Assessment of Noise & Vibration Performance of Composite Powertrain Brackets using NVH Simulator Models

Revathi Rengarajan, Hottinger Bruel & Kjaer
Ricardo Mercado, BASF
Chris Korson, BASF

Overview

- Introduction
- Technical Approach
- Instrumentation & Testing Considerations
- Case Study: EV Application, Rear Motor Mount

Introduction

- Lightweighting is a key focus area for the automotive industry
  - Improved fuel efficiency and reduced emissions
  - Improved range on Electric vehicles
  - Challenges with respect to cost, safety, durability and comfort targets

- Composite materials like Ultramid® Glass Fiber Reinforced (GFR) composites, are growing to be cost-effective light weighting option.

- The focus of this presentation is
  - to evaluate the NVH performance of these composites as powertrain mounts in comparison to traditional metal mounts, not just at the component level, but in-situ as well.
  - To showcase a set of tools and methodologies to evaluate the subjective performance of these mounts, in the right context.
  - To demonstrate other what-if studies that quickly become possible by combining test and simulation methods using the NVH Simulator.

HBK HOTTINGER BRÜEL & KJÆR

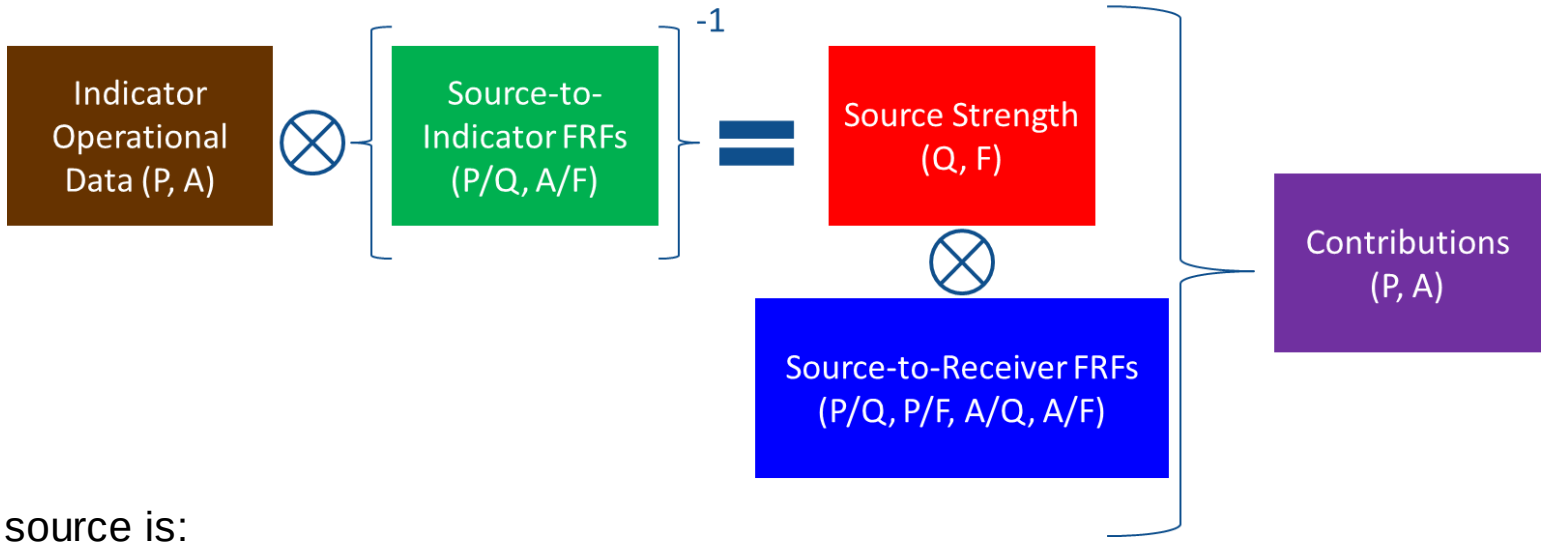
Technical Approach

- Source Path Contribution (SPC)/Transfer Path Analysis (TPA) technique use to quantify the NVH performance of the mounts and their contributions to the in-cabin experience.

