Adaptive Road Noise Control

Vehicle Dynamics without Compromise

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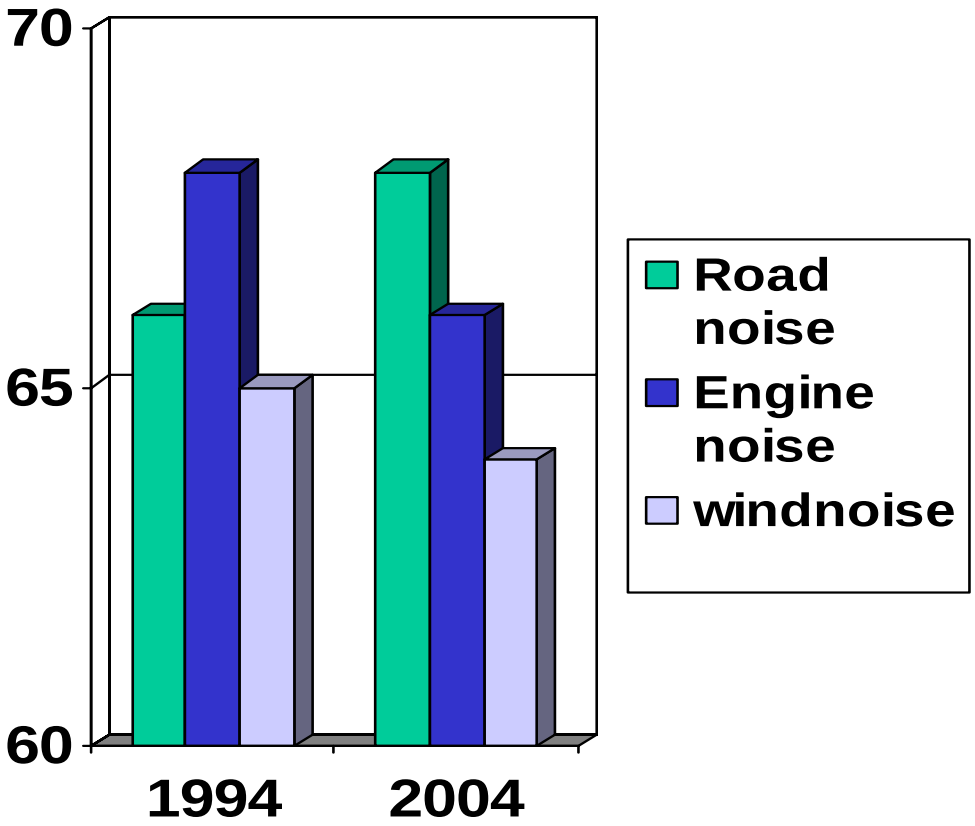
Overview

- Modern vehicle suspensions balance refinement (isolation) and dynamics (control).
- OEM's frequently compromise dynamics to keep refinement acceptable (and vice versa).
- Active noise control (ANC) was developed by Lotus to reduce low frequency noise inside the vehicle cabin by generating an opposing sound field through the audio system.
- Using ANC the level of compromise can be reduced and the vehicle optimised for dynamics with less regard for roadnoise as the NVH problems can be resolved using active technology.

How Sound Balance in cars has changed



Lotus Data – C segment model

- Roadnoise has increased
- Engine noise has decreased
- Windnoise has marginally decreased

- Roadnoise is now dominant sound when cruising.

- Engine noise conveys purpose / power & provides driver feedback for gear change etc..
- Roadnoise is just fatiguing and annoying and has zero purpose or benefit.

Why is Roadnoise increasing?

Universal trend for wider low profile tyres

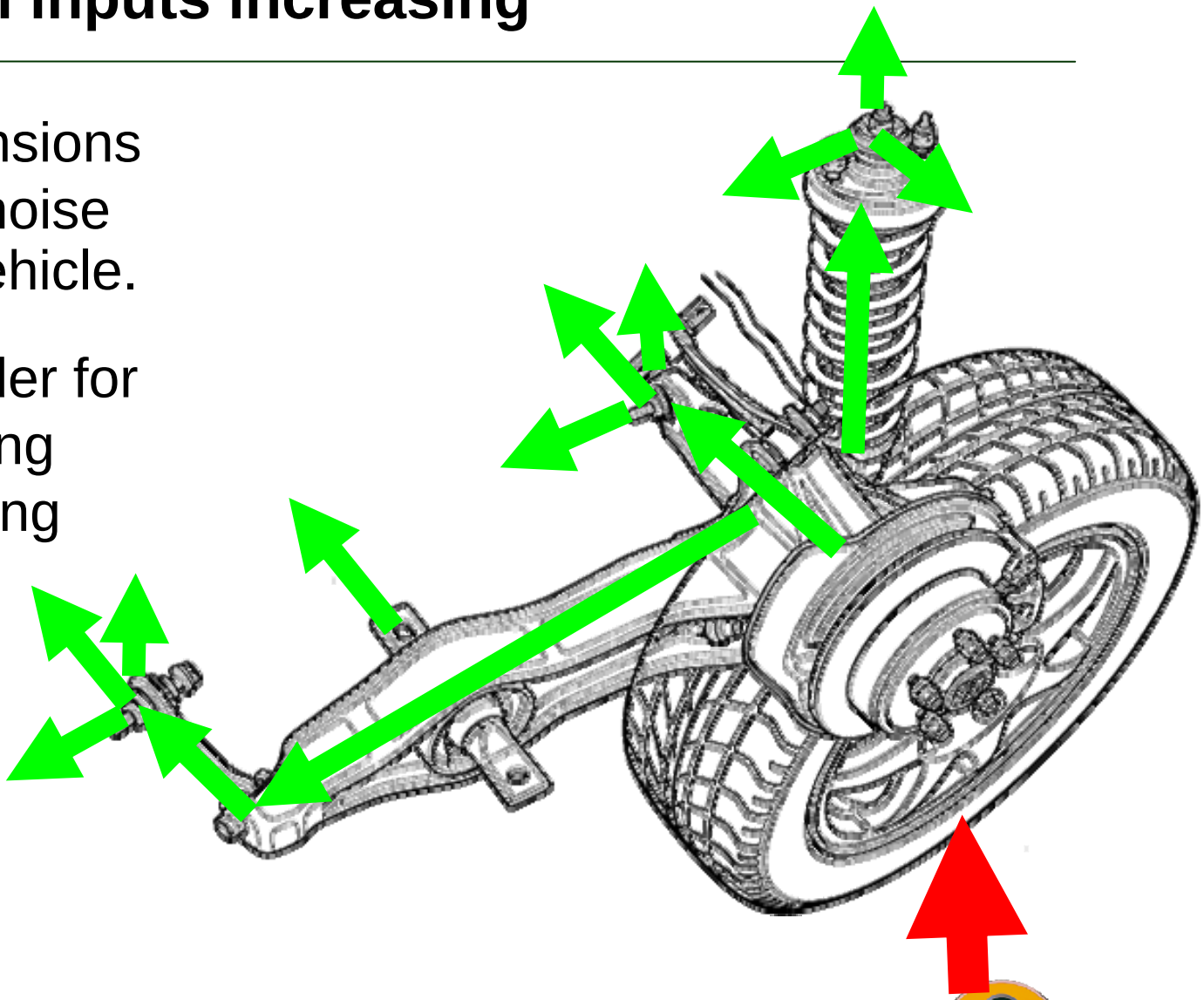
Example of VW Golf

Model	Standard Tyre Size
Volkswagen GOLF II	155/80T13
Volkswagen Golf II. Gti	185/60V14
Volkswagen GOLF III	175/70T13
Volkswagen Golf III. 1.8i GT	185/60H14
Volkswagen GOLF IV	175/80T14
Volkswagen Golf IV. 1.8 GTi	195/65V15
Volkswagen GOLF V	195/65H15
Volkswagen Golf V. GTi	225/45W17

