OROS

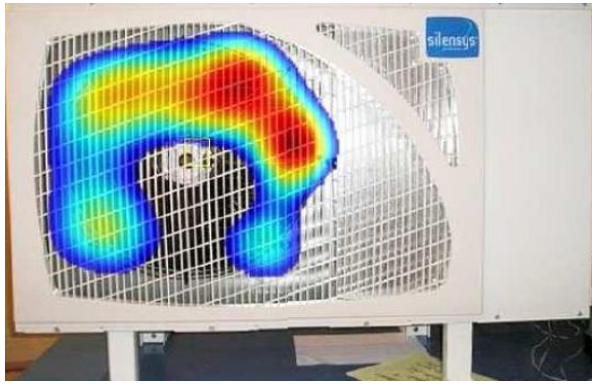
MEASURING NOISE & VIBRATION

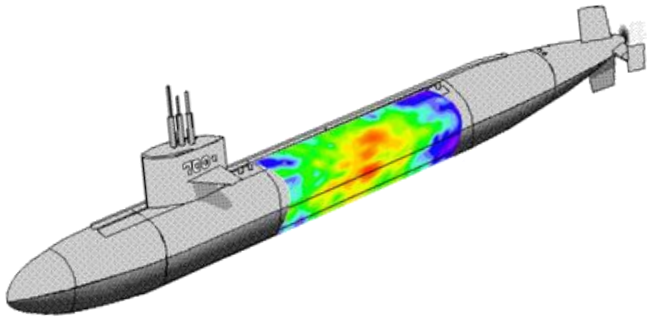
Sound Source Identification:

What techniques to find the root cause of noise problems?

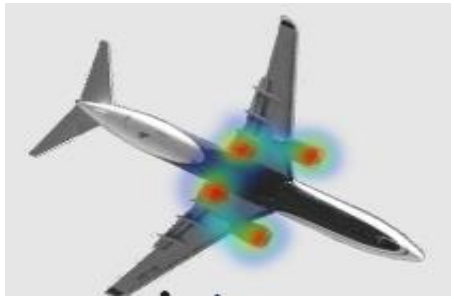
Sound Source Identification (SSI) Objectives

See what you hear





- Identify the most important sub-sources on an object
  - Position
  - Frequency content
  - Sound power
- In order to
  - Identify the cause
  - Rank sub-sources



SSI Solutions – Acoustic Imaging Methods

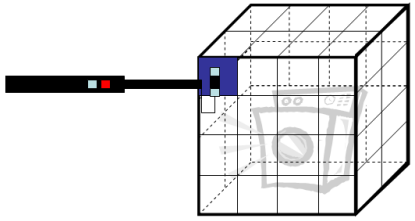
Use sound intensity probe

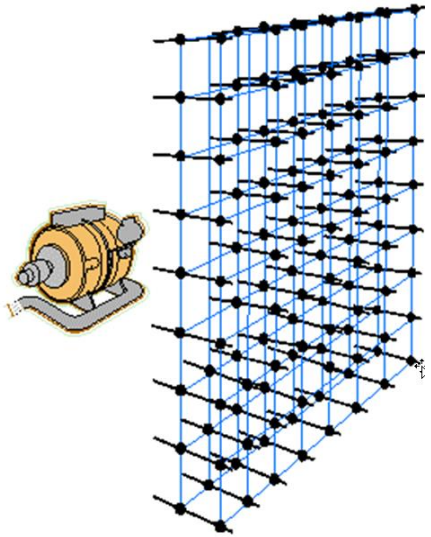
Use microphone array

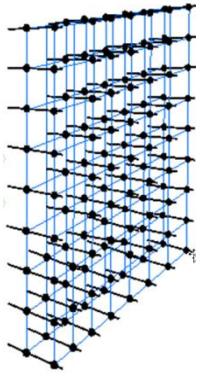
Sound Intensity

Near-field Acoustical Holography (NAH)

