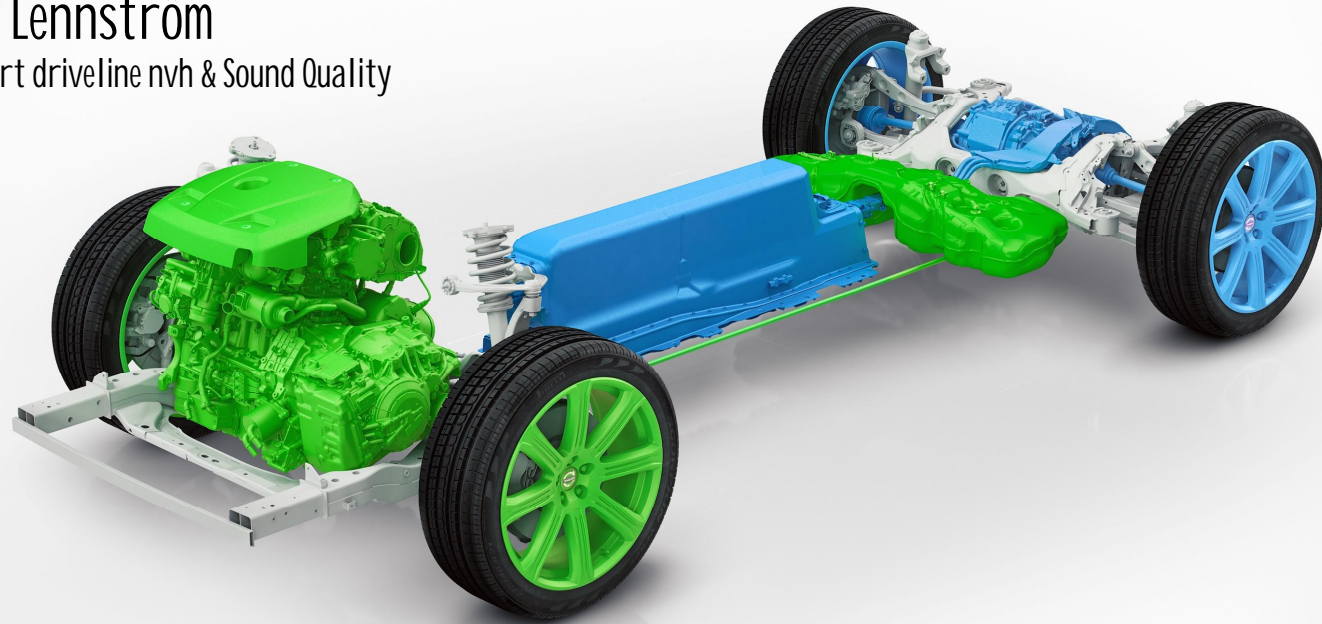


Electric Propulsion NVH at Volvo Cars

Dr. David Lennström

Technical expert driveline nvh & Sound Quality



outline



- Introduction
- Three EV specific phenomena
- Inverter modulation techniques and perceived annoyance
- Electromagnetic noise; radial and tangential excitation
- Remedies for gear whine
- Challenges with EV NVH

Leadership in Electrification

- From 2019, all internal combustion engines in new Volvo cars will be supplemented with electric propulsion in the form of mild or plug-in hybrid powertrains, or be fully electric.
- Polestar, our performance arm, becomes a separately-branded electrified global high performance company.
- In 2025, 50% of the Volvo sales will be BEV



C30 BEV 2011



V60 PHEV 2012



S60L PHEV 2015



XC90 PHEV 2015

S90 T8 PHEV
V90 T8 PHEV
XC60 T8 PHEV

NEW TECHNOLOGY

SPECIFIC PHENOMENA

- Magnetic motor whine
- Inverter whine
- Gear whine

ABSENCE OF ENGINE NOISE

- Prominent auxiliaries
- Road, wind noise

Acoustics of electrified cars

LEGAL REQ.