- Use of NVH Simulator to auralize the SPC results and conduct subjective evaluations of the GFR mounts vs traditional mounts.

Source Path Contribution Methodology

- SPC analysis is performed to characterize independent sources and paths of Powertrain and Road noise

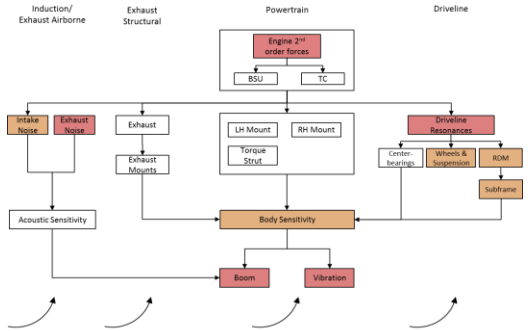


- Output for each source is:
  - Time-domain Source Strength (Units of Force, Volume-Velocity)
  - Frequency-domain Sensitivity (Transfer function from Source to Receiver)
  - Time-domain Contribution (Receiver signals from each Source)

- The Sum of Contributions to each Receiver gives us a measure of total sound captured by the SPC model and allows for validation of the model by comparison to the measured Receiver signals
  - We expect this sum to be similar to the measured signals over the valid frequency range

SPC Data and Migration to NVH Simulator Model

- Utilize existing Transfer-Path-Analysis (TPA/SPC) models
  - For key components (engine, motor, exhaust, tires, gears, HVAC, etc.)
- Combine TPA/SPC model with contributions from other sources to provide full context for the customer experience.
- Jury studies and listening evaluations
- Target setting and target cascading
- Assess and plan for performance prior to availability of hardware



Existing SPC/TPA models

Road Noise

Gear Noise

Powertrain Noise

Instrumentation Considerations

- Powertrain SPC study
- Transducer placement on the subframe/body structure instead of active side of powertrain component
  - Excludes participation from any rubber isolating elements
  - Easier to measure using hammer excitation

- Matrix inversion SPC approach
  - Successful inversion of transfer function matrix requires redundant (indicator) transducers per source location
  - Indicator to source ratio >2x
  - Instrumentation only on body side – only 1 set of transfer functions measured per vehicle & operational measurements repeated for each powertrain mount

Sensitivity Measurement Considerations

- Artificial excitation method for local and global transfer functions

- Impact hammer test for SB measurements in X,Y,Z directions for each mount
  - Powertrain components remain attached – proven to be time efficient and provide comparable results to disconnected method

- Volume Velocity source used for AB measurements
  - Airborne sources identified at each side/face of the powertrain.

- Frequency range considerations
  - higher RPM operation ranges of e-motor and switching frequencies of inverters => higher frequency range requirements of SB and AB sensitivities

