MEASURING NOISE & VIBRATION

NVH assessment and optimization in EVs and HEVs

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Contents

- > NVH New challenges
- > Different noise problems to be tackled
- > Electromagnetic noise and tools
- > Sound design challenges
- > Transfer from sources to response
- > Testing solutions

From Combustion (ICE) to Electric (EV/HEV)

- ICE replaced by a Motor
- Weight reduction (chassis, engine, drive line)
- Powertrain excitation content changes (Gearbox)
- New components (Inverter, Battery charging etc…)
- Chassis adaptation required to receive the new generation powertrains (motor, gearbox etc…)

From Combustion (ICE) to Electric (EV/HEV)

NVH Consequences:

- Different sound content (electromagnetic noise): From a broadband spectrum (appreciated) **SOUND** to a more tonal and annoying **NOISE.**

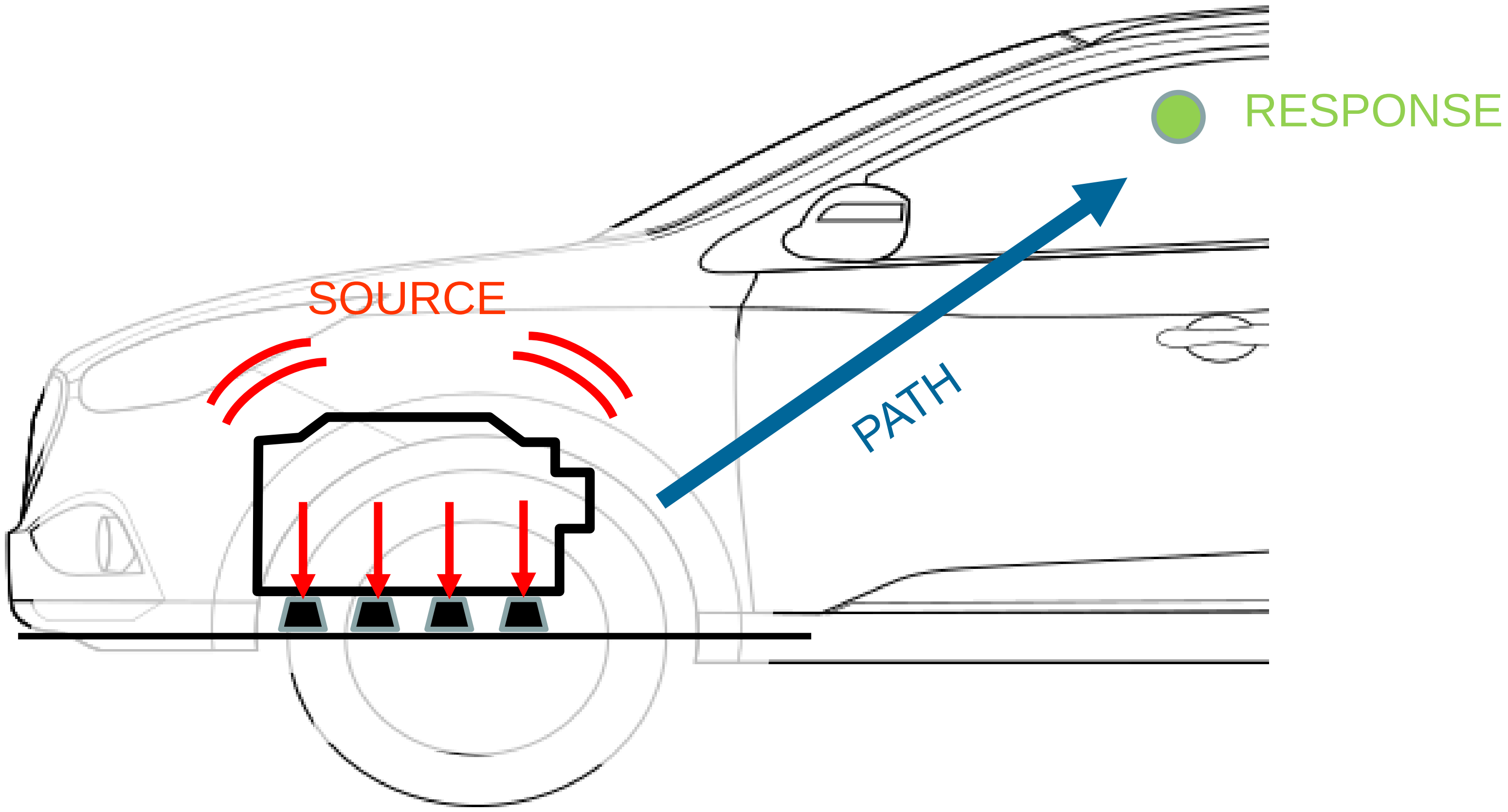
- Reduction of the ICE **masking effect** (Aerodynamic, Accessories motors, Tires)

- Modifications of the connection points (**need for TPA analysis**)

- New structural **excitation** frequencies and **response** (frame & body weight decrease)

	ENGINE	MOTOR
High speed	Engine, Tire , Aero	Motor, Tire , Aero
Low speed	Engine	Accessories, Tire

Where to solve the challenges ?

