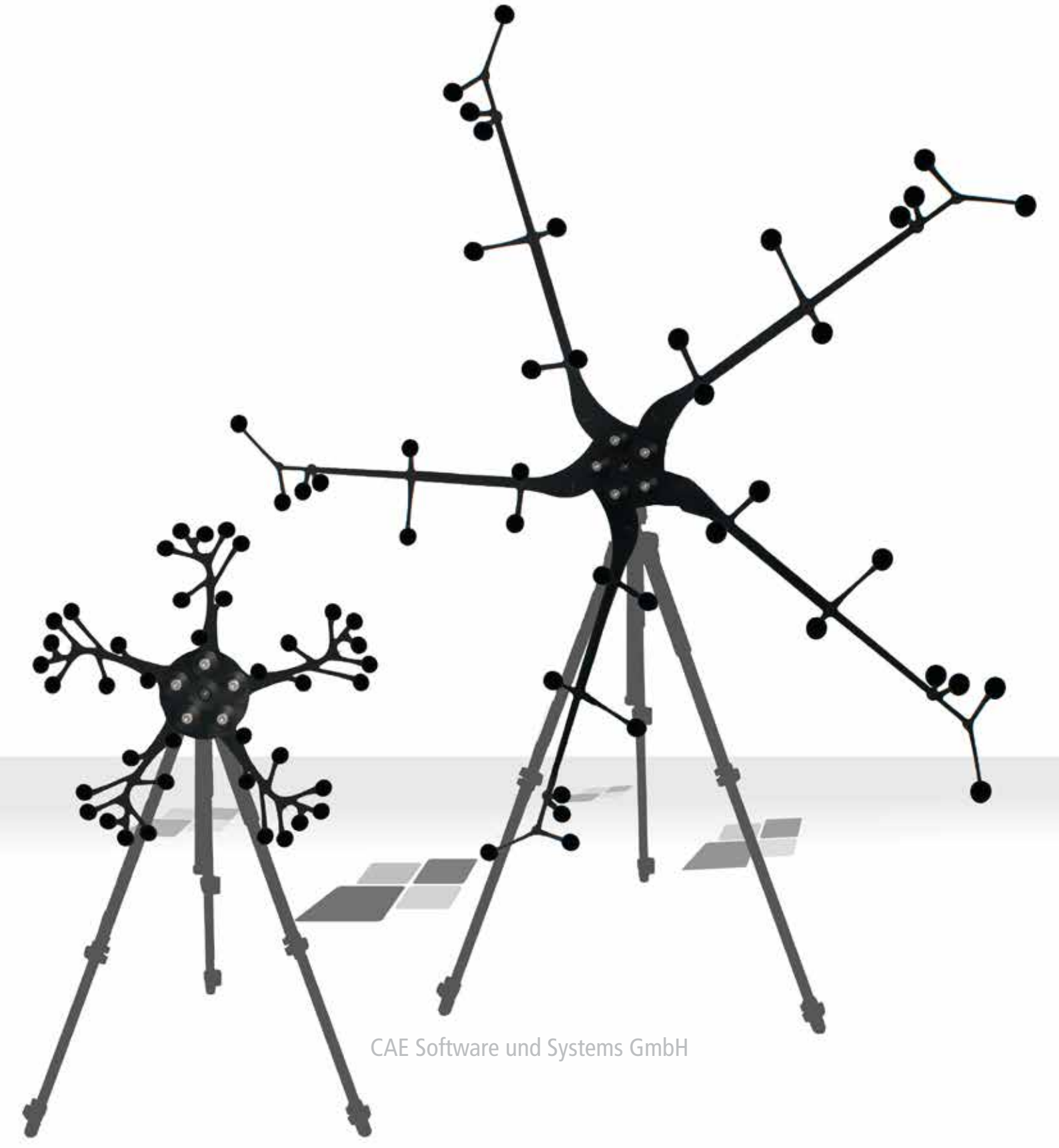
Noise Inspector

Innovation leader in acoustic cameras



CAE Software und Systems GmbH

# See Sound and Vibration

During the last years new technologies for the visualization of sound sources "acoustic cameras" became extraordinary relevant in the industry due to its practical and intuitive use. Acoustic design of a product is an important aspect of product development. Easy to use and obvious results gives engineers a new sense - "See sound sources with your eyes". This accelerates product development, quality control and environmental measurements enormously.

Therefore CAE Software & Systems develops powerful and flexible measurement systems. Our acoustic camera "Noise Inspector" improves continuously to give you the advantages of an accurate, fast and smart technology. With this system sound and vibration becomes visible in real-time. Furthermore the software is easy to use for non-acoustician and offers great functionality for professionals. The results are easy to interpret for everybody. Noise Inspector is an important product to improve your product quality, minimize development time and to save your resources.

It can be adopted to your needs due its flexibility in array design, number of microphones and state of the art algorithms. The smooth transition between beamforming, holography and sound intensity measurements enables to analyze a broad band of objects.

Everything is designed to have a very high performance. More advantages – less costs!

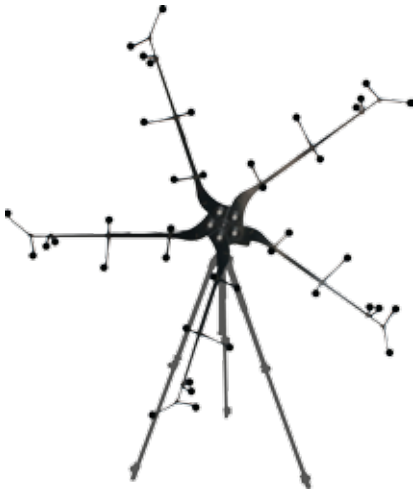
## Features

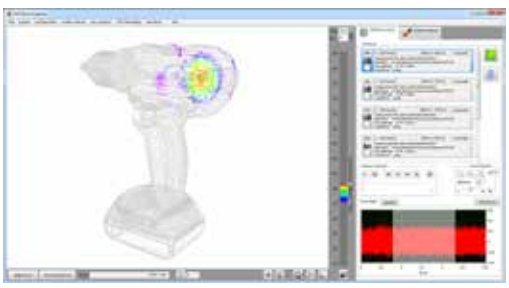
**Hardware**

- One system for near and far field
- 24 bit synchronous sampling
- Channels: 8 - 1000
- High resolution results
- High resolution optical camera
- Battery operation (low power consumption)
- Trigger and RPM channel
- Light weight and small packaging dimensions
- Flexible and mobile

**Software**

- Real-time sound imaging for quick results
- Postprocessing for high accuracy results
- Powerful HD algorithms
- AVI, WAV and result export
- Localization from 40 Hz up to 20kHz
- Dynamic range more than 40 dB possible
- Acoustic weightings filters
- LabVIEW- and Matlab interface for algorithms
- Batch or manual processing
- Unique real 3D beamforming
- Intuitive and easy to use





# Noise Inspector is a Solution

The Noise Inspector is designed for quick setup to save time and start immediately with measurements. Therefore we designed a system which can be setup by only one person in about one minute. Immediately after setting up the hardware, the first acoustic pictures are only one mouse click away.