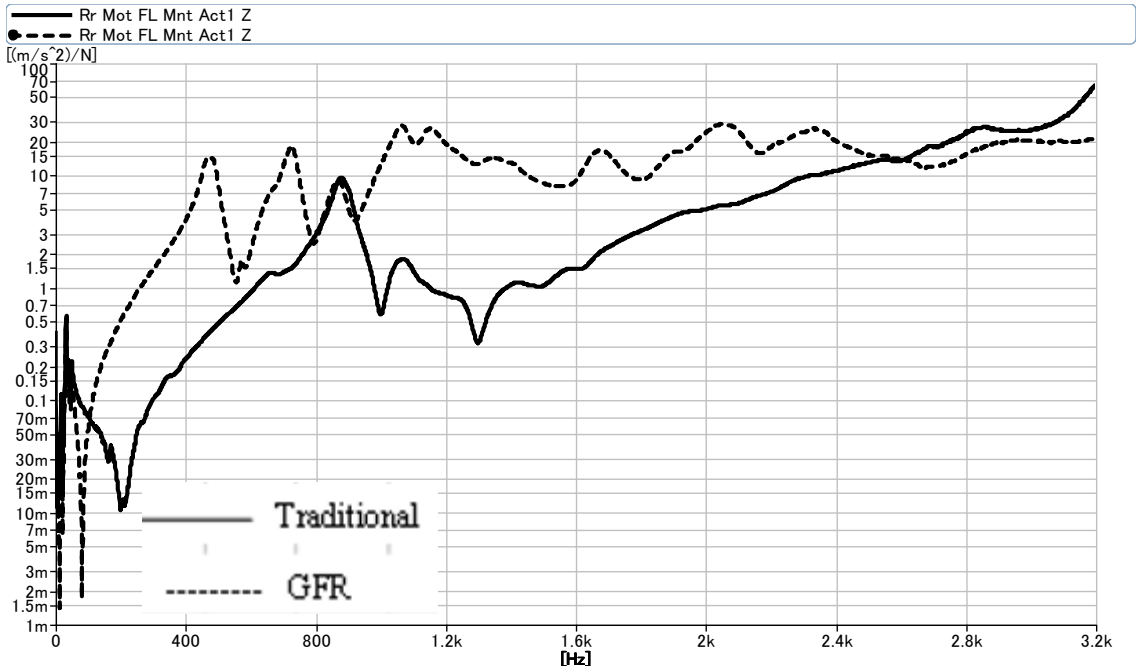
Operational Measurement Considerations

- Powertrain SPC focus – Operational measurements conducted on a Chassis Dynamometer
- Several operating conditions measured
  - Several throttle/pedal % for one or more gears
  - Steady state measurements
- Operational measurements repeated for each mount (GFR and traditional mount)

Case Study – EV , Rear Motor Mount

- Dual Motor EV – 3 motor mounts per motor - Rear left motor mount is of interest for this study

- Motor Mount local transfer function comparison



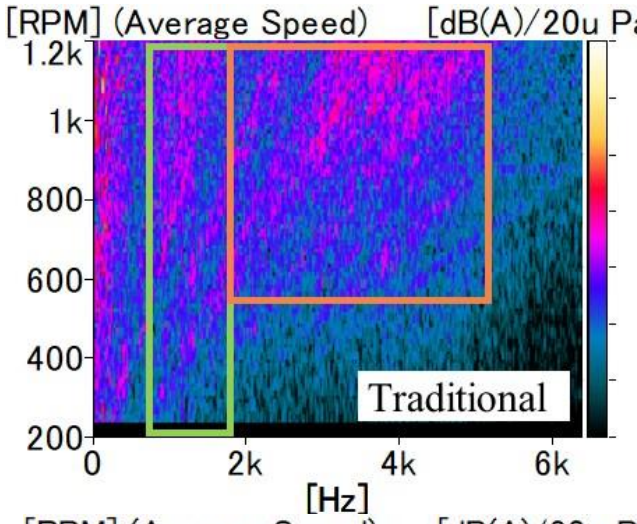
- Traditional mount has very flat response below 800 Hz and above 1200 Hz.

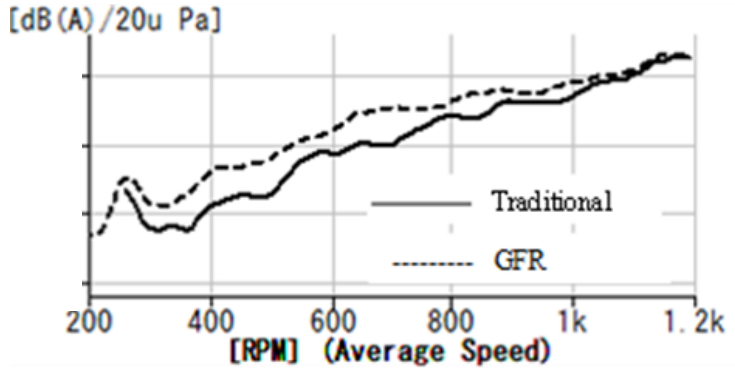
- GFR Bracket has elevated vibration levels and several resonant peaks up to 2400Hz
  - May indicate deterioration of NVH performance at source, but SPC analysis required to say conclusively.