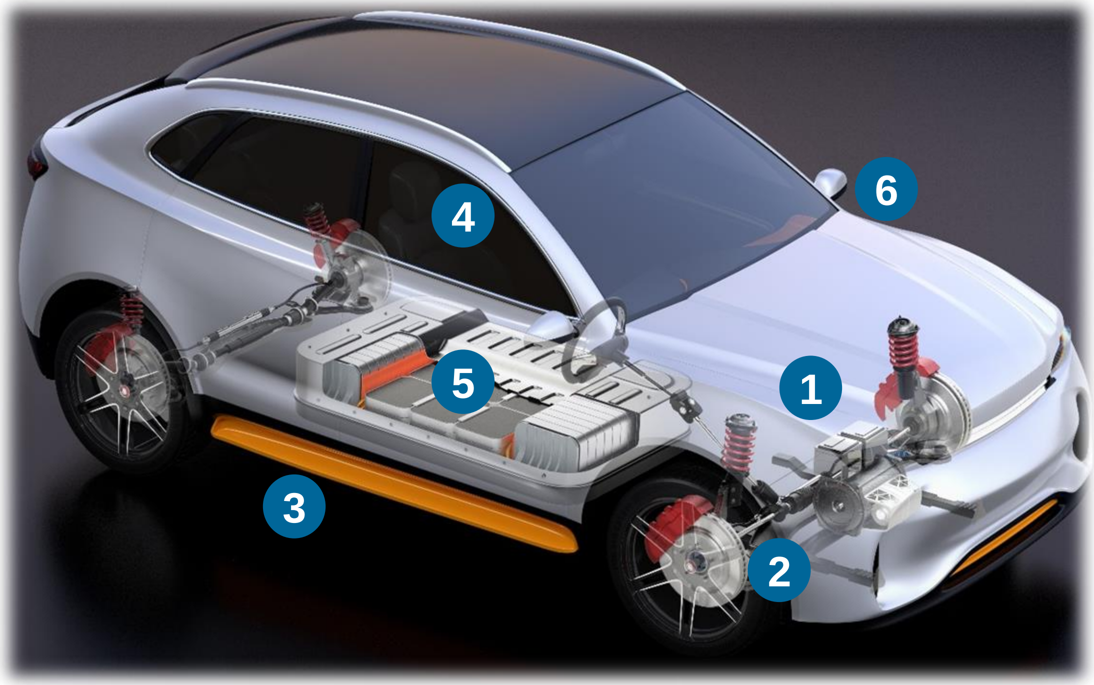


EV/HEV Testing solutions: from sources to response

1 Electric Powertrain

2 Accessories & Components

3 Chassis



4 Panels

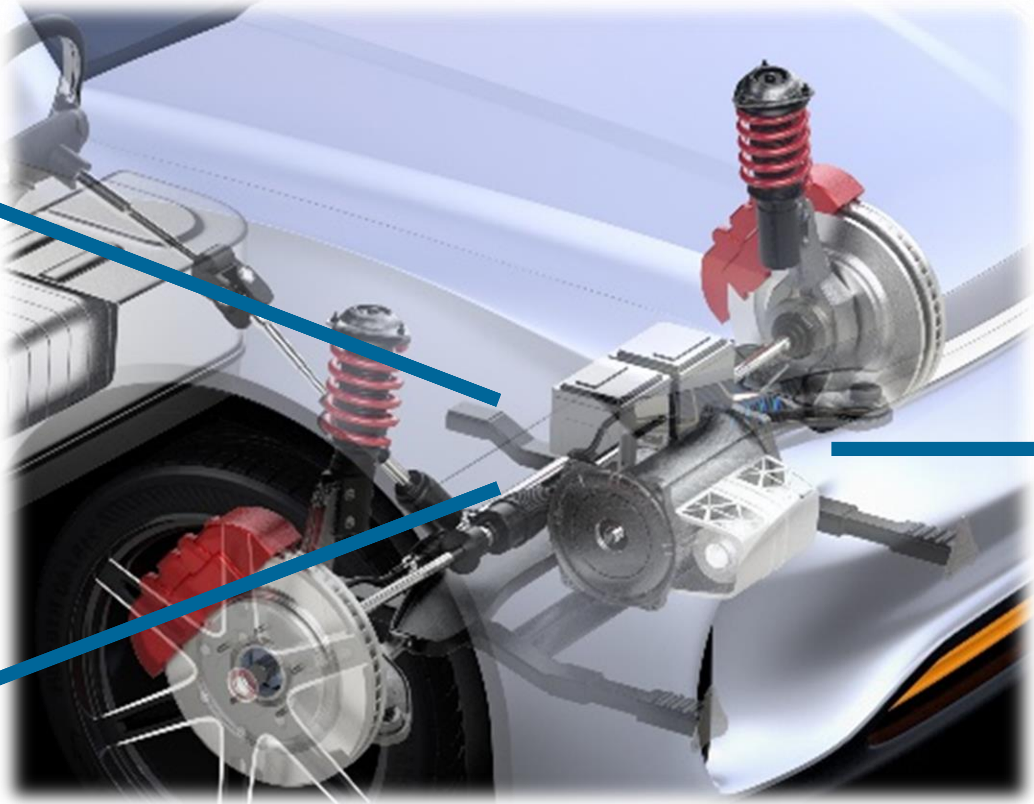
5 Battery charging noise

6 Aerodynamic sources

Electrical powertrain sources

Mechanical Sources:

- Ball passing frequencies
- Gear mesh frequencies
- Tire road noise



Aerodynamic Sources:

- Fan blades passing frequencies
- Wind noise

Motor
Slot/pole passing frequencies

Electromagnetic Sources

Inverter
PWM switching frequencies

Motors configurations

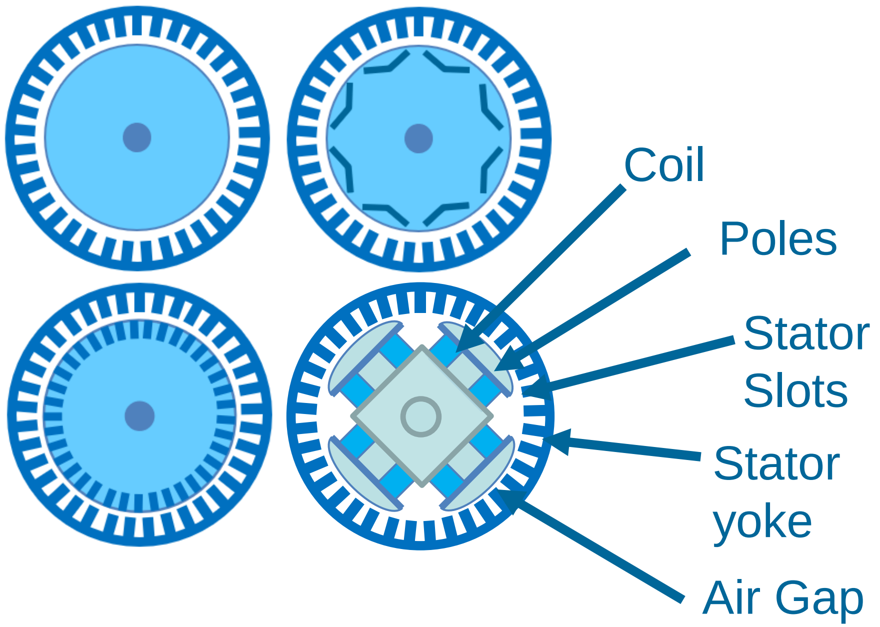
AC

ASYNC (Induction / IM)

- Squirrel Cage Induction Machines (SCIM)
- Doubly Fed Induction machines (DFIM)
- Wound Rotor (Slip ring wound rotor)

SYNC (SM)

- Wound Rotor (WRSM)
- Permanent Magnet SM (IPMSM,SPMSM)
- Synchronous Reluctance Machines (SyncRM)
- Switched Reluctance Machines (SRM)



