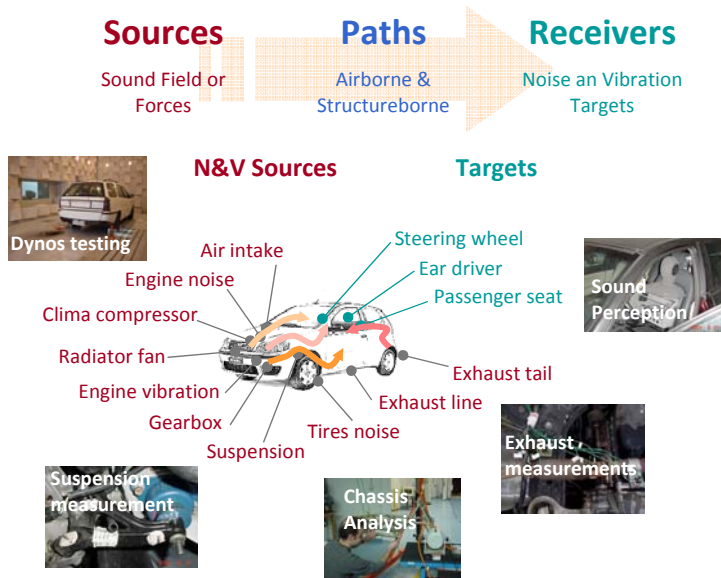


Transfer Path Analysis Tool

Finding airborne and structureborne sources contribution
 "Unique" coupling feature with (optional) V-Noise FEM-BEM solvers



Typical workflow :

- Use V-PATH in order to extract from measured data and measured transfer functions the most critical sources and paths that need to be improved.
- Define the design modifications
- From the FEM structural model compute the modes for both the basic and modified design
- Import the modes in V-Noise
- Compute with V-Noise the virtual transfer functions for both the basic design
- Use V-PATH with the two sets of virtual transfer functions and assess the benefit of the design change

Vibroacoustic analysis and Simulation in the fields of: Automotive, Aeronautics, Railway, Ships, Construction, machines, Building construction

V-Path Software Key features and Usage

The basic idea is to measure for a number of measuring points the noise in a given operating condition, and then measure in the lab a set of transfer function between a set of exciting forces or acoustic sources, and the noise measuring points. Importing all the measurements in VPATH is then possible to reconstruct what are the most important sources for any given operating condition and frequency.

Rules of Tumbs

- Measure ear driver Noise and other listed points either for Noise or Vibration targets request
- Apply known amplitude Sound Pressure or Forces to selected Body points and measure Noise and Vibration at target position and a consistent ensemble of additional positions
- Evaluate Transfer Function for each combination of Input/Output
- Invert the System matrix to determine sources strength from measured outputs and Transfer Function

The inverse matrix approach of *Single value Decomposition*

V-PATH is a powerful tool that help to understand what are the major sources that contribute to the cabin noise in any given operating conditions, and so it can be very useful in order to understand in which direction to move in order to optimize and reduce the cabin noise.

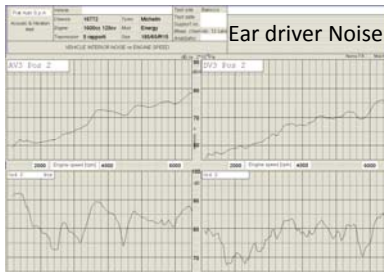
Advanced Numerical techniques (Singular value Decomposition) are used by V-PATH in the matrix inversion process in order to ensure maximum stability and reliability, and measures of the quality of the obtained solution are provided to the user, as well as indication on critical points and measure sets that can adversely affect accuracy in such a way that the user can eventually optimize the choice of the excitation sources and measure sets.

V-PATH capabilities can be further increased when V-PATH is coupled with V-Noise that is a powerful tool for vibro-acoustic simulations. V-Noise is based on an advanced, reliable and efficient BEM-FEM acoustic solver, that can be coupled with any commercial structural FEM code (NASTRAN, ANSYS, ABAQUS, ...), and that permit to easily perform complex fully coupled vibro-acoustic simulations. Additional modules are also available for aeroacoustic applications.

