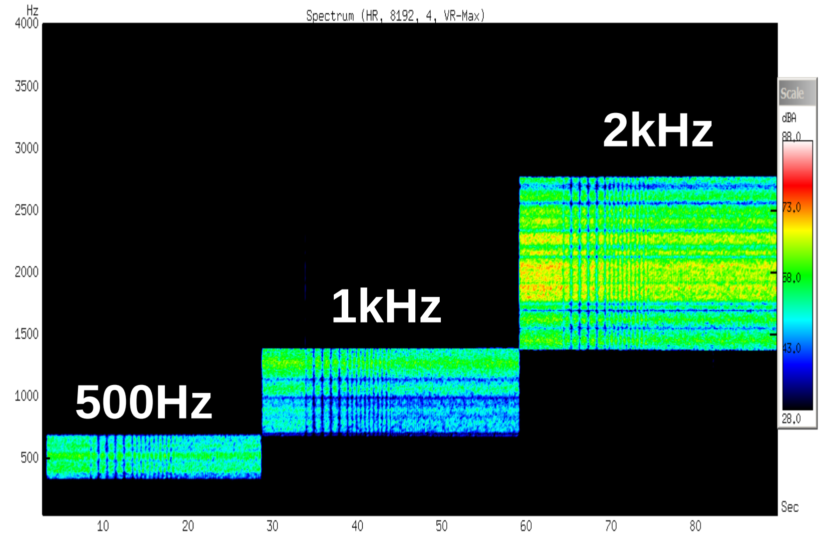
1. On the road:
   - Subjective evaluation in vehicle using pre-recorded sentences played back from “talking heads”
2. In-lab
   - Subjective evaluation of played back sentences recorded on the road
   - RASTI-type tests using Loudness inputs

Talking Head in front seat

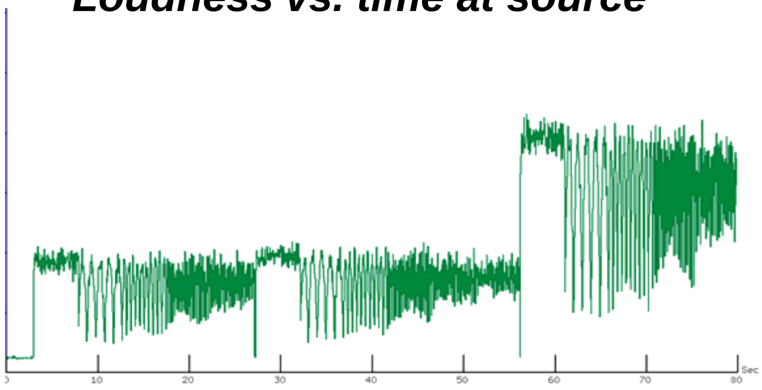
Talking Head in rear seat

# Speech Transmission Index tests in lab

- Subset of RASTI-like signals generated:
  - 500Hz, 1kHz and 2 kHz center frequency bandpassed noise
  - 1, 2, 4 and 8 Hz amplitude modulation
- Signals generated with “talking” head (source) and recorded at other two binaural heads (“receivers”)
- Engine OFF and condition of minimum background noise