Case Study – EV , Rear Motor Mount

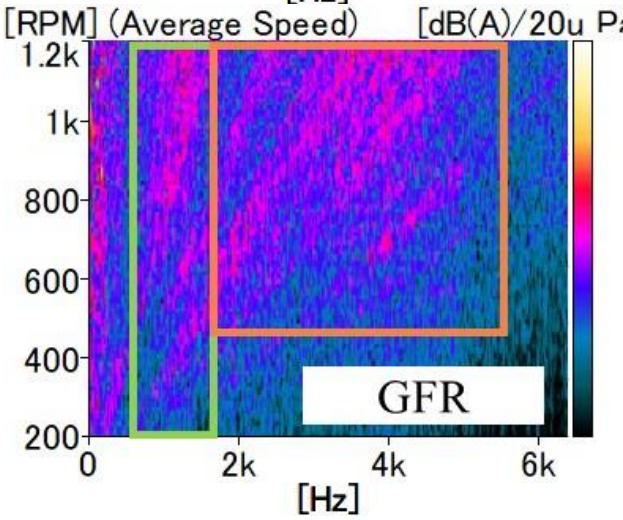
Operational data at Receiver Ear

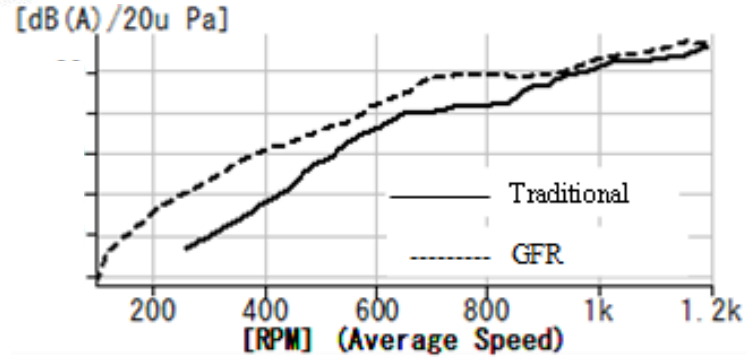
- Primary motor & Gear mesh order content did not show much variations.
- Looking at broadband content, elevated response for the GFR brackets in 900-1500 Hz and 2000-4500 Hz ranges by up to 5dB.
- Important to note that this data was collected on a Chassis Dyno
- Impact of realistic Road/Wind masking should be considered





