



ACOUSTICS2008/2977

Automotive tire/road sound quality

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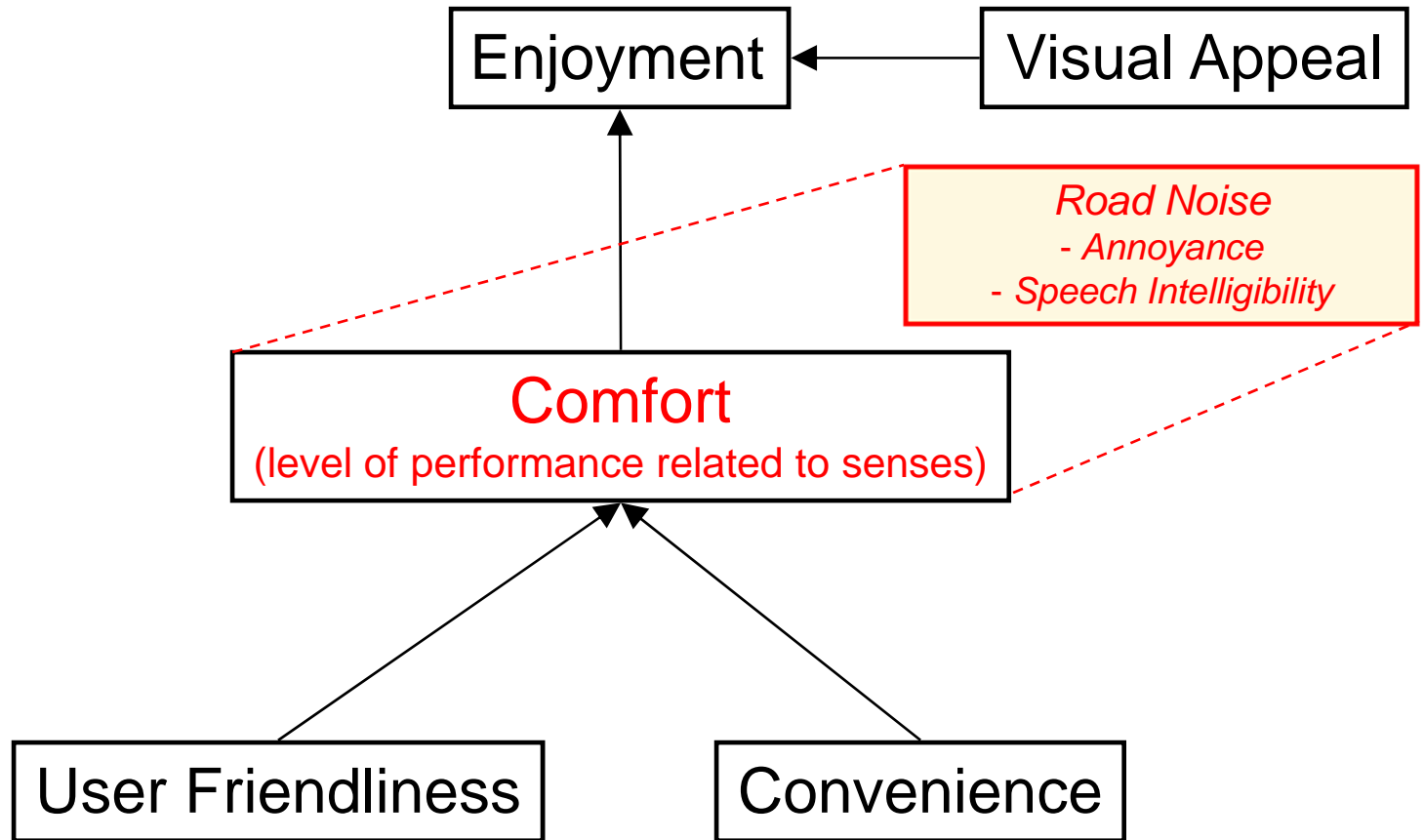
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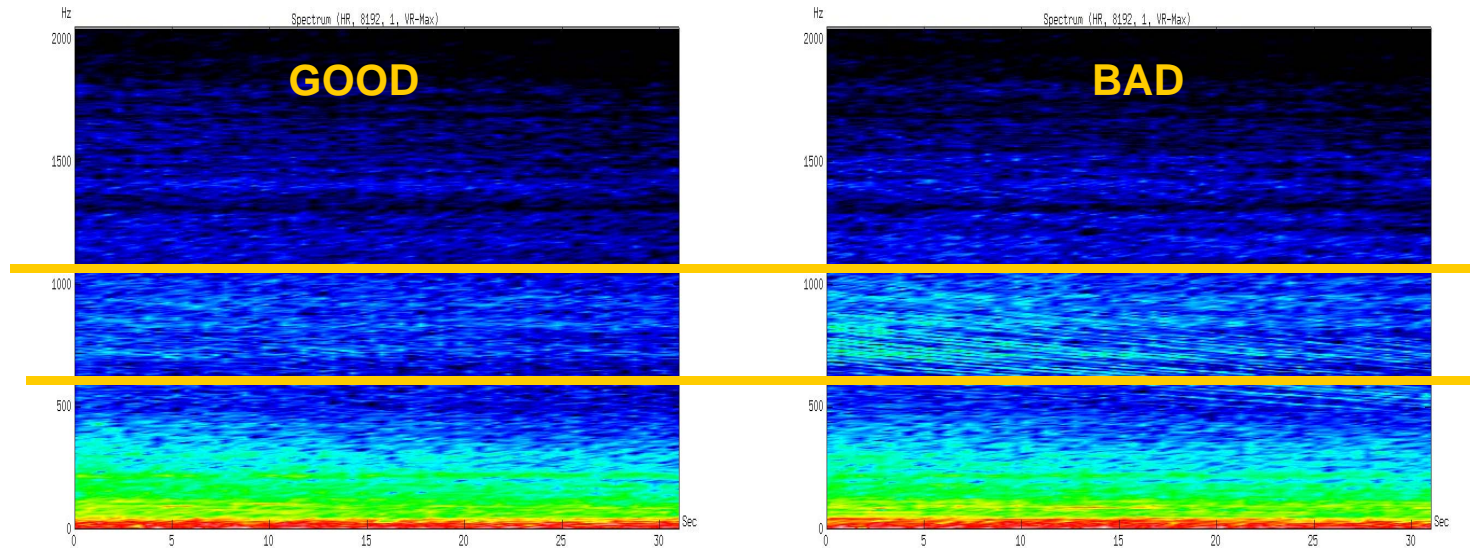
SOUND *answers*