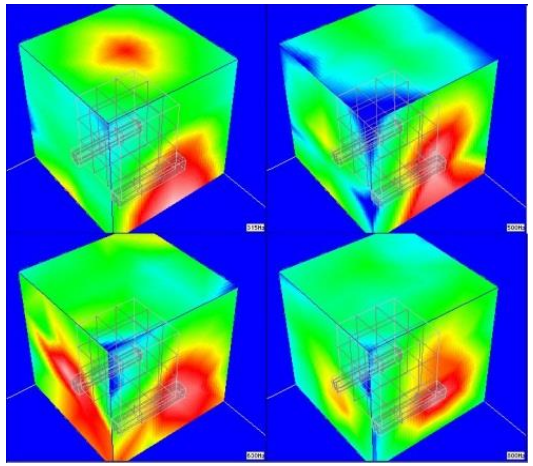
Beamforming

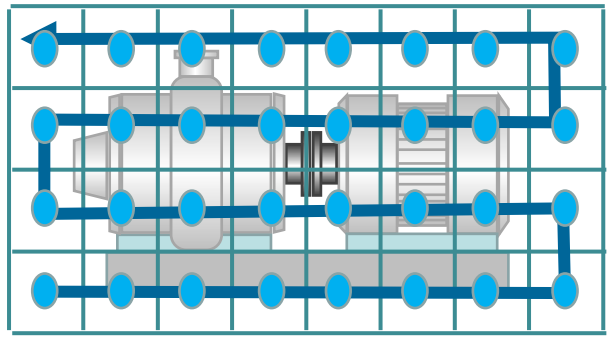






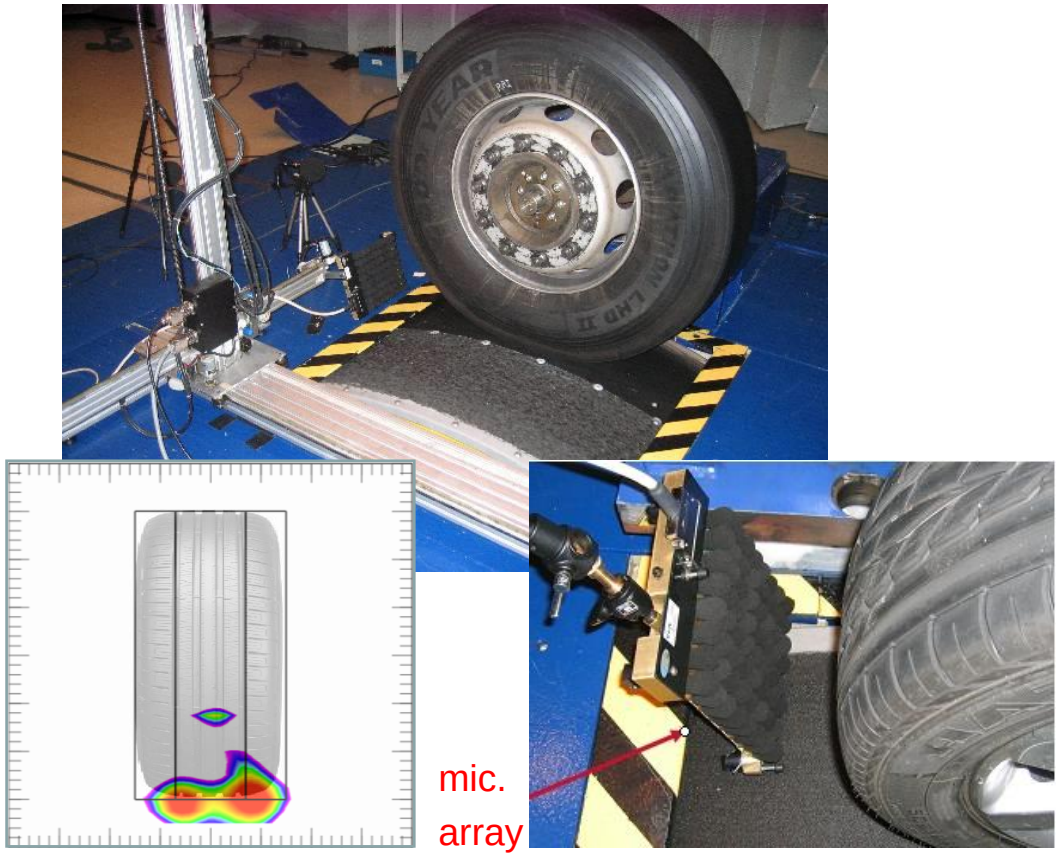
Sound Intensity Solution





- Use the probe to measure sound intensity at a number of points on a surface mesh close to the test object
- Acoustic maps are generated based on the measured sound intensity values, no calculation involved

Near-Field Acoustical Holography (NAH)



- Use a large microphone array, or move a small array to cover the surface of the test object, measuring the sound pressure on a plane very close to the test object
- Acoustic maps on the *source plane* are generated after back-propagation computation.

Beamforming

> Point the microphone array towards the test object, and the real-time acoustic map of the area covered by the camera will be displayed instantaneously

SSI Solutions – Acoustic Imaging Methods

	Sound Intensity	NAH	Beamforming
Application fields	Associated to sound power estimation of machines (ISO 9614-1/2) Provides sound pressure and sound intensity maps	Source identification and diagnosis on machines, benchmarking Provides sound pressure, sound intensity, and particle velocity maps, plus sound power estimation and source ranking	Source localization, noise leakage detection, environmental acoustics Provides acoustic maps

SSI Solutions – Acoustic Imaging Methods

	Sound Intensity	NAH	Beamforming
Measurement time	Long Point by point measurements	Short when large mic. array is used Instantaneous if the mic. array is larger than the test object	Instantaneous Real-time results
Frequency range	50 Hz – 10 kHz Different spacer are needed for different frequency range	Low-mid range Typically < 6 kHz, can be higher at the price of acquiring more measurements	Mid-high range Typically > 1 kHz

SSI Solutions – Acoustic Imaging Methods

	Sound Intensity	NAH	Beamforming
Type of sound sources	Stationary sources	Stationary or repeatable transient sources	Stationary or transient sources
Distance between sensors and test object	Measurement in the near-field, close to the sound sources ~20 cm	Measurement in the near-field, very close to the sound sources Few centimeters	Measurement in the far-field, far away from the sound sources Few meters

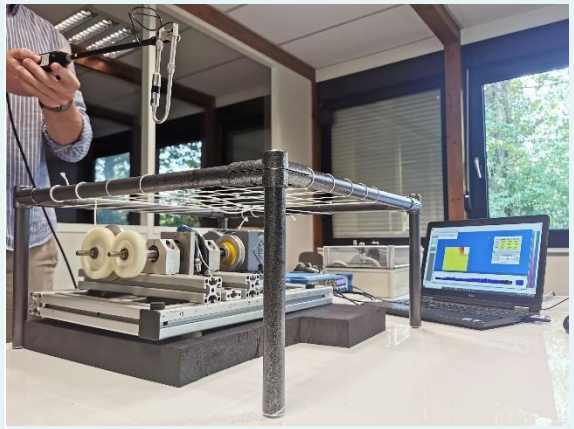
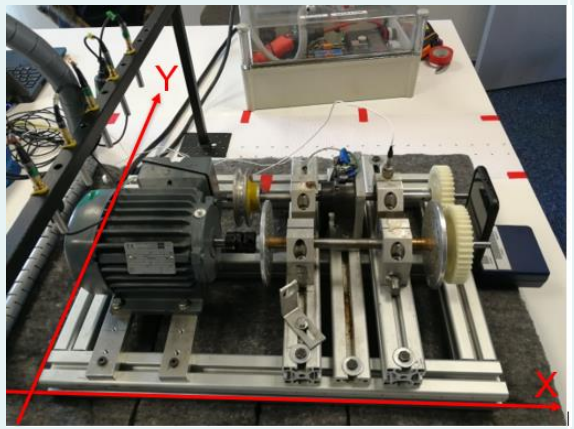
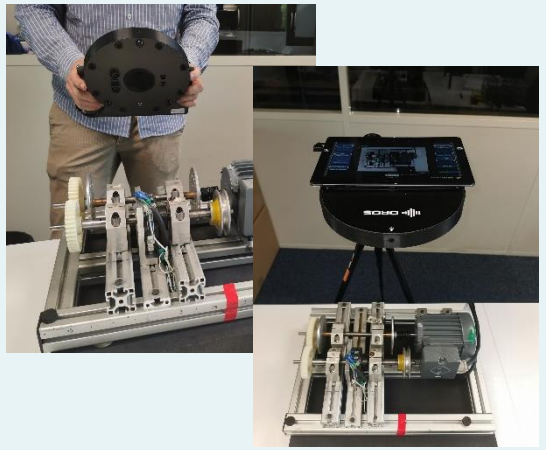
SSI Solutions – Acoustic Imaging Methods

