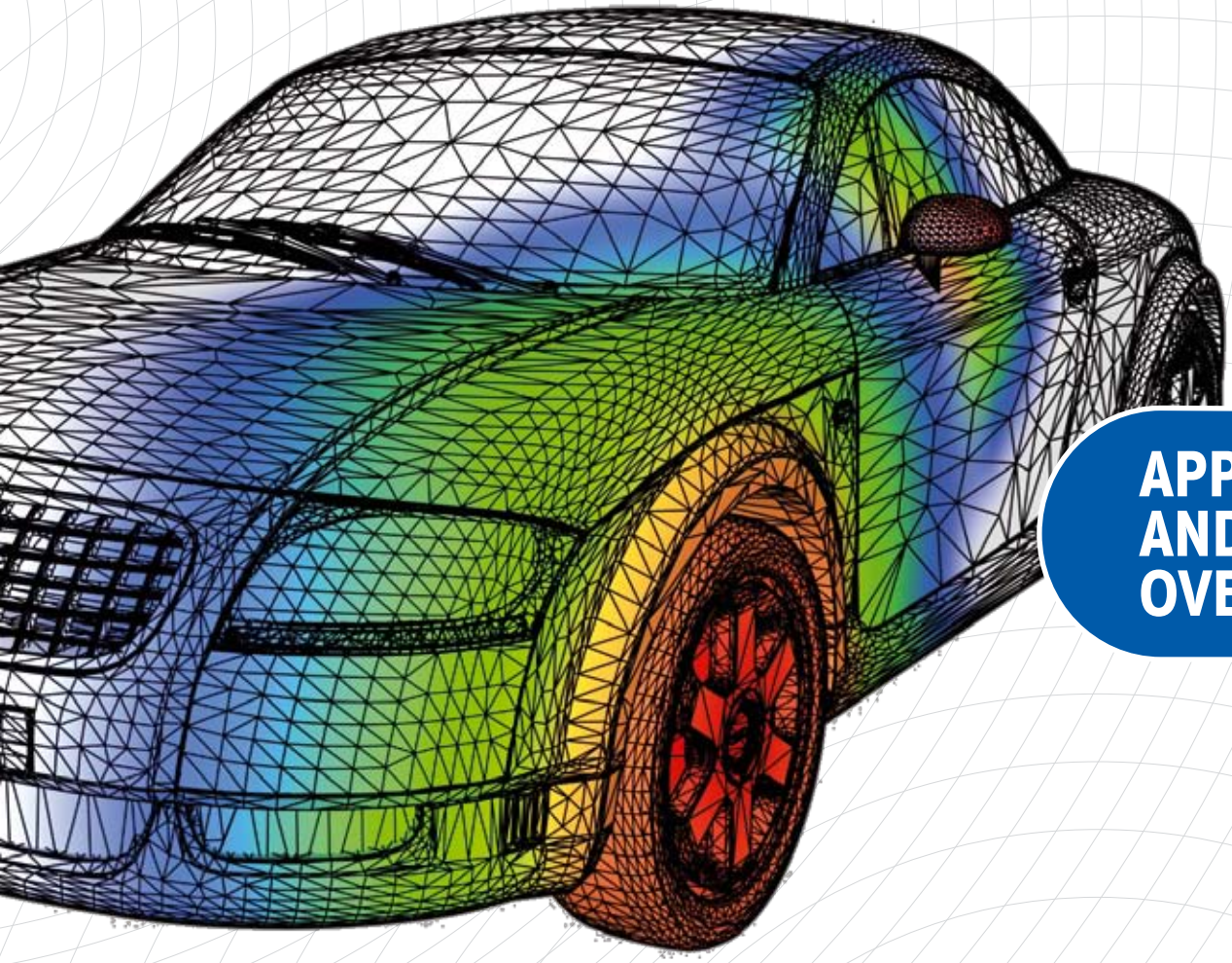

APPLICATIONS AND SYSTEM OVERVIEW

LISTENING WITH YOUR EYES

acoustic camera

The intelligent solution to locate sources of noise

acoustic camera

CONTENTS

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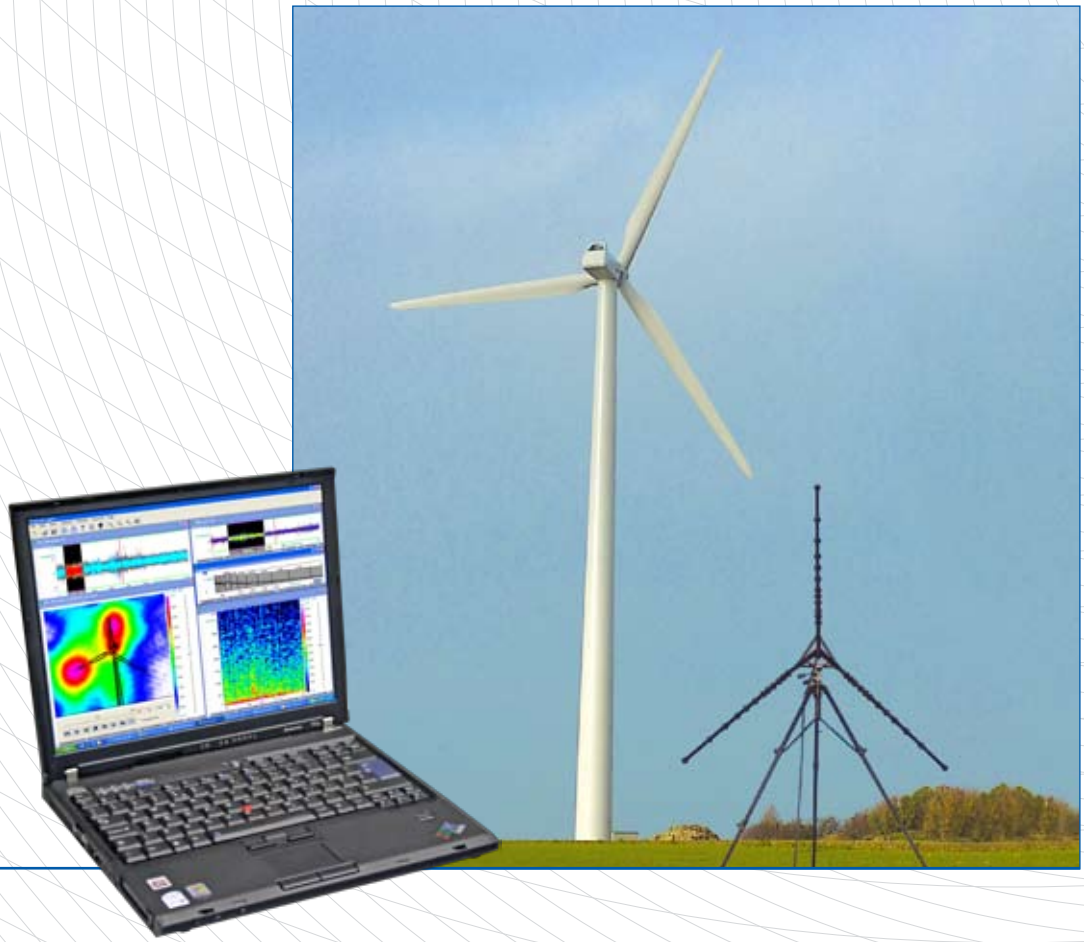