Vehicle Harmony Elements

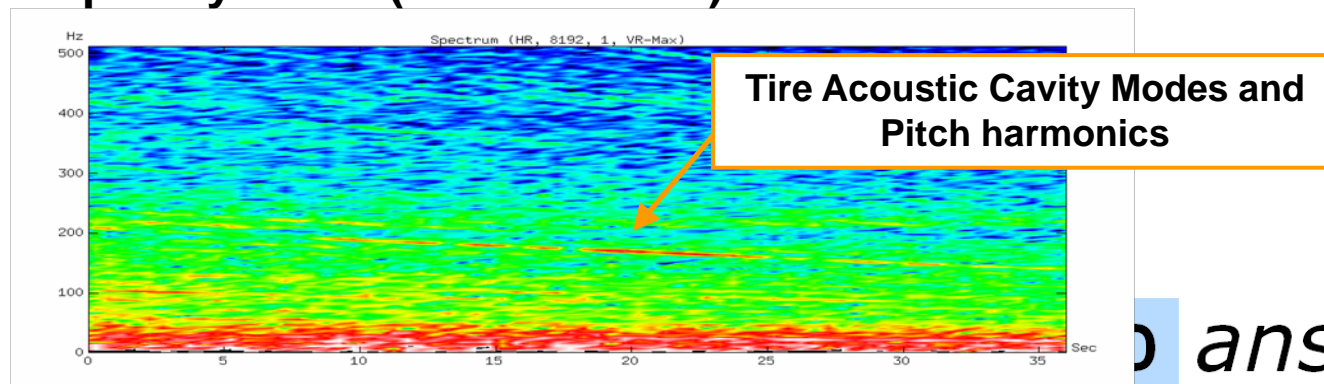


PERCEPTION of ROAD NOISE

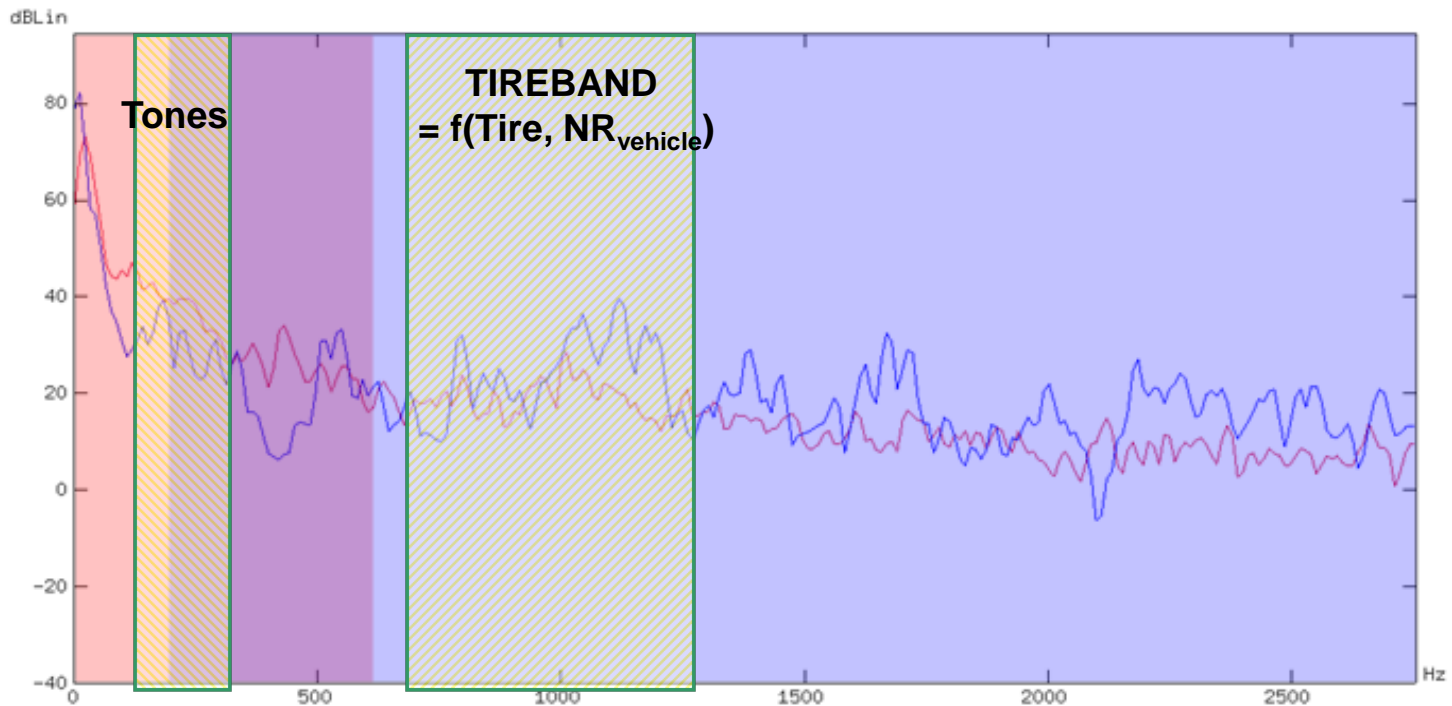
1) 600 to 1200 Hz range (Tire band)



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



Road Noise Contributions



**STRUCTUREBORNE
DOMINANT**

**AIRBORNE
DOMINANT**

The perspective of the Aftermarket Tire Manufacturer

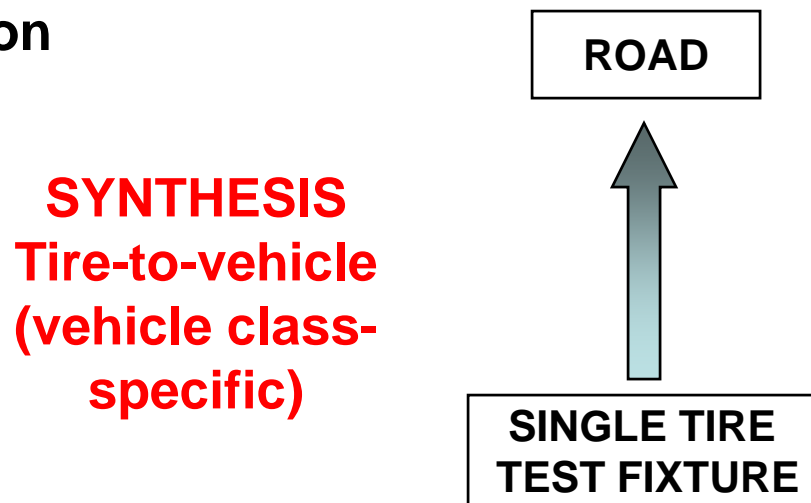
- **Background**

- Current component test does not correlate to on-road SQ evaluation of tire noise (detectability/annoyance)
- Vehicle not always available to tire OEM