- Auditory vehicle alert system (AVAS)
- Sound design

NEEDS

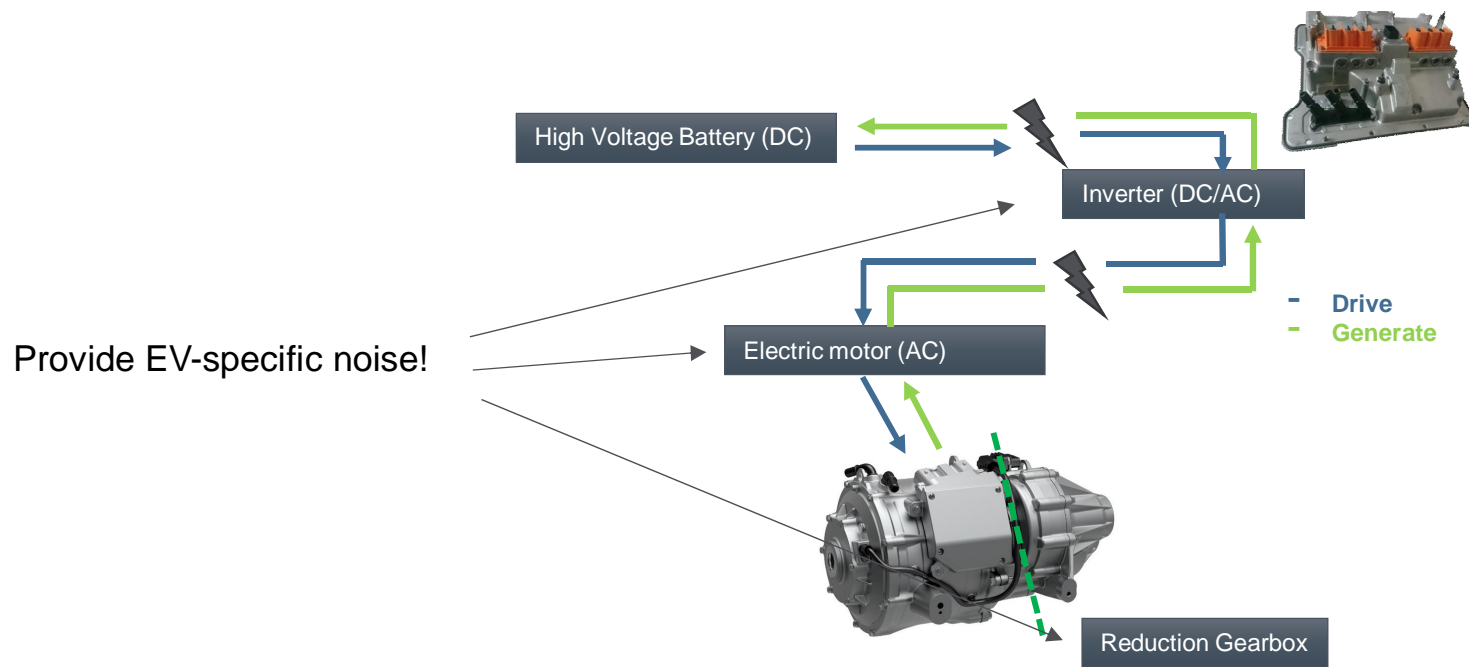
- Evaluate concepts
- Complete vehicle & subsystem requirements.