Sound measurement using the software NoiseImage and the Star36 array

EDITORIAL

More than 10 years have passed since the first acoustic camera was built. This period has been marked by continuous growth and improvement. The **acoustic camera** team launched an innovation that continues to surpass any competitor products both technically and when applied 'in the field' – proven by the growing number of customers from various industries, ranging from automotive and engineering to consulting. As a result, the acoustic camera continues to inspire other vendors of beamforming systems.

Our success is built upon 3 pillars: innovative power, strict quality standards and the solid engineering capabilities of our team. The development curve shows a constant upward trend – evidence of our enduring power to compete in an international environment.

The GFaI is increasingly recognized in the acoustic society as the driver for developing the beamforming technology from an academic instrument to a commercially viable product.

The purpose of this booklet is to present the wide field of applications for the **acoustic camera** and to introduce the system itself with a selection of its most interesting features. However, there is much more to discover!

Dr. Ralf Schroeder
Managing Director
gfai tech GmbH

Sound measurement of a train pass-by using the acoustic camera

New solution approaches for noise reduction, sound optimization and fault visualization

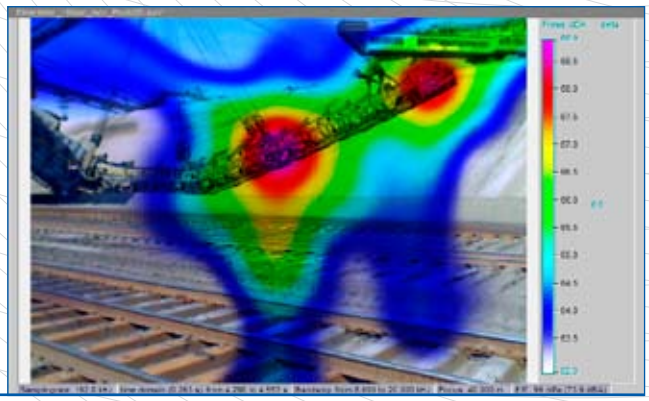
acoustic camera

ACOUSTIC CAMERA – LISTENING WITH THE EYES

Using their eyes, human beings can gather information more quickly and with more flexibility than with any other sense organ. This is why complex processes are "visualized" and great technical effort is made to extend vision to fields that the eye usually cannot see. X-ray machines, magnetic resonance imaging devices and infrared cameras are only a couple of examples for technical instruments visualizing the invisible. As far as sound is concerned, there has not been a groundbreaking solution yet. What would be the advantages if sound was visible? What would the world around us look like if seen through an **acoustic camera**?

NOISE – ENVIRONMENTAL SOUND POLLUTION

Sound and noise are omnipresent in our everyday life. In the car, at work or at home – unlike your eyes you can never close your ears. Increasing traffic density, more air traffic, faster production lines and more powerful wind turbines are only a few of examples contributing to an increasing noise level which affects people's everyday life while also polluting the environment. The first step in making the environment quieter and more comfortable is to perform a detailed analysis of the undesired noise sources in a fast and efficient way. Designers and engineers can take effective measures to reduce noise only if the sources of noise emission are exactly known. But this is where the problems usually start: Which components, assemblies, car body parts or installations are really responsible for noise emissions? How is it possible to measure and document the successfully identified noise?



Measuring a part of a mining bridge with the Star48 array

PRODUCT SOUND – PRODUCT QUALITY

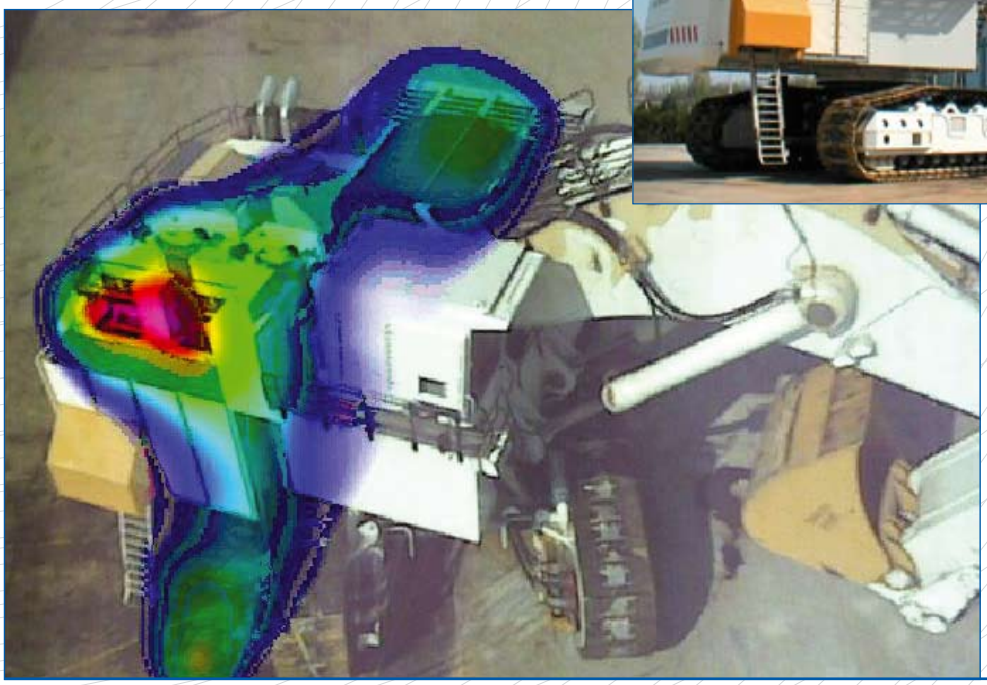
The higher we rate the sound quality of a product, the more quality is assigned to the product. Year after year, the automotive industry invests tremendous amounts of money to locate and analyze noise sources and to reduce their intensity if not their occurrence. The characteristic sound of a car has always been a very important marketing argument. A sports car must be distinguishable by its characteristic sound when it passes by. Any type of side tone is undesired and must be eliminated. How is it possible to achieve these aims faster and more effectively than ever before?

