Müller-BBM
Vehicle acoustics

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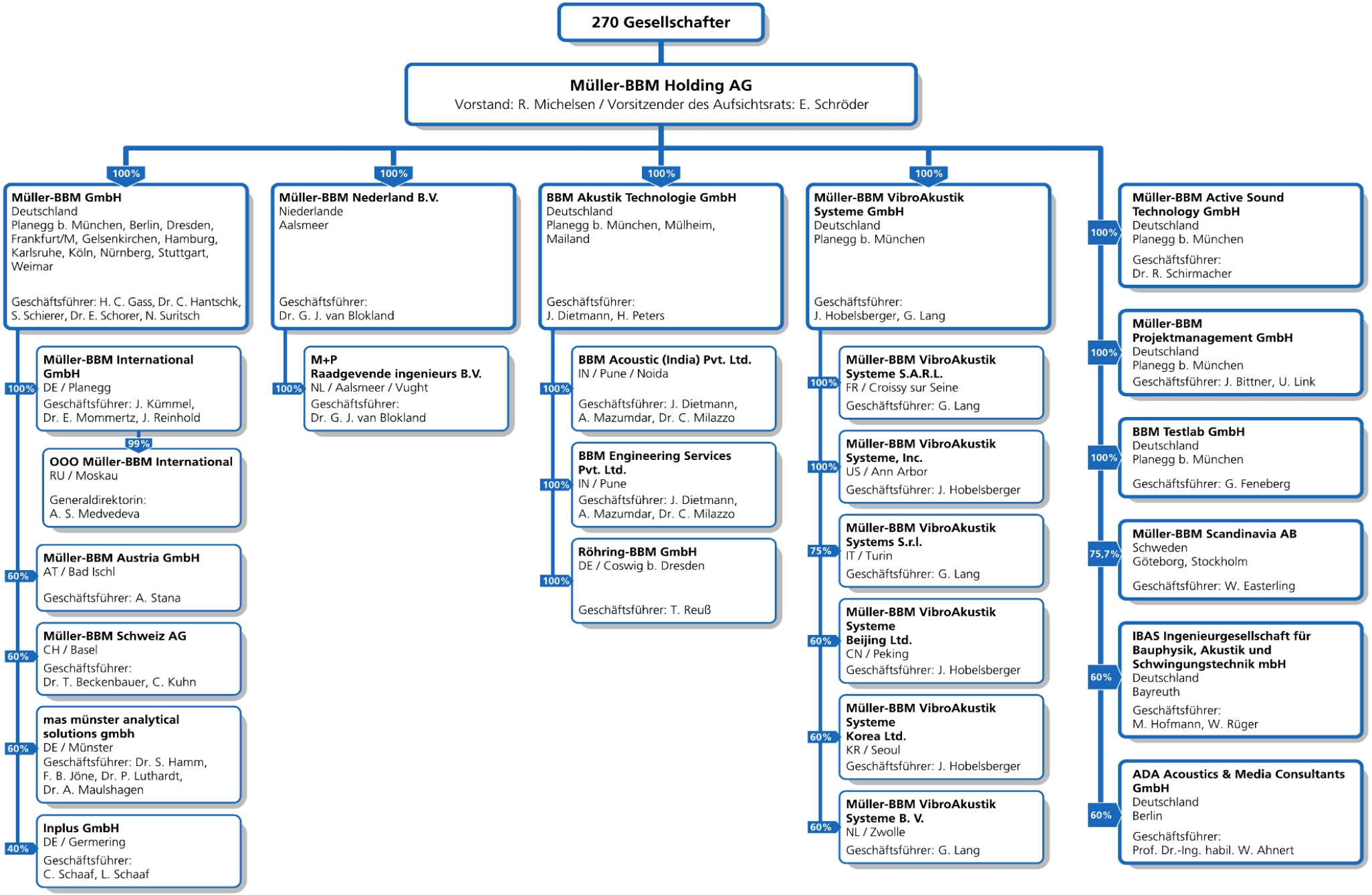