4 Important parts of acoustic cameras:

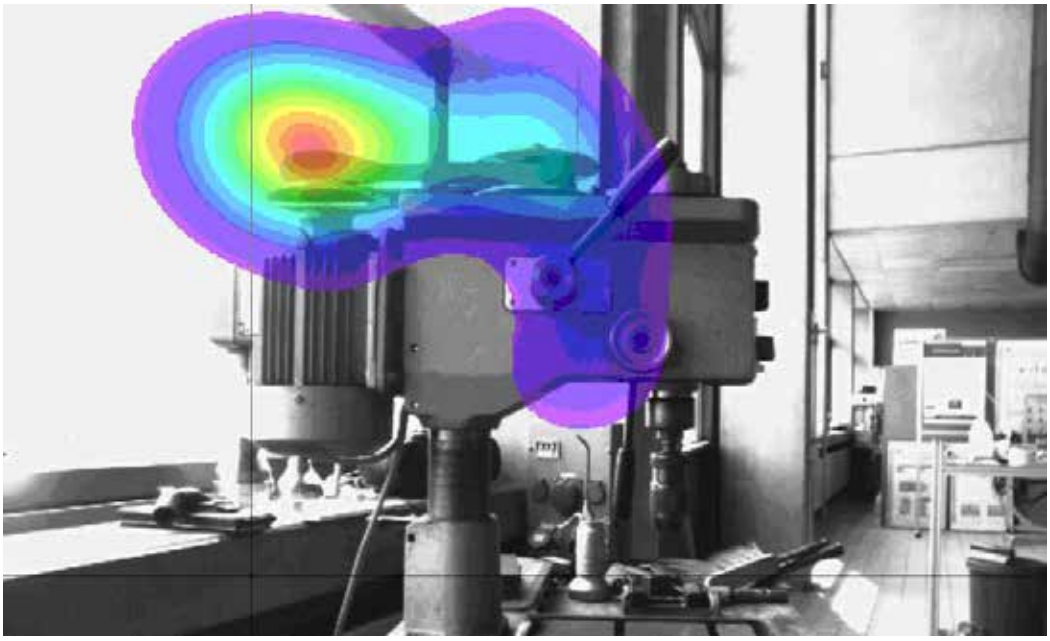
- Microphone array
  It's very important to have a well-designed array.
- Data acquisition (analog or digital)
  24 bit resolution, anti-aliasing filters and simultanious sampling for each microphone is very important for most applications
- Camera
  High Definition cameras are used (USB & IP camera)
- Computation Software
  The software is the heart of the system, of course. Our software is made to be for high definition acoustic pictures and movies.



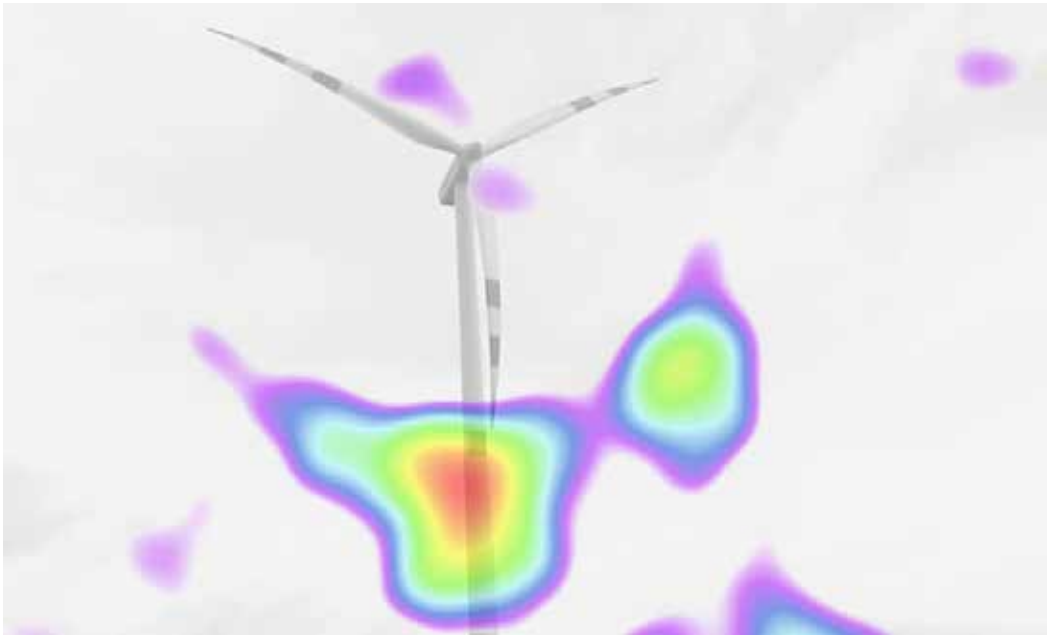
# Endless Applications for Acoustic Cameras

Our Noise Inspector is optimized to deliver best performance and most accurate result for every possible application. It is a system for very low to very high frequencies.