ACOUSTIC QUALITY ASSURANCE

Faults in machinery and plant installations can often be detected by a change in their noise emissions. An experienced mechanic can actually hear a fault. Some manufacturers rely on the excellent hearing skills of a few staff members to identify faulty products in the final quality control. But how can tests like these be automated and made more objective? Up to now, time consuming and costly technologies had to be employed to yield the desired results. Isn't an innovative and intelligent approach urgently required?

THE SOLUTION: MAKING SOUND VISIBLE – FAST AND EASY

The **acoustic camera** delivers a groundbreaking tool to solve these types of problems. For the first time, a portable system can be used to visualize sounds and their sources. Maps of sound sources that look similar to thermographic images are created within minutes. "An image says more than a thousand words." For the **acoustic camera** there is a vast range of applications from noise reduction, sound analysis and quality assurance.



Sound measurement of a giant excavator using the acoustic camera

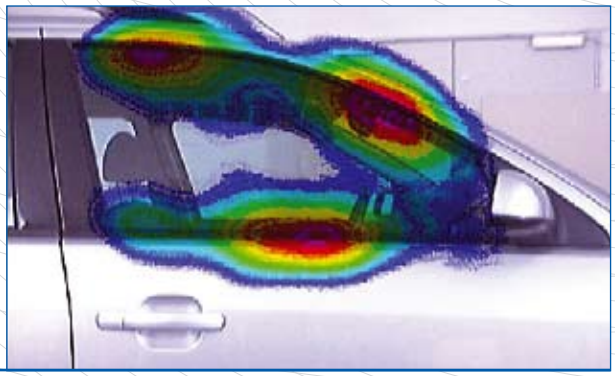
Easy visualization and separation of sound sources within minutes

acoustic camera

PHOTOGRAPHING AND FILMING SOUND

There is a simple, yet ingenious idea behind this revolutionary solution. A digital camera is used to acquire an image of the noise-emitting object. At the same time an exact defined array of microphones acquires and records the sound waves emitted by the object. Dedicated software then calculates a sound map and combines the acoustical and the optical images of the noise source. The handling and operation of the **acoustic camera** is almost as easy as with a common camera. You can monitor the target object in real time on-screen in a preview window. When you are done with the setup you just press the "shutter release button" – and that's it! The acoustic "fingerprint" of the target object has been acquired. The computer can calculate various sound maps, i. e. acoustic still images or videos. The complete soundscape which usually consists of a combination of many sound sources can be broken down into individual sources which are displayed through different coloring. The map visualizes the distribution of the sound pressure. It is now possible to identify the relevant

Measuring car engine noise



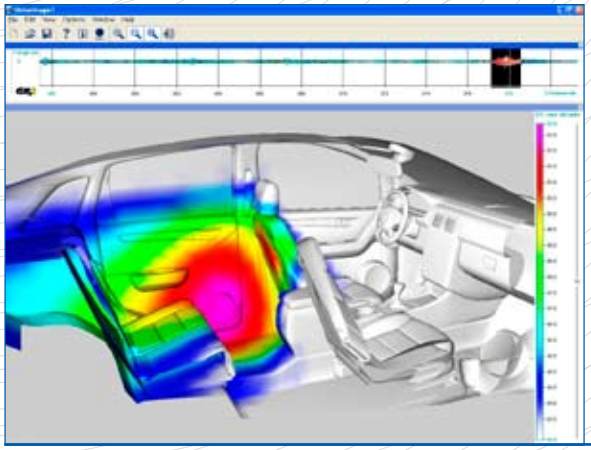
Sound emission from an electric window lift

sources of high sound levels. Up to now, this has never been done within a short time frame. The **acoustic camera** has established itself as an indispensable tool whenever fast and reliable answers are needed.

INTELLIGENT SYSTEM CONCEPT

Engineers in the industries work under immense pressure with respect to time and money. They need tools helping them to identify and to solve problems without creating new difficulties. Thus, the design of the **acoustic camera** is built upon modularity, ease of use and intuitive operation of the software. The system comprises the microphone array with the implemented camera, a data recording device and a notebook. The customized arrays are designed for different fields of application. The array setup is done within minutes. The system is immediately ready to use. In addition to the sound recording it is possible to acquire parameters like revolutions per minute, angle of rotation, voltages and currents. This facilitates a temporal and spatial allocation of sound sources to the operating state of the measured object.

Sphere Array: for interior or room measurements



Visualization in 3D mode projecting acoustic information onto a 3D model

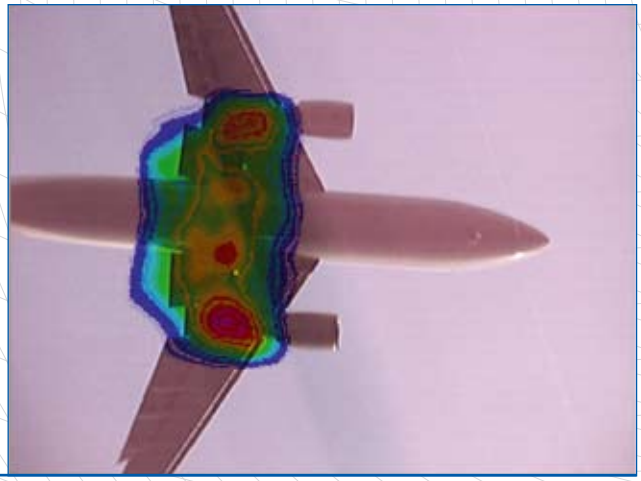
Star Array: on test track

Exact localization
of noise sources
Instant documentation
of noise reduction

acoustic camera

NOISE REDUCTION – A COMPELLING TASK FOR INDUSTRIAL SOCIETIES

Noise – an often underestimated pollutant. The human heart rate increases when exposed to sound levels above 65 decibels. At night, when cars and other vehicles only penetrate the subconsciousness, traffic noise can disturb human's health by affecting the quality of sleep. Therefore, the requirements defined by the legislation for the operation of technical devices are becoming more and more restrictive. This is true not only for planes and industrial installations but also for simple drilling machines. In addition, lower noise level is a good sales argument. However, machines and equipment must become more and more powerful, faster and lighter which leads in many cases to increased noise emissions. And even eco-friendly wind turbines can become a factor of annoyance. To meet these conflicting demands enormous investments have been mandatory in the planning and development stages.