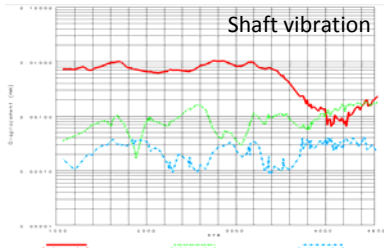
V-Noise when coupled with **V-PATH** permits to numerically simulate the transfer functions between any source and any measuring point, and so it becomes possible to simulate the transfer functions for both the basic design and a modified design and using the two sets of transfer functions in VPATH it becomes possible to quantitatively assess the effect of the design change

V-Noise is a Product of STS Scientific Technical Software

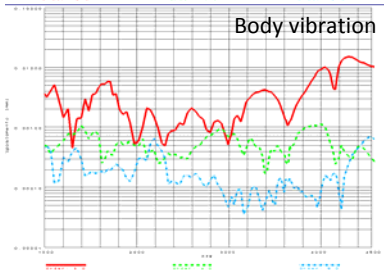
V-Path data inputs & outputs



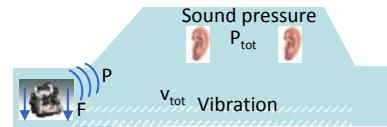
Cabin Noise



Sensors positioning

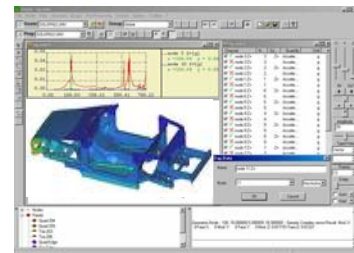


Hammer excitation



$$P_{tot} = \sum P_{partial} = \sum P_i \times H_s$$

$$v_{tot} = \sum v_{partial} = \sum F_i \times H_v$$



Step	Inputs	H	Outputs	Ranking
Engine running	Unknown	Unknown	Meas.	
Force excitation on engine mounts	Meas.	Meas.	Meas.	R
Inverting Matrix to obtain Inputs Forces	Calcul.	Meas.	Meas.	C
Loudspeaker test	Meas.	Meas.	Meas.	R
Inverting Matrix to obtain Inputs Sound Pressure	Calcul.	Meas.	Meas.	C
Do the same for each individual additional sources	-	-	-	

V-Path data Acquisition - Exchange

V-Path is ready to get geometries and experimental data from a wide range of market available Analysis System, either through direct links or via UFF file format; other format can be implemented.

V-Path is a self contained application: from data input it perform all calculation and present results both as table and graphics guiding the user to obtain the best estimate of sources ranking.

Transfer Function measured or estimated can be exported to FEM-BEM software V-Noise for improving of prediction models or to SEA prediction software, while V-Path can also import calculated Transfer Function from V-Noise.



V-Path is also available as « TPA package » with an integrated 4 channels NVH Analysis system, however a 12-16 or more channels configuration is recommended to optimized testing time.

Packages can be configured upon customers needs and might includes: V-Path software, Acquisition system with complete software for TF measurements (Impact or Continuous excitation), Impact hammer, Accelerometers set, Microphones set, Cables and Accessories, Binaural recording system, etc.

V-Path General description and Theoretical background (1)

V-Path is a powerful tool that permit to understand what are the major sources that contribute to the cabin noise in any given operating conditions, and so it can be very useful in order to understand in which direction to move in order to optimize and reduce the cabin noise.

The basic idea is to measure for a number of measuring points the noise in a given operating condition, and then measure in the lab a set of transfer function between a set of exciting forces or acoustic sources, and the noise measuring points. Importing all the measurements in V-Path is then possible to reconstruct what are the most important sources for any given operating condition and frequency.

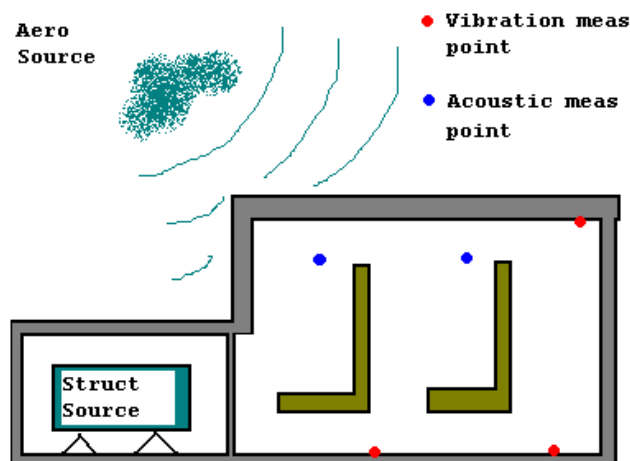
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The typical workflow can therefore be summarized as follow:

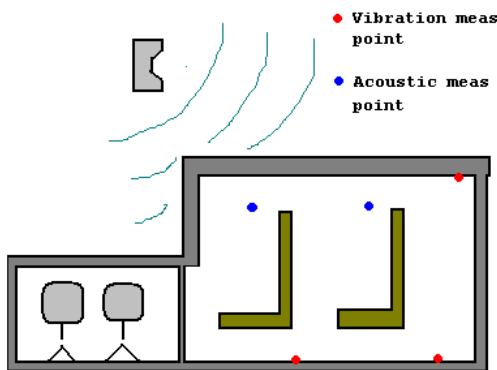
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The measurements of the operating conditions permits to obtain both SPL values (p_1, p_2, \dots) at some acoustic measurements points (●) and accelerations values (a_1, a_2, \dots) at some vibration measurements points (●).

Then the real sources are removed and shakers or acoustic volume sources are used to characterize the transfer functions H between the different measurements points and the different sources.

V-Path General description and Theoretical background (2)



Then the measured values are written as:

$$p_i = \sum_j^{n_{sources}} H_{ij} F_j \quad v_i = \sum_j^{n_{sources}} H_{ij} F_j$$

A System is then written as:

$$\begin{bmatrix} H_p & | & H_v \end{bmatrix} \{F\} = \begin{Bmatrix} p \\ v \end{Bmatrix}$$

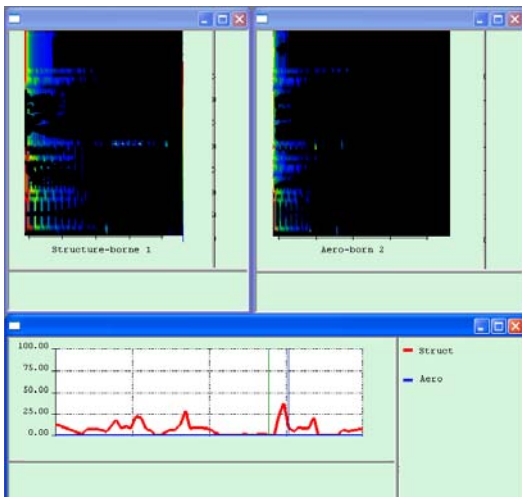
Then using SVD the matrix H is written as:

$$[H] = [U][W][V]^T$$

Where W is a diagonal matrix.

Then solution of the system can be written as:

$$\{F\} = [V][diag(1/w_i)][U]^T \begin{Bmatrix} p \\ v \end{Bmatrix}$$



In order to ensure stability of the reconstruction only the largest W_i are considered and the other are dropped to zero ensuring in this way that only the most significant physics is taken into account in the reconstruction. Once that the forces are obtained VPATH can reconstruct the contribution of each source to a given measurement point using the transfer functions.

When considering measurements in different operating conditions (i.e. RPM ramp) then contour plots graphs can be obtained that shows the relative contribution of the different sources at each frequency .

The coupling with VNoise permits to simulate the Transfer function instead of measuring them. In automotive applications this is typically used in the low frequency range where BEM / FEM methods can provide accurate and reliable results.

The approach has the advantage that the numerical simulation of the transfer function (or of some of the transfer functions) is when applicable surely more flexible and less expensive in respect of measurements.

Besides it once that the reference model is available it can be very easily applied to evaluate design changes and understand how each design change translate in noise/vibrations reduction at the measurements points.

For the evaluation of the coupled vibro-acoustic transfer function VNoise use a modal approach in which the BEM or FEM equations of wave propagation (Helmholtz equation) are coupled with the modal equation of the structure. The coupling is a full 2-way coupling that ensure to take into account both the effects of the structural vibration on acoustics and the effects of acoustic on structural vibrations.

V-Path General description and Theoretical background (3)

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The overall path for the evaluation of the transfer function with VNoise is summarized in the table below.