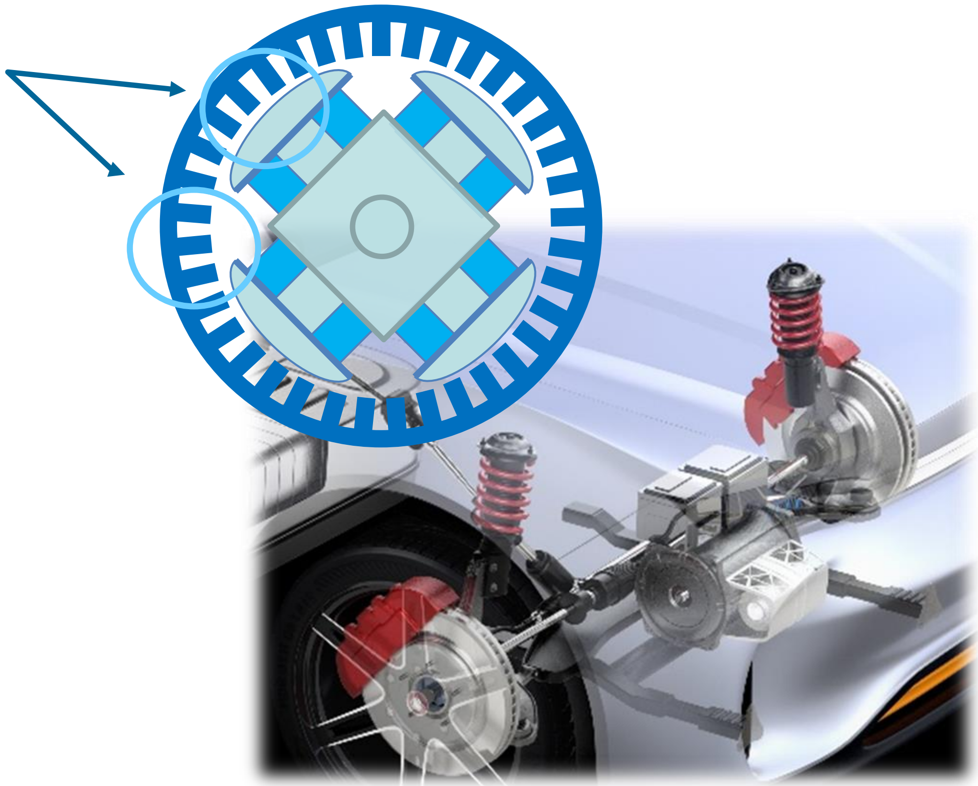
CONTROL : different PWM strategy

Electromagnetic Noise

Motor

Slot/Pole interaction

Slotting Noise

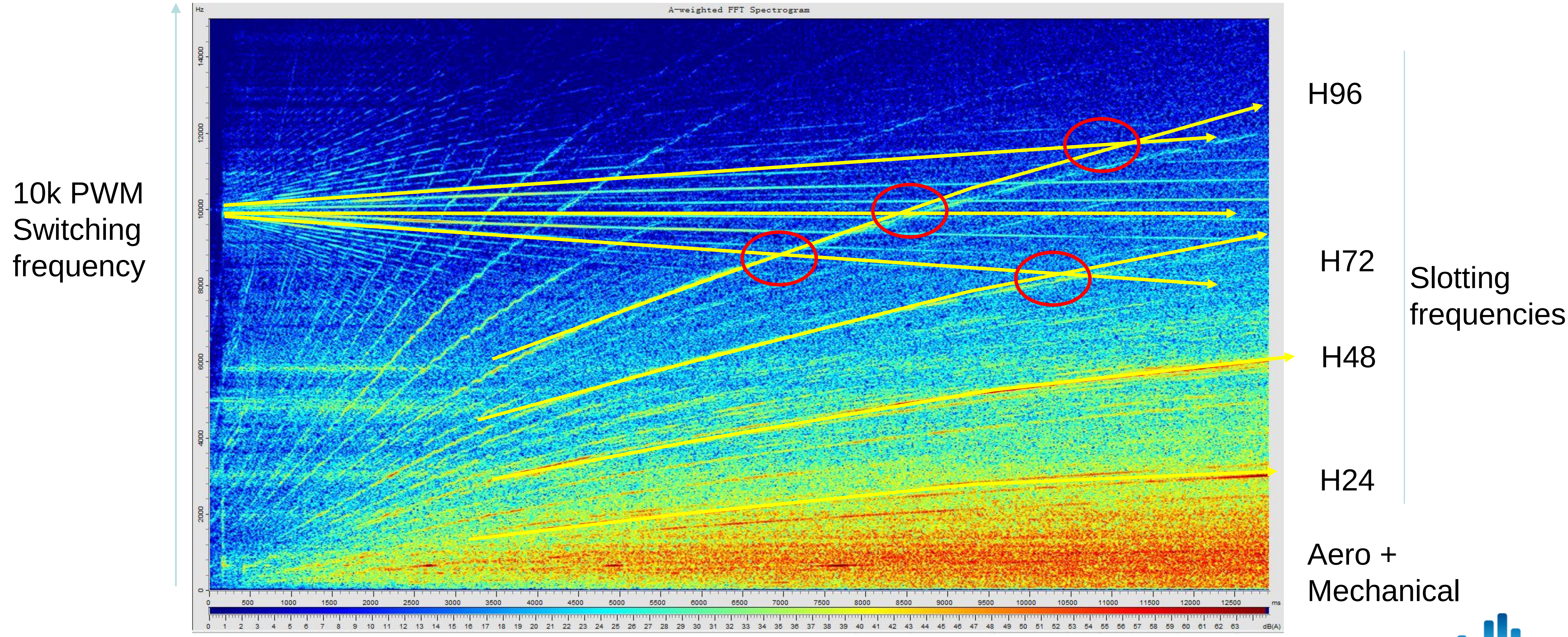


Inverter

PWM (Pulse Width Modulation)

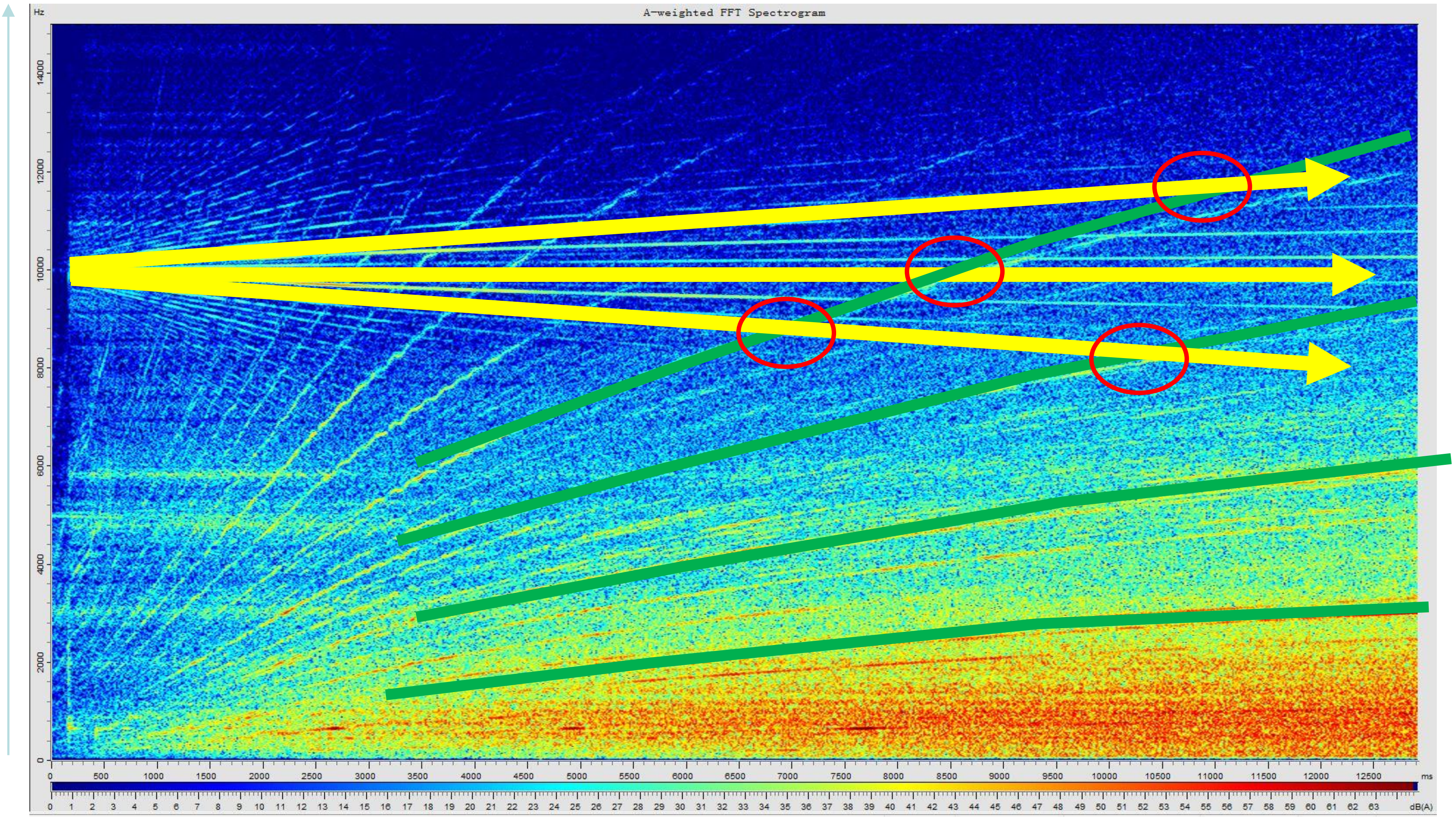
Switching Noise (characterized by the switching frequency)