Noise radiation from engines, gear and flaps

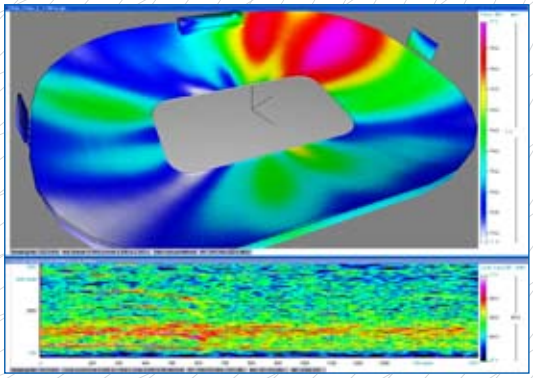
Star array during fly-over measurement

ACCURATELY IDENTIFYING AND DOCUMENTING SOURCES OF NOISE – IN BEST TIME

An **acoustic camera** can save an immense amount of time and corresponding money. Noise sources can be localized rapidly and very precisely from the position of the listener – even at distances of several hundred meters. The method has numerous advantages. Instead of placing microphones in a machine or plant and strenuously looking for noise sources, the object as a whole can be surveyed in only a few measurements from the relevant perspectives. When traditional technology is used to measure a wind turbine, for example, data from numerous measurement points must be acquired using microphones or vibration transducers. This is certainly not an easy task taking into account the size of the object and the rotation of the blades. Afterwards it remains questionable whether the sources that are found to be especially loud are responsible for the elevated noise emissions. There is always the risk of taking the wrong measures to reduce the noise emissions since these measures would be based on insufficient (and sometimes inadequate) data.

Vast amounts of money could easily be spent without the desired effects. When the true origins of noise exposure are not exactly known, it becomes harder or even impossible to correctly assign the responsibilities. Last but not least, documenting the success of the noise reduction is much easier with the **acoustic camera** system. Gathering two acoustic images one "before" and one "after" can clearly show the effectiveness of a modification.

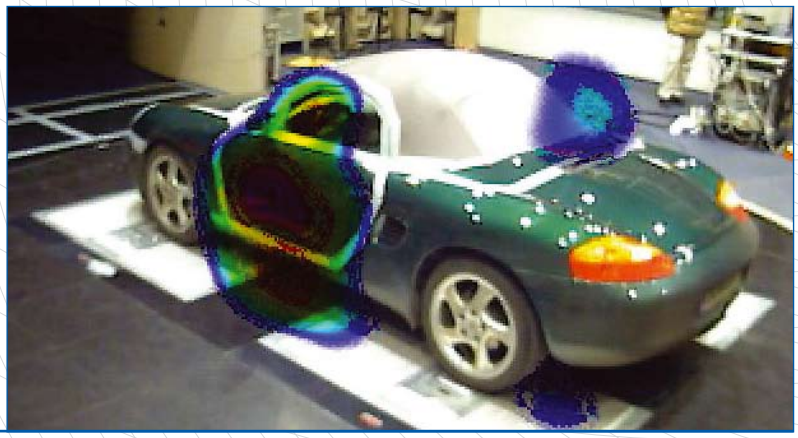
Noise from turbine and rotor blades in an acoustic image



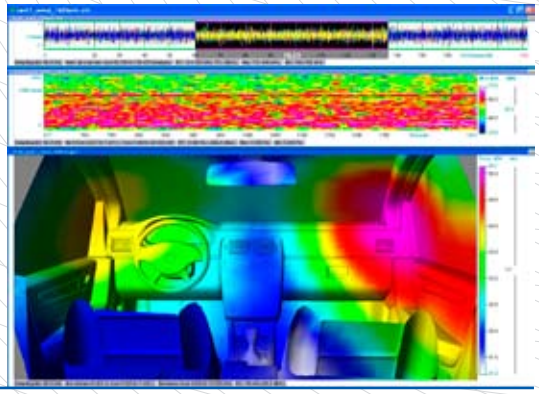
Crowd noise measurement in a large stadium and acoustic image

HIGH-QUALITY SOUND – HIGH-QUALITY PRODUCT

Sounds do not necessarily have to be loud to cause discomfort. In many cases there are sources far quieter than the dominant sound that seem to be psychoacoustically dominating. Some of the most significant examples for this phenomenon exist in the automotive industry where the **acoustic camera** has already been applied with great success. Rattling, hissing or clicking noises are undesired in any vehicle. Even at high speed the pianissimo parts of classic music should not be drowned by driving noise. Shutting the door, however, must produce a solid sound despite the lightweight construction. There are similar requirements for the sound of car engines. The roar of a sports car or the smooth and refined sound of a sedan are typical distinctive characteristics of car brands. That is why big effort is conducted to model the desired sound and to eliminate disturbances. Sound issues are also playing an increasingly important role in household appliances. Some high-value products can already be identified by their "high-value sound". Noises that are usually associated with faults, like clicking, crackling or whistling sounds, can irritate customers and frequently lead to unnecessary complaints. Time, frequency and modal analyses have been the means of choice so far to trace undesired noises. But these methods have a decisive disadvantage: The spatial resolution is limited if not missing. If the sound from several spots of an appliance is to be acquired simultaneously, individual microphones are required for each measurement point and they all must be placed very close to the object – without employing an innovative solution a time consuming and costly method.



Noise emission from a vehicle in a wind tunnel



Acoustic Photo 3D of car interior showing wind noise at 160km/h

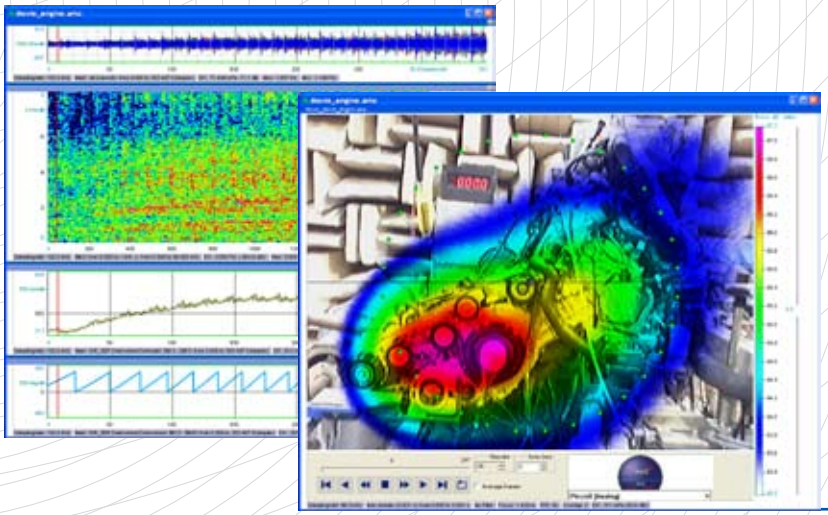
AN ENTIRELY NEW DIMENSION FOR SOURCE LOCALIZATION