	Sound Intensity	NAH	Beamforming
Spatial resolution	Depend on frequency and measurement step	Independent of frequency, good at all applicable frequency Best resolution of all three methods	Depend on frequency, good at high frequency only*
Accuracy	Less accurate than NAH	Best accuracy of all three methods	Least accuracy of all three methods
Quantification	Sound power estimation (ISO 9614-1/2)	Sound power and partial sound power estimation	Gives relative results

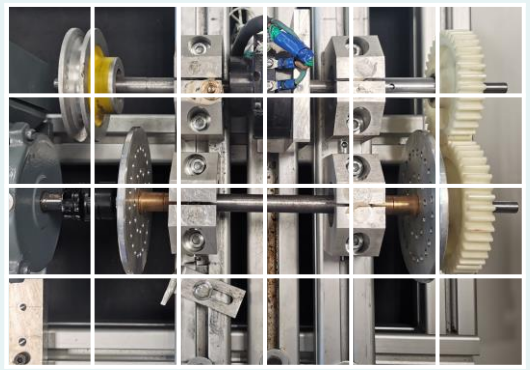
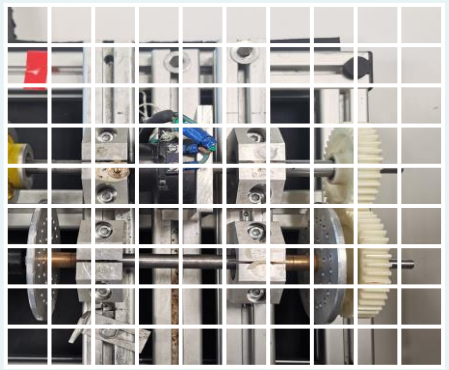
SSI Solutions – Acoustic Imaging Methods

Testing environment	Sound Intensity	NAH	Beamforming
Free field	√	√	√
Reverberant field	√ Usable frequency range is reduced	√	X
Noisy environment	√	√	X
On-site measurement	√ Simple setup	√	X

Example: Geared Electric Motor

	Sound Intensity	NAH	Beamforming
Measurement setup		 	

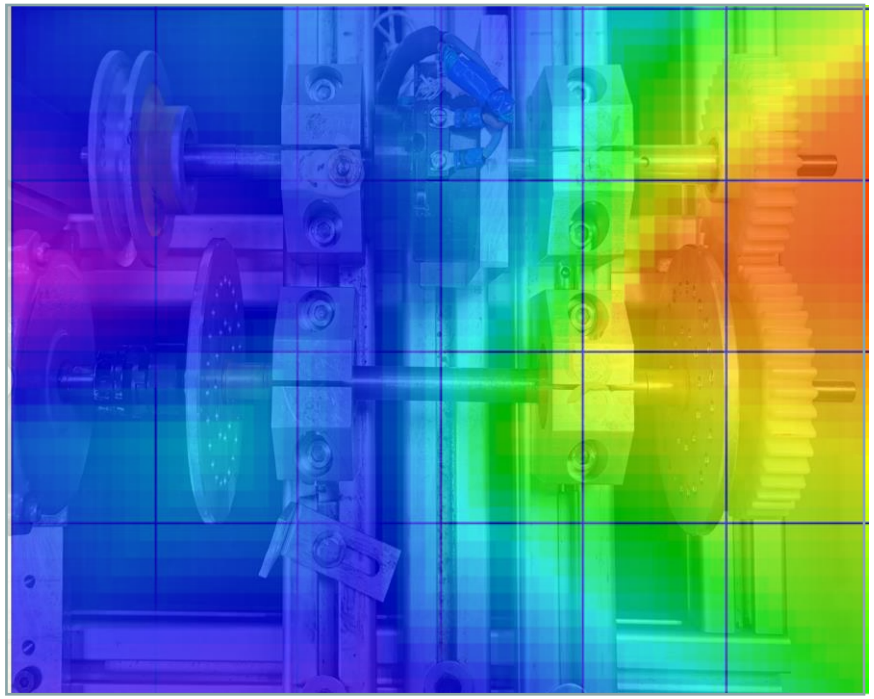
Example: Geared Electric Motor

	Sound Intensity	NAH	Beamforming
Sensors	p-p intensity probe with 12 mm spacer	Linear array with 5 ¼ inch mics 1 ½ inch mic as ref.	Integrated circular array with 8 electret mics
Measurement time	24 points 10 secs at each point	22 positions* 10 secs at each position	Instantaneously
Measurement surface & Grid size (L * H)	30 cm * 24 cm 5 cm * 6 cm 	30 cm * 27 cm 3 cm * 3 cm 	—