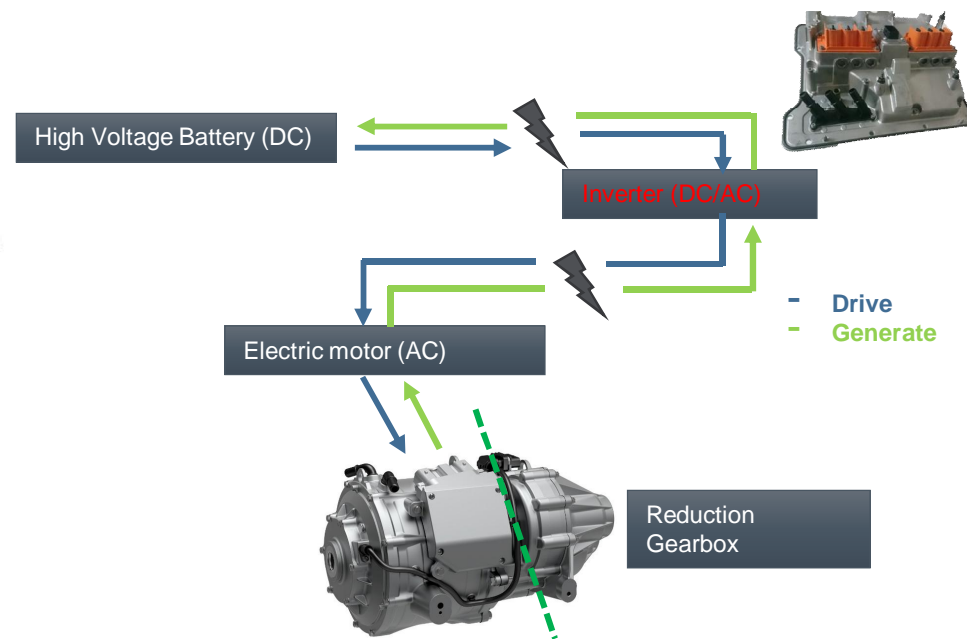
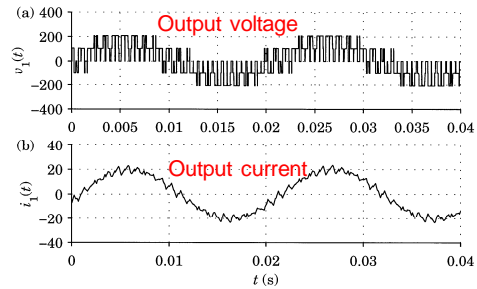
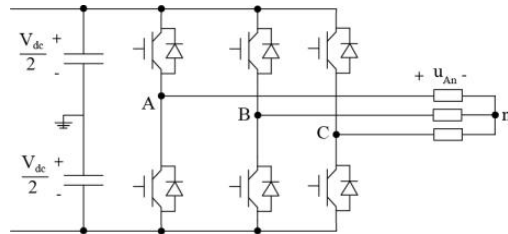
CUSTOMERS' EXPECTATIONS