Electromagnetic Noise

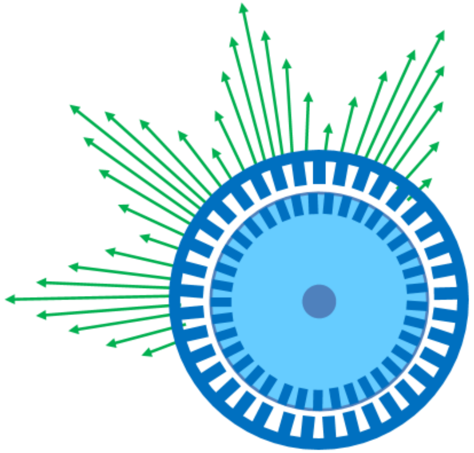


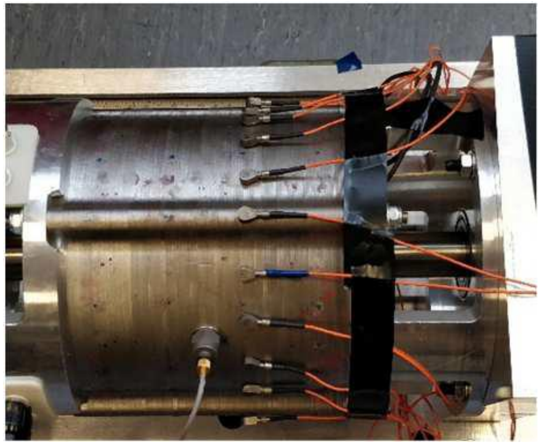
Electromagnetic Noise: e-markers

10k PWM Switching frequency



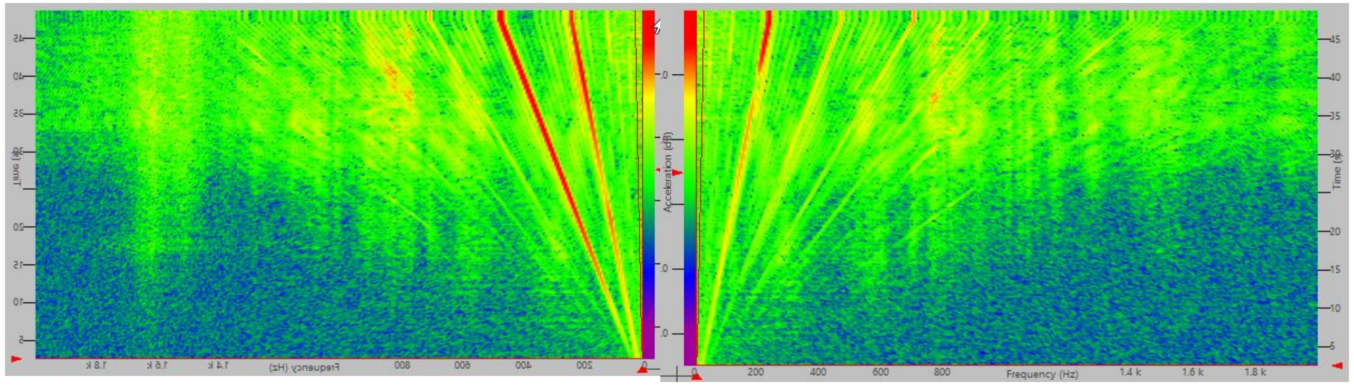
Spatiogram: a unique tool



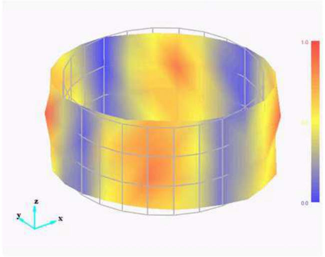


R=- 4

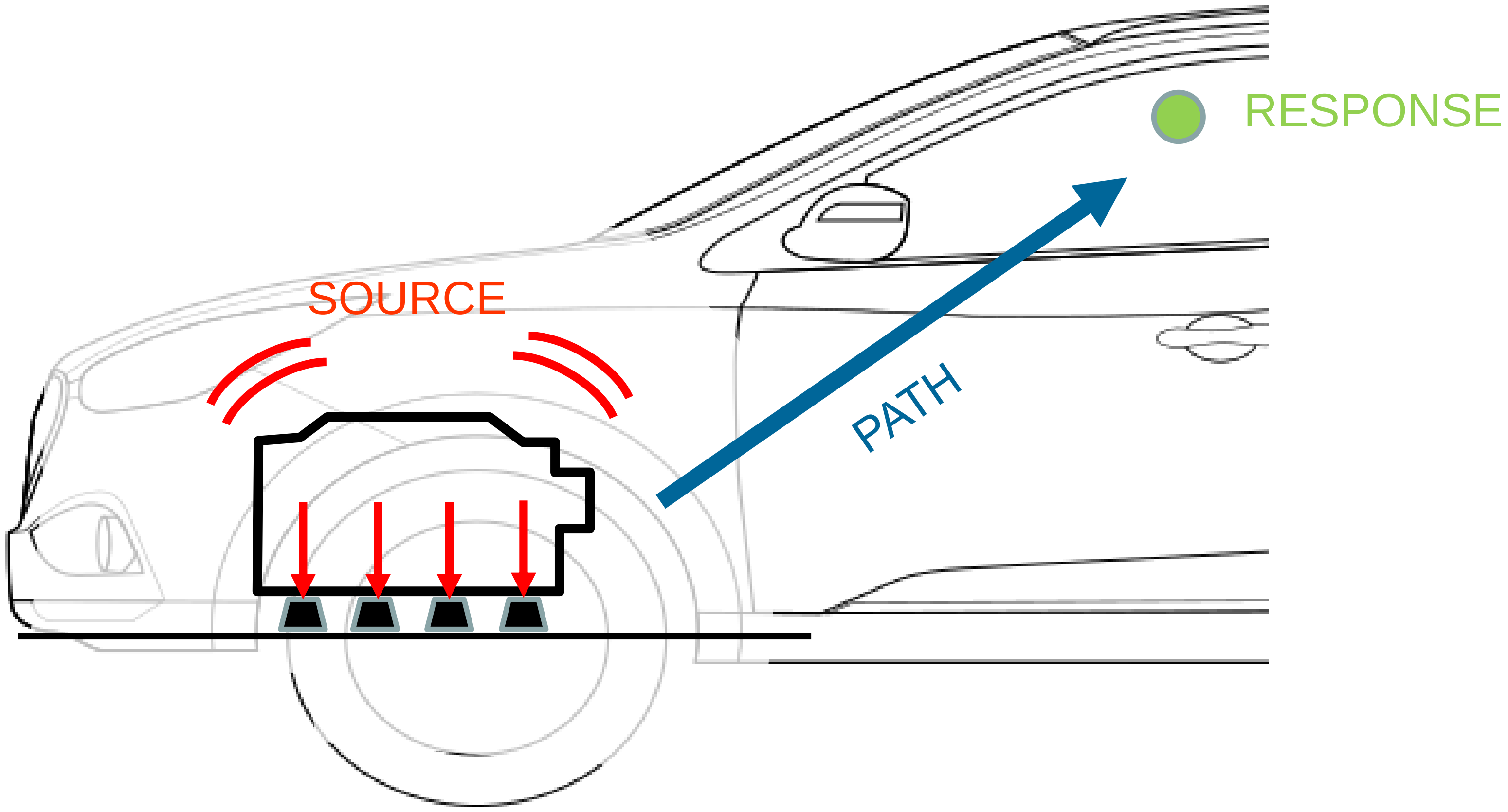
R= 4



- Based:
  - On motor topology
  - Load state, control strategy
- Characterize the circumferential distribution (using wavenumbers) of e-forces (electromagnetic forces) with their exciting associated frequencies -> avoid sensitive frequencies
- Completes the ODS approach



Where to solve the challenges?



Sound Design

- Different sound content (electromagnetic noise): From a broadband spectrum (appreciated) **SOUND** to a more tonal and annoying **NOISE with a higher frequency content.**

- Reduction of the ICE **masking effect** (Aerodynamic, Accessories motors, Tires).

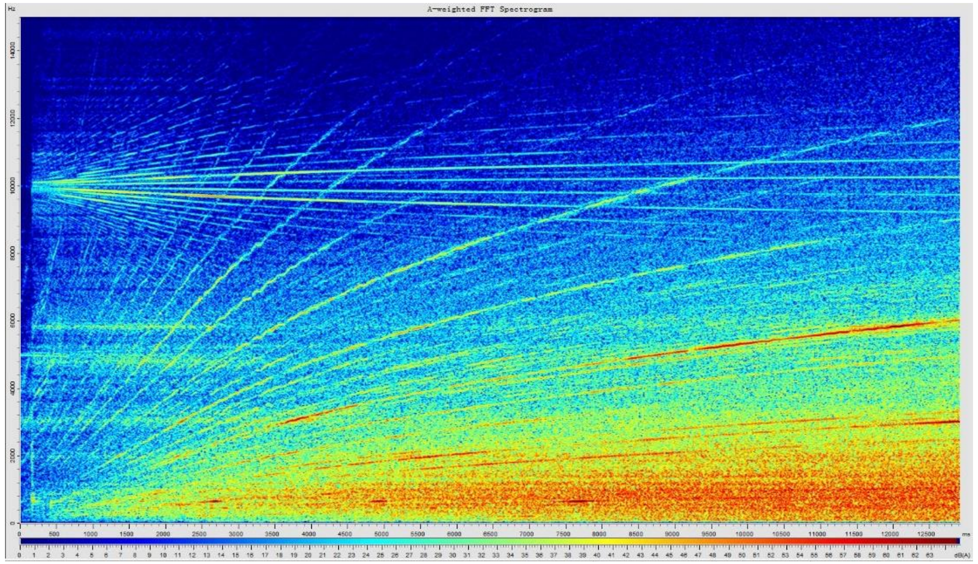
SOUND DESIGN based on
Psychoacoustics Indicators &
Filtering Playback

- Quantifies the perception of sound: Measure what we ear