Frequency slice 900-1500 Hz

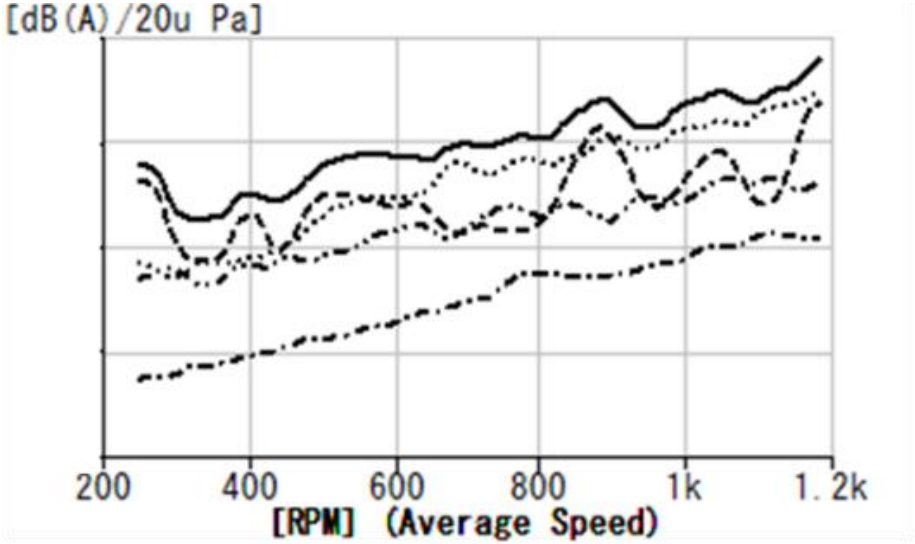




Frequency slice 2000-4500 Hz

Case Study – EV , Rear Motor Mount

- SPC Analysis performed to understand contributions
  - Front v Rear motor
  - Airborne v Structure-borne contributions
- Rear AB> Rear SB > Front SB > Front AB
- Rear left motor AB contributions are the top contributions in 2000-4500 Hz range, and the rear left motor mount SB contributions are the highest in the 900-1500 Hz.
  - This is based on data collected on a chassis dyno – impact of realistic road and wind masking should be considered.