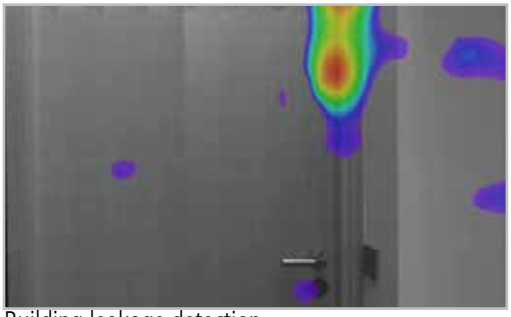
## Friction noise of a belt drive



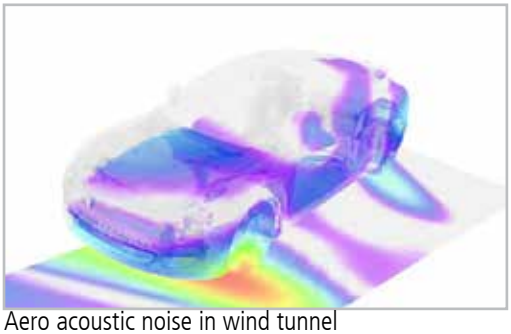
## Airborne noise of wing tip

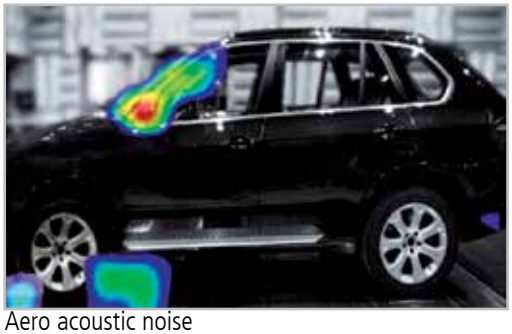


## Endless applications


Building leakage detection

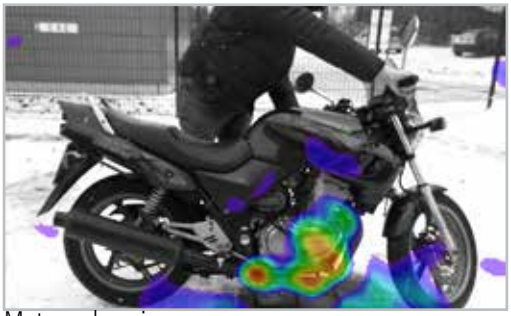

Printer noise

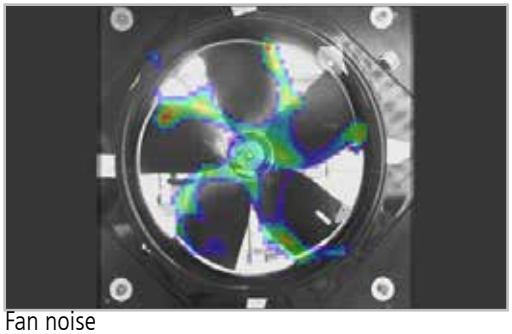

Aero acoustic noise in wind tunnel


Aero acoustic noise


Drill noise


Fan noise

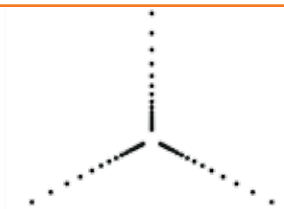
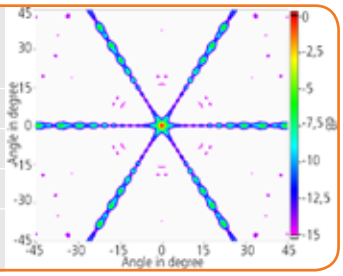
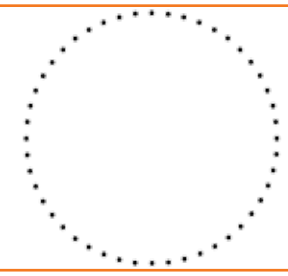
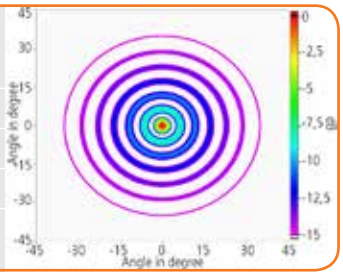
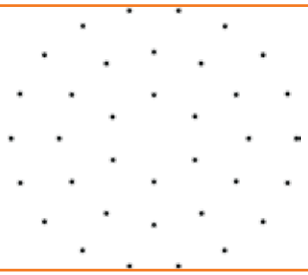
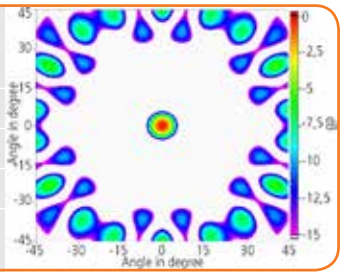
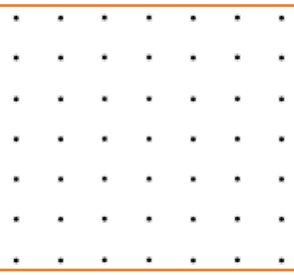
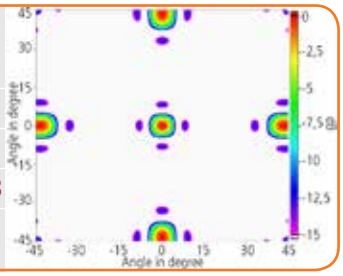

Motorcycle noise


Fan noise

# Common Arrays

The array design is an important physical property to deliver very high resolution results. Therefore we put a lot of engineering know-how into the shape of the arrays. Standard designs give results with poor resolution and/or poor dynamic range.

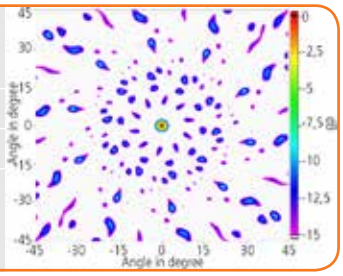
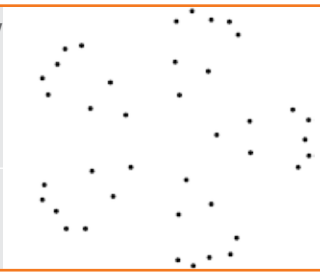
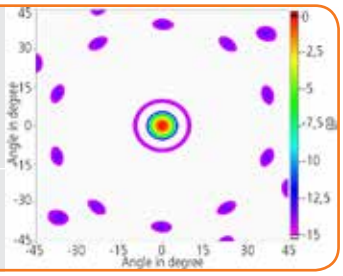
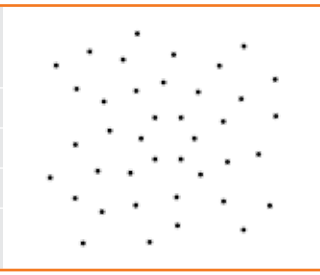
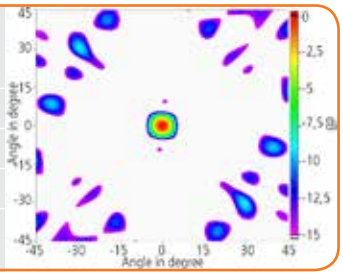
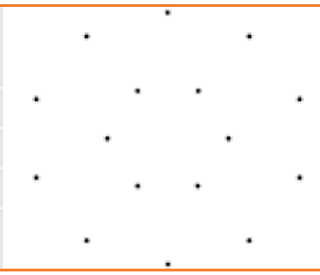
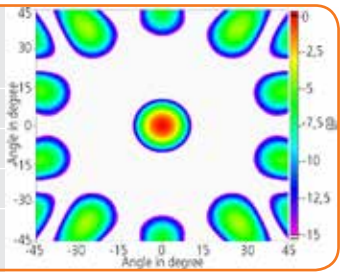
## Common array designs

| | | | |
|---|---|---|---|
| **Star array**<br>Microphones:<br>48<br>Diameter:<br>1,6 m |  | **Beampattern**<br>-3dB width:<br>±1,07414 °<br>max side lobe:<br>-5,53551 dB |  |
| **Ring array**<br>Microphones:<br>48<br>Diameter:<br>0,75 m |  | **Beampattern**<br>-3dB width:<br>±1,92012 °<br>max side lobe:<br>-7,89909 dB |  |
| **Concentric ring array**<br>Microphones:<br>36<br>Diameter:<br>0,6 m |  | **Beampattern**<br>-3dB width:<br>±2,96055 °<br>max side lobe:<br>-5,49043 dB |  |
| **Chess array**<br>Microphones:<br>49<br>Diameter:<br>0,6 m |  | **Beampattern**<br>-3dB width:<br>±2,59681 °<br>max side lobe:<br>-0,0001821 dB<br>Simulation at 5 kHz |  |

# Leading Array Technology

As the influence of the array designs are that significant, we created a portfolio of good microphone distributions (see below). Also it is absolutly possible to create customized array designs to fulfill the customers needs.

## Our array designs

| | | | |
|---|---|---|---|
| **Bionic L array** |  | **Beampattern** |  |
| Microphones: | | -3dB width: | |
| 40 | | ±1,30365 ° | |
| Diameter: | | max side lobe: | |
| 1,6 m | | -9,61437 dB | |
| **Bionic S array** |  | **Beampattern** |  |
| Microphones: | | -3dB width: | |
| 40 | | ±3,02449 ° | |
| Diameter: | | max side lobe: | |
| 0,6 m | | -13,2983 dB | |
| **Spider array** |  | **Beampattern** |  |
| Microphones: | | -3dB width: | |
| 40 | | ±3,00837 ° | |
| Diameter: | | max side lobe: | |
| 0,65 m | | -9,10779 dB | |
| **Mobile array** |  | **Beampattern** |  |
| Microphones: | | -3dB width: | |
| 16 | | ±5,41066 ° | |
| Diameter: | | max side lobe: | |
| 0,3 m | | -4,17054 dB | |
| | | Simulation at 5 kHz | |