- "EV's are (too) quiet"
- EV's = \$\$\$

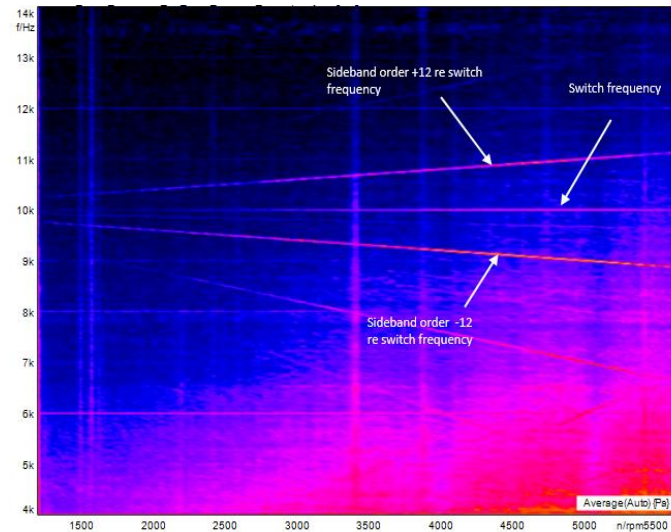
The electric driveline



The inverter

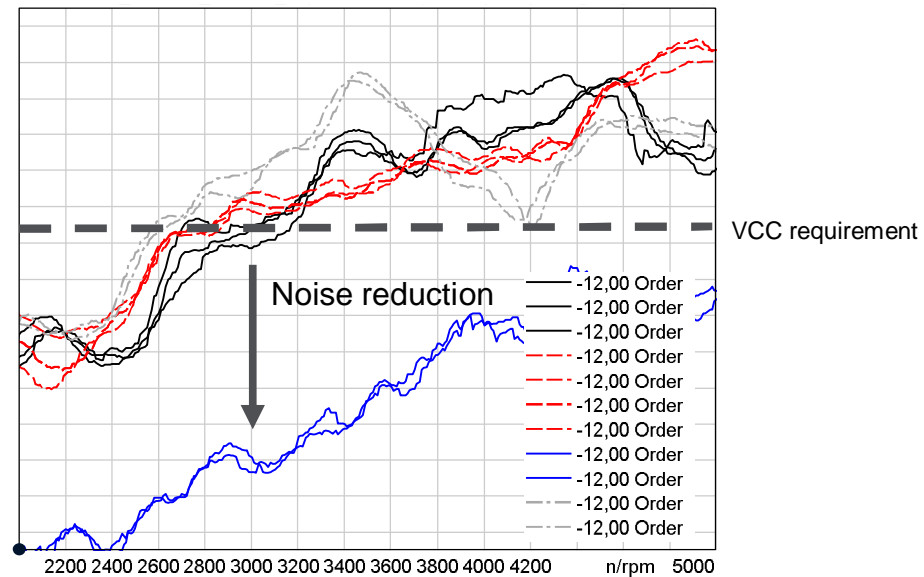


Example of vehicle measurement- inverter noise