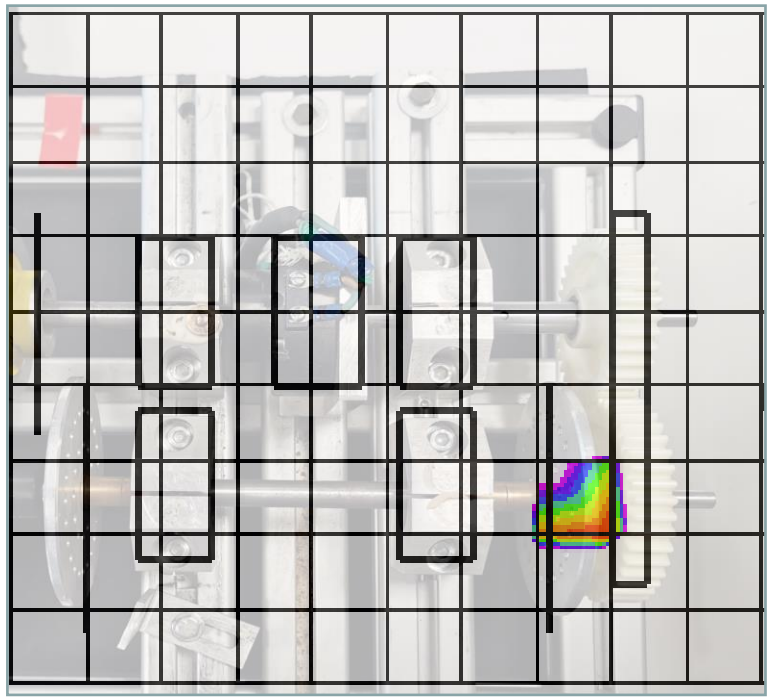
Example: Geared Electric Motor

@ 4 kHz

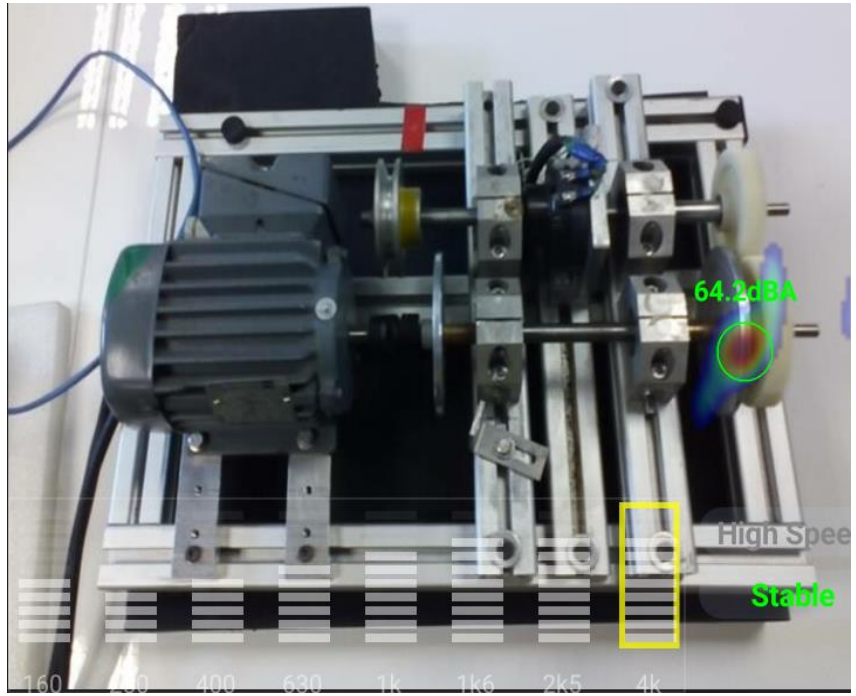
Main source: Metal plate next to the gear