- **Need**

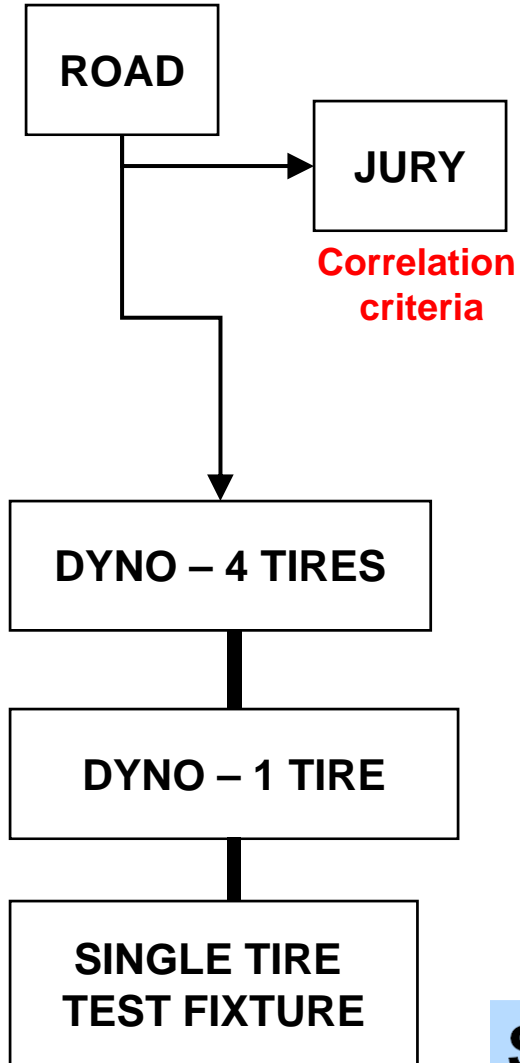
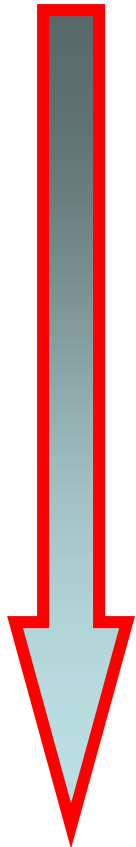
- Improved tire-only test that can be used to predict on-the-road SQ rating of set of tires

- **Solution**



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DECOMPOSITION
Vehicle SQ to Tire Noise