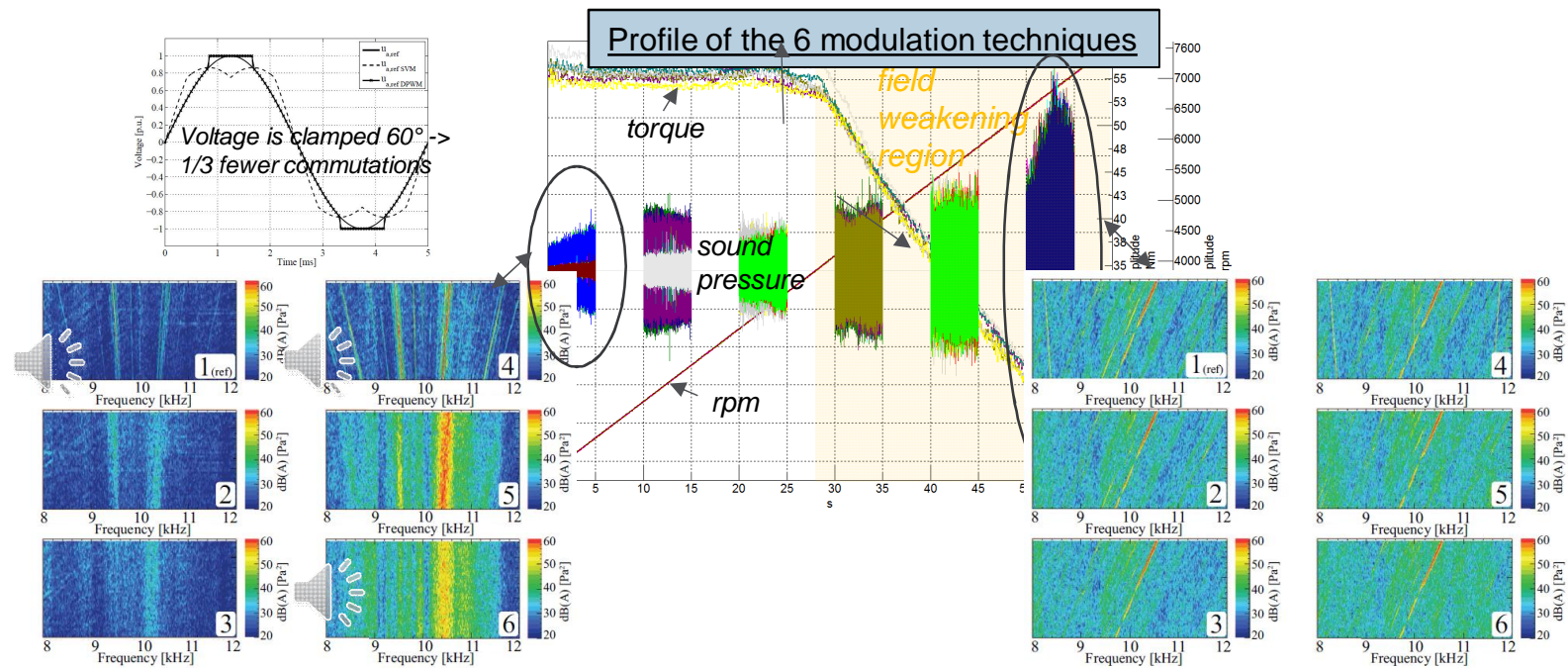


Vibration isolation of inverter bracket



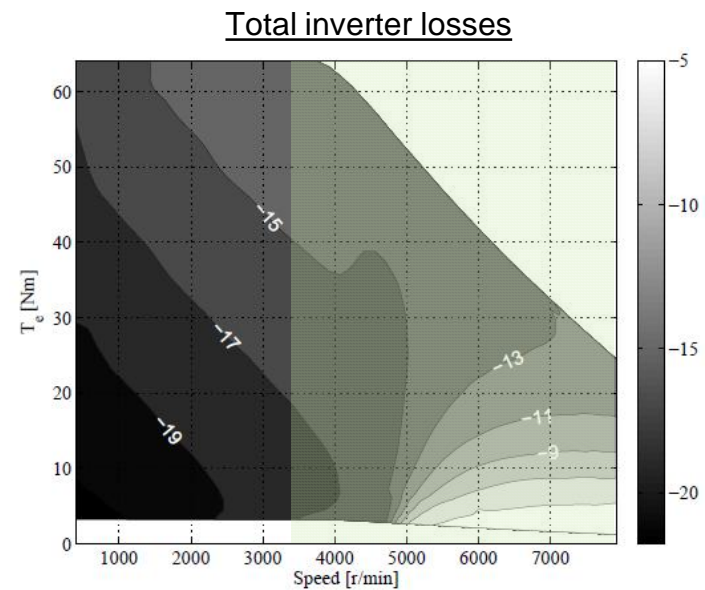
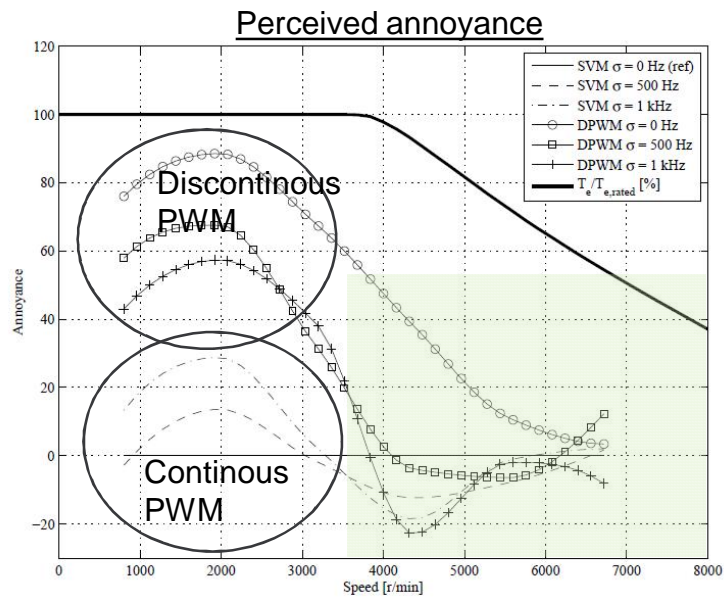