Sound Intensity



NAH

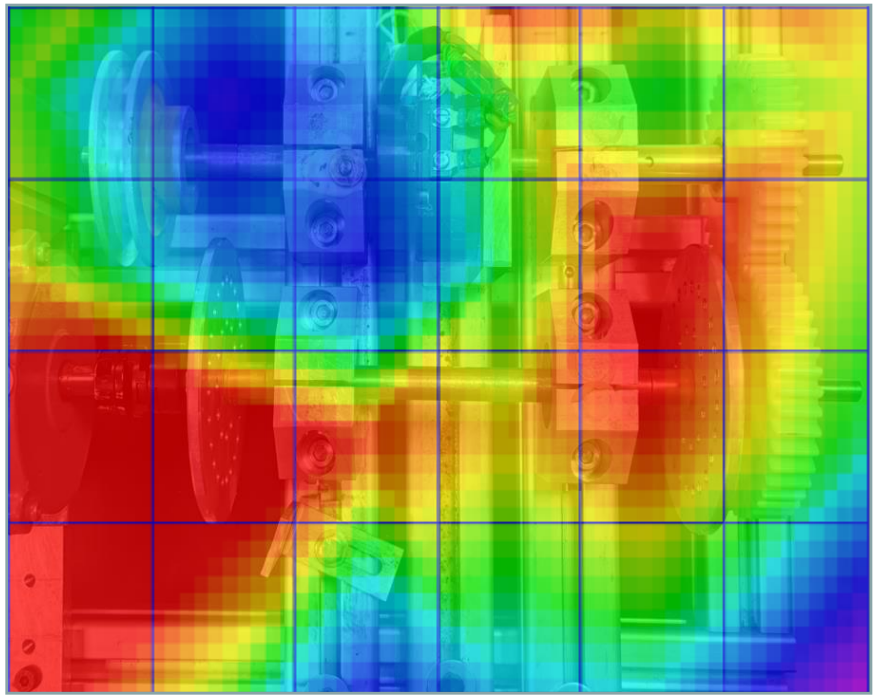


Beamforming

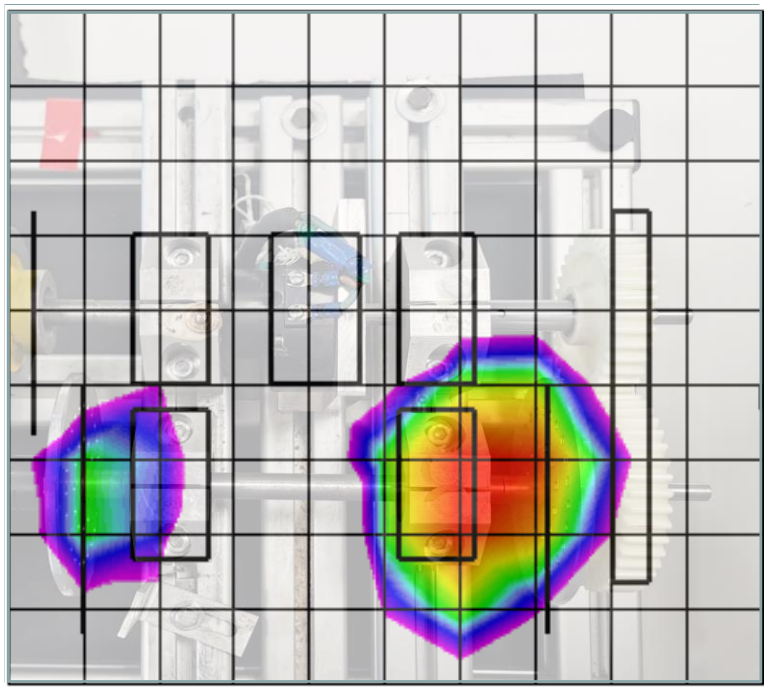
Example: Geared Electric Motor

@ 2.5 kHz

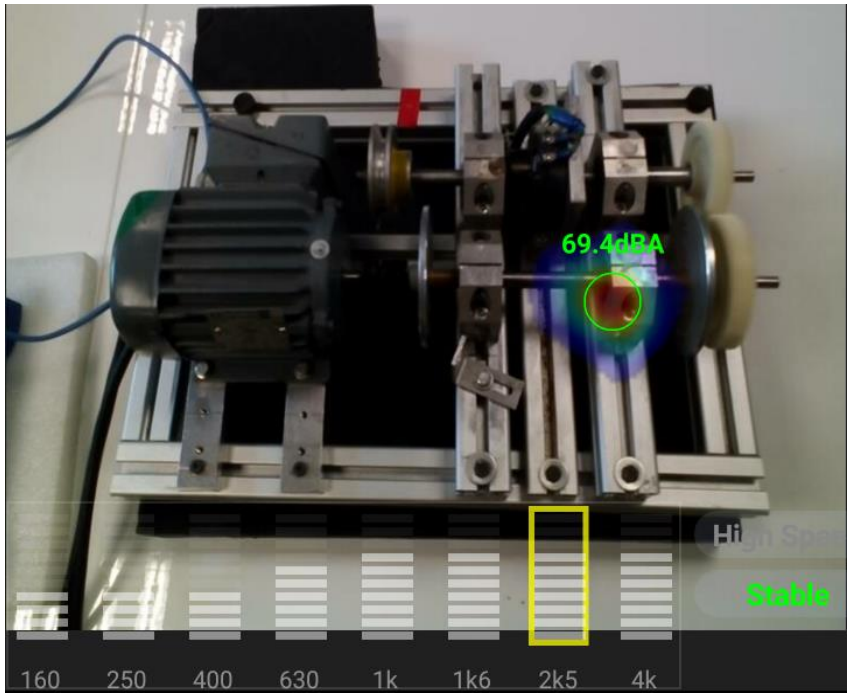
Main sources: Lower-right bearing & Left metal plate