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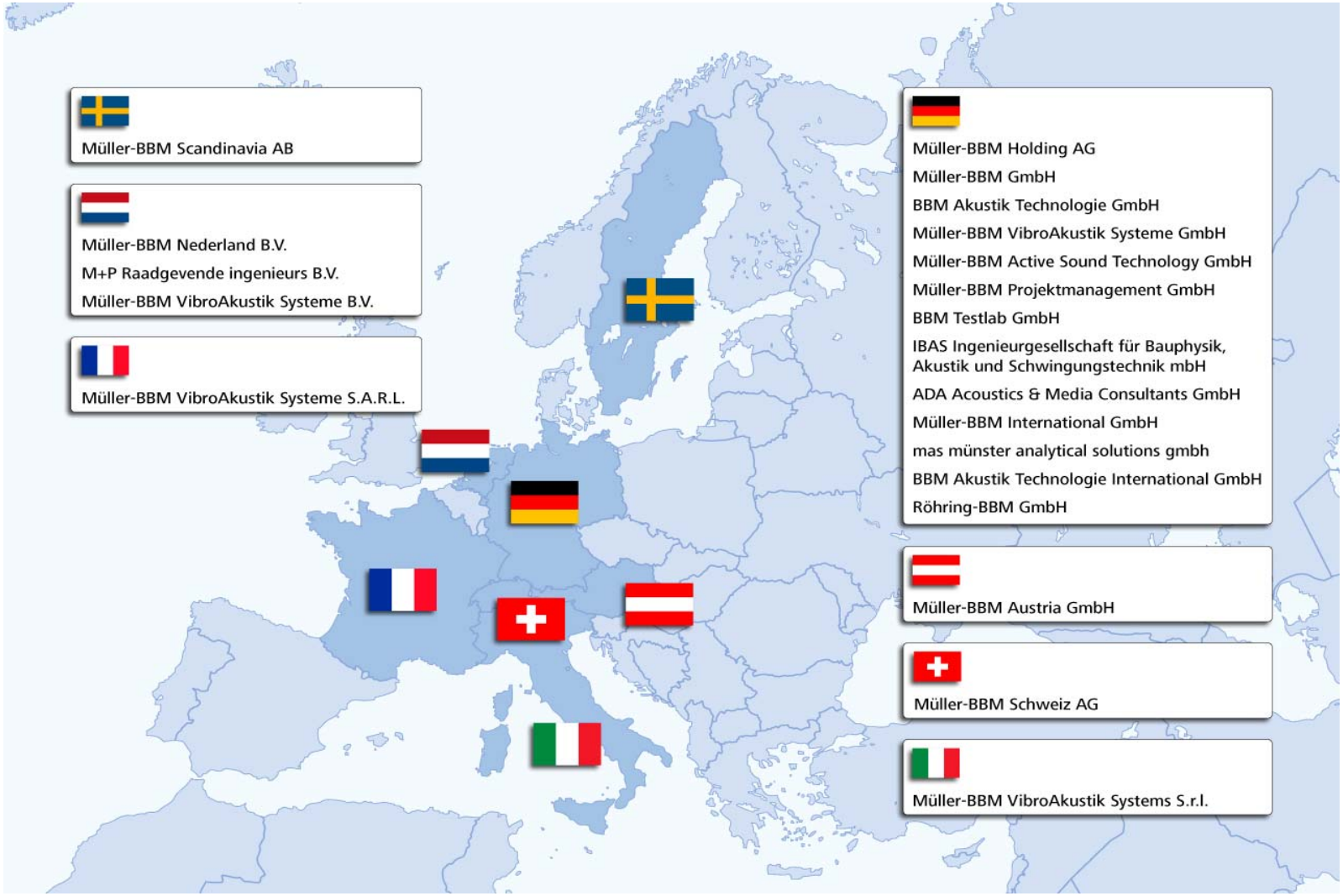