SPACE- TIME- AND FREQUENCY-SELECTIVE MEASUREMENTS

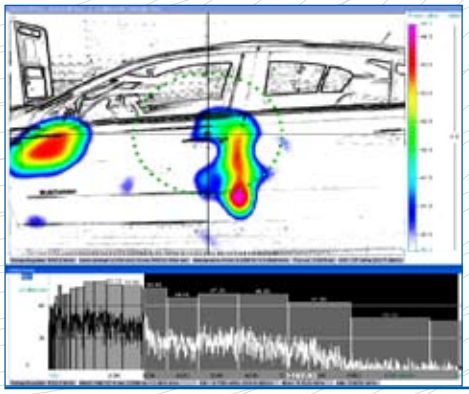
The **acoustic camera** can extend the known standard time and frequency selective analysis and add a location-selective component. With this method not only the progression of the sound signal is shown but a sequence of acoustic images can be acquired: Acoustic films are generated. The analysis clearly shows which sound sources are active in time and location. Extreme slow motion is possible – up to a resolution of 192,000 images per second if required. It is possible to monitor ignition, intake and exhaust sounds of individual cylinders. Noise paths become visible, active sound sources and passive reflections are isolated. Entirely new insights and perceptions about the development of sound and noise are offered. It is also possible to analyze sounds from moving objects.

THE ACOUSTIC CAMERA EXTENDS AND ENHANCES EXISTING ANALYSIS METHODS

The **acoustic camera** also comprises traditional analysis methods like A-weighting, one-third octave band analysis, narrow band analysis, filters, and many more. Based on these methods far more detailed research becomes possible. In a spectrogram, for example, sounds can be highlighted in the time and frequency domain. The **acoustic camera** then shows the exact origin of this sound. The approach can also be made from the other end: After selecting a spot on the measured object, the sound originating from that spot can be reconstructed, visualized and broken down into its spectral components. It is also possible to replay the sound via speakers – any time after the measurement has been completed.

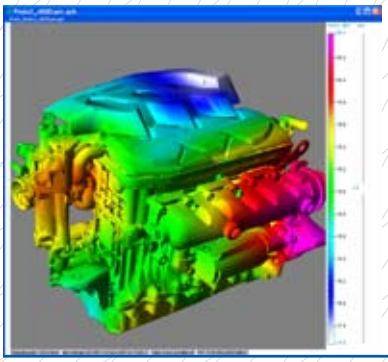


Engine sound relating to crankshafts angle and rpm



Frequency-selective acoustic image

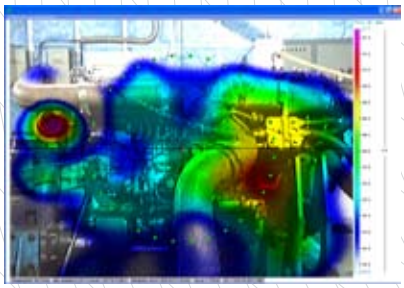
White noise inside car, showing door leakage

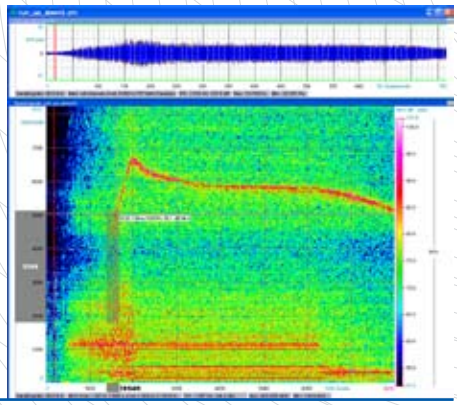


3D Acoustic Image of a Rotax Engine

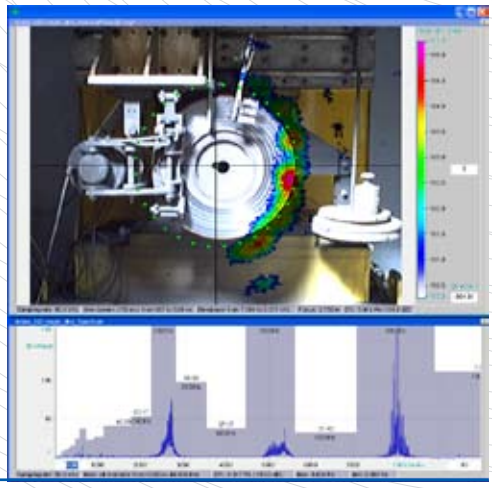
MULTI SENSOR TECHNOLOGY – VIRTUAL SOUND STUDIO

The more senses are used to gather information, the better human beings can recognize complex situations and act accordingly. This is why acoustic and visual signals are used in cockpits of aircraft to present information. The **acoustic camera** acts according to the same principle in order to show interrelations between heard and "seen" sounds. When the measurement is complete the acoustic image or the acoustic film can be virtually replayed – as if the running machine was scanned in real-time using a directional microphone. The sound originating from the predefined spot will be replayed using the speakers of the computer system. Sound sources that are usually drowned by louder sources become audible. The image can be animated by the software resulting in an acoustic film. The spectrum of the spot can be displayed if required. One convincing advantage of this method is that all the calculations can be done anytime after the measurement is completed. Neither the measured object nor the camera needs to be mounted in place. All data required for these functions is recorded and saved during the measuring session. The analysis of the data acquired can be performed any time using a standard computer. Taking into account the efforts usually required for test runs and test facilities, the **acoustic camera** offers in comparison immense advantages in terms of time and money.