***Loudness vs. time at source***

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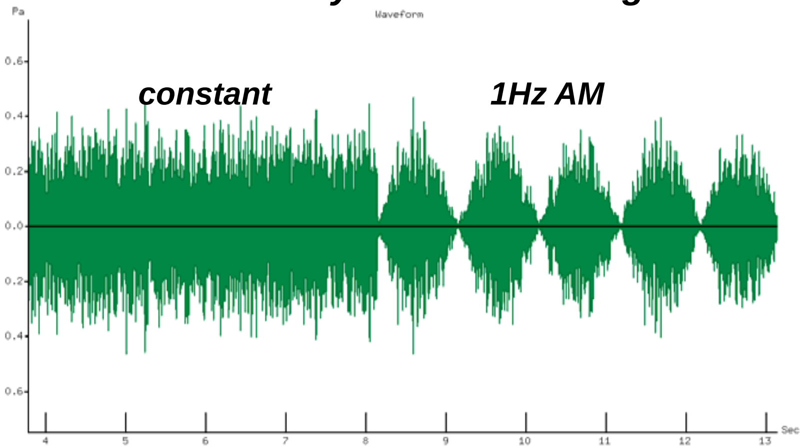
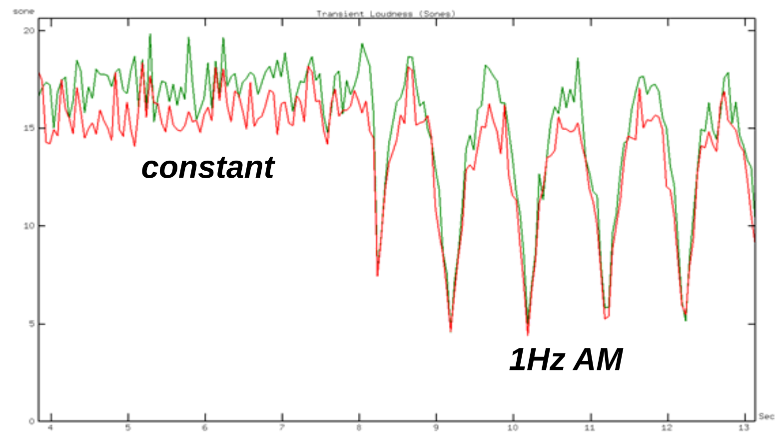
# Loss of Modulation Depth