... and worldwide for example in China, India, Korea, Russia and USA

Company Structure of Müller-BBM GmbH

Technology

Vehicle Acoustics

Machinery Acoustics

Psychoacoustics

Sound and Vibration Control

Ship Acoustics

Mobile Communication

Product Tests

Environment

Air Quality Control

Noise Control for Traffic and Environmental Noise

Industrial Noise Control

Vibration Control

Electromagnetic Environ-mental Compatibility

Lighting Engineering

Harmful Substances in Buildings

Safety Engineering

Buildings

Room Acoustics

Electro Acoustics and Audio/Video

Building Acoustics

Thermal and Hygric Building Physics

Building Climatology

Facade Technology

Fire Protection

Building Dynamics

NVH customers of the Müller-BBM Group

OEMs (extract):

Audi
BMW
Caterpillar
Daimler
Ford
Fiat
Honda
Hyundai
IVECO
MAN
Mercedes Benz
Mitsubishi
Nissan
Opel (GM Europe)
PSA
Renault
Renault (Engines)
Rolls Royce
Scania
Suzuki
Toyota
Volkswagen
Volvo CC
AB Volvo Group

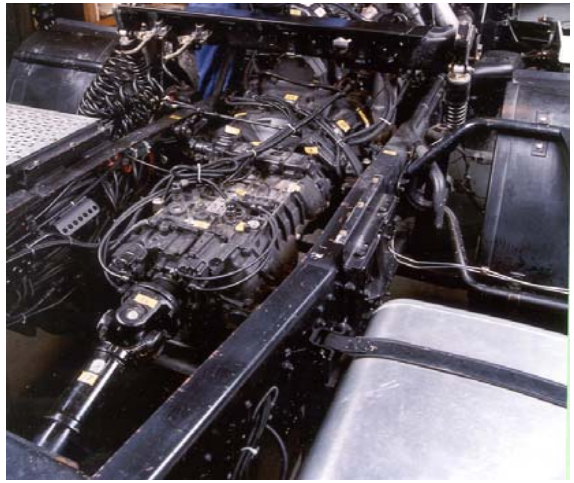
Suppliers (extract):

AVL
Autoliv
BASF
Behr
Boysen
Borg Warner
Continental
Eberspächer
Edscha
EMCON (Arvin Meritor)
FEV
Getrag
Johnson Controls
Lear
Mann & Hummel
Michelin
Rieter (Autoneum)
Siemens
Takata Petri
Tenneco/Walker
ThyssenKrupp Presta
TRW Automotive
Valeo
Visteon
Webasto
WET
ZF

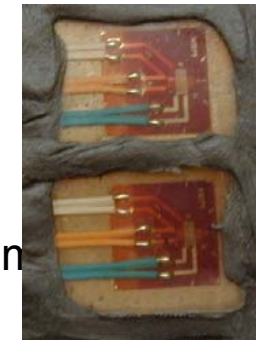
Typical fields of work

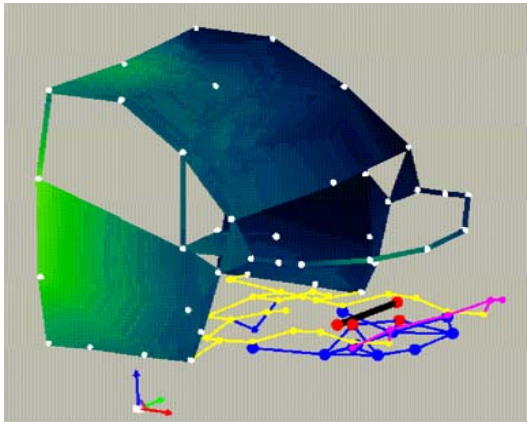
- Support in the acoustical development process
- Development of new methods
- Selection of methods in direct relation to the task
- Application of the acoustic analysis methods through experts with broad expertise
- Trouble-shooting with experimental airborne and structure-borne sound investigations
- Psychoacoustics and sound design
- Standard tests for acoustic parameters
- Synthesis of interior sounds based on OTPA
- Simulation based on FE and EMA

Vehicle NVH methods



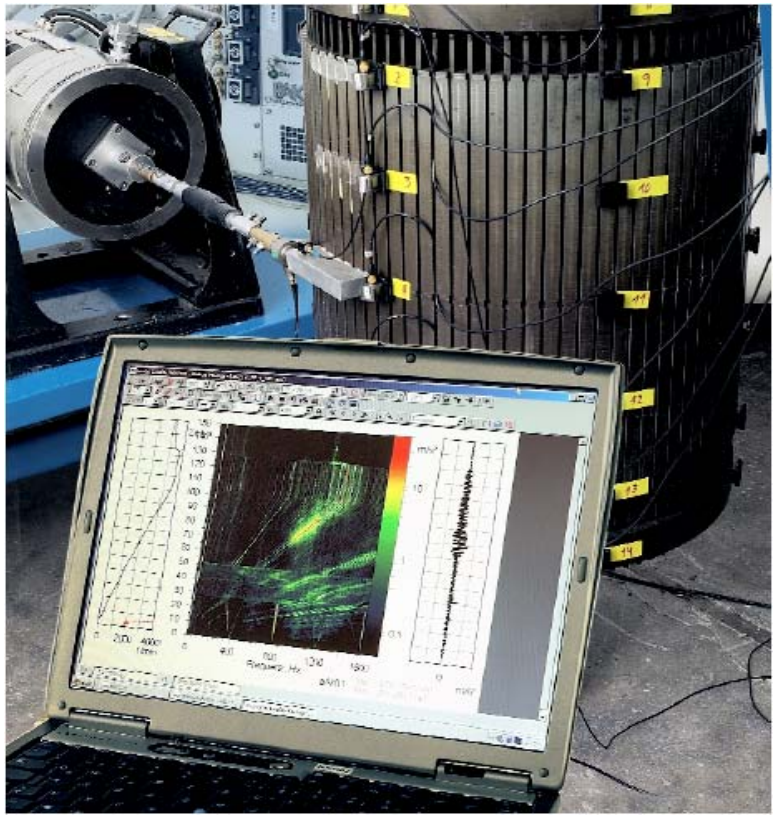
- **Numerical methods and simulations**
  FE, BE, SEA, engineering models
- **Experimental methods and analysis**
  TPA/TPS, CTC, AMM, modal analysis, DMS, telemetry, order analysis, intensity measurement, array measurement technique (sound localisation), psycho acoustics
- **Test facilities**
  Dynamic stiffness, reverberation & anechoic rooms, vehicle measurement room materials test facilities, problem-special test stands, on-site measurements
- **Psychoacoustics and sound design**
  Subjective evaluation, listening tests, quantities & parameters, Active Sound Design (ASD)