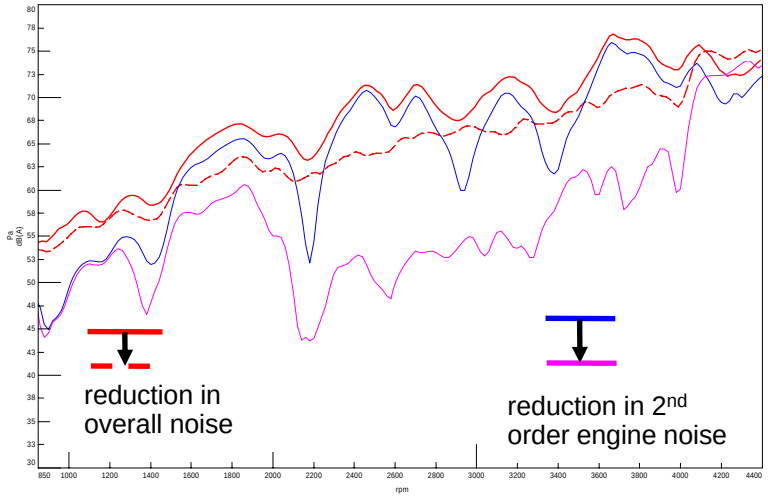
Suspension inputs increasing

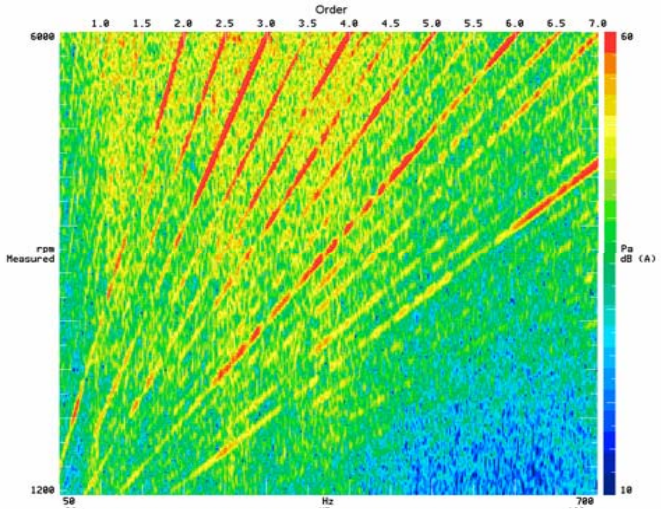
Multi link suspensions create multiple noise paths into the vehicle.

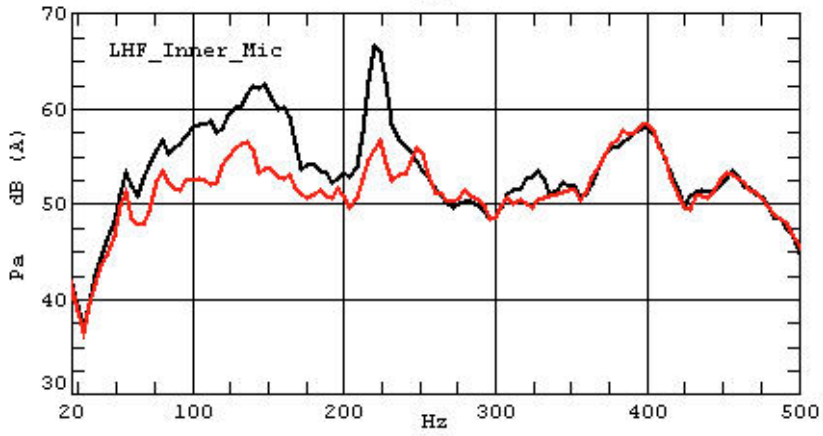
Bushes are harder for improved handling capability reducing isolation levels.