Possibilities for inverter noise



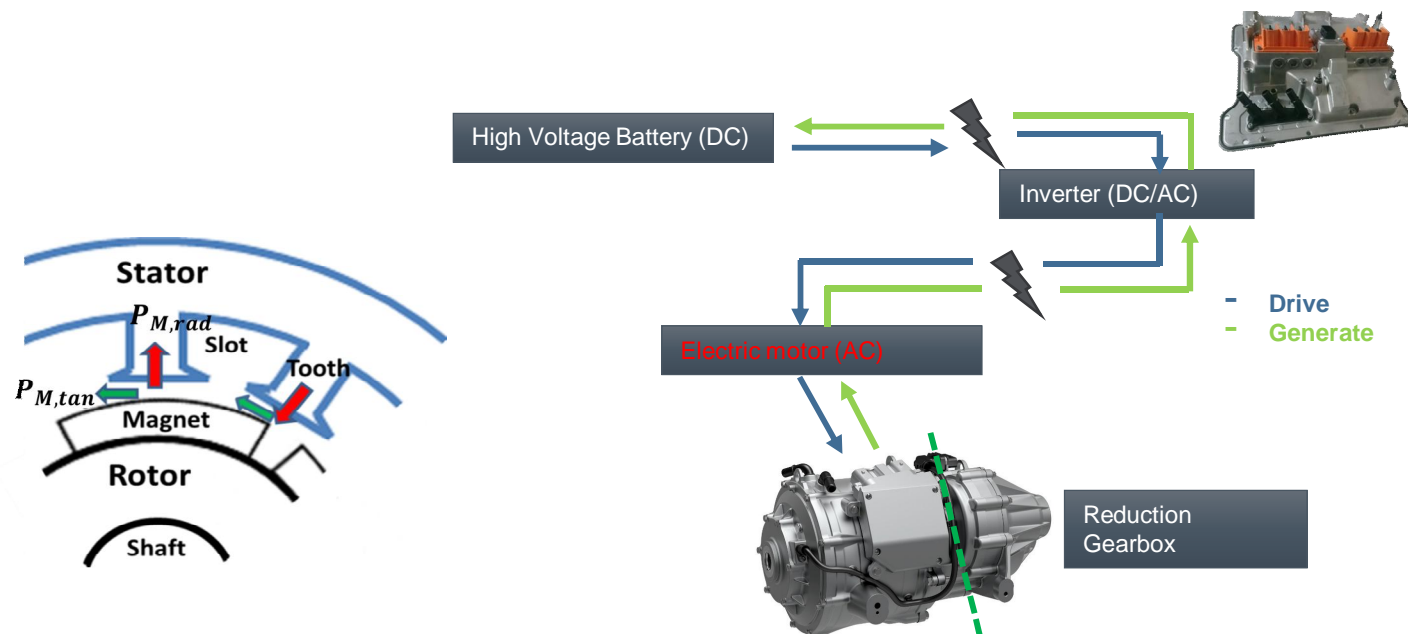


Perceived annoyance and losses



Ref: A. Andersson, D. Lennström, A. Nykänen: "Influence of Inverter Modulation Strategy on Electric Drive Efficiency and Perceived Sound Quality", IEEE 2016