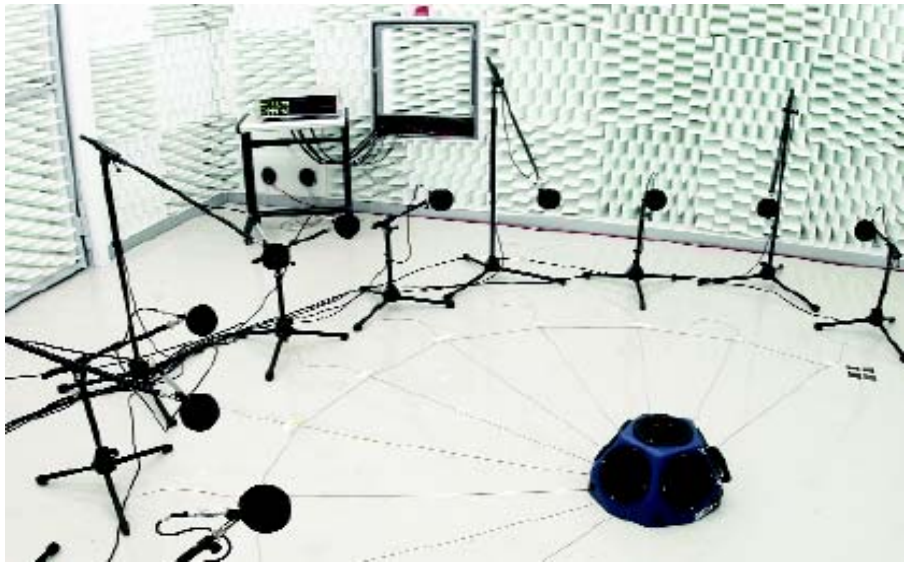




General Methods

- Multi-Channel measuring technique for airborne and structure-borne sound with PAK. Time domain, frequency domain
- Rotational speed-related measurements
  crank angle analysis, order analysis
- Sound power measurements
  semi anechoic room, ISO 3745