SYNTHESIS
Tire Noise to Vehicle SQ

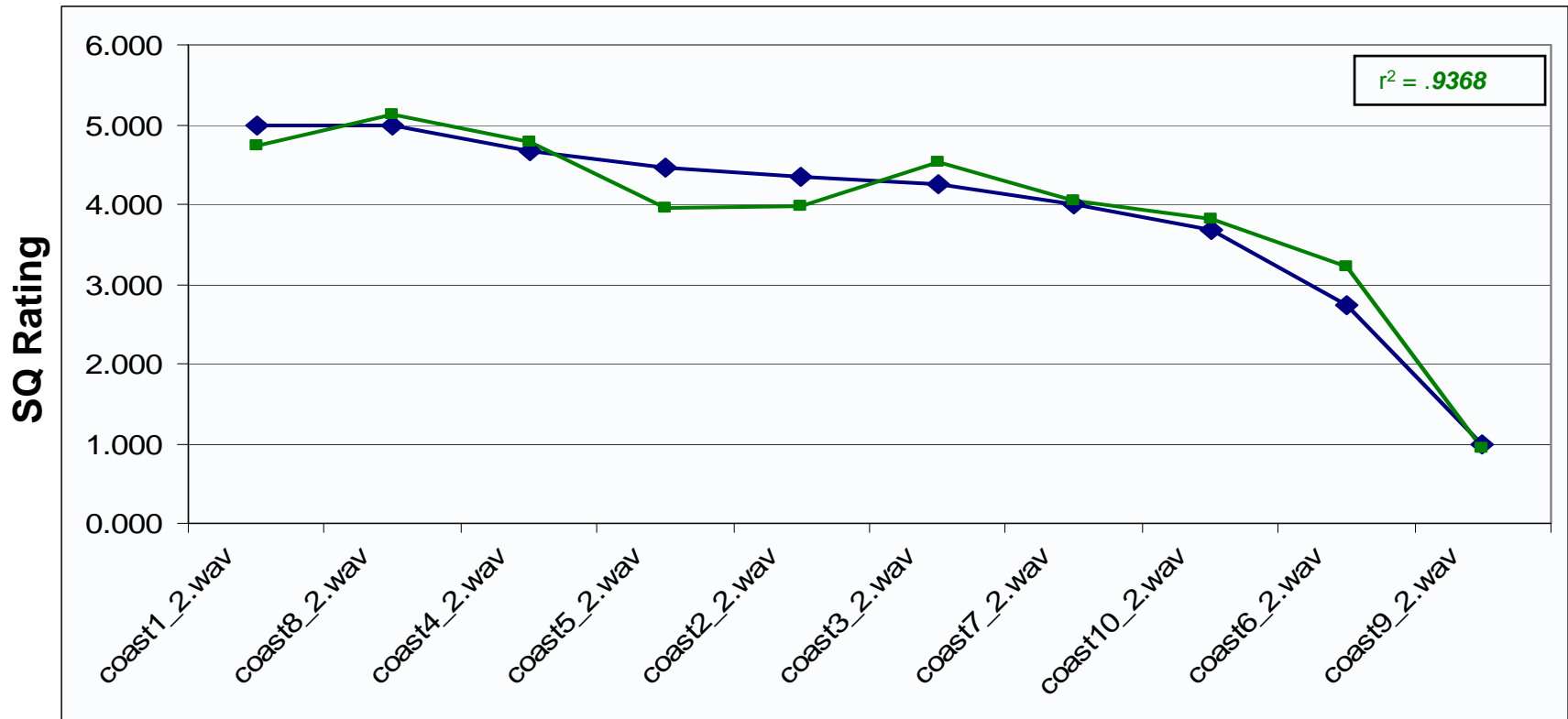


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ROAD NOISE ANNOYANCE/DETECTABILITY METRIC

R²

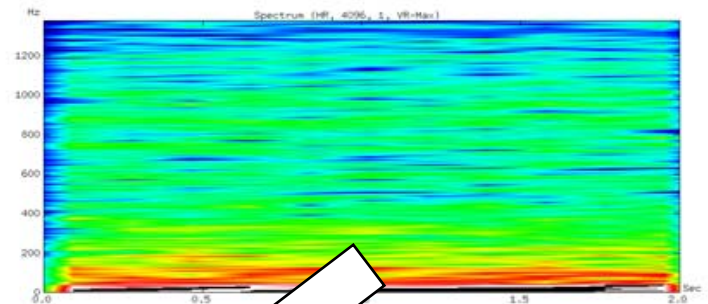