Time and frequency selective images (as in spectrogram highlighted)



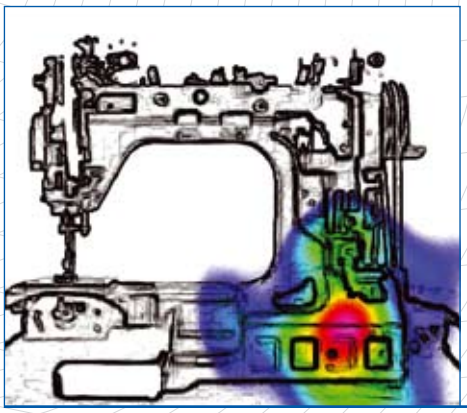
Virtual scanning of a brake showing the location-selective spectrum of mouse cursor

acoustic camera

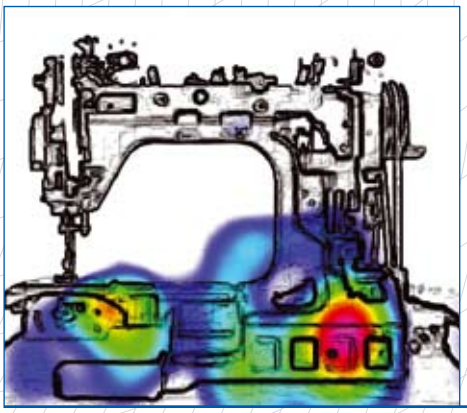
Fault detection and localization based on variations in sound emissions

THE ACOUSTIC CAMERA FACILITATES IDENTIFICATION OF FAULTS AND DEFECTS

Many of us have already experienced the following situation: The car engine is running but something seems to be wrong. The sound field appears different. An experienced driver can hear that something is wrong with the car even before any warning light on the dashboard comes up. The same is true for many industrial applications: Numerous faults can be detected just from variations in the sound emission. In quality control experienced staff can often identify faulty products just from their abnormal sound. The **acoustic camera** can find faults resulting in variations in the sound field as an objective instrument without depending on the disposition of quality assurance staff. Two acoustic images can be placed side by side in the software to perform a simple comparison of nominal and actual values. The same value range is applied to both images with a click of a mouse button. Any variations become obvious and the visual presentation also reveals where exactly the fault is located.



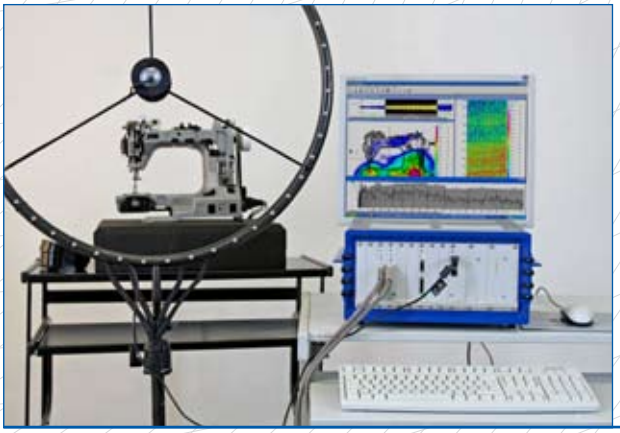
Normal soundscape of a sewing machine



Fault in bobbin mechanics

FAST, CONVENIENT, INFORMATIVE, REPRODUCIBLE RESULTS

The **acoustic camera** is an innovative device allowing to locate sound sources easily, to analyze them according to various criteria and to document them. The large number of successful applications has proven its capability and reliability over all these years.



Ring48-75 measuring Sewing Machine

Ring arrays for acoustic labs
Star arrays for open-air applications
Sphere arrays for interiors

acoustic camera

DATA RECORDER mcdRec 721

The newest generation data recorder has been designed especially for high channel count application and harmonises best with the **acoustic camera** in any laboratory and in the field. Featuring a modular system configuration it provides a remarkably high data transfer rate and a high level of interface connectivity, e. g. Ethernet. With its newly developed design the data recorder can easily adapt to changing requirements or new technical developments. The data recorder offers a sampling frequency ranging from 48 kHz to 192 kHz parallel in 48 to 144 microphone channels in a 10" rack (24 channels per card) and an additional 12 digital channel input with a maximum sampling frequency of 6.14 MHz.

Data Recorder mcdRec

MICROPHONE ARRAY RING36/48 SYSTEM FOR THE ACOUSTIC LAB

Since the acoustic camera is using Beamforming technology the following arrays are designed to serve the specific needs of the user and its application. If the following arrays do not serve your special case you can use some of our freely configurable microphone bundles to design your own array to suit your needs (each consisting of especially selected 24 advanced disturbance tolerant 1/4' symmetrically buffered electret pressure microphones). The Ring48 Microphone array is the preferred choice for a broad range of applications. When measuring higher frequencies and smaller components an array of smaller diameter may be favored.

The Ring36/48 microphone arrays are mounted on a carbon fiber ring with a diameter of 0.35 m or 0.75 m. This leads to a recommended mapping frequency range for the 35 cm Ring Array of 1 kHz to 20 kHz (50 kHz) and for the 75 cm Ring Array from 400 Hz to 20 kHz. All arrays include a video camera and microphones which are advanced disturbance tolerant with 1/4' symmetrically buffered electret pressure receivers. That makes 36 for the smaller and 48 for the larger Array. The maximum equivalent sound level is at 130 dB for our standard Arrays. The usual frequency response of these microphones goes from 100 Hz to 20 kHz. The recommended measurement distance for the smaller Array Ring36 ranges from 0.40 m to 2 m and for the Ring48 from 0.7 m up to 5 m.

GFaI's partnership with SenSound (USA) allows GFaI to offer a comprehensive acoustic imaging package; the existing Acoustic Camera Beamforming hardware platform now seamlessly integrates with SenSound's Nearfield Acoustic Holography software by using the free configurable microphones. For more information on Holography please see also:

SenSound
Sound, as we see it.
www.sensound.com

Low Frequency, Free configurable 24 channel microphone bundle (10Hz-10kHz)