- Determine objective psychoacoustic metrics in order to match the acoustic perception obtained through the human ear

Relevant psychoacoustics indicators for electric motors

Electromagnetic noise characteristics:

- Involves strong Tonalities:
  - Tone to noise ratio
  - Prominence ratio
- Noise shifted to high frequencies
- Low frequencies: Humming noise
- High frequencies: Whining noise
- Strong tonal content of pole/slot effect
- PWM effects: Roughness

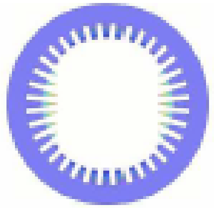


Emerging accessories noise

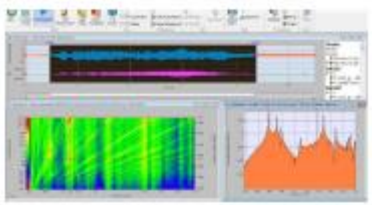
Masking effect decrease
→
Emergence of accessories components (electric motor based)
→
Sound Quality R&D required

Example of electric motors for levelling headlamps

OROS e-NVH module

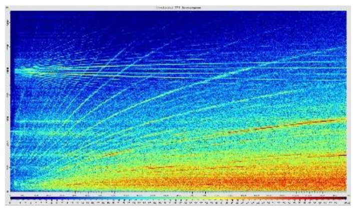


1- Applicative setup: e-motor + converter characteristics



2- Dedicated e-NVH tools to efficiently:

- Identify the magnetic vibration wave involved in noise generation
- Identify the wavenumber associated to a given vibration / noise line
- Separate the structural response from the magnetic excitations