Sound Intensity



NAH

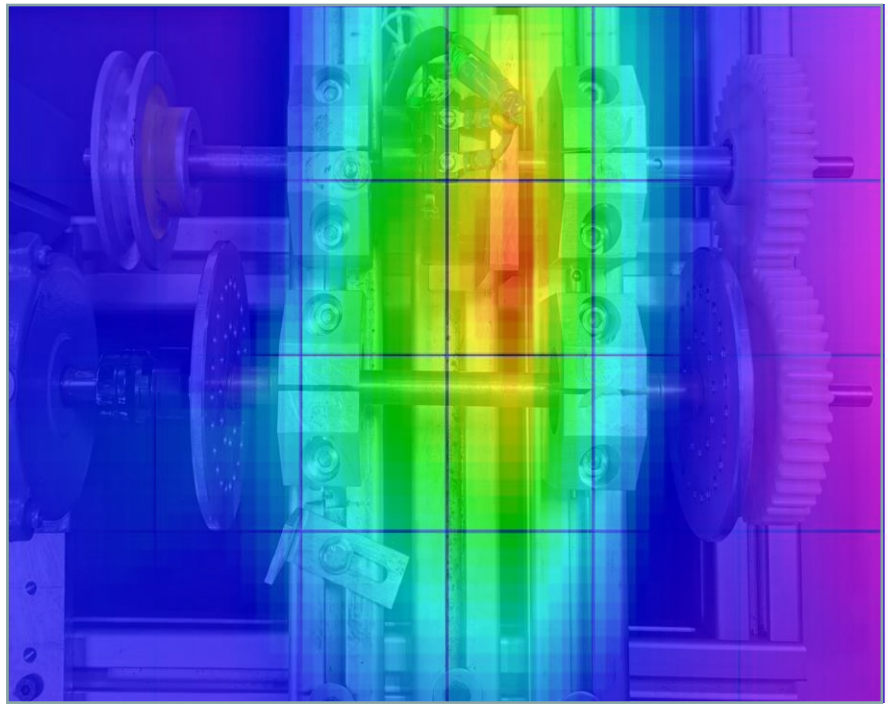


Beamforming

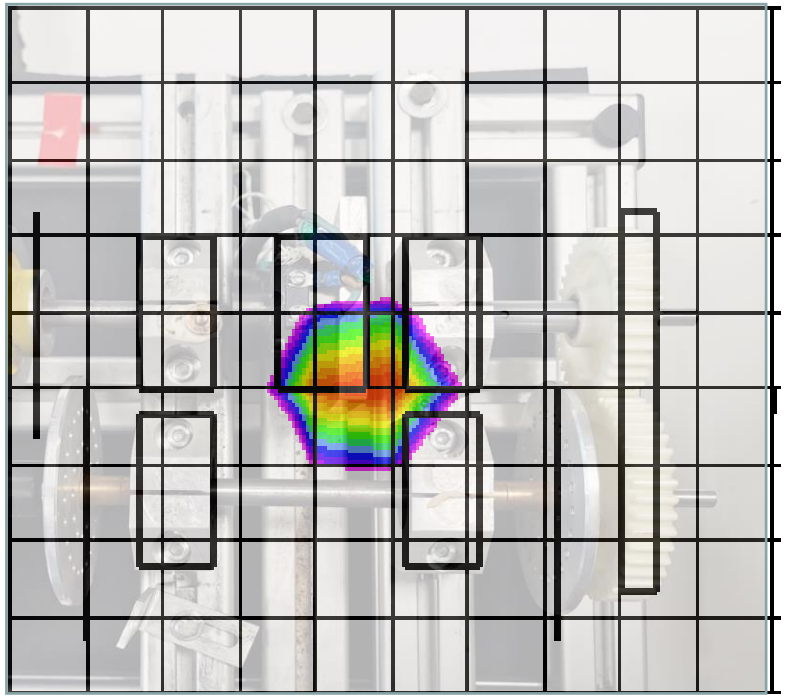
Example: Geared Electric Motor

@ 1 kHz

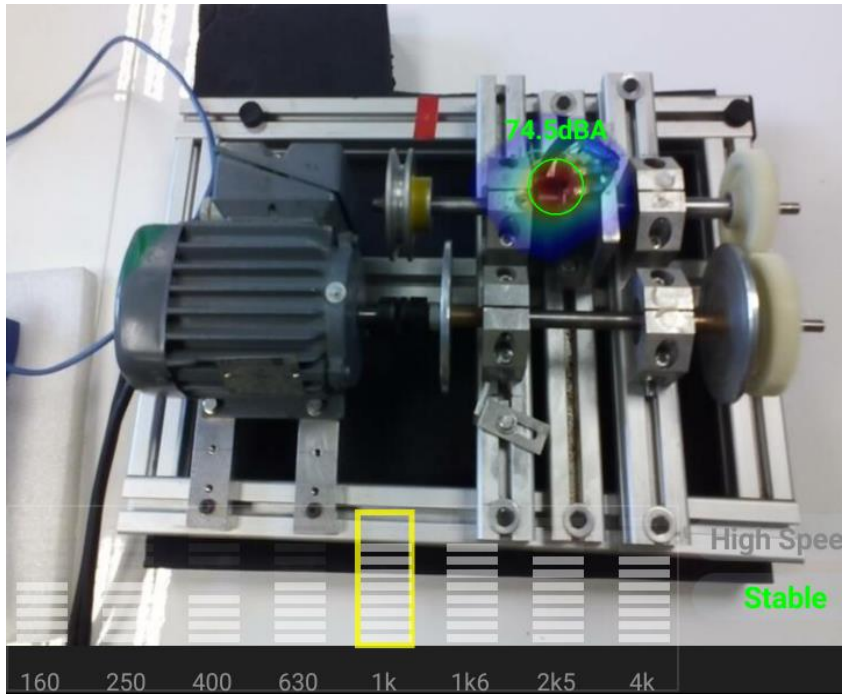
Main source: Lower part of the brake



Sound Intensity



NAH

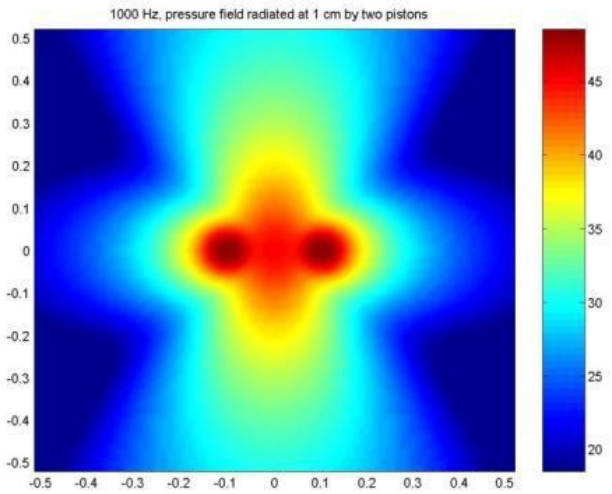


Beamforming

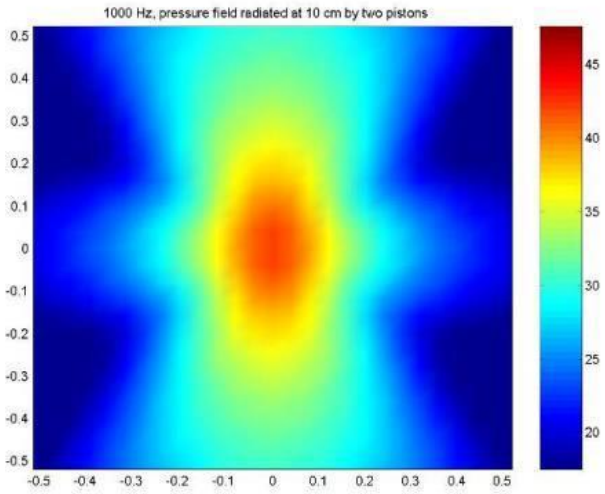
Remarks of SI Solution

> The results of Sound Intensity solution are less focused.

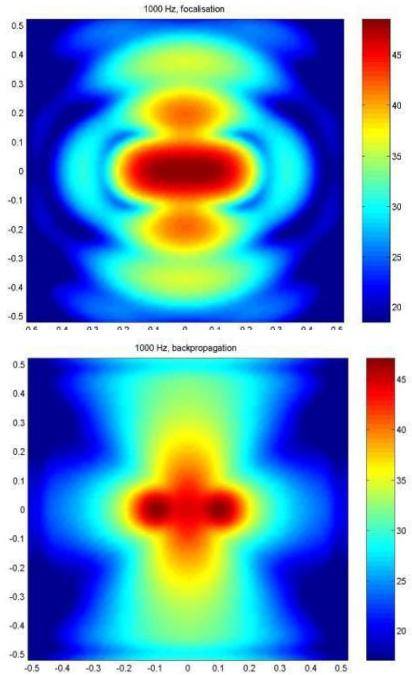
- SI show the values on the measurement plane without computation
- NAH and beamforming show the values on the source plane after calculation.



on the plan 1 cm away from 2 circular pistons (true value)



on the plan 10 cm away from the pistons (measurement)