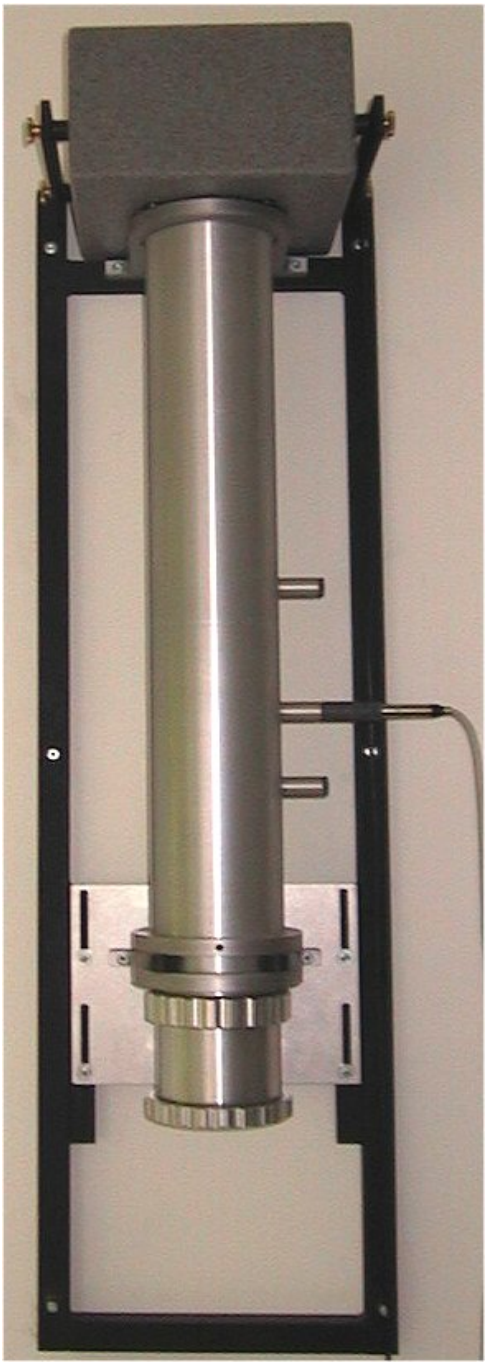


General Methods - Parameters

- Structural-dynamic measurements
- Impedance
- Damping factors
- Modal analysis
  eigen-frequencies –
  mode shapes, damping loss
- Dynamic stiffness of
  damping elements

General Methods - Parameters

- Coupling loss factors
- Transmission and insertion loss
- Absorption coefficient
- Flow resistance



Testing of materials

Aerogele

Aerogele have advantageous thermal properties for hot components. The relevant acoustic properties such as damping loss factor, sound insulation, sound radiation and sound absorption were determined for different combinations of the material in the test stands at the Müller-BBM laboratories. The acoustic properties of those materials now can be compared to others.

Rear axle mounts

In a sporty car a tonal component of the rear axle mount was clearly audible in the interior during certain driving conditions. By OTPA and checks with additional masses at the car body side it was found that the damping of the rear axle mounts was not sufficient at that frequency. By testing several types of mounts in the test stand for dynamic stiffness at the Müller-BBM laboratories the improved versions of the mounts were selected.

Introduction of new methods

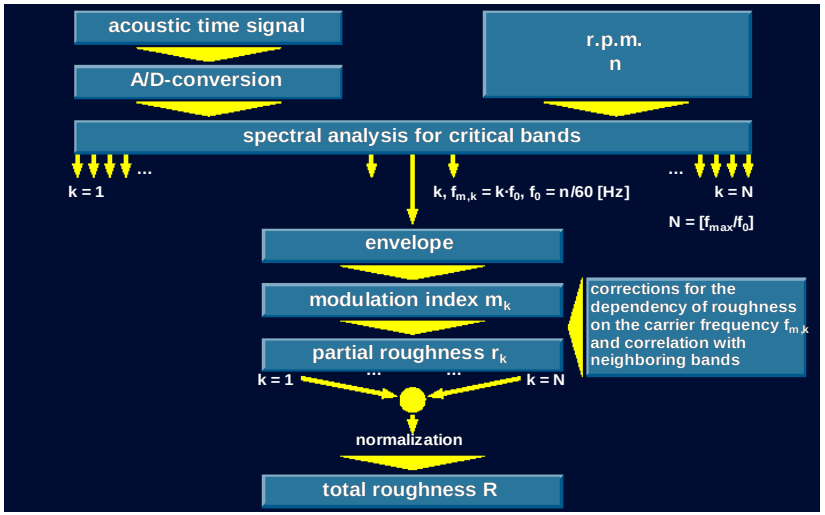
Sound source localization using beamforming with microphone arrays

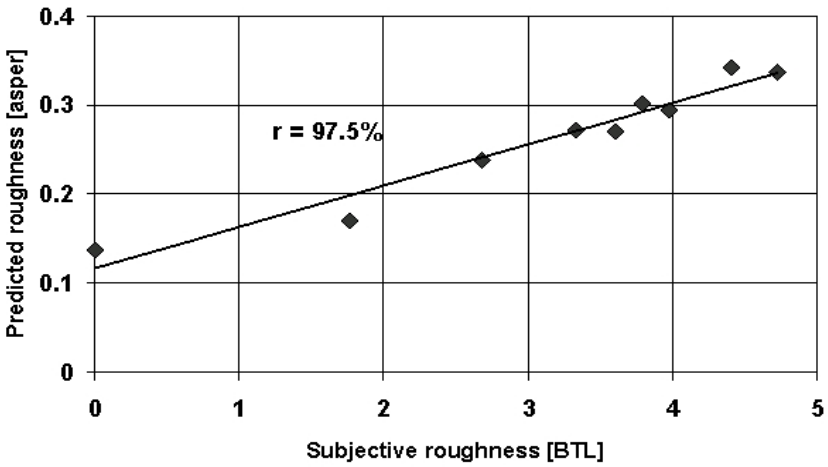
Already in 1995 Müller-BBM developed and realized the sound source localisation procedure together with BMW. The system is based on the beamforming procedure. The system was applicated in engine test benches or pass-by measurements for the detection of main contributing sound sources. The modern system is continuously improved and is integrated in the measurement and analysis system PAK of the Müller-BBM VibroAkustik Systems.