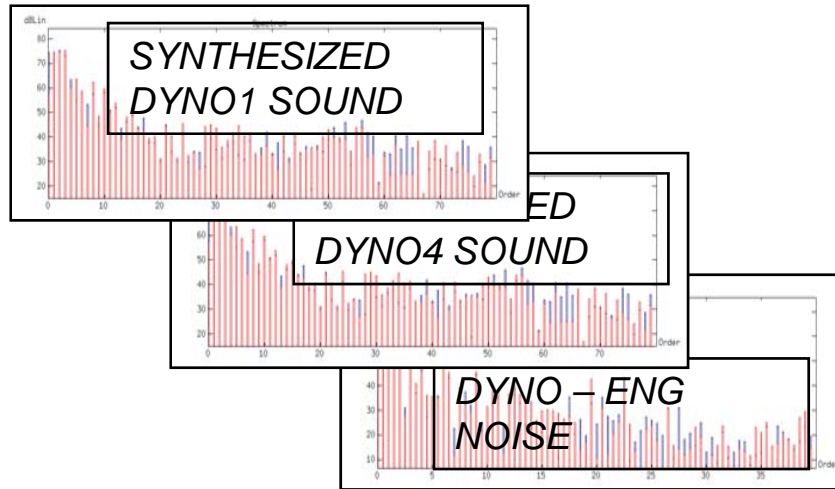
SQ Rating (Loudness, Spectral Balance, Tonality)



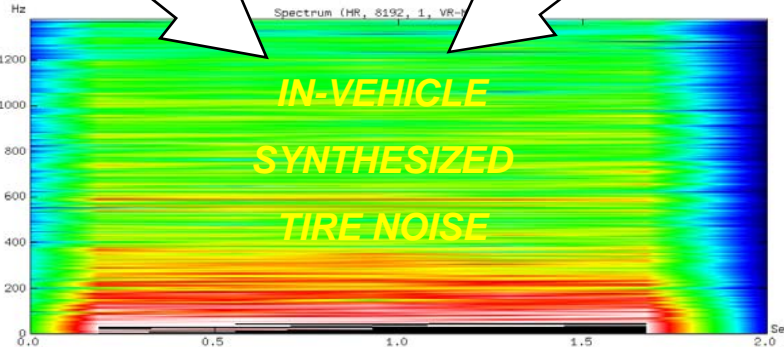
Tires

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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