# Excellent Software Makes the Difference

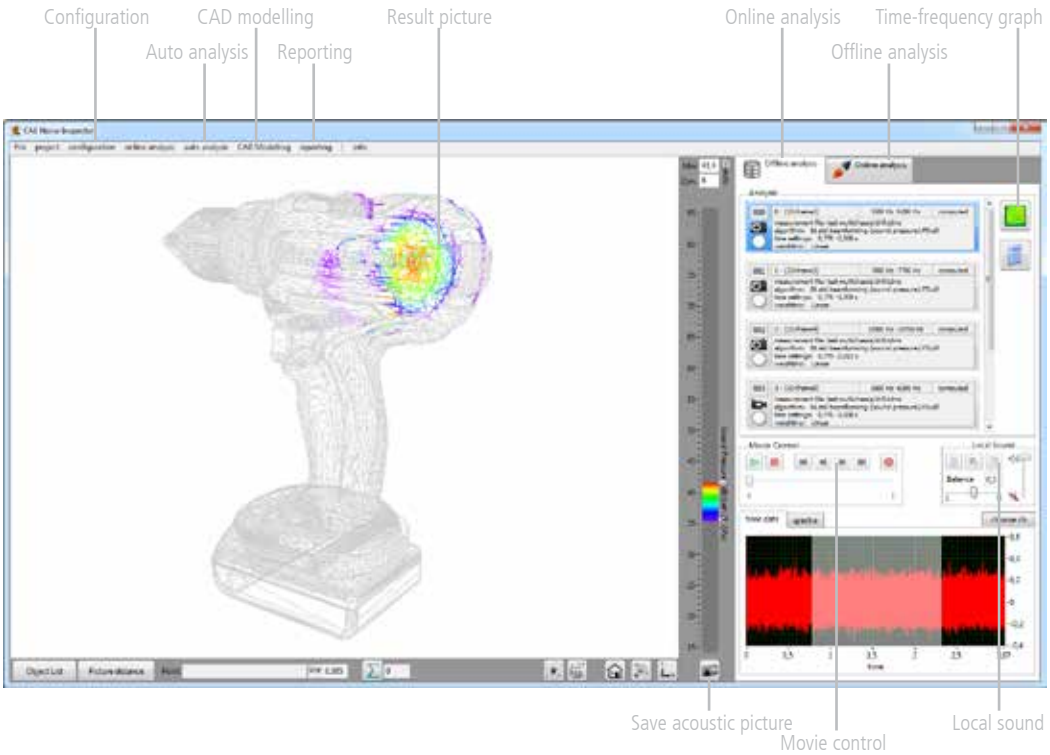
The Noise Inspector software is a turn key solution to visualize sound sources. Acoustic pictures and movies show the user fast and directly where the noise is coming from. The user friendly interface guides the user through the whole process from data aquisition through analysis to reporting. We implemented in the software many well-known and new algorithms for getting detailed pictures. A comprehensive reporting tool allows the user a fast documentation and visualization of the results.

With the acoustic pictures and movies the next necessary development steps can be started.

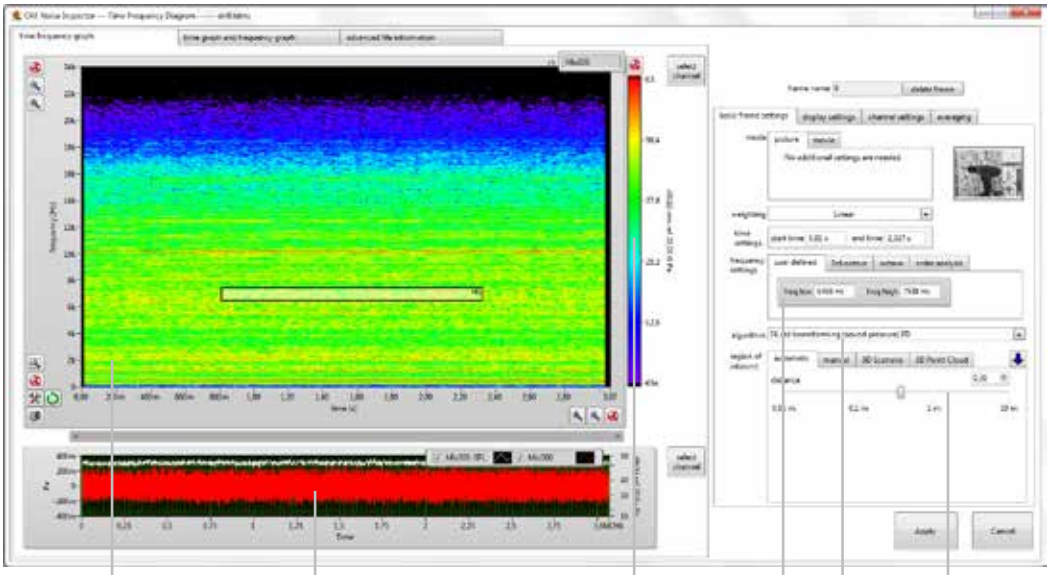
The Noise Inspector Software is not a closed software solution, the export possibility allows the usage of the results and measurements on different software platforms. The raw data files and the result files are stored on the hard disc in the TDMS-fileformat from National Instruments and can be read in external software easily.

The open LabVIEW and Matlab interface provides a simple way for our customers to develop their own algorithms and to integrate these into the Noise Inspector, which is often used for research properties.

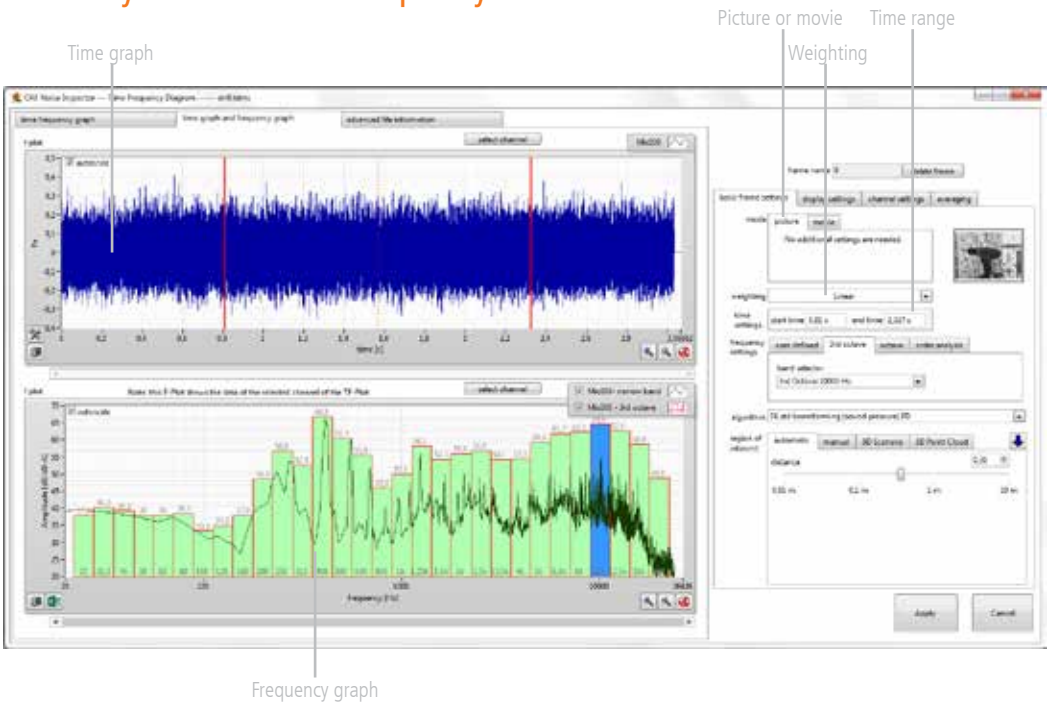
## Main interface of the Noise Inspector



## Pre-analysis in time-frequency domain




## Pre-analysis in time and frequency domain



# Wide Selection of Algorithms

The Noise Inspector software comes with the largest range of algorithms available on the market. You can choose between standard beamforming or high resolution beamforming algorithms for far field measurements.