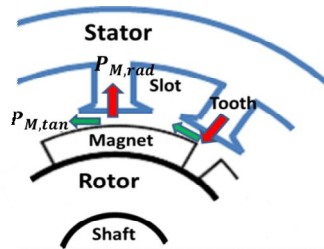
The electric motor



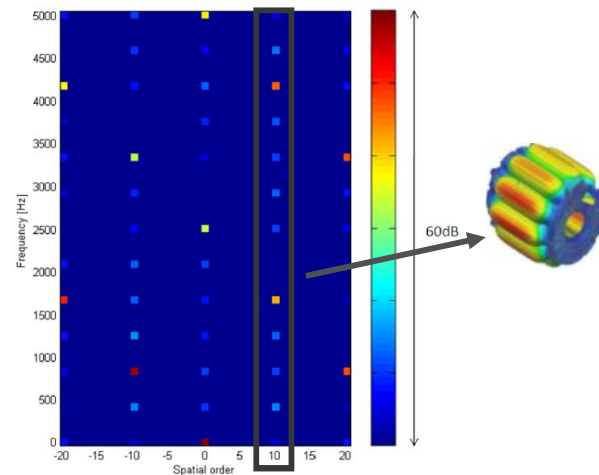


Radial force waves

Motor design

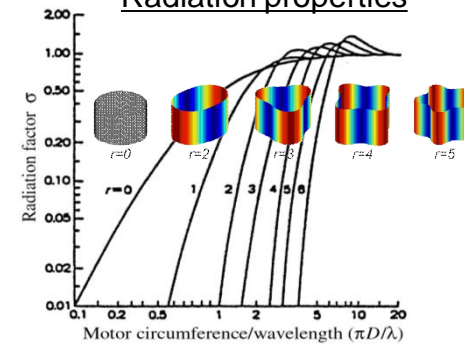


Force characteristics



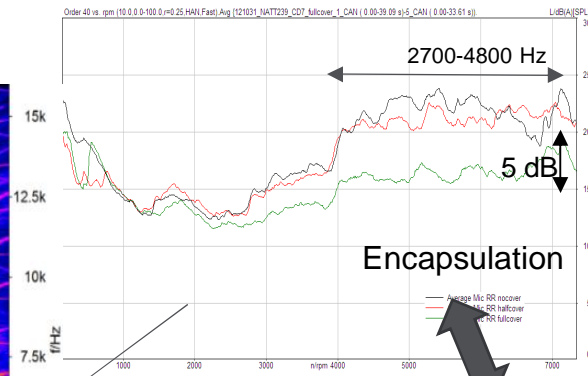
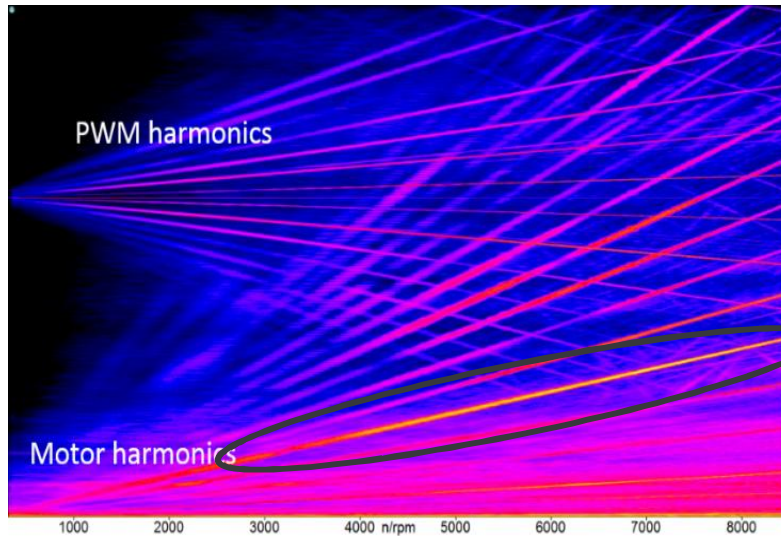
Ref: J-B Dupont, P. Bouvet, 2012