SOUND *answers*

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)

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

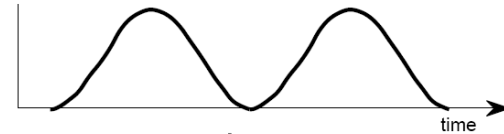
- **Reverberation**

Depends on the absorption of the interior acoustic package

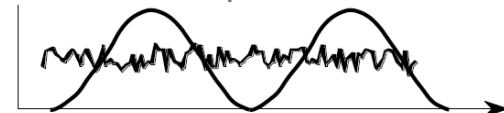


Tests in the lab following RASTI procedure

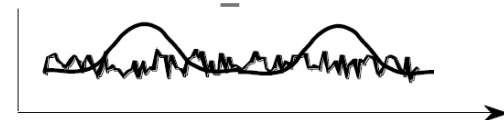
Original modulation



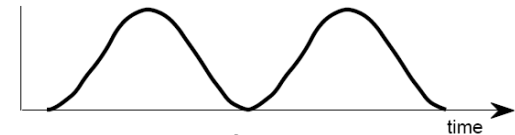
Corruption by background noise



Resulting lower modulation at listener



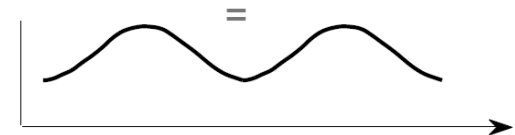
Original modulation



Corruption by reverberation