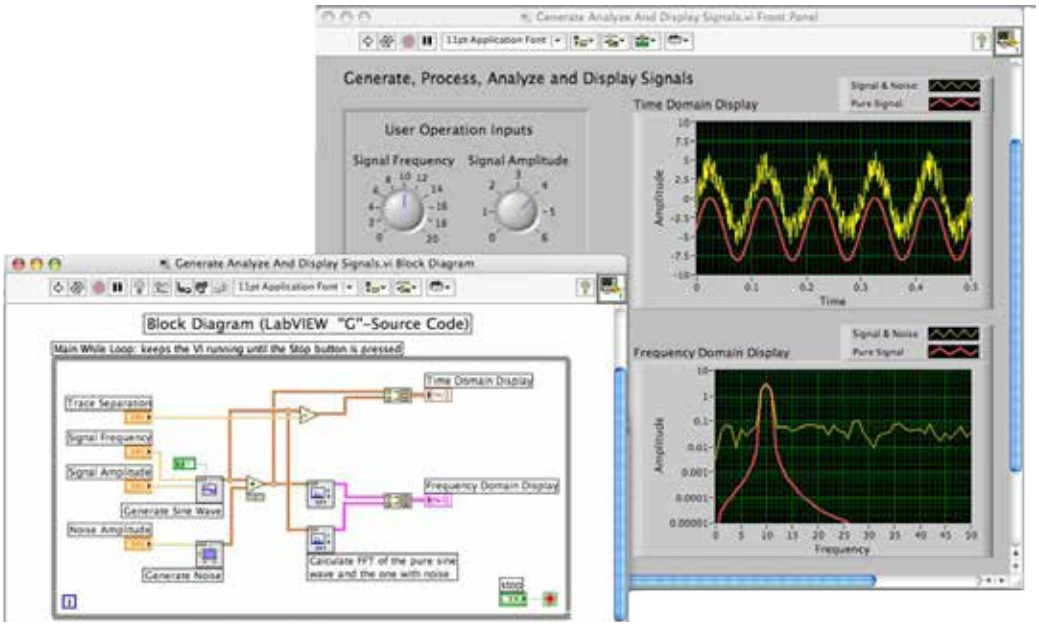
If you are facing lower frequency sources the Noise Inspector can be used for acoustic holography measurements or intensity mapping tasks, as well the user is able to design own analysis algorithms and implement them via the LabVIEW interface for plugins.

## Features

**Algorithms for best results**

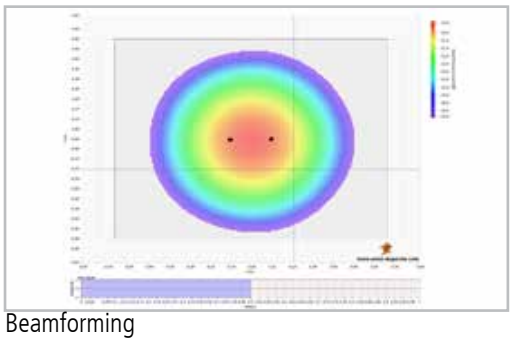
**from 40 Hz**
- Intensity - Intensity mapping method
- Online-Intensity - from 40 Hz
- SONAH - statistically optimized near field acoustic holography
- 3D intensity mapping (3D vectors)

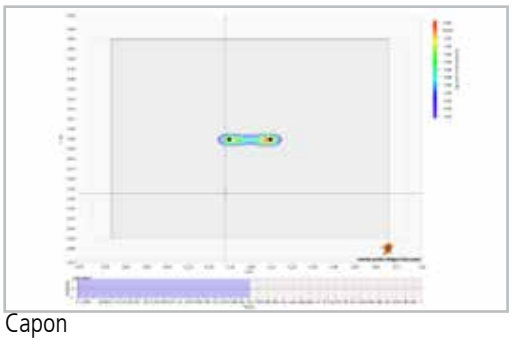
**from 500 Hz**
- Standard Beamforming - very fast and robust
- Deconvolution algorithms
  - CLEAN SC
  - MUSIC - Multiple Signal Classification
  - Capon
  - DAMAS
  - Orthogonal Beamforming
  - And others
- Real 3D beamforming - object is inside of the microphone array
- Rotating beamforming - for fast rotating parts e.g. fans
- "user" - interface for your own methods

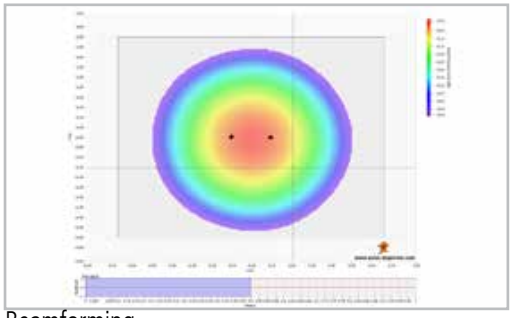


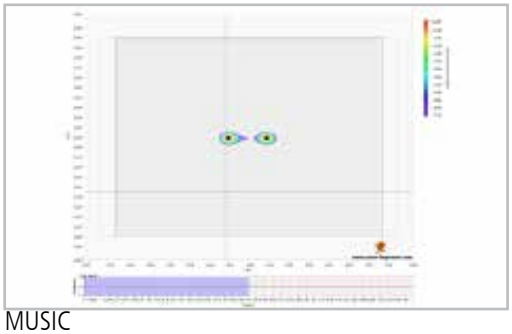
# Advanced HD Algorithms

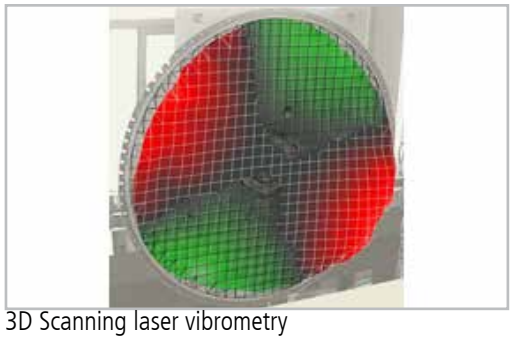
## Comparison


Beamforming

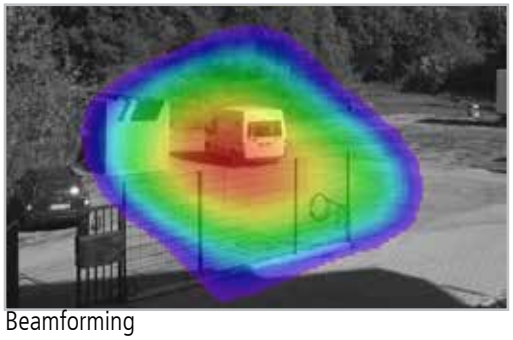

Capon


Beamforming


MUSIC


3D Scanning laser vibrometry


Acoustic holography (SONAH)


Beamforming


Clean SC

# Acoustic Camera
# Bionic Array L and XL



## Features

- Integrated design
- High resolution
- High dynamic range
- Small package volume
- Designed for farfield measurement
- from 300 Hz

| The CAE "Bionic Array": | |
|---|---|
| Standard-Size | Diameter 1600 mm |
| Material | Composite material |
| Weight | 3,5 kg |
| Microphones | 40(L) or 80(XL) |
| Tripod | Aluminium |

## Application

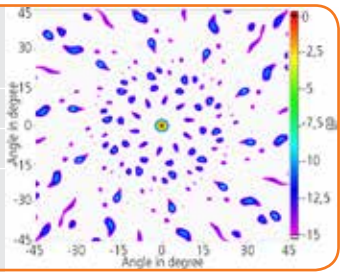
- NVH
- Squeak and rattle
- Noise leakage detection
- Environmental acoustics
- Building acoustics
- For transient and stationary noise sources
- And many more

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

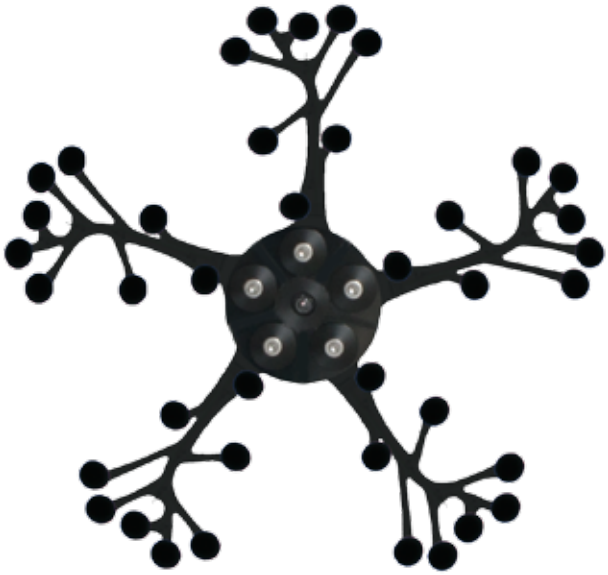
| Bionic L array | |
|---|---|
| Microphones: | |
| 40 | |
| Diameter: | |
| 1,6 m | |



| Beampattern | |
|---|---|
| -3dB width: | |
| ±1,30365 ° | |
| max side lobe: | |
| -9,61437 dB | |