Beamforming

NAH

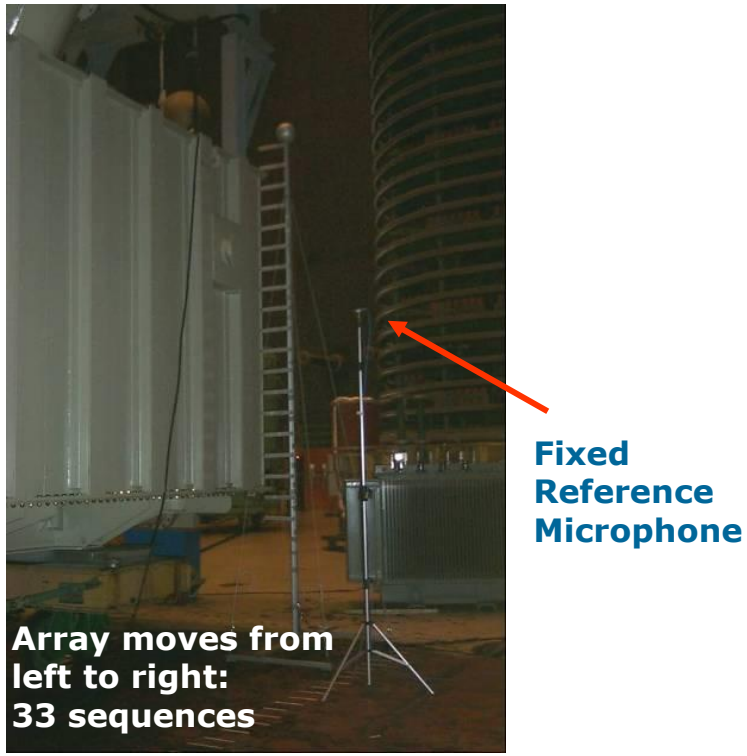
Highlights of OROS Beamforming Solution

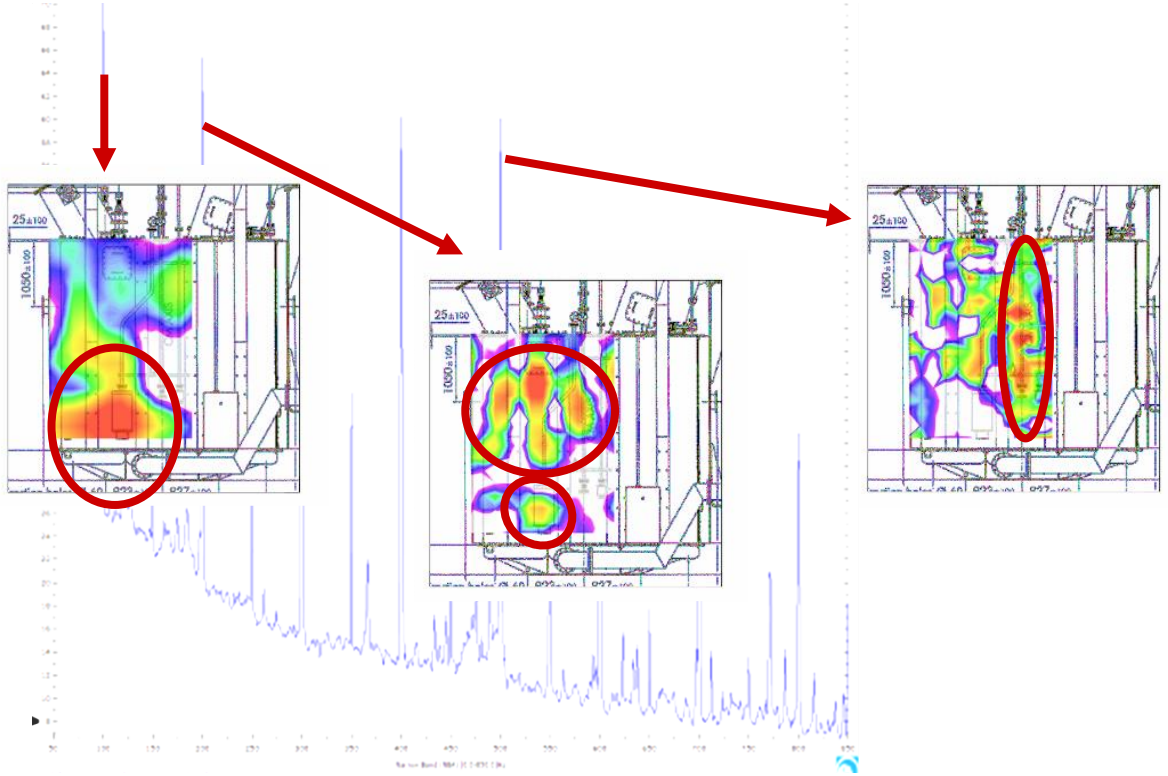
- **SoundSpot** focuses on the dominant source: Most efficient way to reduce overall noise
- Innovative algorithm “Iterative Matrix Calculation (IMC)”
  - Small array size and ultra-light weight: easy to use at any place
  - Use only 8 microphones: competitive price
  - Wide frequency range: 160 Hz to 5000 Hz
  - Constant spatial resolution: small size of “spot” for the full frequency range
  - Can detect the loudest source in each octave band