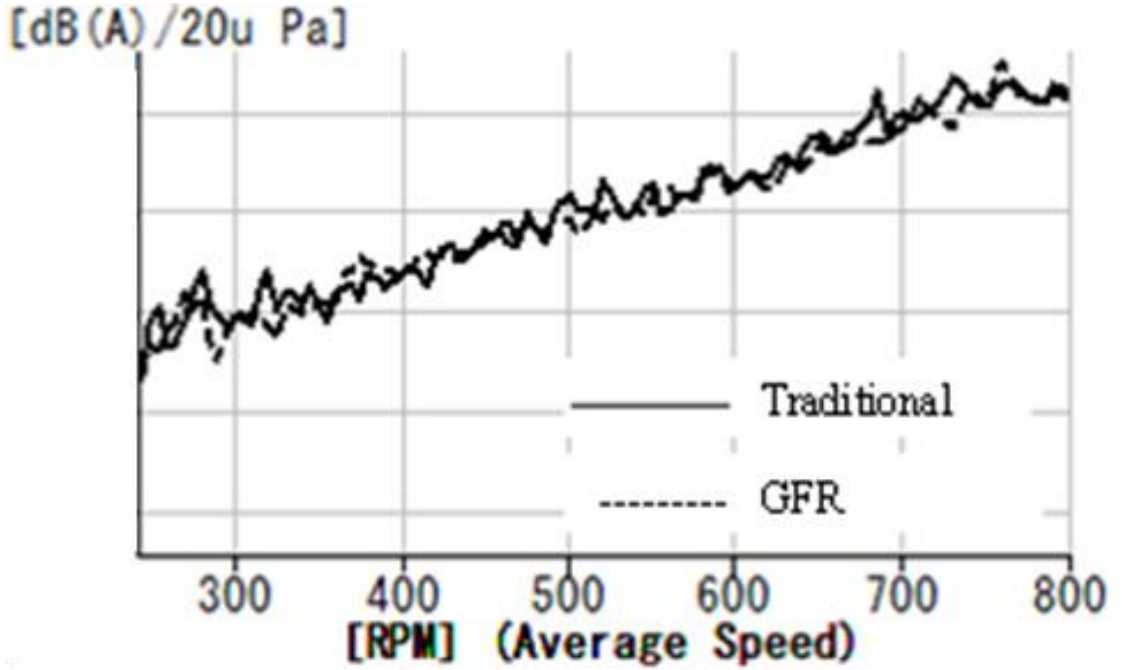


Case Study – EV , Rear Motor Mount

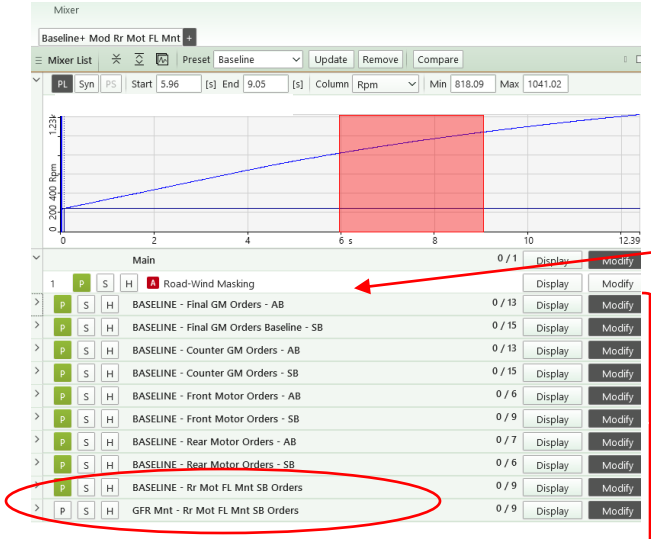
- NVH Vehicle Simulator Modeling
  - The order content was combined with more realistic road/wind masking from 0-130kph using the NVH Simulator tool.

- Traditional and GFR mount results at the receiver ear is very comparable.
  - Road/wind masking masks differences in the brackets