Microphone Array Ring48-75

Microphone Array Ring36-35

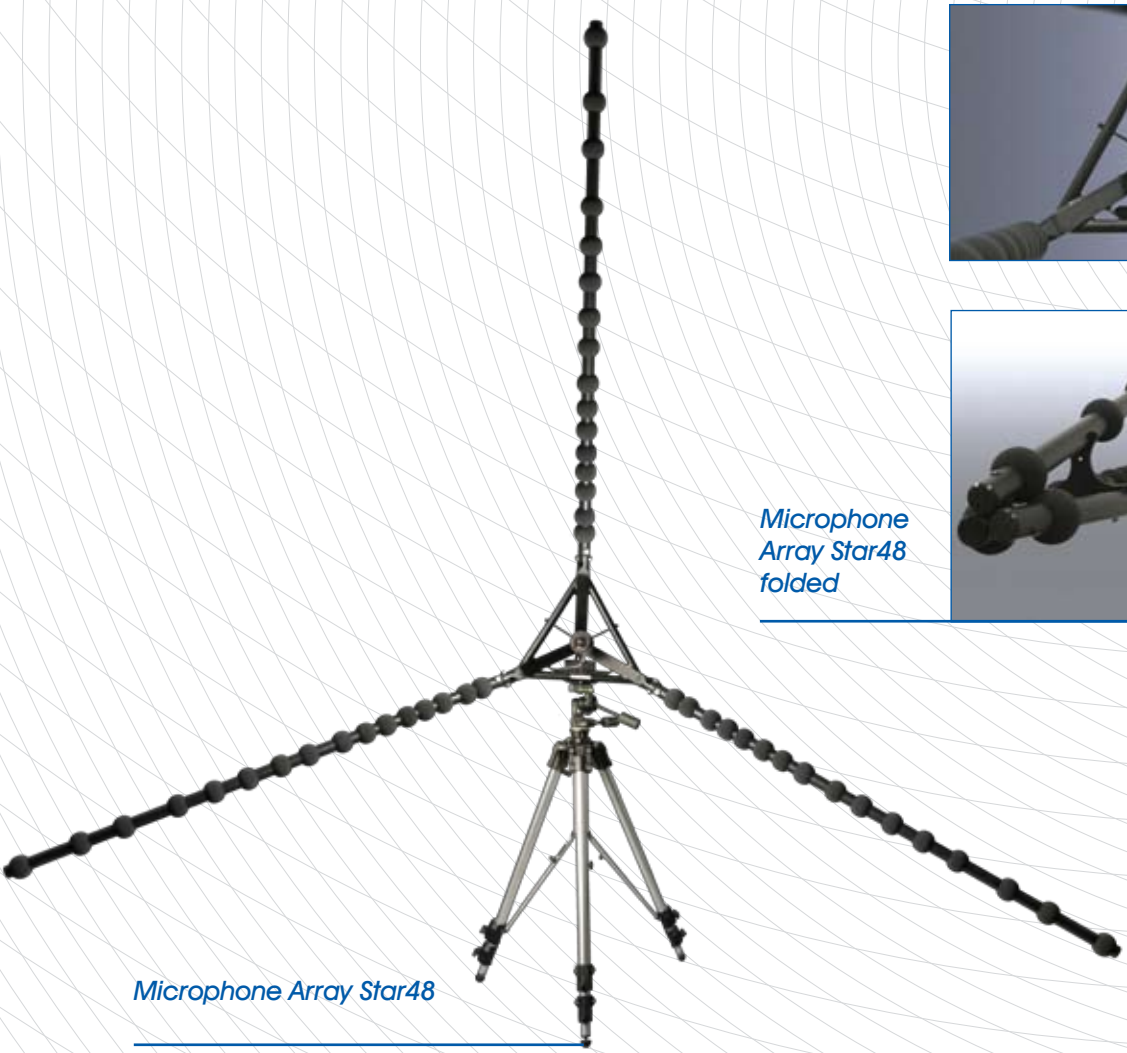
Ring arrays for acoustic labs
Star arrays for open-air applications
Sphere arrays for interiors

ARRAY STAR48 48 CHANNEL MEASUREMENT SYSTEM FOR LONG DISTANCES AND LOW FREQUENCY APPLICATION

The star-shaped array with 48 measurement channels has been designed for measurements over longer distances. The maximum span width is 3.40 m. Thanks to the folding mechanism the entire system can be easily transported in a standard station wagon and quickly set up within a few minutes. The array comprises a camera and 48, 1/4‘ condenser pressure microphones which are symmetrical buffered and so highly disturbance tolerant. The Star48 is non-planar and the patented construction guarantees a maximum backward attenuation which is a prerequisite for measurements in environments that are not disturbance-free. Pass-by measurement is featured. The included 3 m tripod is fitted with a 3-way head and allows for a setup at the optimum angle.

The recommended mapping frequency ranges from 100 Hz to 7 kHz (> 6 dB) while the recommended measurement distance ranges between 3 m and 300 m.