Highlights of OROS NAH Solution

> Various frequency analysis modes

– Narrowband, Octave, 1/3 Octave, 1/12 Octave, User-defined bands

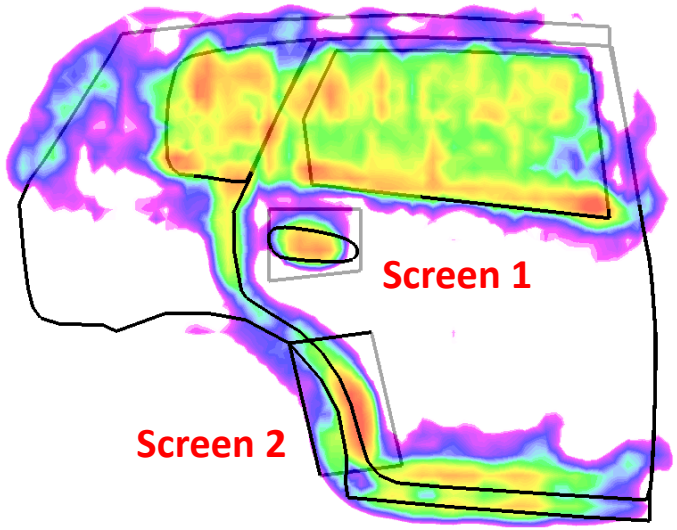


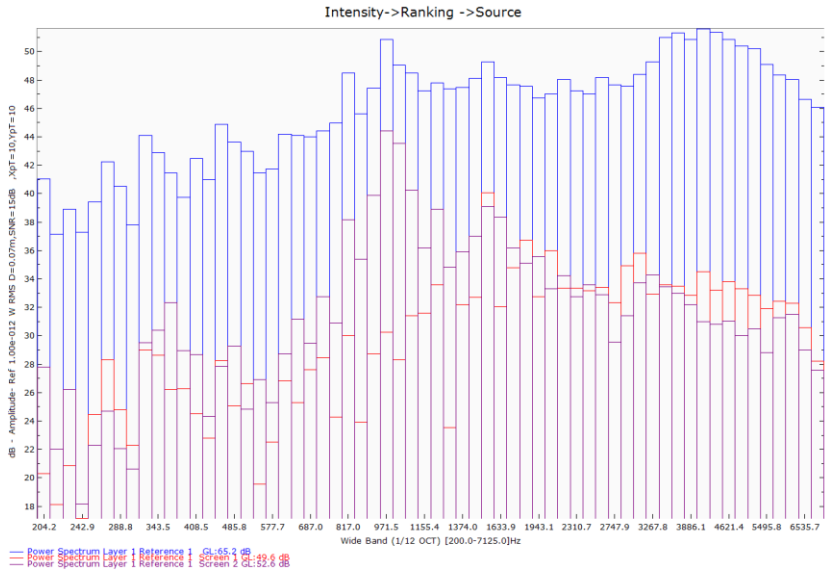


Highlights of OROS NAH Solution

> Source ranking

- Evaluate sound power through user-defined polygonal patches
  - Allow user to get a direct insight on the relative contribution of each source to the radiated acoustic power
  - Provide indications on where the noise reduction effort is to be concentrated

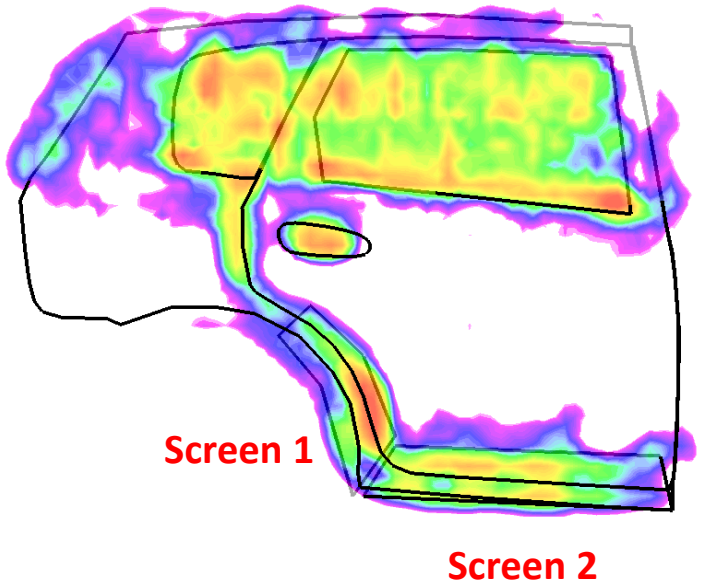


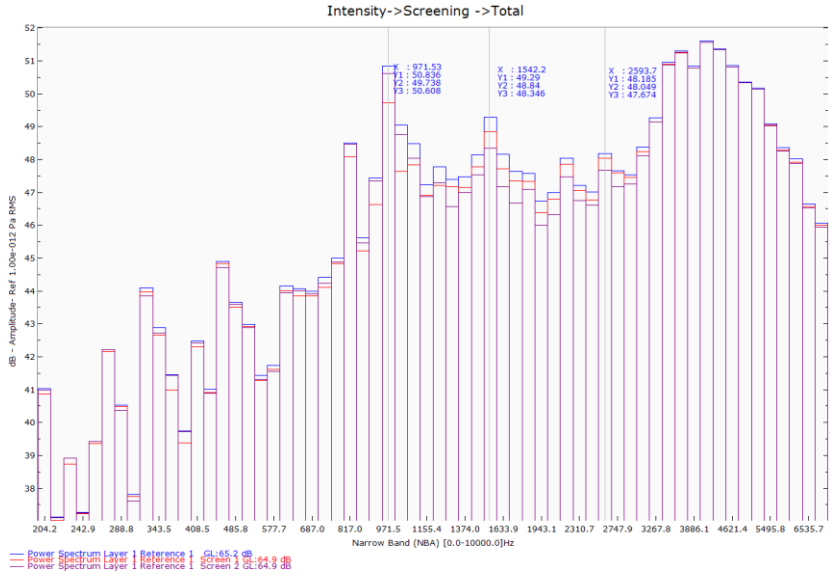


Highlights of OROS NAH Solution

> Source screening

- Evaluate radiated sound power outside user-defined polygonal patches
  - Simulate source removal impact
  - Possibly reveal poor radiating sources





General Guidelines

- Use Beamforming for a quick overview of the complete test object, finding the noisiest area requiring further detailed investigation;
- Use Sound Intensity solution when sound power estimation is of interest, especially when simple setup is required for on-site measurement;
- Use NAH to obtain detailed information of the sound field, most suitable for diagnosis or benchmarking.

What is the best solution for my need ?

Car manufacturer R&D department's choice - **Holography**

Why Holography ?

+ Dedicated test bench available
+ Large array with many microphones can provide real-time results with the optimum accuracy
+ Source ranking feature
+ Easily reproduce the measurements, perfect tool for benchmarking competing solutions

Why not Beamforming ?

- Less accurate
- Less acoustical information of the test object

Why not Sound Intensity ?

- Measuring time is longer
- Need to add a robot system for measurement to achieve the required accuracy

What is the best solution for my need ?

Vibration and acoustic consultant's choice – **Sound Intensity**

Why Sound Intensity ?

+ Flexible and easy to use
+ Sound power determination at any place, complying with ISO standards
+ Automatic sound power report
+ Portable hardware
+ Good return on investment with services in a wide range of applications

Why not Beamforming ?

– Less accurate
+ Can only be a complement for real-time diagnosis and troubleshooting

Why not Holography ?

– Less convenient to carry around
– Different microphone array might be required to adapt to different cases

What is the best solution for my need ?

Automotive after-sale service team's choice – **Beamforming**

Why Beamforming ?

+ Fully automatic setup, ready to use right out of the package by anyone
+ Real-time measurements detect main problems of any part of the vehicle
+ Intuitive results can be quickly and easily shared with other teams

Why not Sound Intensity ?

– Measuring time is longer
– Not necessary to know sound power

Why not Holography ?

– Requires operator know-how
– Less convenient to carry around
– Different microphone array might be required to adapt to different scenarios