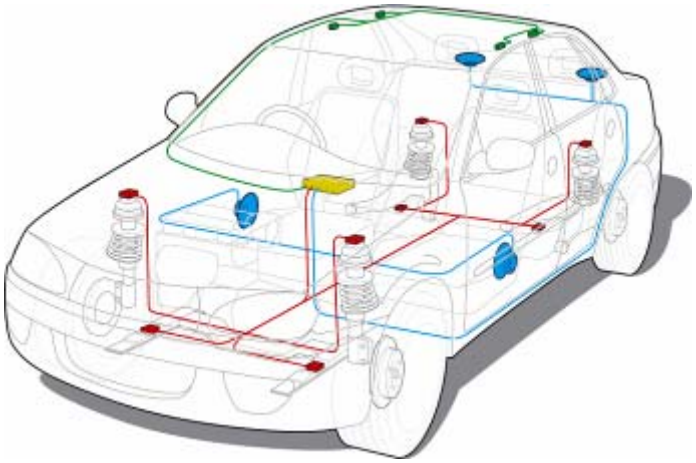


Lotus ANC technologies

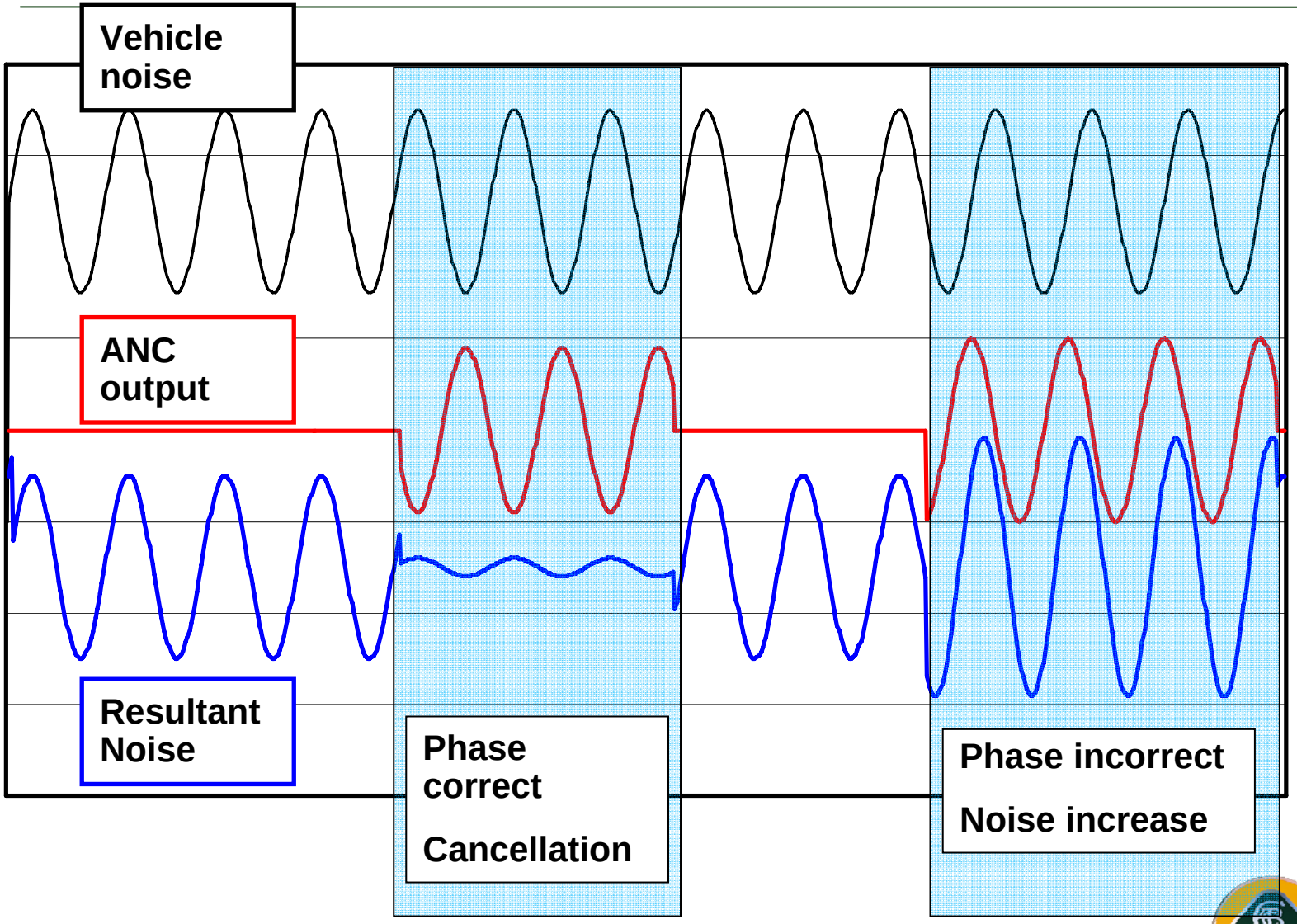




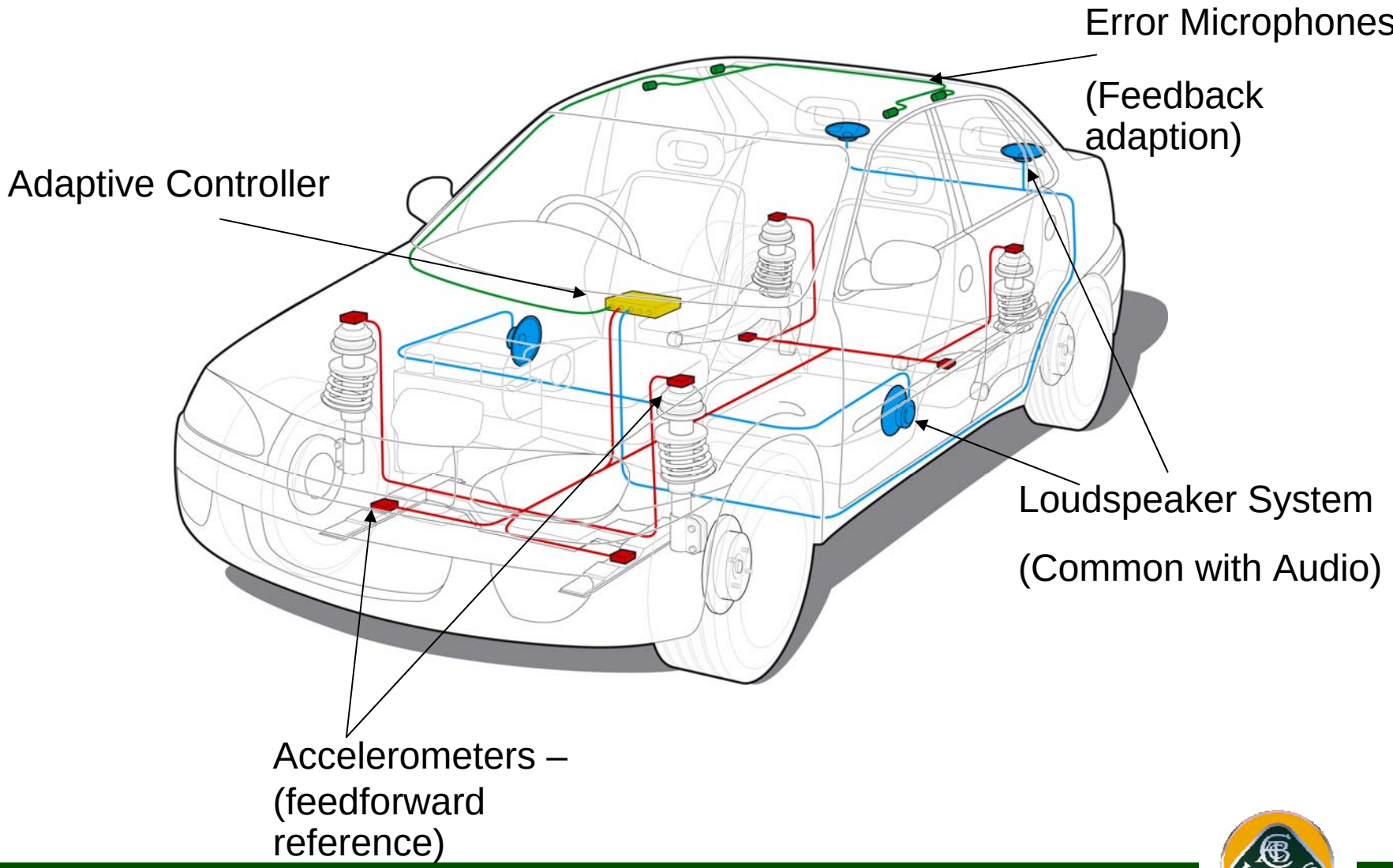




Principle of Noise Cancellation



Schematic of Lotus RNC System



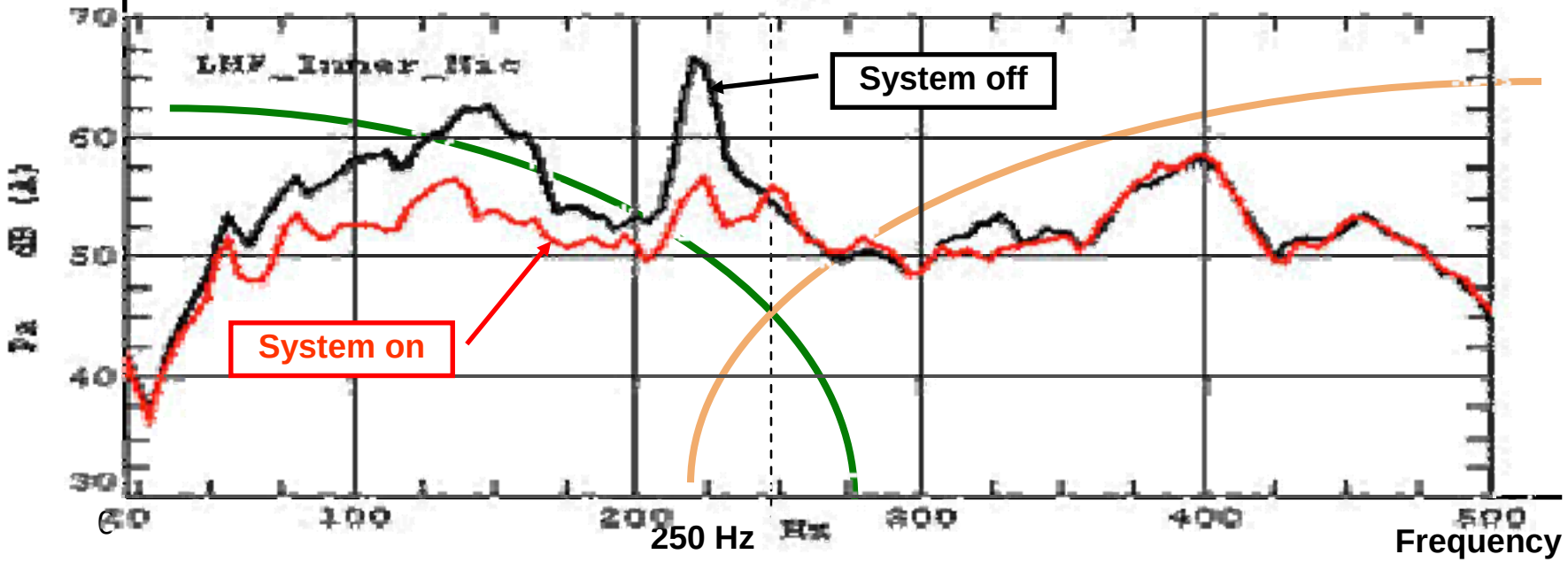
Frequency range of Active Control

ACTIVE RANGE

(Conventional treatments are mass and stiffness)

PASSIVE RANGE

(Sealing and absorption treatments)