Introduction of new methods

Definition of the engine roughness

The issue engine roughness is very important to characterise the different engine concepts (cylinders) and the exhaust system especially of the sporty cars and roadster. In several projects extensive studies with listening tests were carried out and the results were used to build a psychoacoustic-based model of the engine roughness. The engine roughness is also implemented in the psychoacoustic module in the PAK-system.



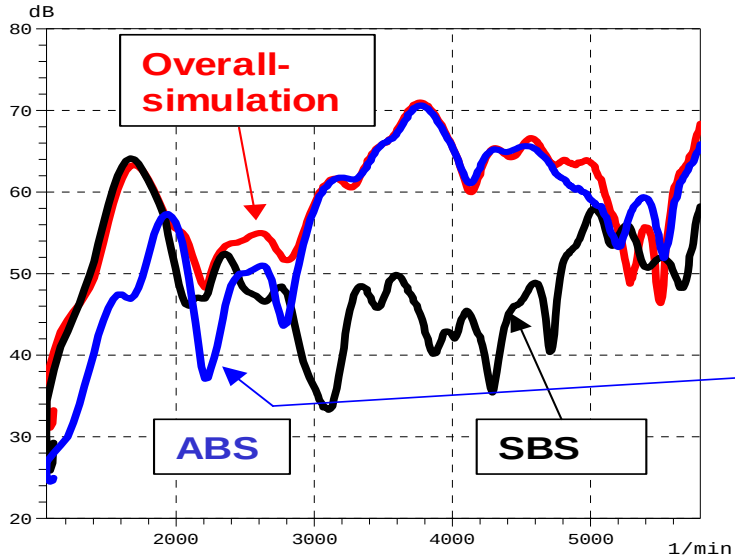


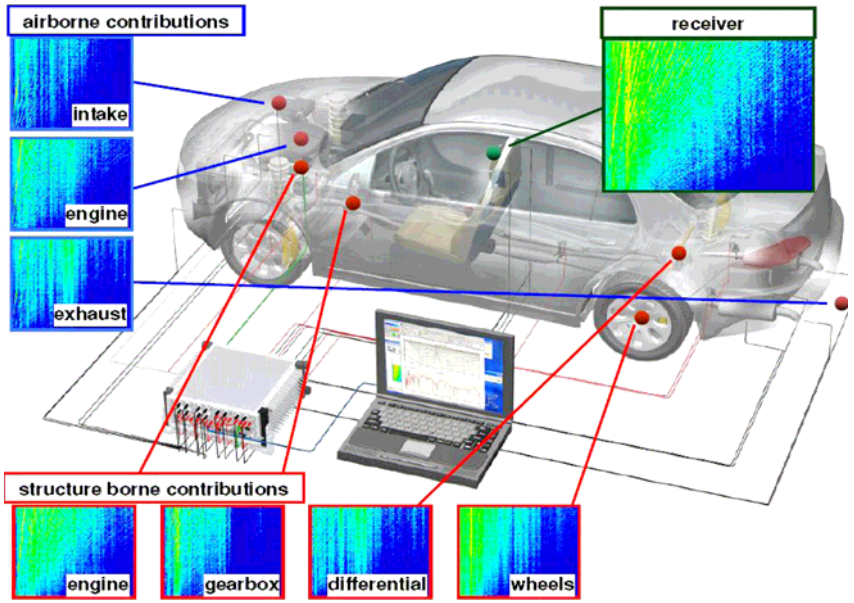
Introduction of new methods

Operational Transfer Path Analysis and Synthesis

This method was developed and refined together with several OEMs. Due to the fact that the time data of simple multi-channel measurements can be used directly to calculate the source contribution and the combination with a crosstalk cancellation algorithm the OTPA is the most flexible tool for trouble- shooting tasks as well as for the development of the car. Working in the time domain, this also allows to listen to the contribution of single sound sources including their transfer path.