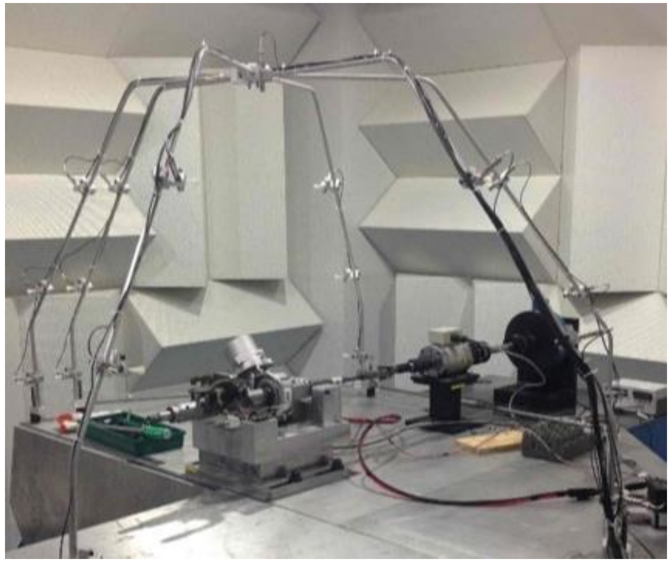


3- Provide a gateway for an efficient e-NVH design workflow

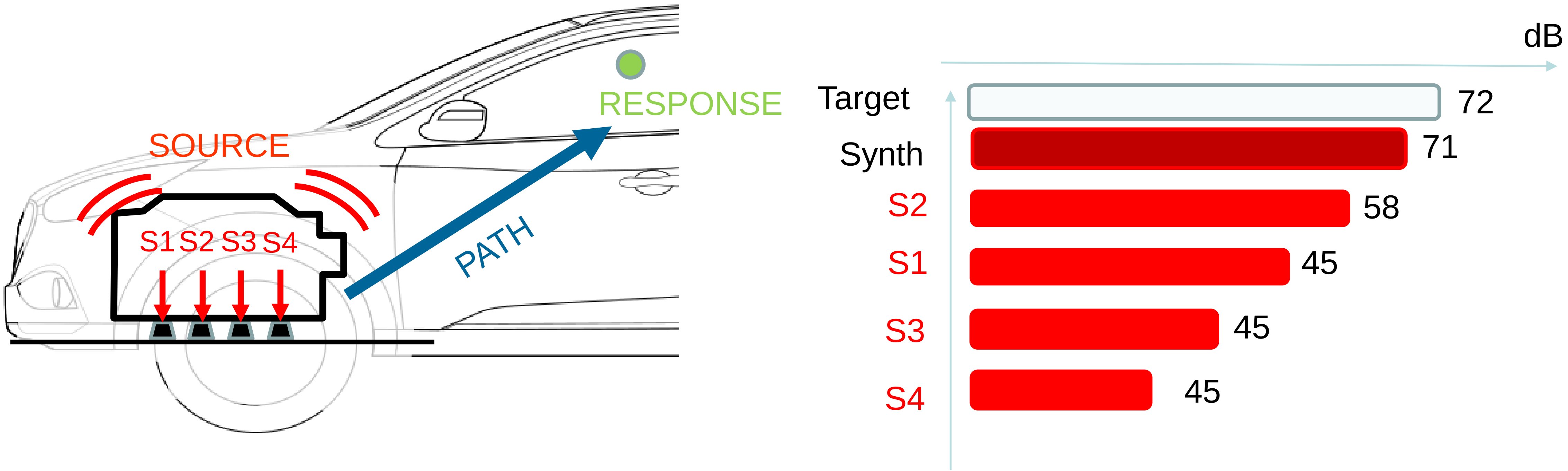
- Providing relevant **psychoacoustic indices** for e-NVH
- **Separating** magnetic from non-magnetic
- Enabling playback (virtual sound design of electric motor or switching signatures)

Quantifying sound: Sound Power

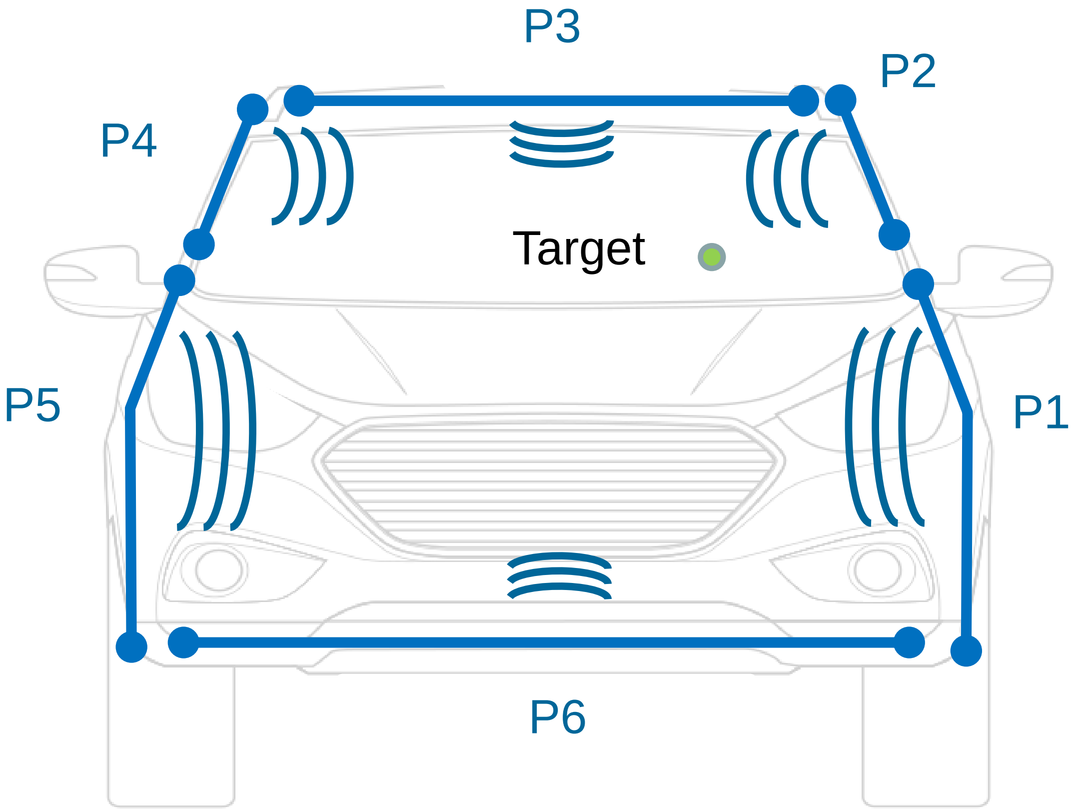
- Objective : Quantifying the emitted Sound Power (ISO based : ISO374x)
- Motor, Inverter, Accessory motors
- Anechoic chamber, Production