  - Confirmed subjectively as well

- **For this vehicle application, the NVH performance of the GFR is comparable to the traditional bracket and can offer tangible weight and cost savings if the other functional performance targets are achieved.**



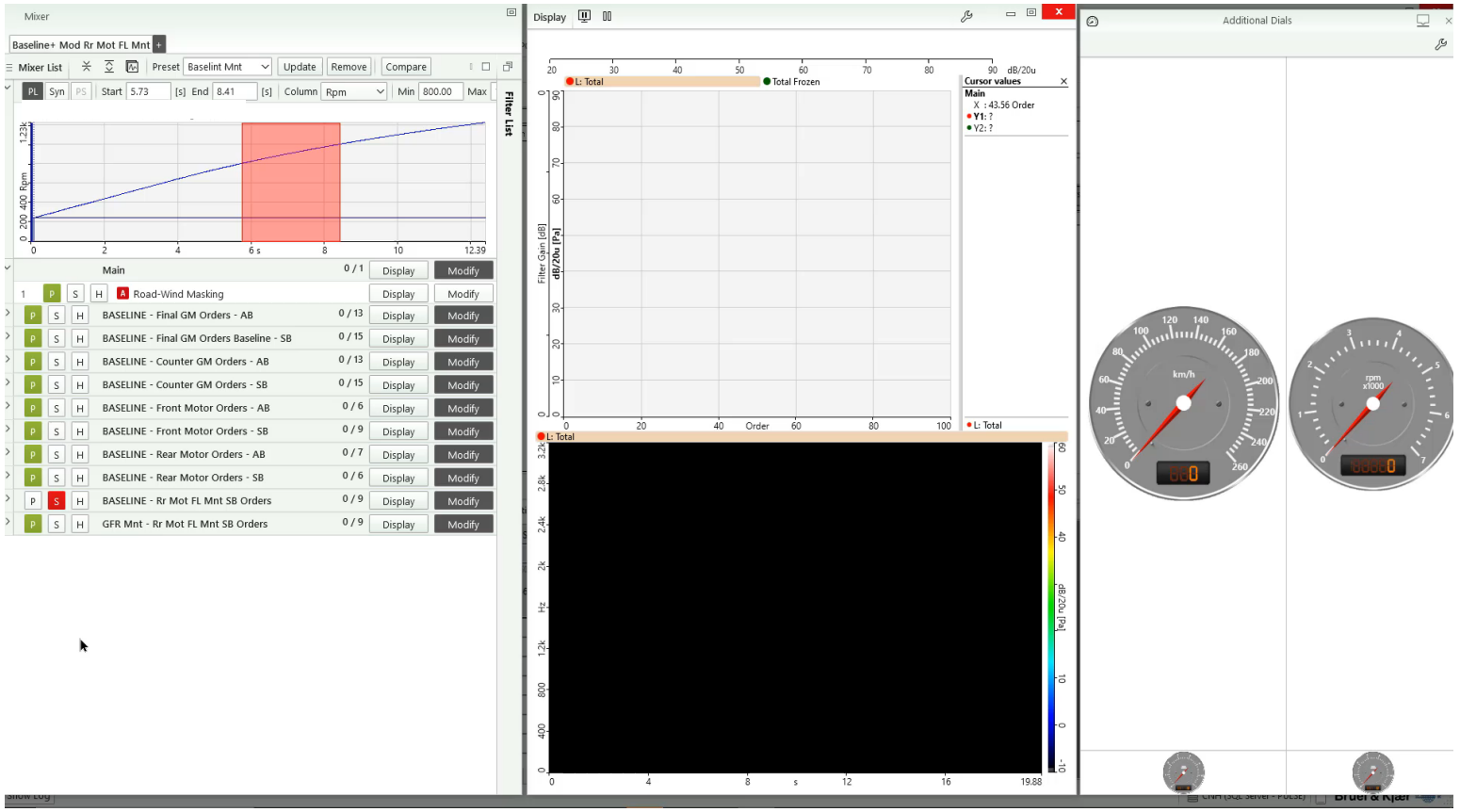
Rear mount Swap - Subjective Evaluation in NVH Simulator