In many applications with OEMs or suppliers Müller-BBM has gained a huge experience in using OTPA in practice.





Introduction of new methods

Evaluation methods for end of line tests (EOL)

The quality check of components directly after the production becomes more and more important. Suppliers have to fulfil special criteria, which have been defined by the OEMs.

Müller-BBM helps the customers in this content by the definition of measurement positions for airborne or structure-borne sound and the special evaluation of the signals by filtering and with application of statistic methods to finally separate the NOK-parts from the OK-Parts.

Acoustic check of a box for EOL-Testing

Sound Quality

Rainfall simulator

A rainfall simulator was developed to investigate a NVH issue concerning the sound quality during rainfall. Due to the random and two-dimensional structure-borne natural excitation and the impact of the water itself an artificial excitation was not feasible. Representative results with highly repeatable accuracy could be performed.

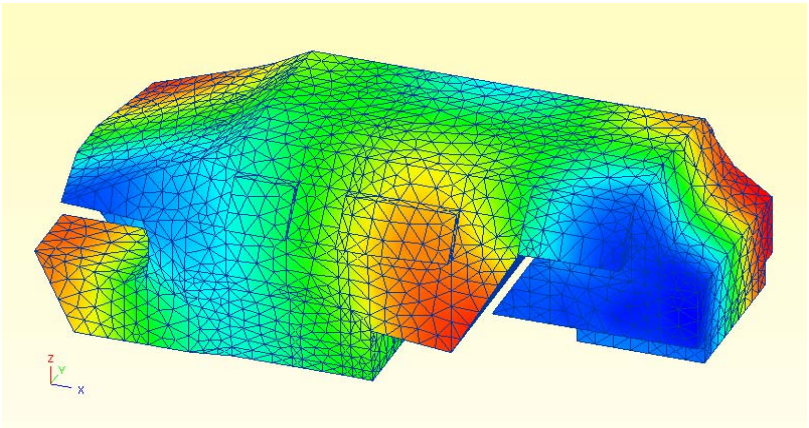
Exp. Modal Analysis and FE-Calculation

Experimental Modal Analysis (EMA) of the car interior

In these often performed projects the data are also used to calibrate the FE-models.

Surface radiation of exhaust pipes, silencers or catalyser

Müller-BBM carried out many measurements during operation, structure-dynamic investigations and experimental modal analysis as well as numeric calculations of the surface radiation of silencers of the exhaust system.



FE-Calculation: Validation procedure

- FE-Modelling
- Test preparation
- Measurement data collection
- Experimental Modal Analysis (Curve Fit)
- Validation and model updating
- Further FE-calculations