# Acoustic Camera
# Bionic Array S



## Features

- Integrated design
- High resolution
- High dynamic range
- Very small package volume
- Designed for farfield measurement
- from 1000 Hz

| The CAE "Bionic Array S": | |
|---|---|
| Standard-Size | Diameter 600 mm |
| Material | Composite Material |
| Weight | 1 kg |
| Microphones | 40 |
| Tripod | Aluminium |

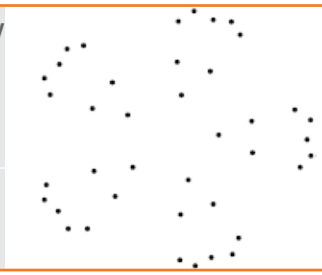
## Application

- NVH
- Squeak and rattle
- Noise leakage detection
- Environmental acoustics
- Building acoustics
- For transient and stationary noise sources
- And many more

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

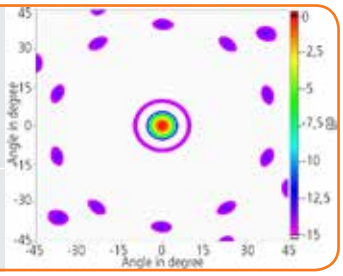
**Bionic S array**

Microphones:
40
Diameter:
0,6 m

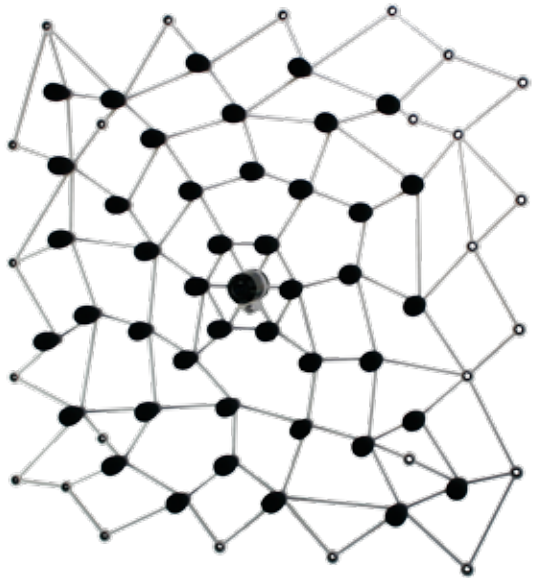


**Beampattern**

-3dB width:
±3,02449 °
max side lobe:
-13,2983 dB



# Acoustic Camera
# Spider Array



## Features

- Far field analysis (Beamforming)
- Near field analysis (Holography)
- Easy to use
- Expandable array size
- Expandable amount of channels
- Changable microphone positions
- Usage from 40 Hz up to 20 kHz

## Application

- NVH
- Squeak and rattle
- Noise leakage detection
- Environmental acoustics
- Building acoustics
- For transient and stationary noise sources
- And many more

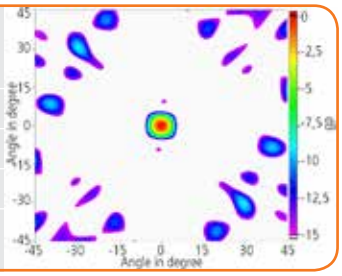
| The CAE "Spider Array": | |
|---|---|
| Standard-Size | 800 mm x 800 mm |
| Material | Aluminium |
| Weight | 2,6 kg |
| Microphones | 40 |
| Expandable with arrays | Yes |
| Tripod | Aluminium |

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

| Spider array |
|---|
| Microphones: |
| 40 |
| Diameter: |
| 0,65 m |



| Beampattern |
|---|
| -3dB width: |
| ±3,00837 ° |
| max side lobe: |
| -9,10779 dB |



# Acoustic Camera
# Mobile Array



## Features

- Ultramobile
- Easy to use
- Small size
- Beamforming only
- Usage from 2 kHz up to 10 kHz

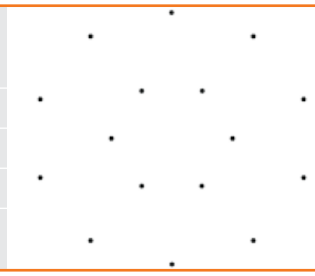
| The CAE "Mobile Array": | |
|---|---|
| Standard-Size | Diameter 300 mm |
| Material | Aluminium |
| Weight | 0,9 kg |
| Microphones | 16 |
| Tripod | Aluminium |

## Application

- NVH
- Squeak and rattle
- Noise leakage detection
- Environmental acoustics
- Building acoustics
- For transient and stationary noise sources
- And many more

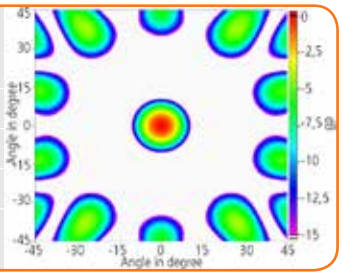
| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

| Mobile array | |
|---|---|
| Microphones: | |
| 16 | |
| Diameter: | |
| 0,3 m | |



| Beampattern | |
|---|---|
| -3dB width: | |
| ±5,41066 ° | |
| max side lobe: | |
| -4,17054 dB | |

Simulation at 5 kHz



# 3D Acoustic Camera

# 3D Array



## Features

- 3D Beamforming
- 3D results on 3D objects
- One measurement for the complete acoustic emission in 3D
- Stationary and non stationary processes
- Array size:  small cube or complete room
- Acoustic photos and videos