Realistic road & wind noise masking

SPC contributions are broken down into Gear Mesh orders & Motor Orders (front and rear).

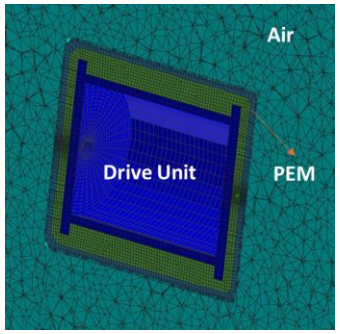
Rear Motor FL Mnt SB contributions – Baseline v GFR Mnt



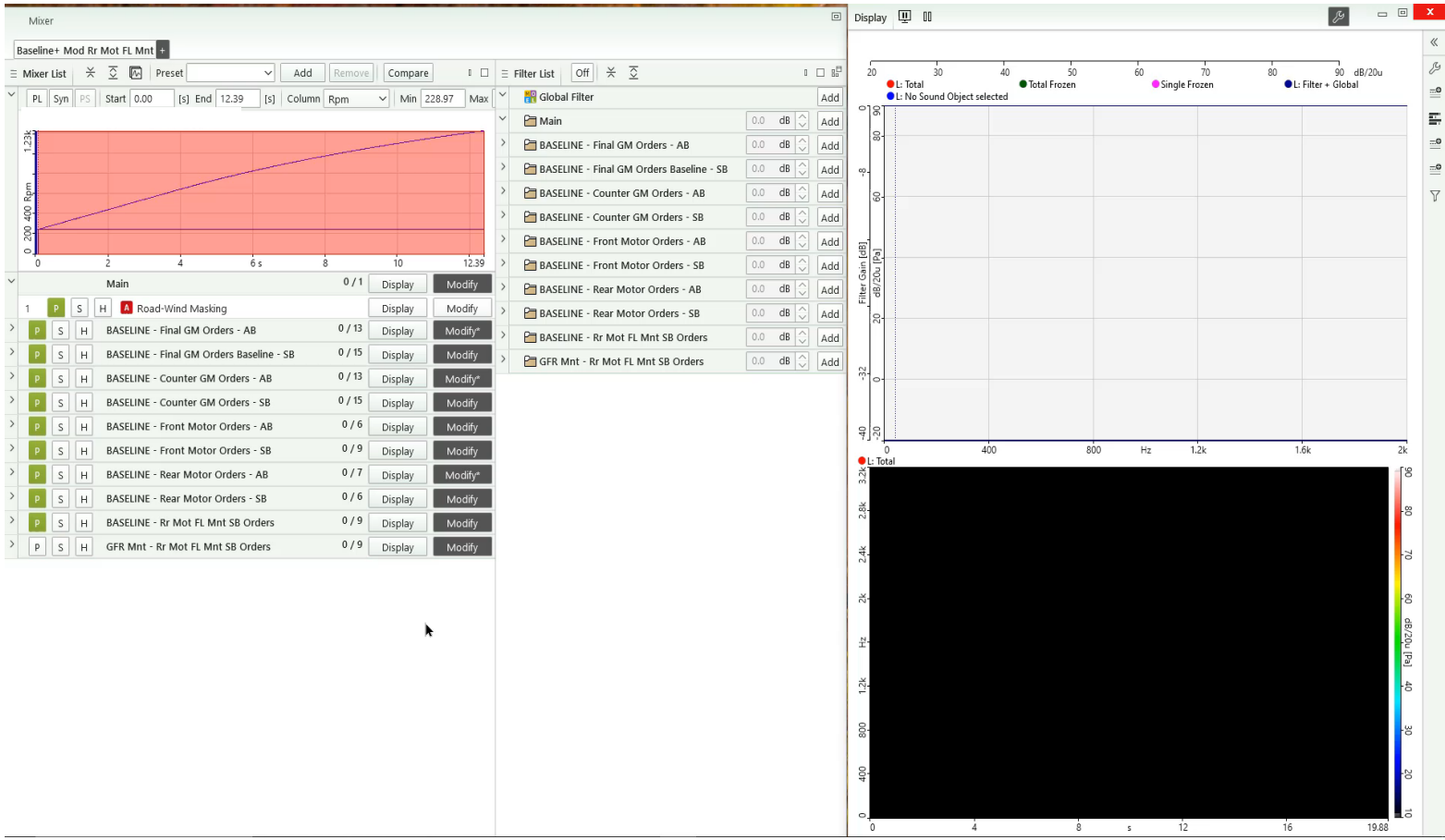
Actively playing groups are highlighted

- Evaluation of the Rear Motor FL Mount contributions shows elevated response for the GFR mount in comparison to the Metal Mount.
- However, when evaluated with the right context of road-wind masking and other contributions, the differences in the mounts are not discernible.

Motor Encapsulation Simulation



- The Main focus of the test-based study discussed so far was to evaluate the SB contributions of the GFR Mount swap.
- Shown here is an additional example of a CAE based motor encapsulation study and its effect on the total sound at the Receiver.
- ESI Group shared with us an example filter for a motor encapsulation study.
  - ESI's VPS NVH Software was used to simulate the effect of drive unit encapsulation
  - The drive unit is excited with EM or generic forces at the stator attachments.
  - A filter is created using the ratio of the sound power with encapsulation over the one without encapsulation.
  - This filter is applied on the Airborne contribution groups to study its effect.



Summary and Conclusions

- Ultramid® brackets have advantages when compared to traditional metal powertrain brackets.
  - Mass savings and a cost-effective part price
- For the EV case, inherent difference in stiffness between the metal and composite brackets could present a challenge.
  - Even if some initial tests suggest potential deterioration in performance, a comprehensive contribution analysis is needed to assess the potential risk and opportunities for metal substitution.
  - As shown in the EV Case study, sufficient Isolation or performance of the electric powertrain can absorb the slight degradation in performance given the relatively low levels of some of the high frequency order content relative to road and wind noise masking.
- An additional example of a CAE based Motor encapsulation study was also shared to demonstrate other what-if studies that could be performed once such a simulator model has been developed.