Resulting lower modulation at listener



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

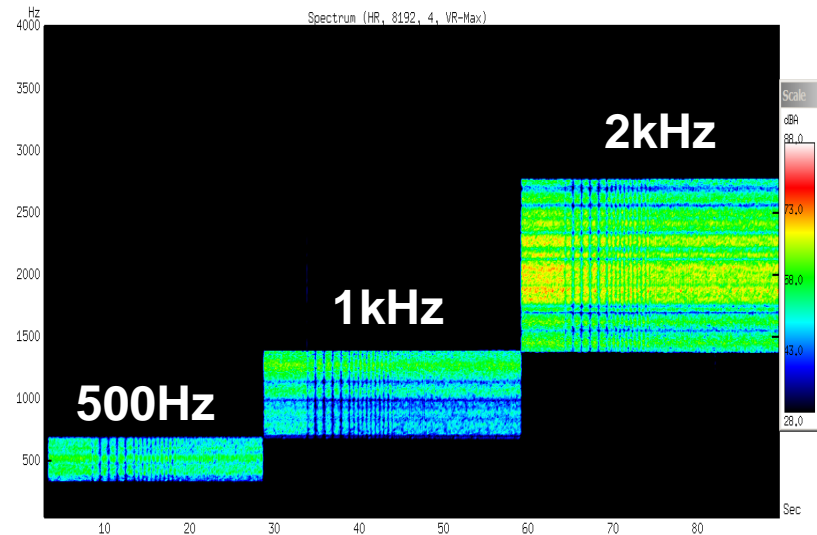


Talking Head in rear seat

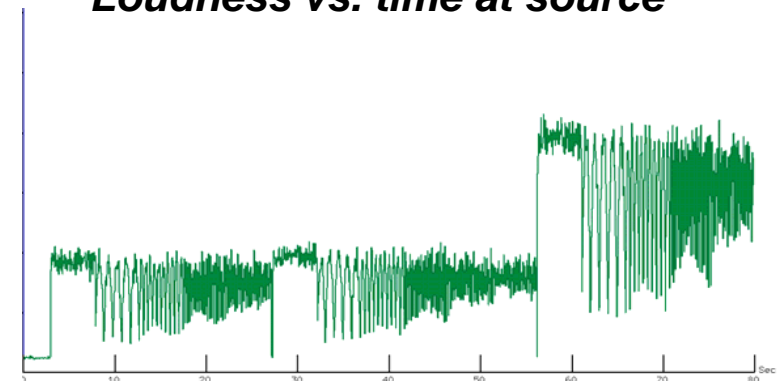


Speech Transmission Index tests in lab

- 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



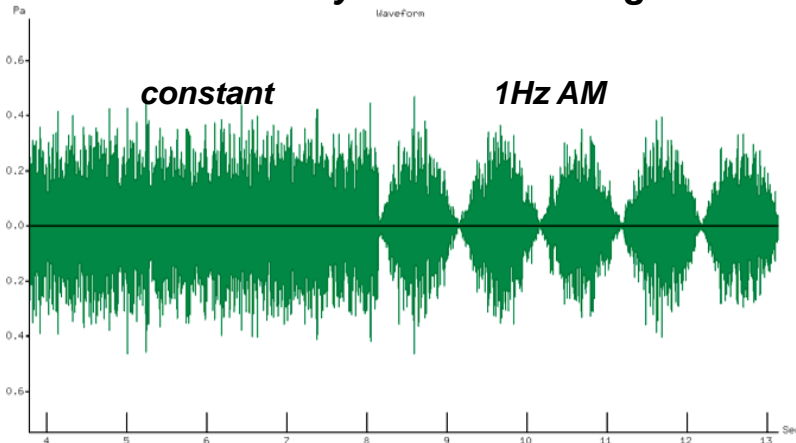
Loudness vs. time at source



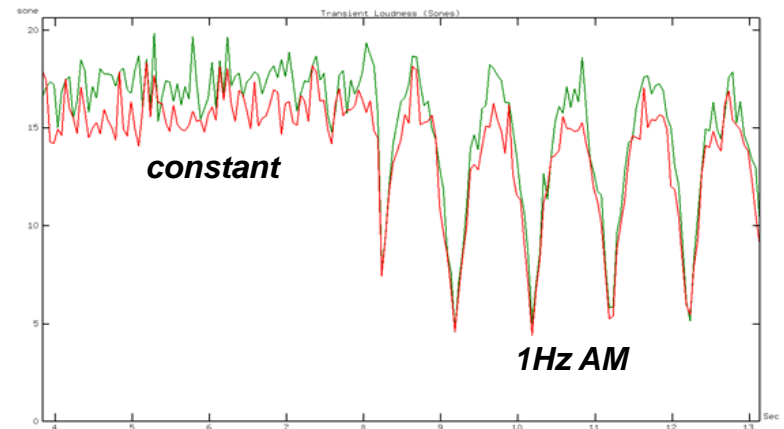
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Loss of Modulation Depth

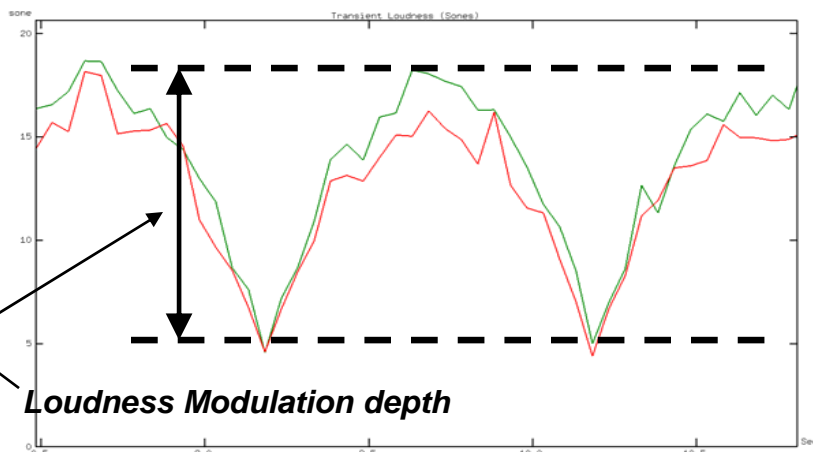
1. Time history of excitation signal



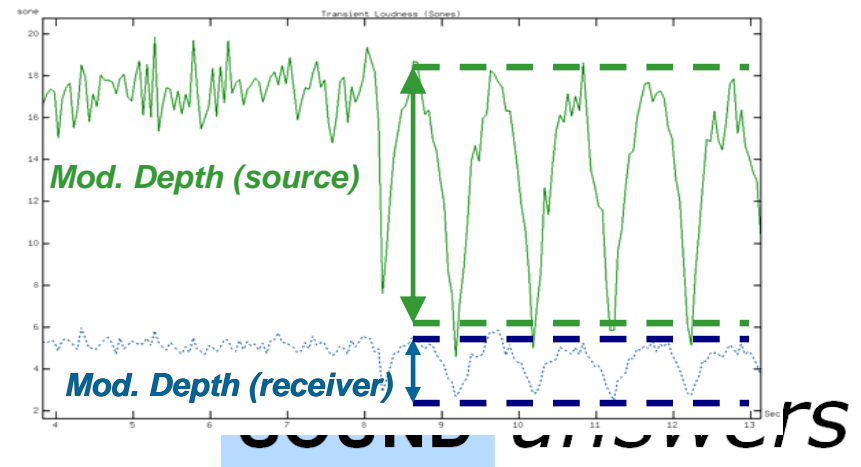
2. Loudness(t)