Radiation properties



Ref: Y.Okuyama, S.Moriyasu, 2000

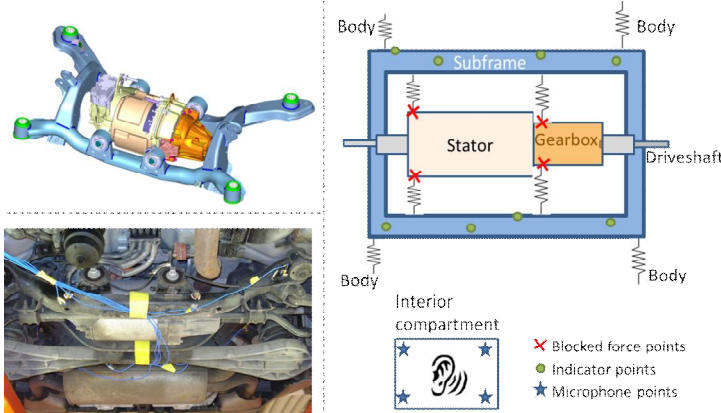
e-motor whine, v60 phev



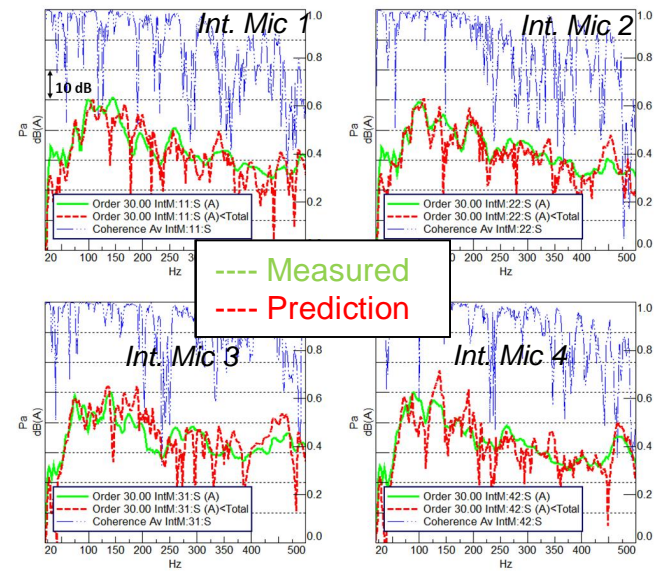


Take off sound, v60 phev

Test Object

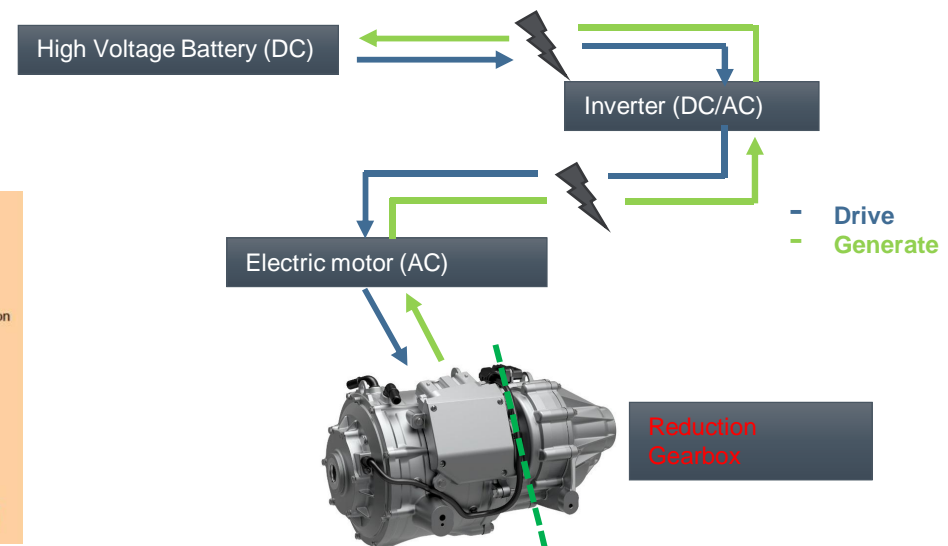
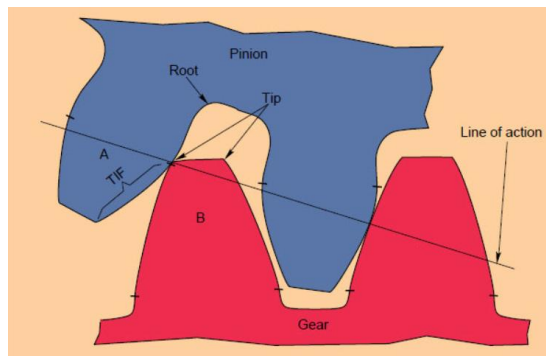


Results





Speed reducer/gearbox



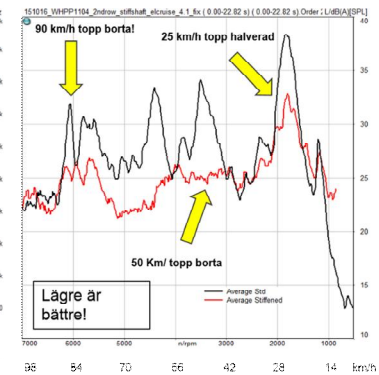
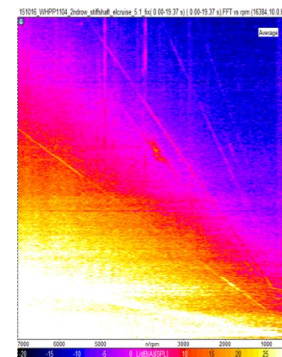
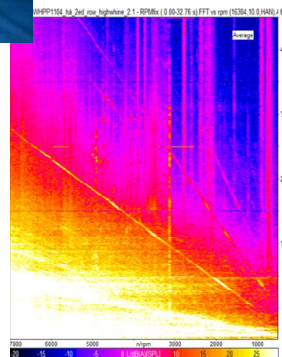


countermeasures example – gear whine



Std intrn gear

Stiffened intrn gear





The daily work; ev nvh development...

EDU Installation

*Source data from
electromagnetic sim.*

Sound pack

*Prediction of sound
pack need*

Benchmarking

*What eq. source data
can be used?
Vibrations/forces?*



Vehicle sensitivity

*High frequency
modelling*

BE DATA DRIVEN!!
Work continuously
with SQ devel.

Bushings

*Gather data for higher
frequencies*

Rig testing

*Anechoic conditions,
low background noise*



Thank you for your attention!