## Application

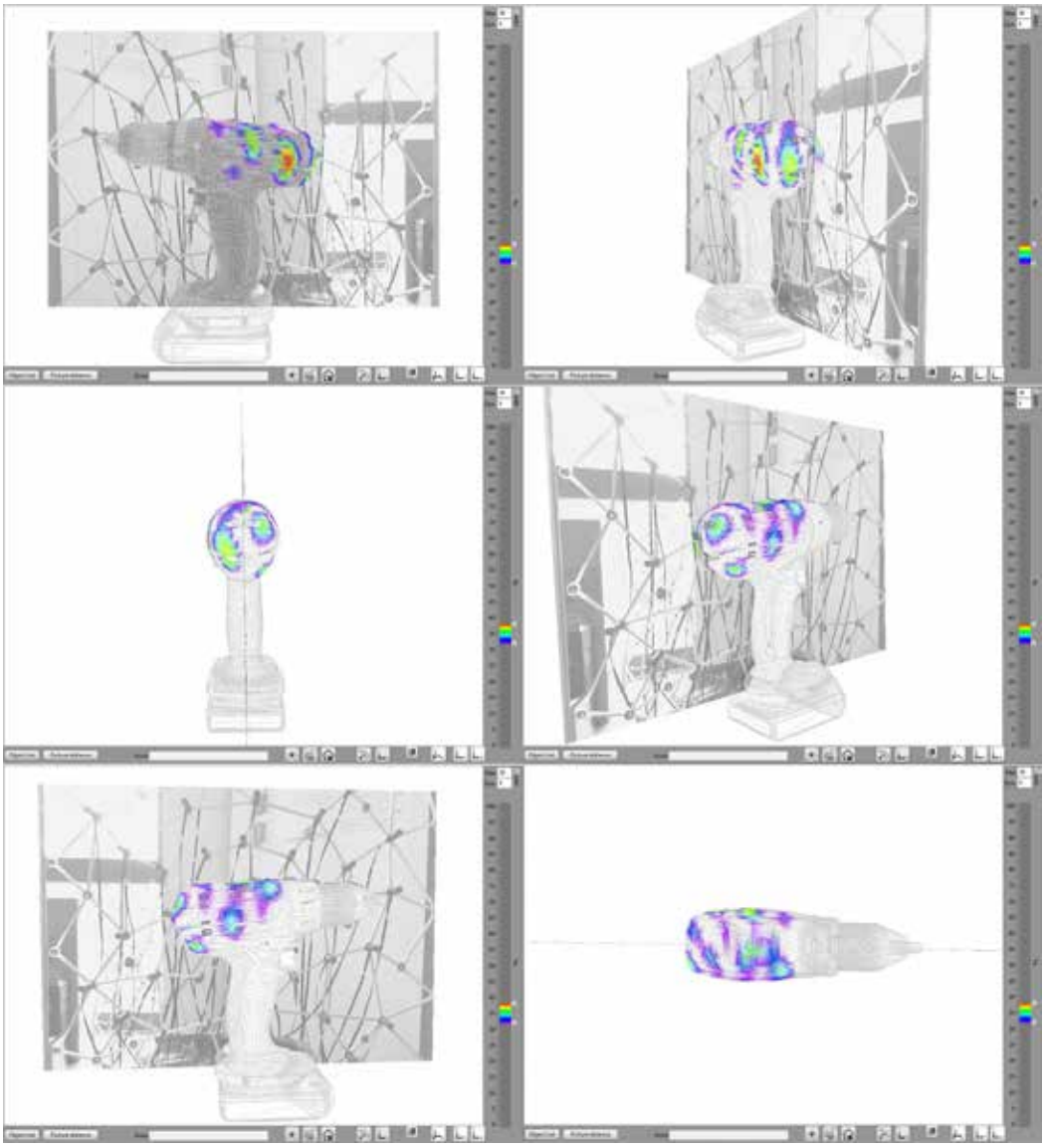
- NVH
- Squeak and rattle
- Noise leakage detection
- And many more
- For transient and stationary noise sources

| The CAE "3D Array": | |
|---|---|
| Standard-Size | Variable |
| Material | Aluminium |
| Weight | 10,5 kg |
| Microphones | 80 - 400 |
| Expandable with arrays | Yes |
| Tripod | Aluminium |

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

# What is Real 3D Beamforming?

Worldwide unique 3D beamforming. The object is surrounded by microphone arrays and is therefore measured from all sides. The results are real 3D measurement results which are projected on the 3D model. Only one measurement shows the complete acoustic emission of the measured object. There is no limit in the microphone array size - from a small cube of 800 mm x 800 mm x 800 mm up to a complete anechoic chamber. High resolution in all dimensions.



# 3D Intensity Camera
# Acoustic Compass



The CAE Acoustic Compass is a 3D sound intensity probe that is able to measure from low frequencies to high frequencies in 3D. The output of the analysis is a spectrum with amplitude and x, y and z coordinates for each frequency line. The Noise Inspector software shows the direction and the intensity on the 3D display.

Intensity measurement systems have a very high dynamic range as there is no algorithm and no beampattern limiting this range.

## Features

- Online and offline analysis
- Localization in small spaces
- Ultramobile
- Easy to use - like a compass
- 3D Intensity Measurement
- Usage from 40 Hz

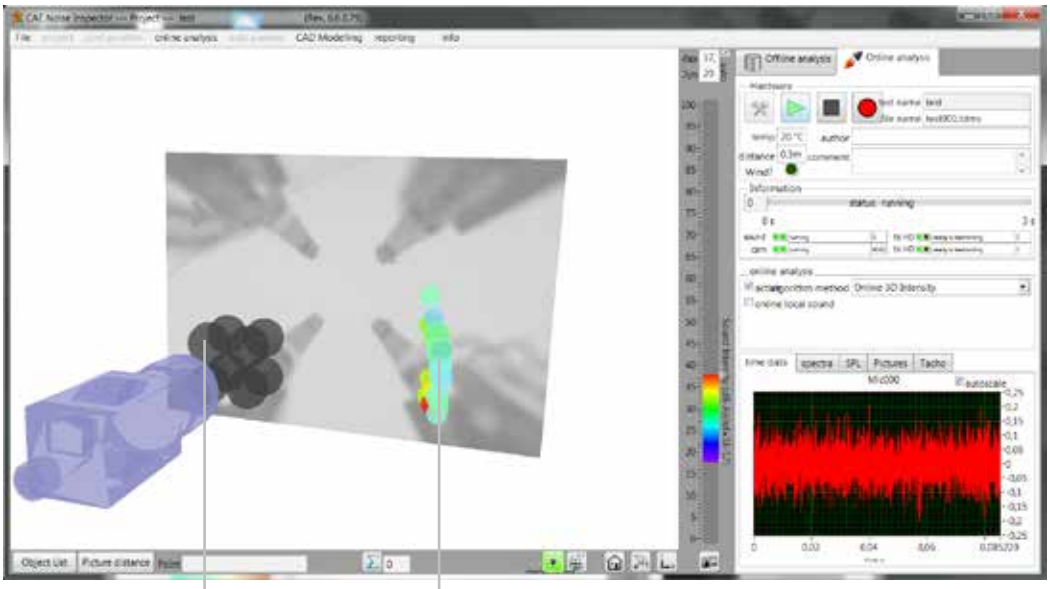
## Application

- NVH
- Squeak and rattle
- Noise leakage detection
- Environmental acoustics
- Building acoustics

| The CAE "Acoustic Compass": | |
|---|---|
| Standard-Size | 50 mm x 50 mm |
| Material | Aluminium |
| Weight | 0,6 kg |
| Intensity probes | 28 |
| Tripod | Aluminium |

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

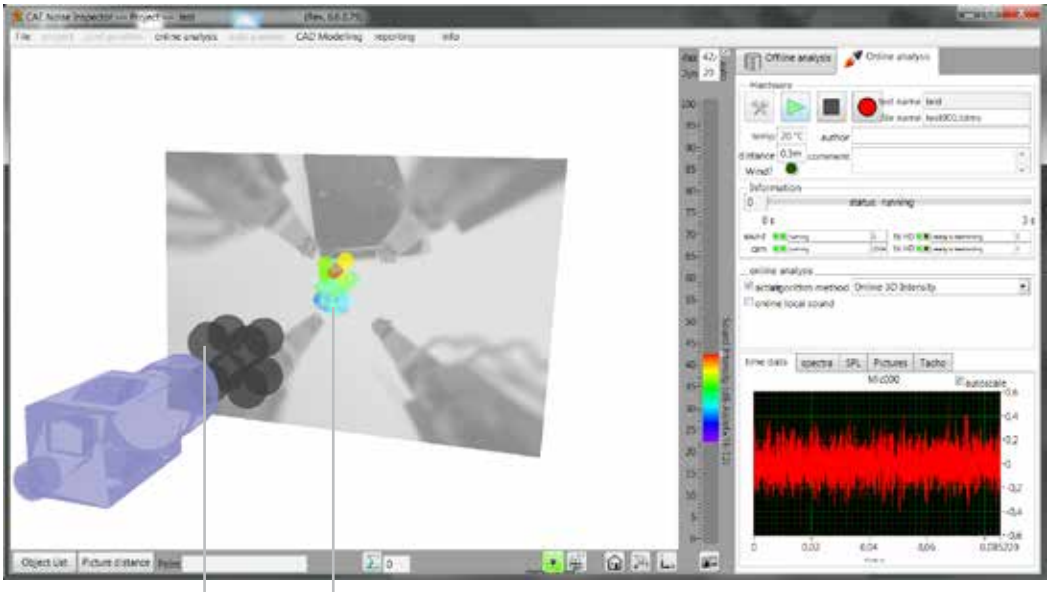
## Noise source is in the right direction of the probe



8 microphones result in 28 intensity probes

Each point represents one frequency line, direction and amplitude (color)

## Noise source (cell phone) is in front of the probe



8 microphones

Localized sound source (intensity vector cloud)

# Intensity Camera

# Intensity Array



The CAE Intensity Array is a one dimensional sound intensity measurement system that is able to detect the source of very low frequencies. The output of the analysis is the sound intensity for each probe mapped on a picture. This measurement system is also able to map stationary and transient noise sources.