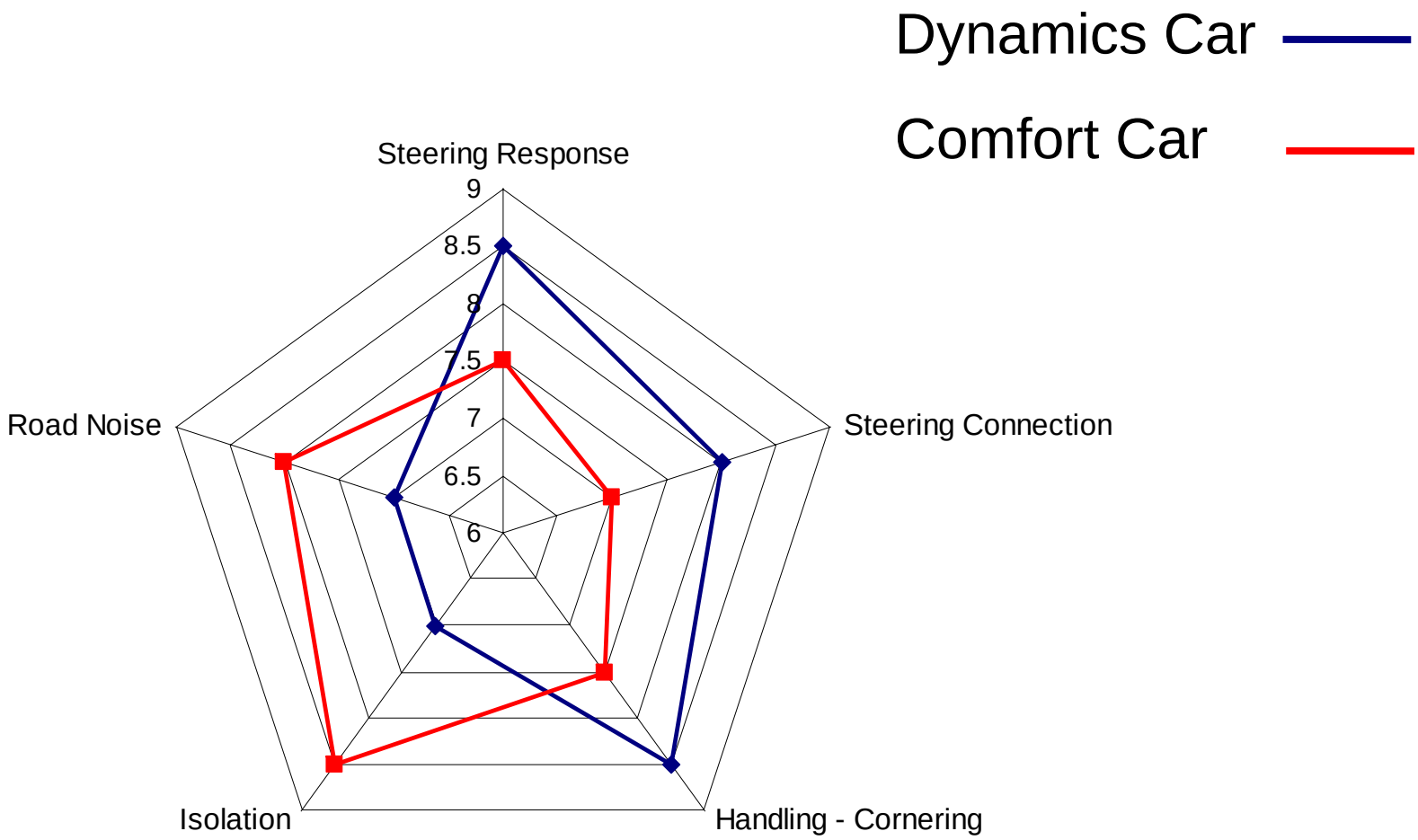
Example of system benefits

- Two European premium sector luxury saloons were tested.
- Comfort Car – premium brand high comfort and refinement RWD
  - Limited to 250 kph
  - Tyres: Front 255/45/18 Rear 275/45/18
- Dynamics Car – premium brand sports saloon 4WD
  - >300 kph maximum speed.
  - Tyres: 275/40/19

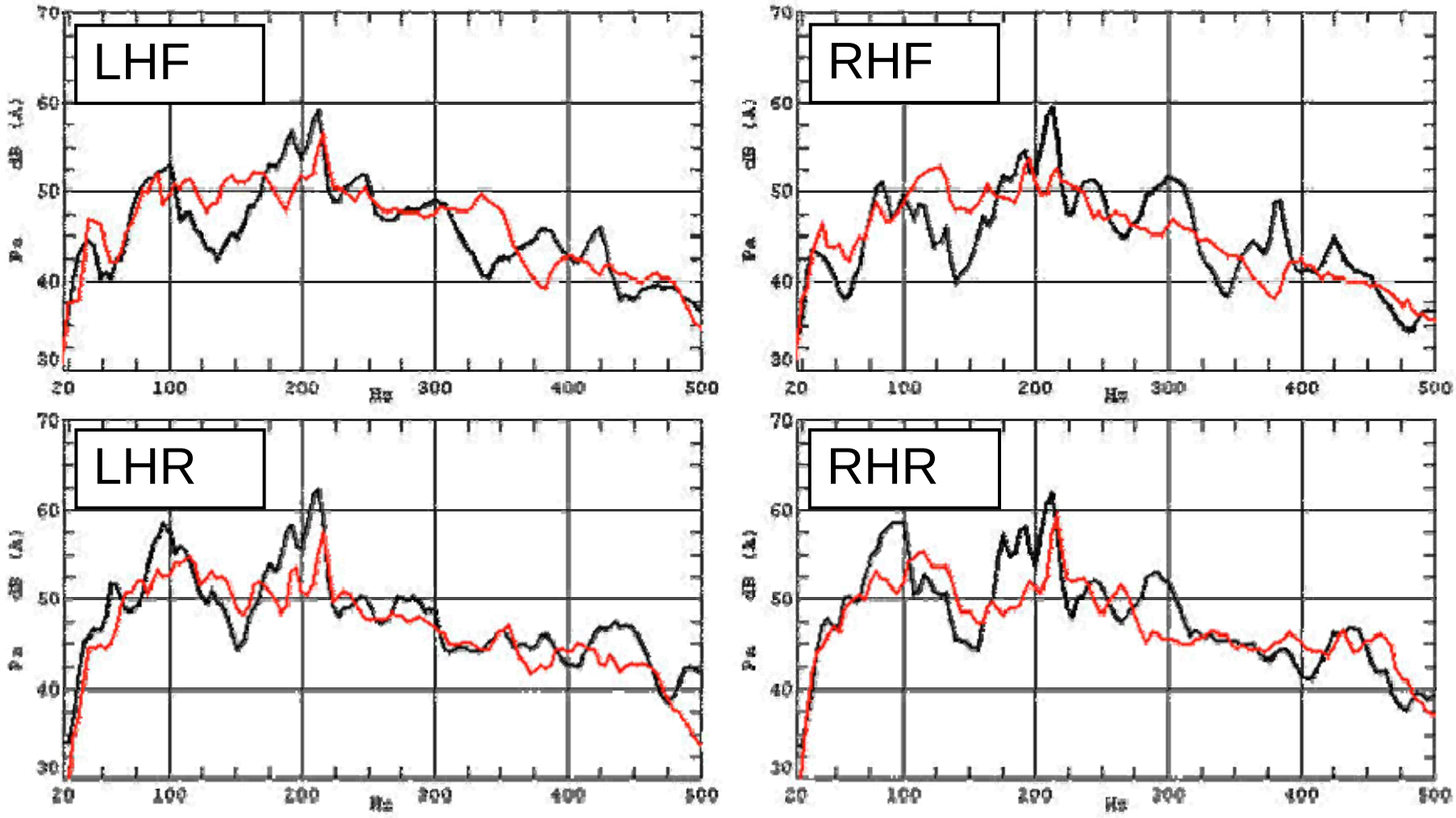
- Both cars were rated subjectively on 1 to 10 scale for all aspects of driving dynamics and comfort and measured for interior noise.

- The Dynamics car was then fitted with the Lotus Active Roadnoise system and re-measured.