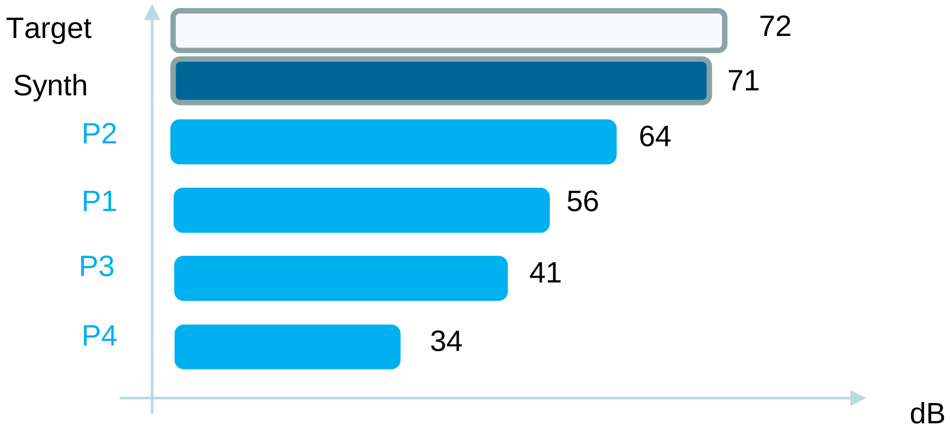


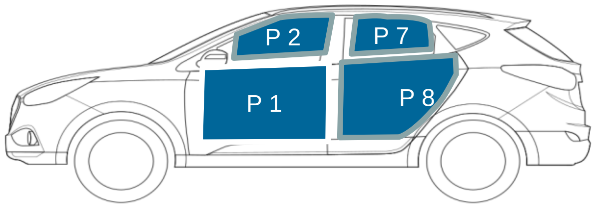
ATPA results: Structural contributions



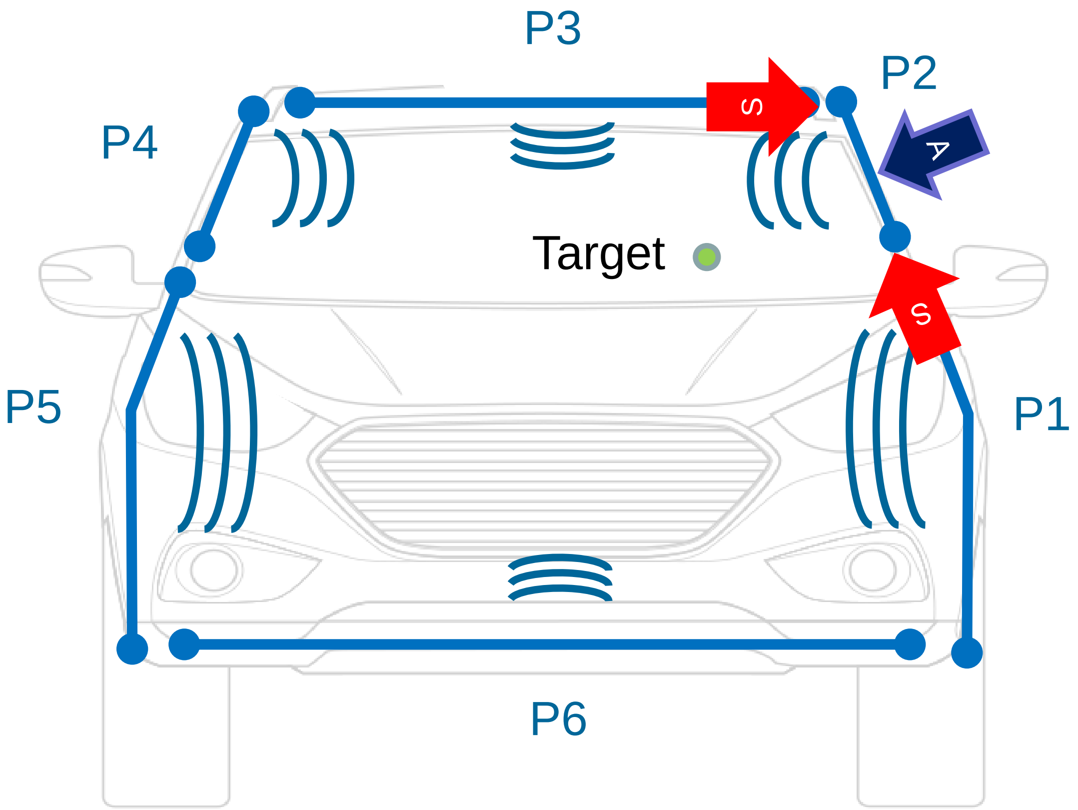
ATPA results: Panels contributions

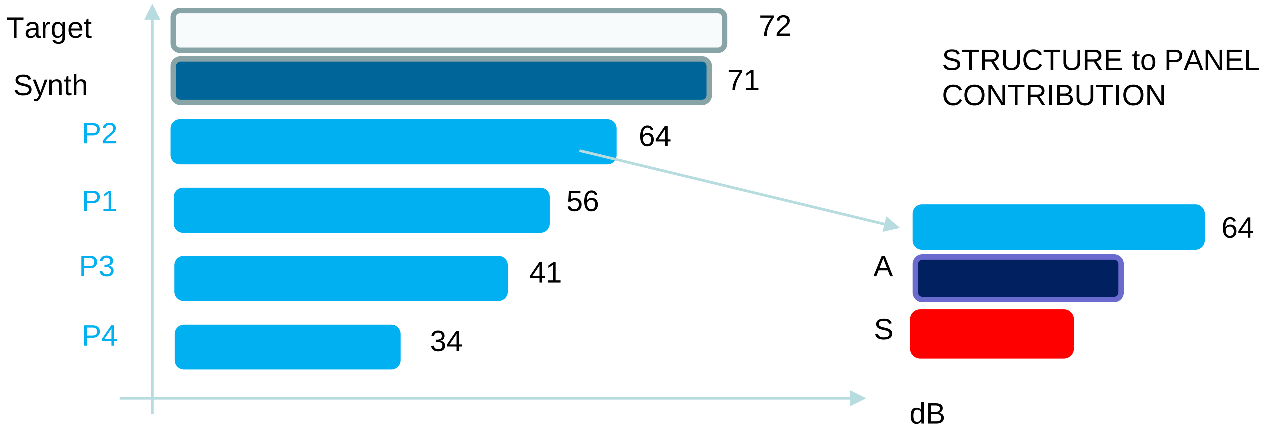


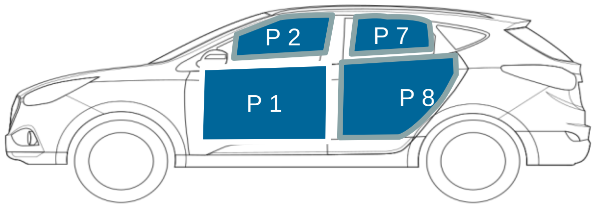




ATPA results: Structure to Panels

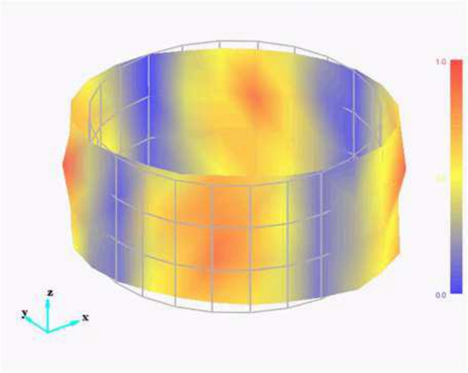


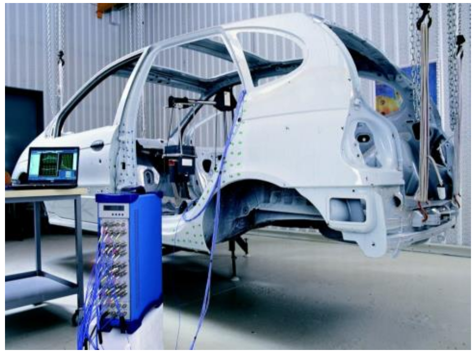




ODS and Modal Analysis

- ODS : Operating deflection shape
- Modal Analysis: SIMO, MIMO, OMA





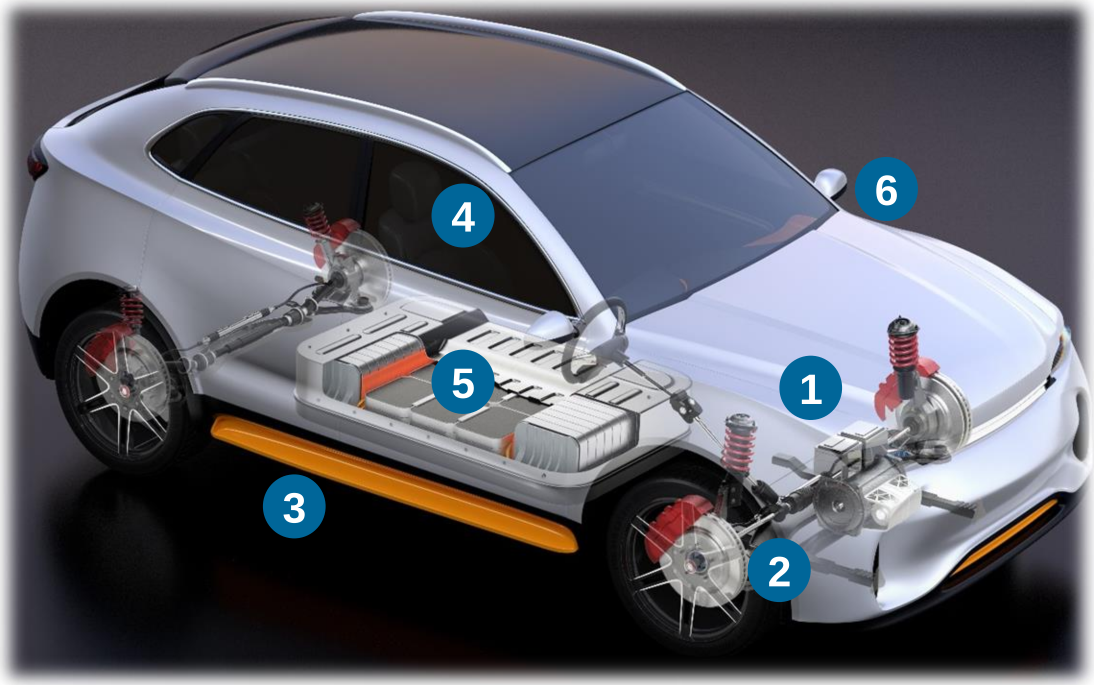
- Resonance frequencies
- Resonance damping
- Stator yoke deflection

EV/HEV Testing solutions: from sources to reponse

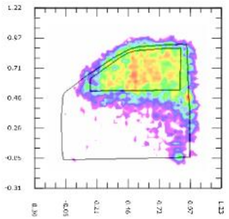
1 Electric Powertrain
Electric motor design
Electric markers
Spatiogram