Intensity measurement systems have a very high dynamic range as there is no algorithm and no beampattern limiting this range.

## Features

- Online intensity analysis
- Localization in small spaces
- Ultramobile
- Easy to use
- Stationary and non stationary processes
- 3D Intensity measurement
- Usage from 40 Hz

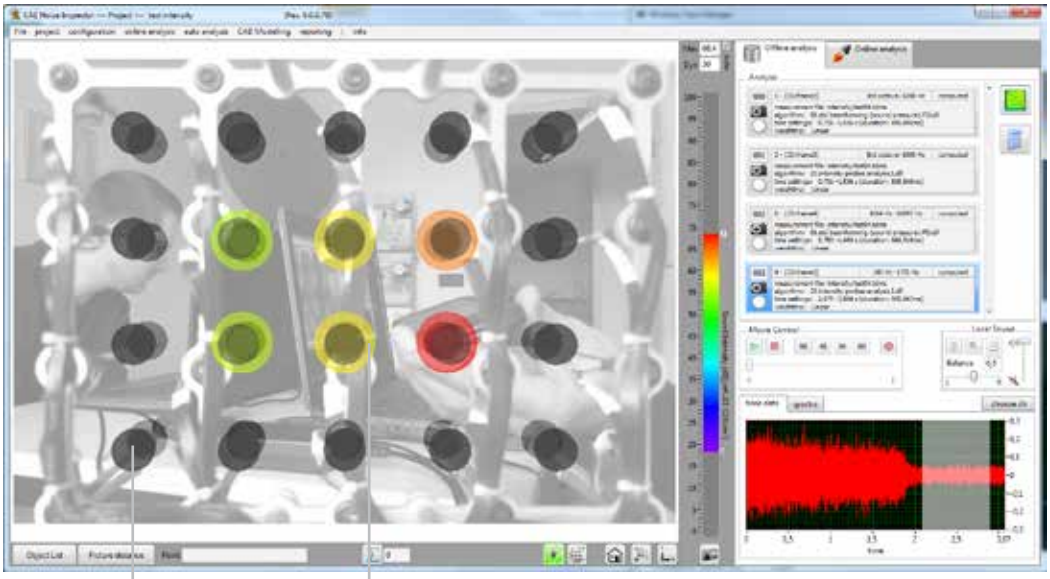
## Application

- NVH
- Squeak and rattle
- Noise leakage detection
- Building acoustics
- For transient and stationary noise sources

| The CAE "Intensity Array": | |
|---|---|
| Standard-Size | 200 mm x 150 mm |
| Material | Aluminium |
| Weight | 0,8 kg |
| Intensity probes | 20 |
| Expandable with arrays | Yes |
| Tripod | Aluminium |

| MEMS-Microphones | |
|---|---|
| Resolution | 24-bit |
| Interface | I²S |
| Dynamic range | 33 dB - 120 dB |
| Flat frequency response | 60Hz - 15 kHz |
| Sample rate | 48 kHz |

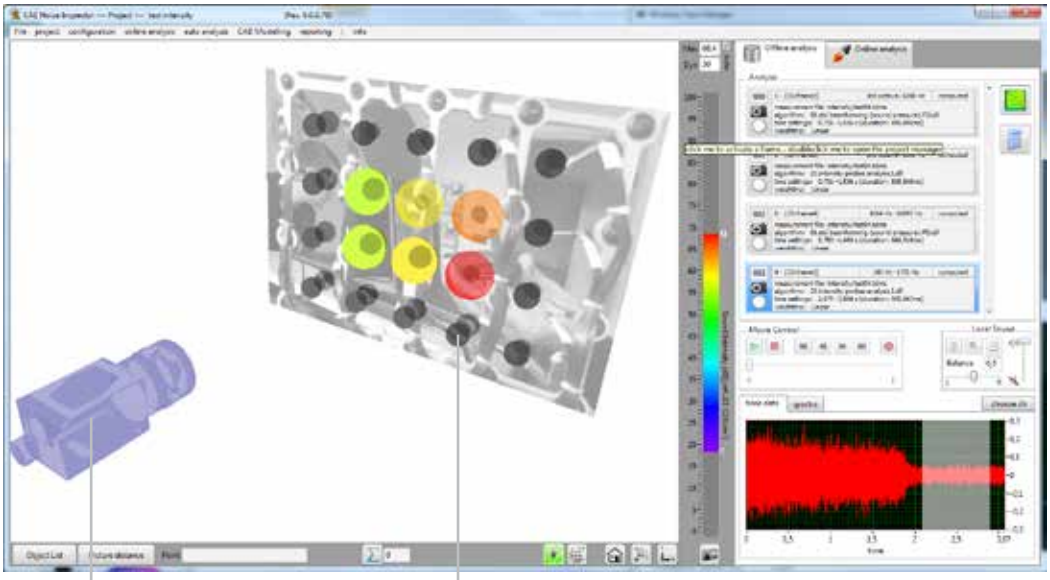
## Typical intensity map for point source



2 microphones result in 1 intensity probes

Intensity amplitude is shown for each probe (color)

## 3D View on the intensity plan



Camera model

The amplitude of the intensity is below dynamic range

# Digital Real-Time I²S Frontend Hardware



The powerful I²S-frontend is robust and light weight. The onboard real-time processor and FPGA guarantees the highest accuracy of the measured data. By synchronizing frontends the system can be extended to more than 1000 channels or measure the RPM of an rotating system simultaneously. Therefore the frontend has a trigger channel and an RPM channel integrated.

The Frontend streams the acquired data of the microphones through high speed ethernet in real time to the host computer.

## Features

- Light weight
- Robust
- Expandable
- Trigger channel
- RPM channel
- Battery option
- Fanless
- Synchronized multi chassis applications
- Up to more than 1000 Mic channels

| I²S-Frontend | |
|---|---|
| Channels | 40 |
| Sample rate | 48 kHz |
| Resolution | 24 bits |
| Simultaneous sampling | Yes |
| Interface to PC | Ethernet |
| Battery option | Yes |
| Power supply | 9-30 V DC |
| Power consumption | < 7 W |
| Length | 230 mm |
| Width | 185 mm |
| Height | 58 mm |
| Weight | 2 kg |

# Conventional Analog hardware Wanted?

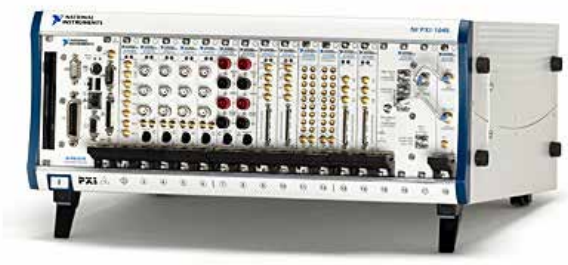
## No problem

All our measurement systems do also support National Instruements hardware for dynamic signal acquisation (DSA). A variety of different microphones is supported.

If a compact and robust hardware is needed we recommened National Instruments ethernet chassis and C-Series modules.



For high speed or ultra sonic measurement the National Instruments PXI system is a perfect platform for the noise inspector system.





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