Overall Vehicle Dynamics Performance

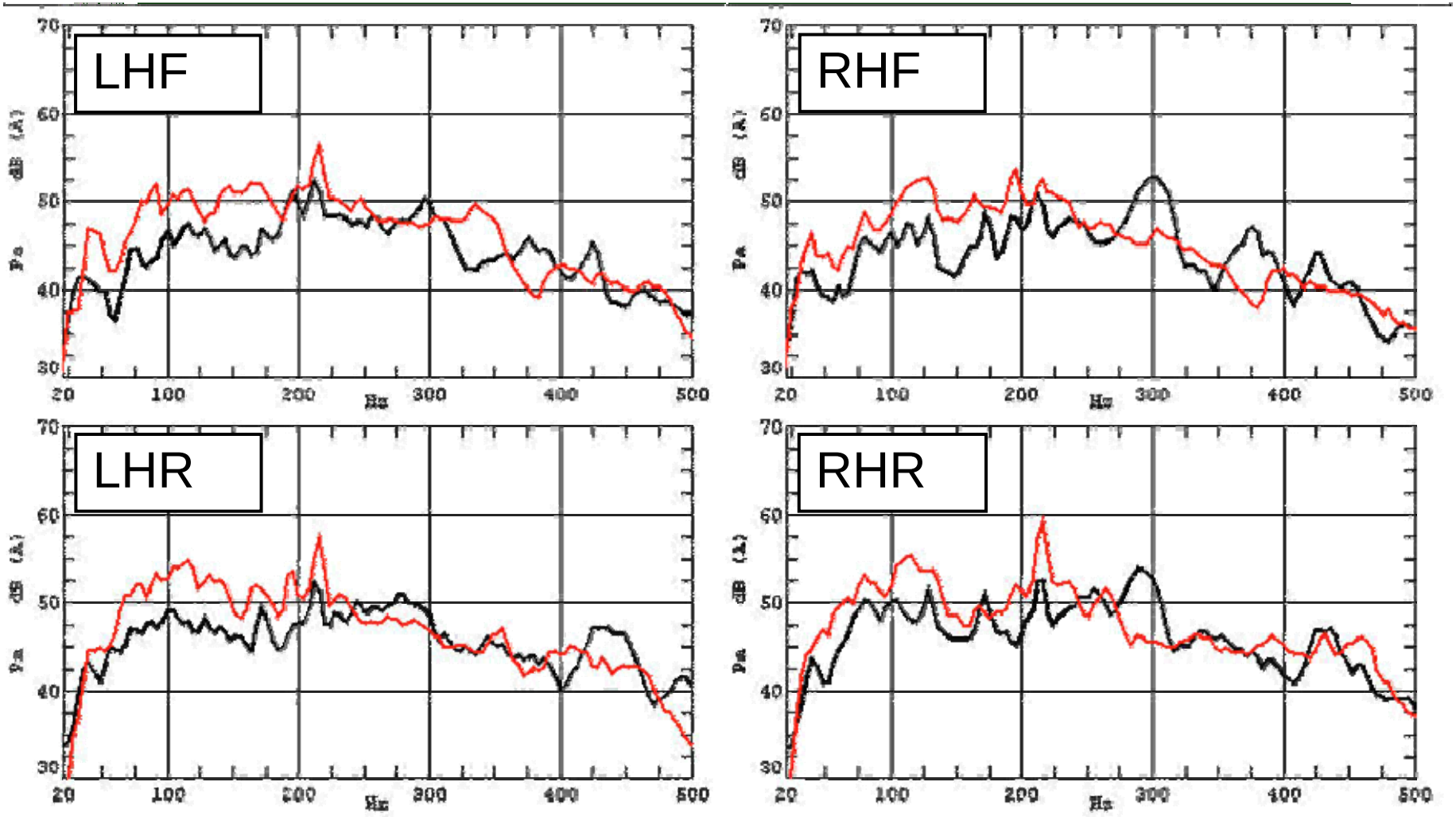


Dynamics Car 1 —— Vs Comfort Car 2 ——



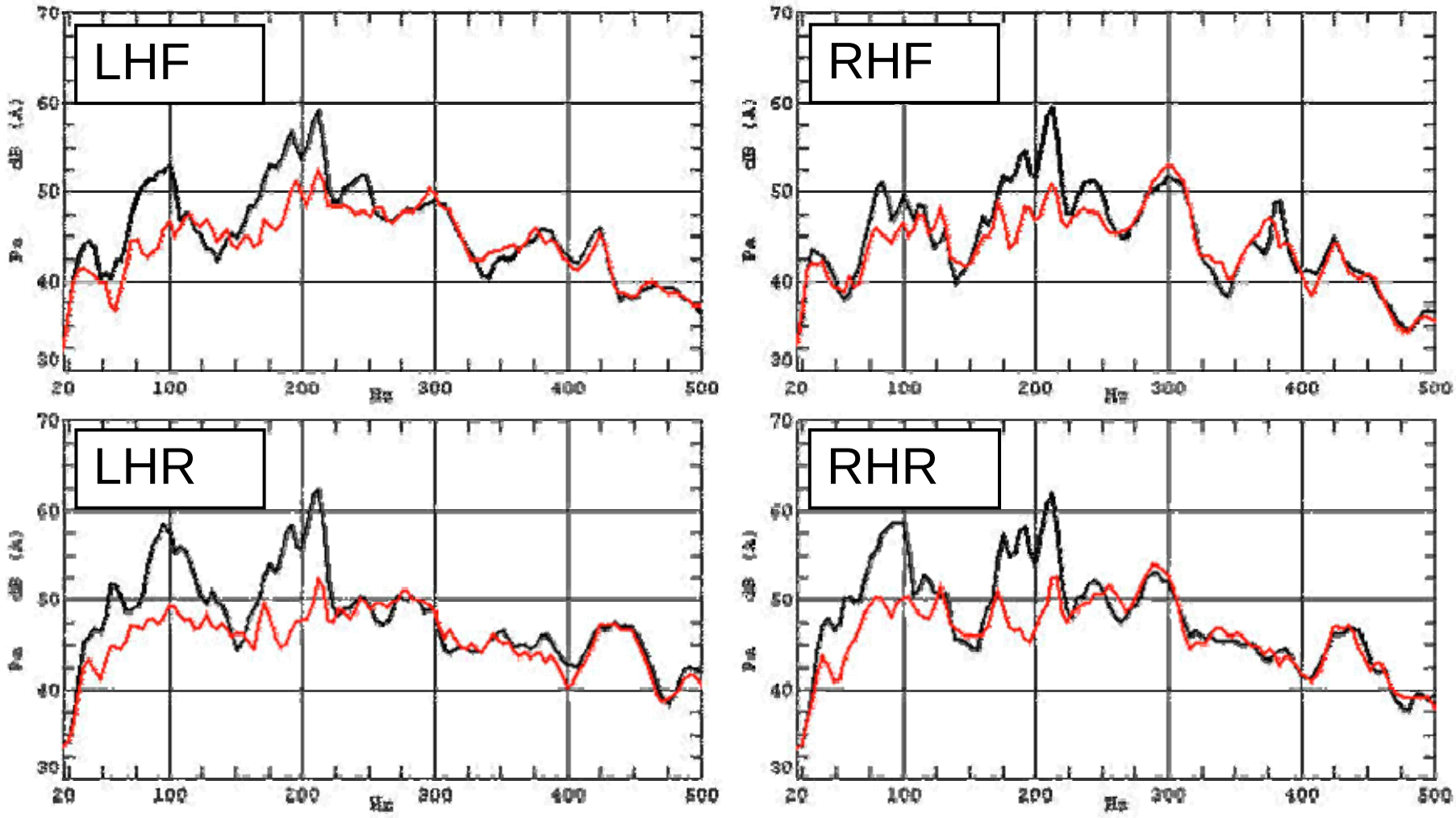
- Base cars no ARNC, Coarse Chip Road 80 km/h