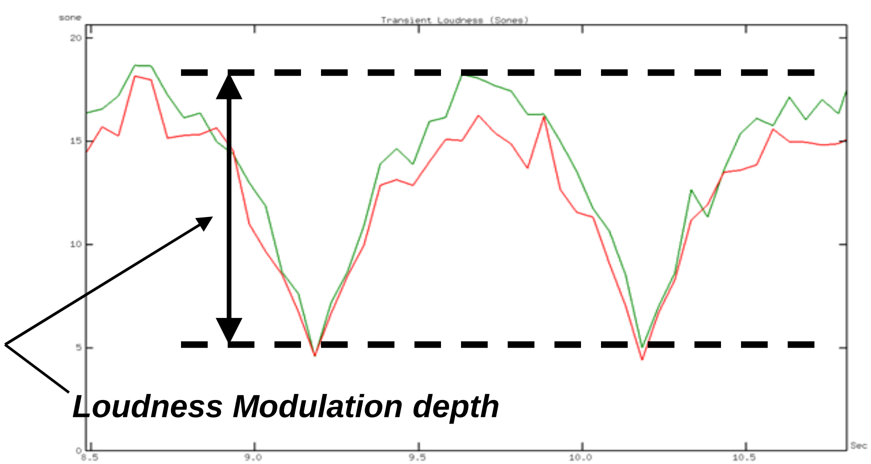
*1. Time history of excitation signal*



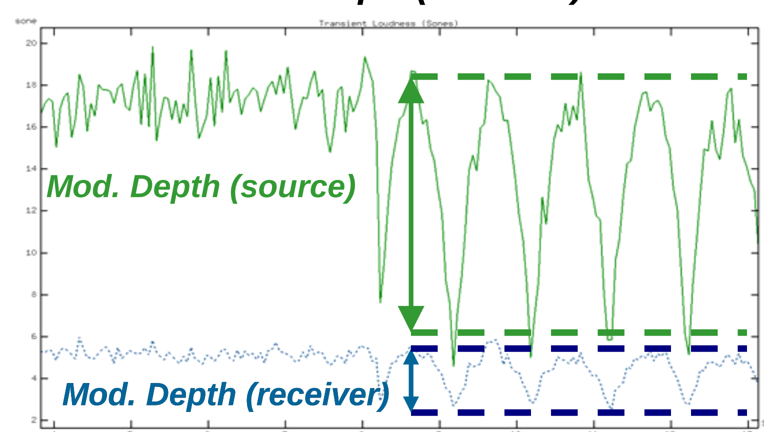

*2. Loudness(t)*




*3. Modulation Depth = Peak-to-Peak of Loudness(t) of AM signal*

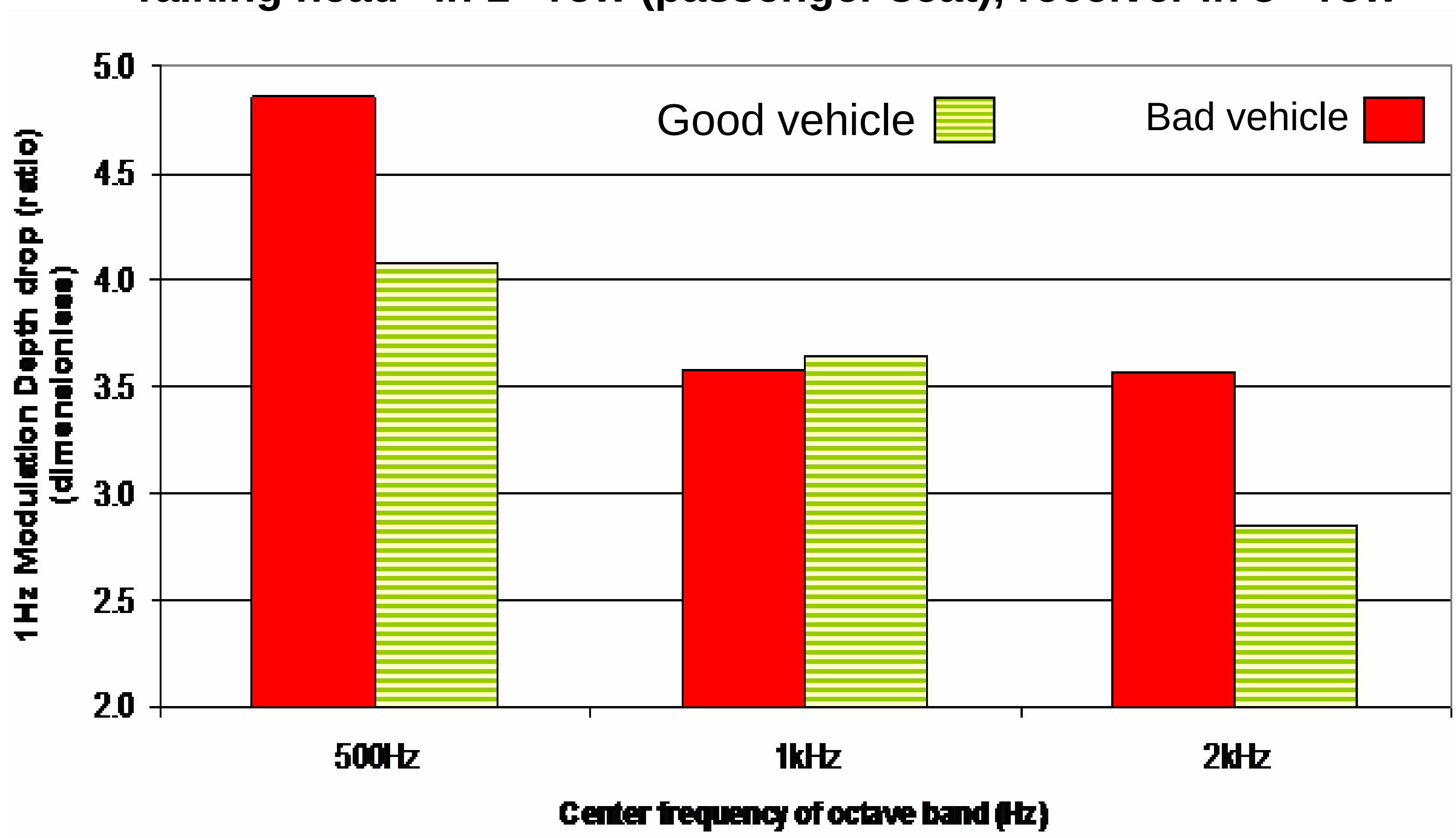



*4. Loss of Modulation = Modulation Depth(source) minus Modulation Depth(receiver)*



# 1 Hz Modulation Depth drop comparison

**“Talking head” in 1st row (passenger seat), receiver in 3rd row**

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# Conclusions

- Noticeable road noise produces:
  - Annoyance
    - Need to reduce contributions of air- and structure-borne paths from the tire
  - Loss of Speech Intelligibility
    - Need to optimize acoustic boundary conditions (reverberation) inside the vehicle
- For the tire manufacturer, the need is to develop a process to predict road noise detectability in-vehicle
- For the vehicle manufacturer, the need is to breakdown the problem in:
  1. noise/vibration transmitted from the tire
  2. reverberation (speech transmission -> speech intelligibility).