ANSYS®

FEMtools

PAK®
MÜLLER-BBM

ME‘scope

FEMtools

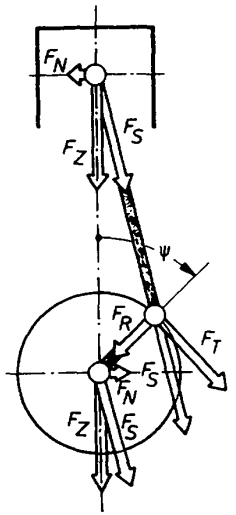
ANSYS®

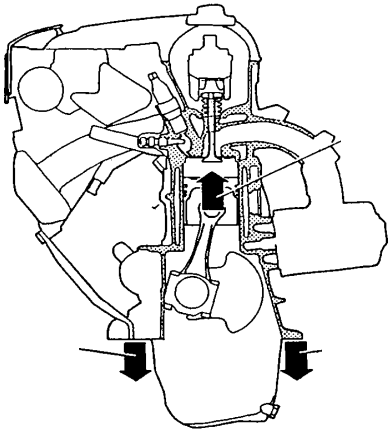
Other measurement technique projects

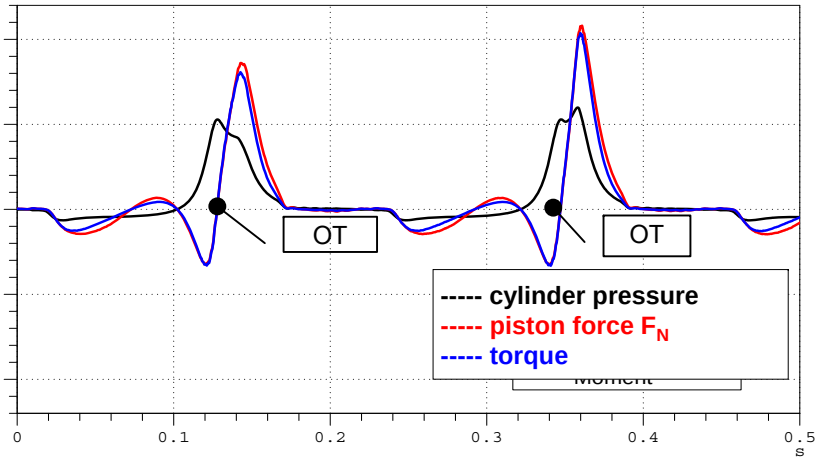
Quality of engine idle vibration

For the determination of the quality of engine idle vibration measurements at the seat rail and the steering wheel were carried out in combination with a high resolution rpm-measurement for the determination of the rotational vibration. In addition, the dynamic cylinder pressure and the crank angle were measured. Based on the arithmetic function in the PAK-system forces of the piston were calculated.

By correlation with subjective assessments of the seat vibration during idle condition an index was developed for the prediction of the subjective assessment for the idle vibration.







Investigation of whole car/ special issues

Hydraulic system for stabilisation

In a development project of a hydraulic system for stabilisation a 40dB-reduction of the noise and vibration contribution was reached by the optimized combination of passive means and improvements.

Steering systems

In many projects for different steering system manufacturers
Müller-BBM supports the acoustic development of alternative steering concepts with noise analysis localisation of the origin of the noise, development of counter measures, communication with suppliers and OEMs.

Investigation of whole car/ special issues

Rattling noise of the instrument panel during driving on cobble stone pavement

A special sporty car showed up clearly audible rattling noise of the instrument panel when driving on a cobble stone pavement with a certain speed. Müller-BBM supported during the noise analysis and during the process of finding the origin of the noise by an ODS of the instrument panel and the mounting position to the car body, a modal analysis for a better description of the vibrating system and a validation of the realised counter measures.

HVAC-systems

These systems were investigated in detail for several HVAC manufacturers by multi-channel measurements of airborne and structure-borne noise as well as quasi-static and dynamic pressure in the fluid of the HVAC-system. ODS and OTPA methods are applied to determine how the interior noise of the HVAC system is composed by the single noise sources.

Investigation of whole car/ special issues

Air-suspension system

A detailed analysis of the acoustic energy flow from the origin of the noise to the measurement position in the interior of the car was carried out in a car at the Müller-BBM laboratories. Due to very low levels the specification of the measurement equipment was very high. The dynamic pressure inside of the system was measured at special positions as well to monitor the system and its components.

Room-acoustic consulting

Müller-BBM supports the customers in the planning of reverberant and anechoic chambers and test benches with a lot of experience. Often, the acceptance inspection is guided by Müller-BBM according to ISO standards. For this purpose a special measurement equipment with spherical radiating sound sources and microphone paths is applied.

Investigation of whole car/ special issues

Active Sound Design – m|klang system

The ASD-activities are concentrated in the sister company Müller-BBM Active Sound Technology (MBBM-AST). This field of work is strongly growing and becomes more and more important for the interior and also the exterior noise of passenger cars. Also, the development and application of an ASD-system for the new electric vehicles will be important.

Müller-BBM applied the m|klang system for ANC and ASD in many different cars and projects in the recent years.

Ride Comfort

Measurement and online calculation

Müller-BBM uses the PAK-system with around 90 channels to investigate ride comfort issues. With the arithmetic tool in the PAK-system the movement of virtual points on the upper part of the driver body based on four measurement positions at the seat rail is calculated.

The typical frequency range for the stucker-vibration goes from 7Hz to 14Hz. Stucker describes the vibrations of the car, which are excited due to not regular road surfaces and which are amplified by natural frequency vibration of the engine-block and/or the gearbox in the engine mounts.

Counter measures for the reduction of these vibrations are hydraulic engine mounts for example.

In some cases also measurements for the detection of micro-stucker effects are carried out. The ride comfort at the premium class vehicle is also measured at the rear seat position.

One of the main questions is: Where is the vibration source? In this context the balancing of wheels plays a big role. Unbalanced masses in the dimension of only a few grams are used in these investigations.

Furthermore the goal conflict between driving safety and driving comfort has to be taken into account.

Thank you very much for your attention

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