Dynamics car with ARNC —— Vs Comfort car —



- Dynamic car with ARNC , Coarse Chip Road 80 km/h

Dynamics car ARNC Off —— ARNC On ——

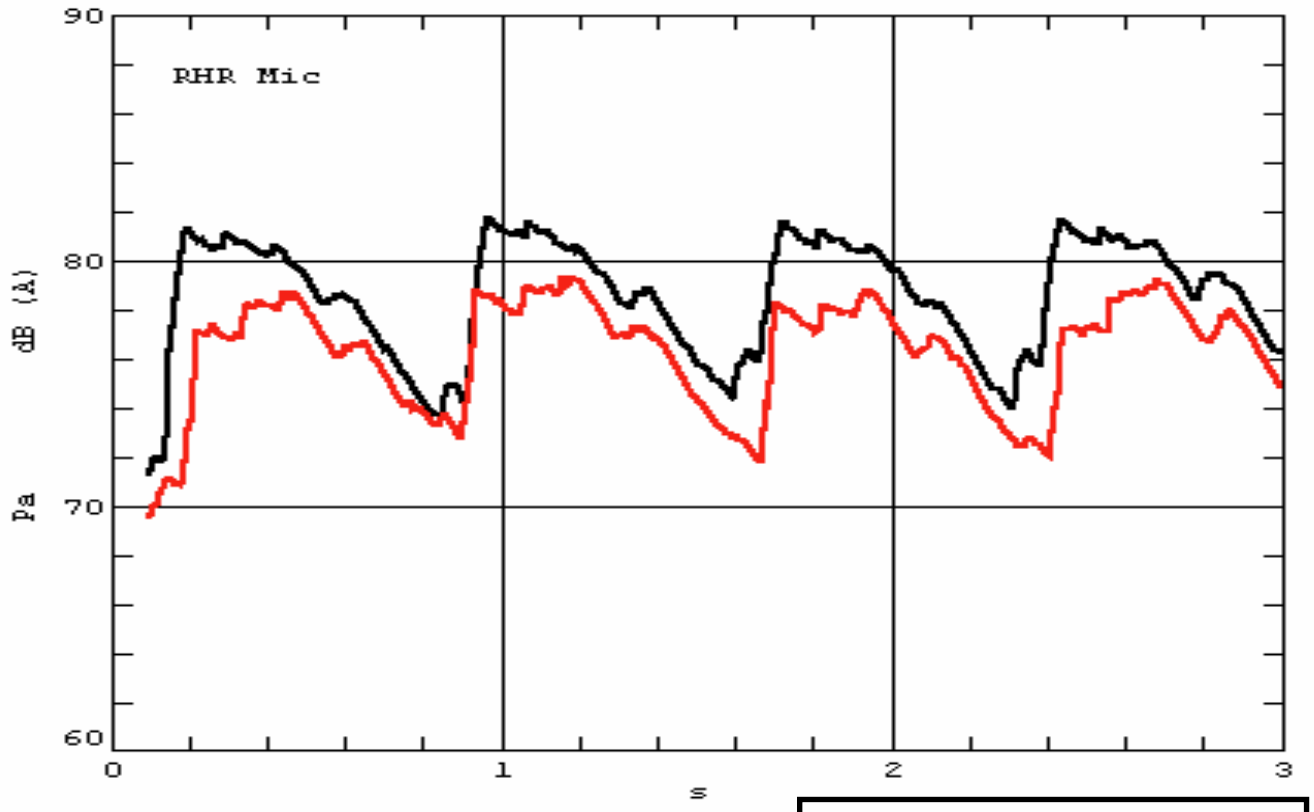


- ARNC Comparison, Coarse chip Road 80 km/h

Noise influence on “isolation feel”

- The subjective “isolation feel” is created by the combined noise and vibration response experienced by the driver.
- Reduced noise response generally creates a more favourable isolation impression even if vibration is unaffected.
- However to maximise vibration isolation the steering column and seat needs to optimised for vibration transmission.
- This is easier to do if the constraint of roadnoise isolation has been reduced as a development priority.
- In addition stiffer suspensions will have better yaw stability which benefits steering response :- hence very rigid rack mounting stiffness may not be essential.