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

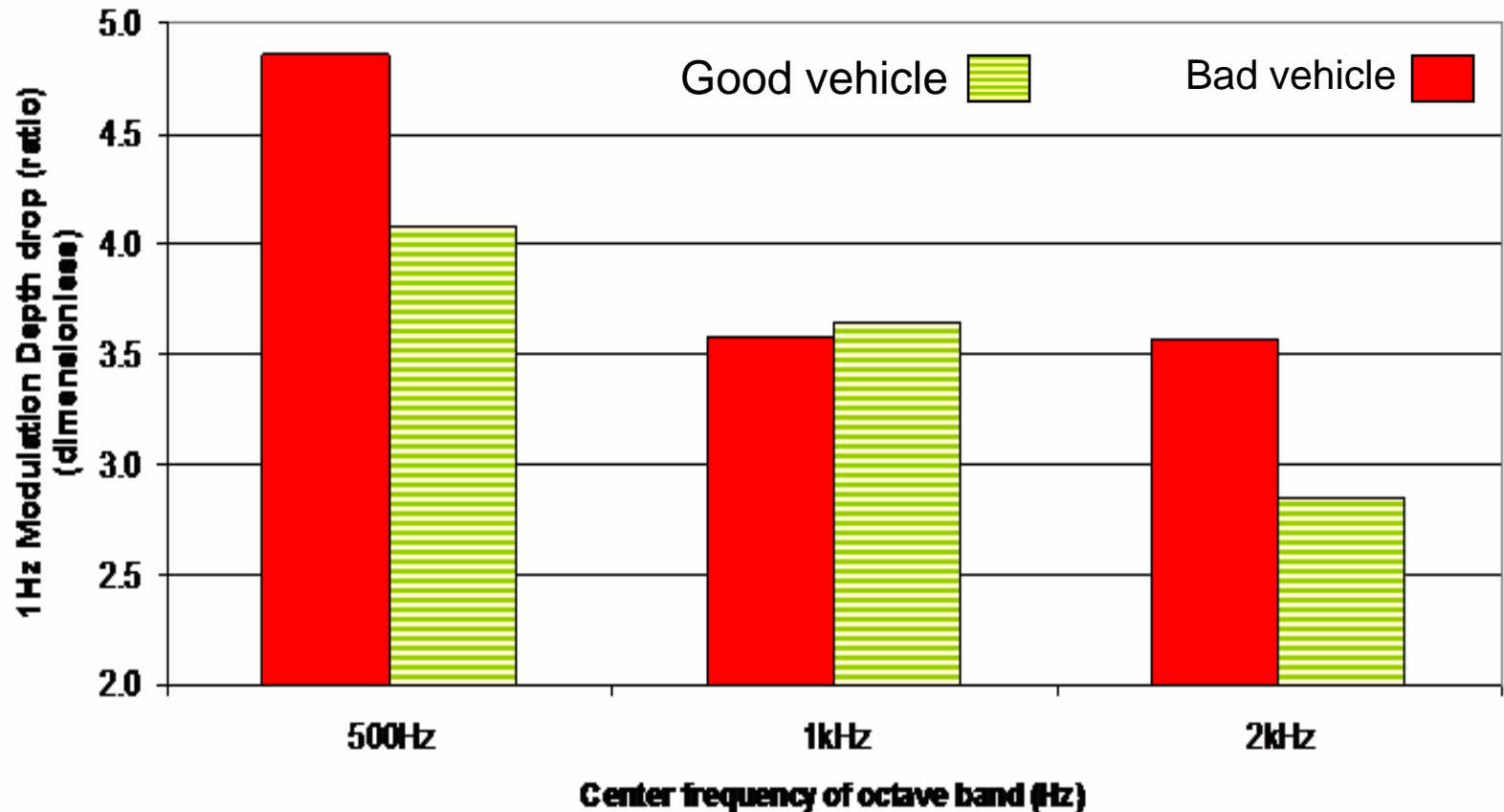


4. Loss of Modulation = Modulation Depth(source) minus Modulation Depth(receiver)



1 Hz Modulation Depth drop comparison

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



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).