Sound design of e-motors
ODS

2 Accessories & Components
Filtered playback
Pyschoacoustics evaluation
Sound Power

3 Chassis
Light structure modal analysis
Transfer path analysis





4 Panels
Transfer path analysis
Panel contributions at target
Sources ranking

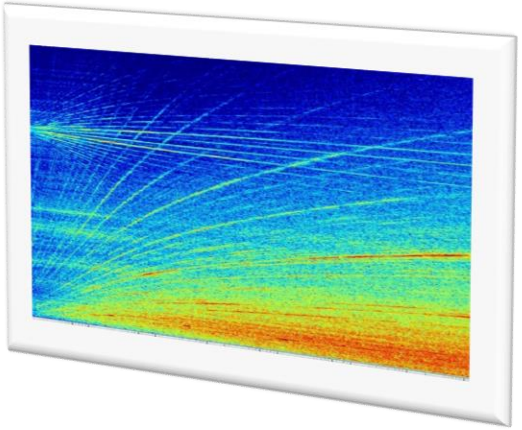
5 Battery charging noise
Noise frequency signature

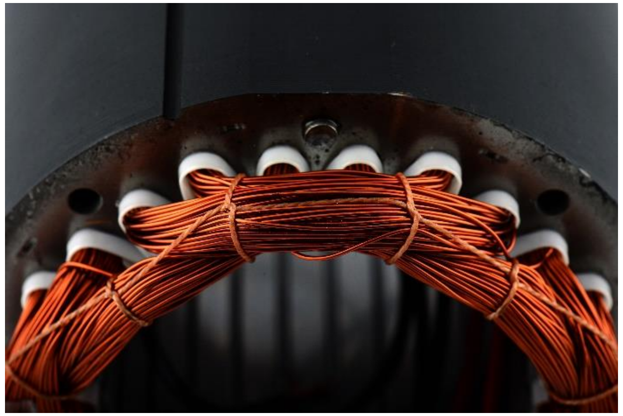
6 Aerodynamic sources
Acoustic holography to locate aerodynamic sources

OROS e-NVH Solutions

Services
Acquisition focused on your needs

Software
E-NVH measurements & analysis





Instrumentation
Acquisition focused on your needs

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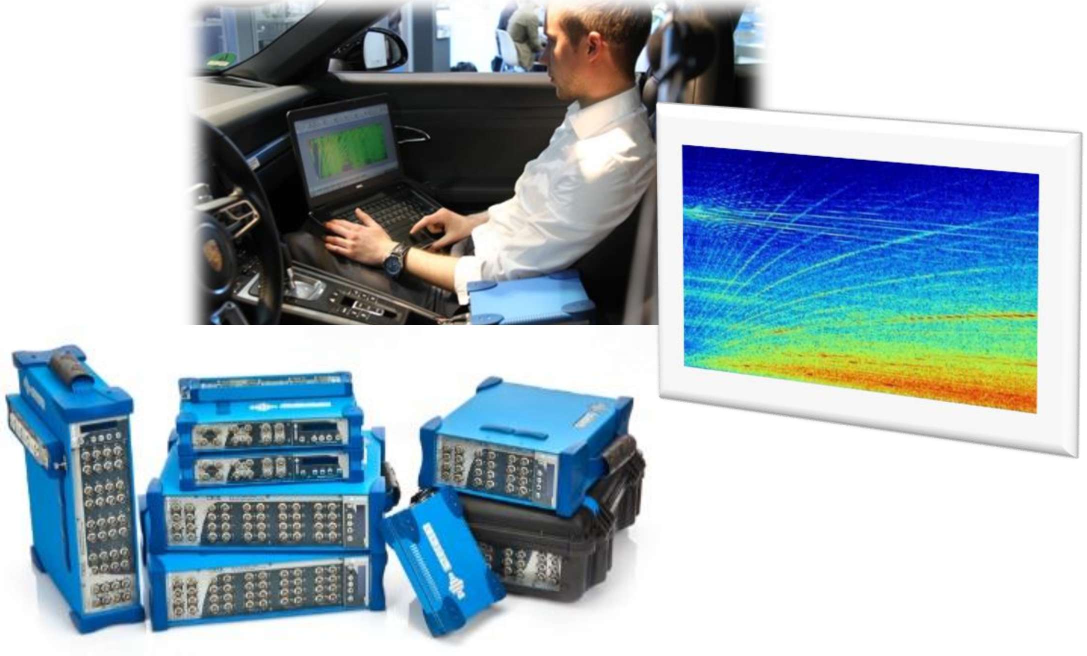
MEASURING NOISE & VIBRATION



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