Effect of Impact Strip – isolation improvement



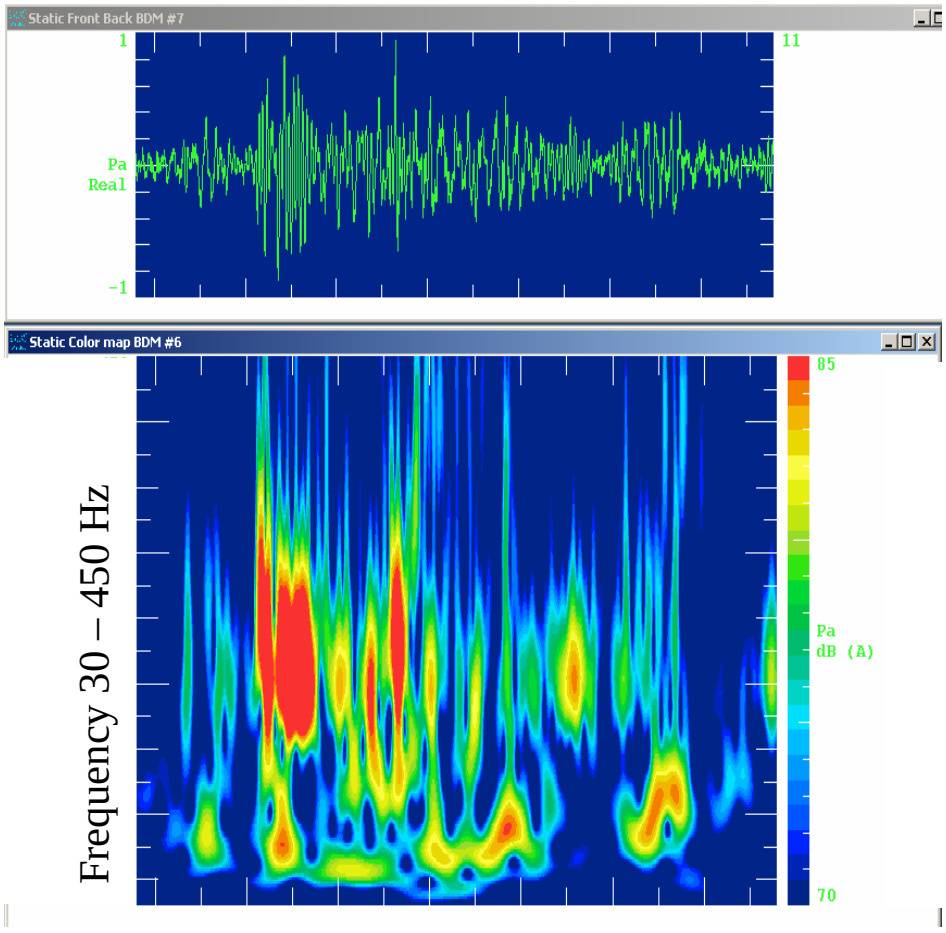
Impact response – RHR noise

ARNC Off

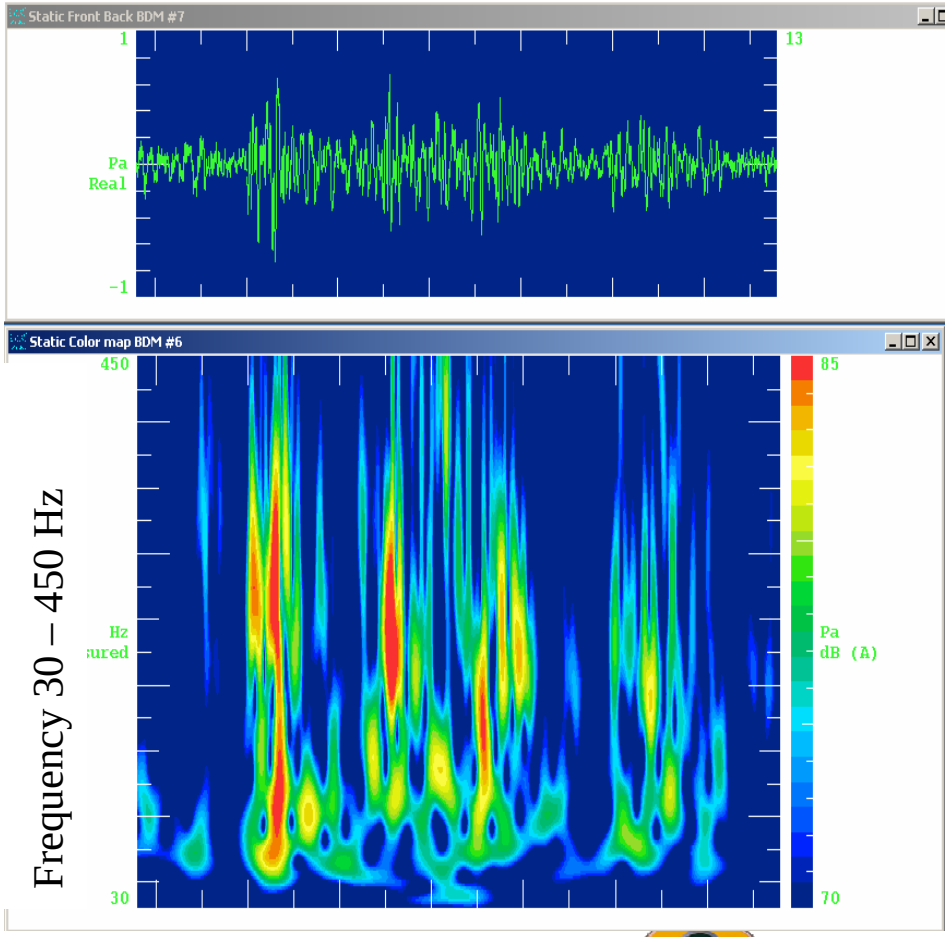
ARNC On

Impact strip noise – Effect of ARNC - detail

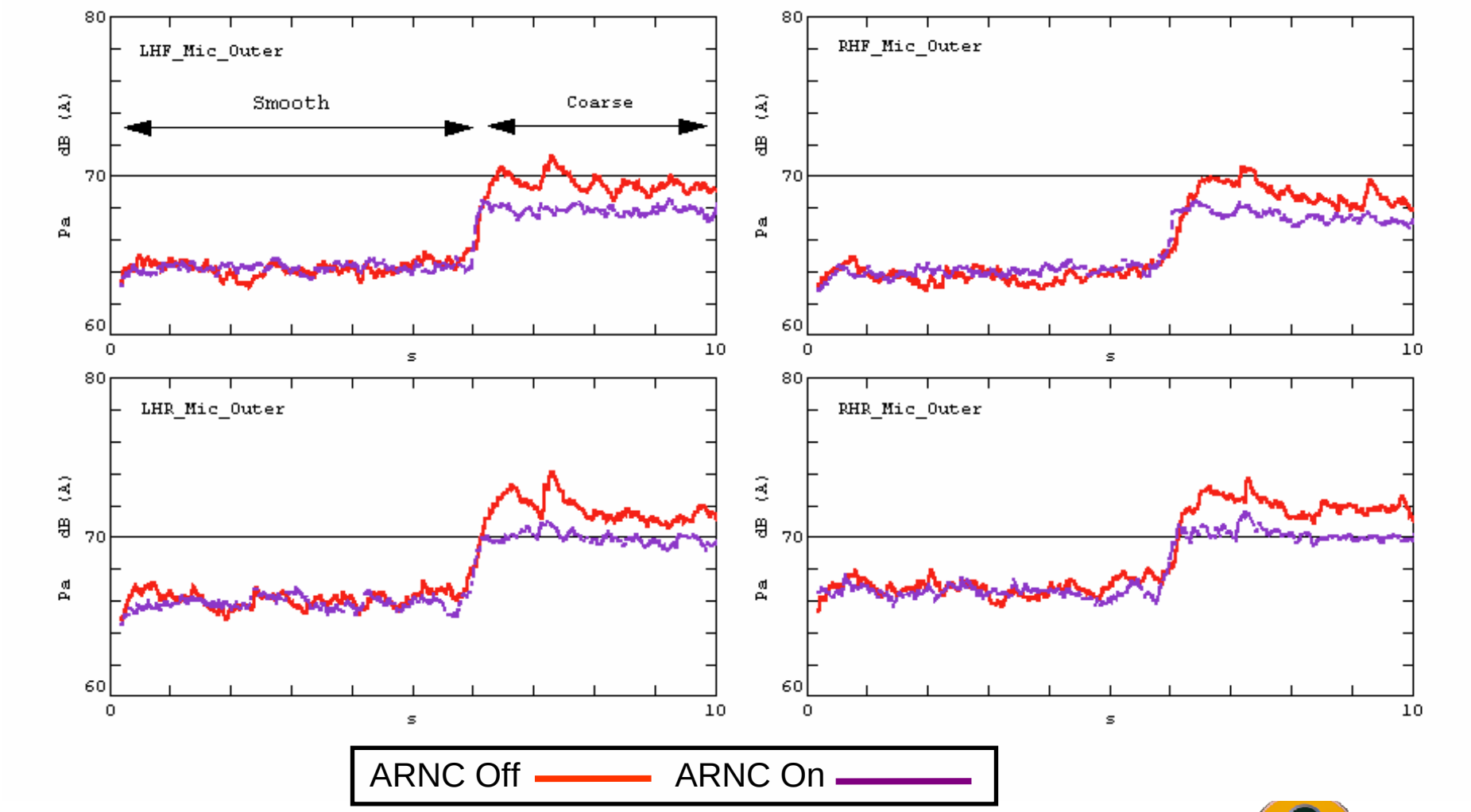
RHR Seat ARNC Off



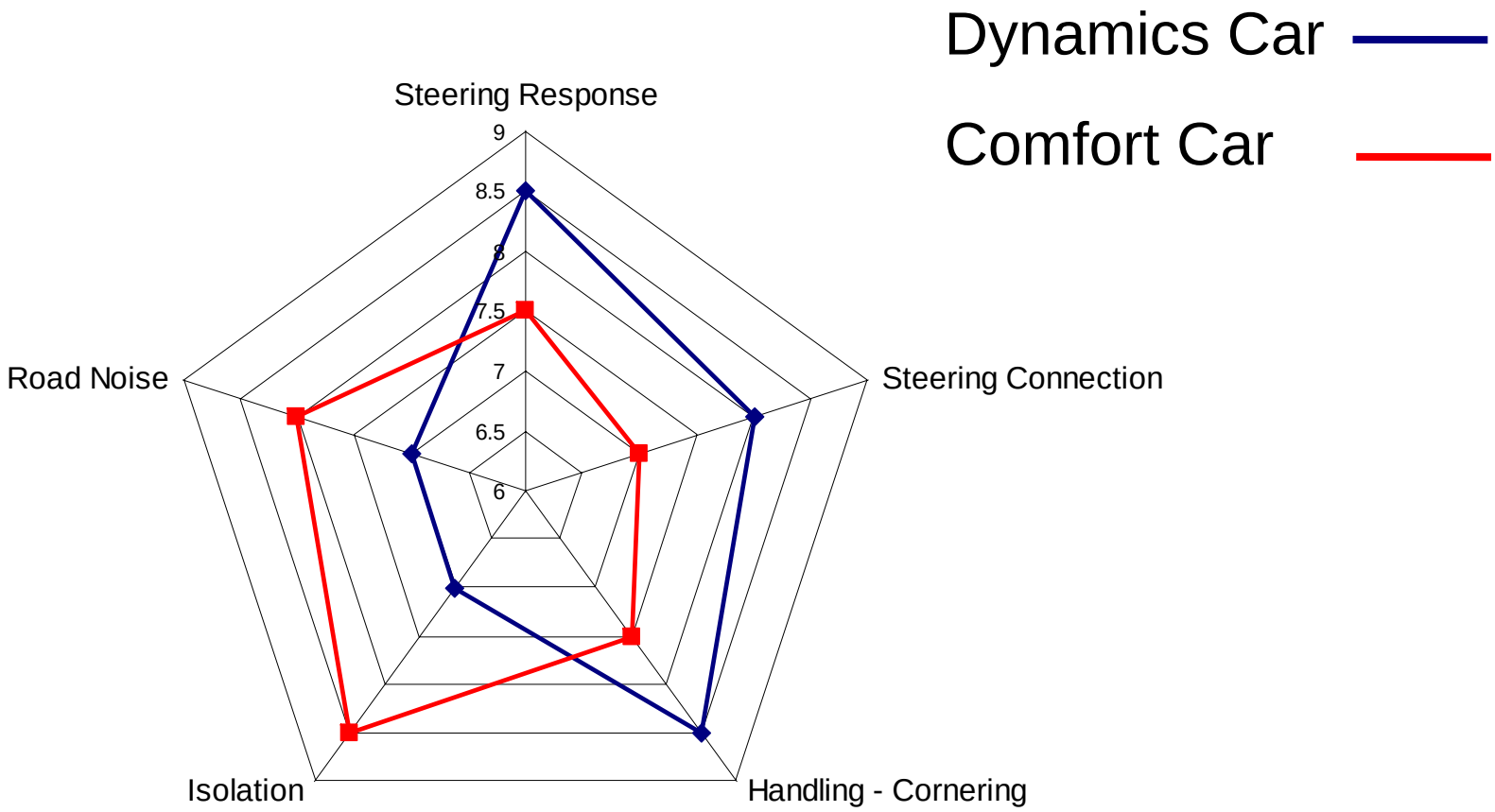
RHR Seat ARNC On



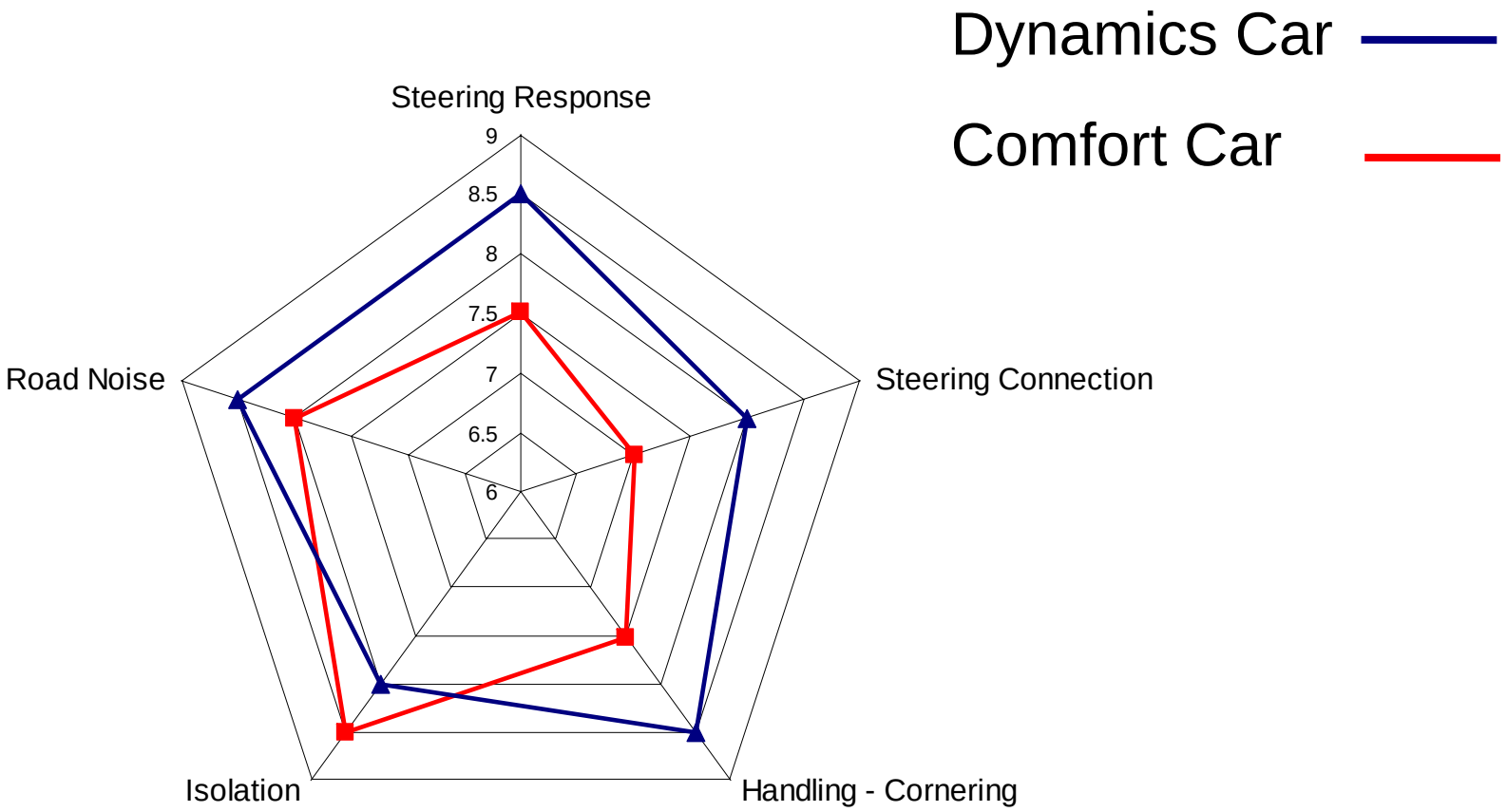
ARNC- Smooth to rough transition response



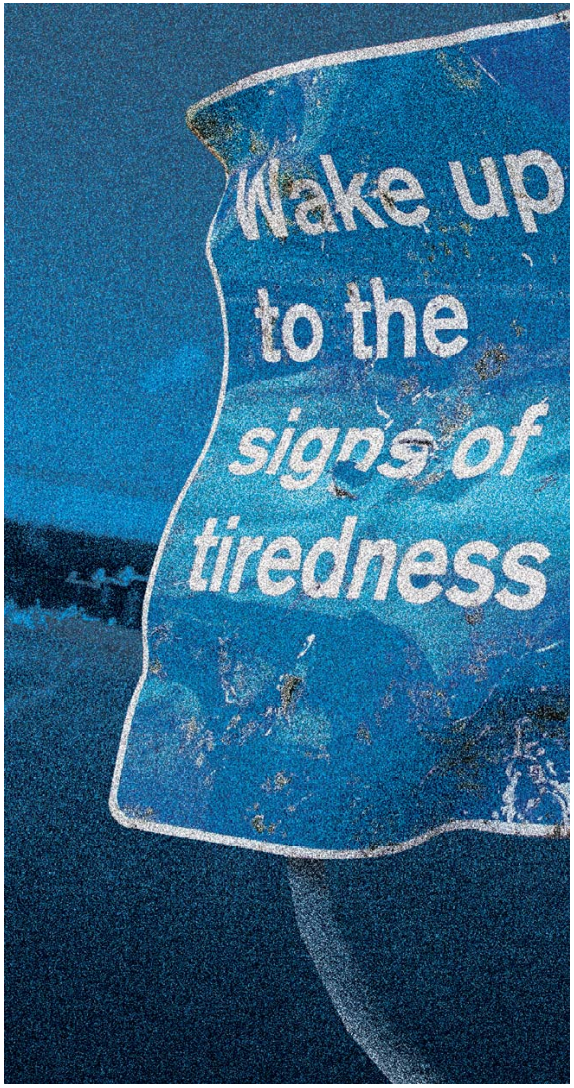
Overall Vehicle Dynamics Performance



Overall vehicle Dynamics Performance – with ARNC



Noise contributes to accidents



- Landstrom and Landstrom (1985) showed low frequency monotonous noise and vibration increased drowsiness levels.
- Loftstedt and Landstrom (1987) showed truckdrivers become more readily fatigued driving trucks that generated high levels of low frequency noise.
- ROSPA (2001) have shown 20% of UK road accidents are fatigue related.

Further Applications of Lotus Active noise technology

- The range of ANC technologies can also be applied to realise other specific benefits.
- CO2 reduction
  - Vehicle weight reduction
  - Extended operation of engine cylinder deactivation
  - Maintain refinement with engine balancer shaft deletion
- Reduced programme costs
  - High end Halo models from high volume platforms
  - Reduced development time for derivative models
  - Increased product differentiation from common platform strategy
- Improved customer feature
  - Improved dynamics
  - Improved refinement
  - Enhanced driver enjoyment (sound synthesis)
  - Pedestrian safety for electric and hybrid vehicles

Summary

- Roadnoise is now the dominant NVH problem in a majority of vehicles.
- Refinement and vehicle dynamics requirements are often in conflict requiring compromise (NVH is usually the victim).
- ANC is a viable solution to low frequency noise in vehicle interiors which can negate much of the conflict.
- The system can have a dramatic effect on vehicles with high levels of low frequency structural noise.

- This technology can be exploited to achieve class leading dynamics and refinement on the same vehicle – and achieve vehicle dynamics without compromise.

- The technology is available now and we are already working with a number of potential suppliers of the production solution.

Further information

For further information on the full range of Lotus active noise technologies please contact:-

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