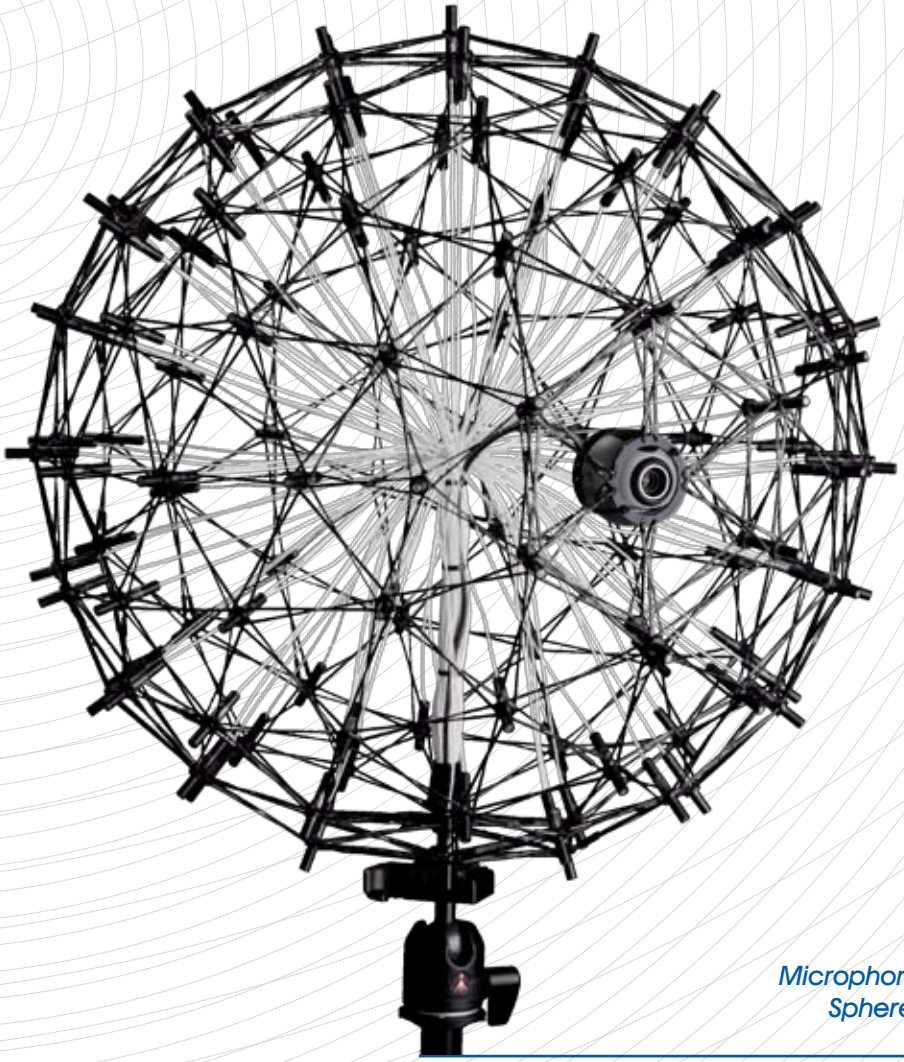
Microphone Array Star48 folded



Microphone Array Star48

ARRAY SPHERE48/120 48 to 120 CHANNEL SYSTEM FOR MEASUREMENTS IN INTERIORS

The sphere design is a 48/120 channel measurement system for small devices, for measurements in very confined spaces and for high frequencies. The microphone construction is made from carbon fiber material and guarantees maximum acoustic transparency. The layout minimizes aliasing effects. The optimum and recommended measurement distance ranges from 0.3 m to 1.5 m. Longer ranges are possible for measurement frequencies above 3 kHz. The sphere arrays are equipped with either 48 or up to 120, 1/4' condenser pressure microphones which are symmetrical buffered and so highly disturbance tolerant and a camera just like all other arrays. The design minimizes partial reflections. The array is built acoustically transparent and has extremely small microphones to minimize distortions of the wave field. The array can be set up at the optimum angle on the included tripod. Backward attenuation is high enough to allow an all-around mapping. This makes the system ideally suited for measurements in vehicle interiors and all applications in the room and building acoustics. The diameter of the sphere is 0.35 m / 0.60 m while the system weighs about 1 kg. The recommended mapping frequencies range from 1 kHz to 10 kHz for the arrays with 0.35 m diameter and 600 Hz to 10 kHz for the arrays with 0.60 m diameter.



Microphone Array Sphere120-60

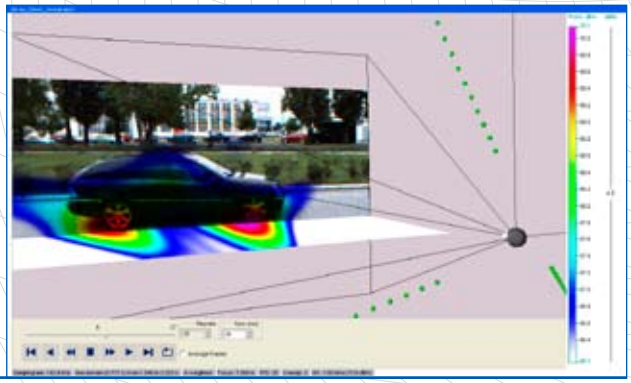
SOFTWARE NOISEIMAGE 3
ACQUISITION, EVALUATION AND STORAGE OF DATA, ACOUSTIC IMAGES AND MOVIES

acoustic camera

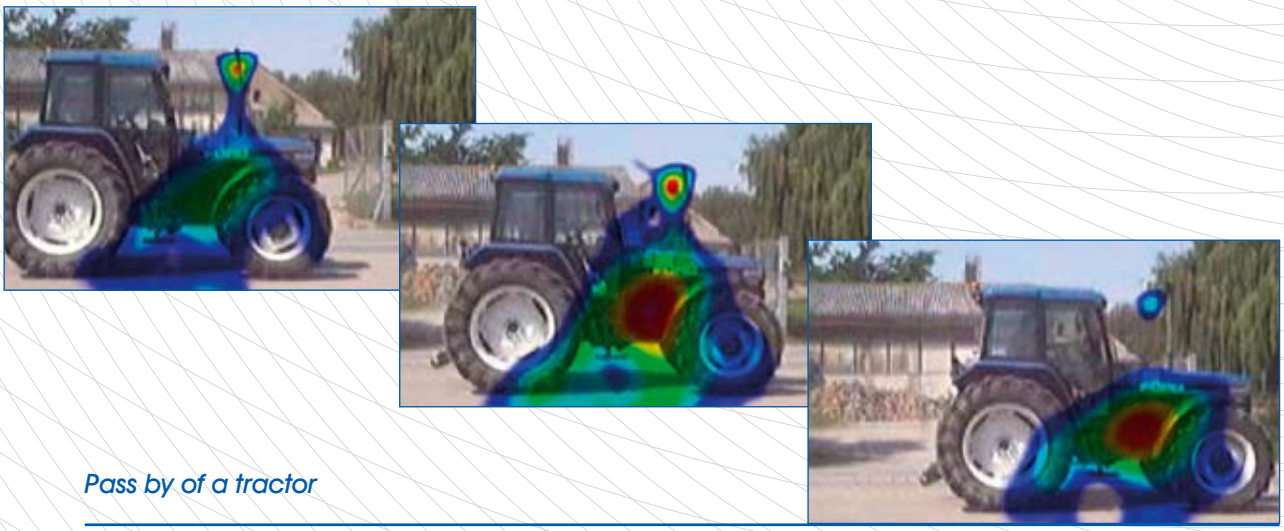
Considering the development of the software great attention has been paid to ease of use, to covering the important questions the user has to answer and to the overall quality and stability of the software. The basic, intuitive and graphically oriented user interface has been continuously upgraded. User experience and recommendations resulting from more than 8 years of practical application have influenced the development of NoiseImage3. There are also many new features within the software architecture. The complete software is now based on a plug-in concept. Extending the basic module every functional plug-in brings along its own graphical interface and its own tools. The user can decide what functionality she/he really wants to use and can thus arrange a software system meeting her/his actual needs and demands.

ANALYSIS METHODS AND SPECIAL FEATURES

- Extended preview in record module
- Oscilloscope for time and spectral functions
- A-, B-, C-standard weightings
- Freely configurable Butterworth filter bank
- Acoustic photos 2D and 3D
- Acoustic movies 2D (including automatic overlay of optical video)
- Frequency selective acoustic photo (SpectralPhoto2D)
- Space selective spectrum and spectrogram
- Space selective order spectrum and ordergram
- Channel data export into ArtemiS from HEAD-Acoustics and MATLAB® from The MathWorks, TXT, WAVE etc. pp.



Acoustic Movie including the ground as a second calculation plane



Pass by of a tractor

ACOUSTIC PHOTO 2D/3D

- Broadband, short time analysis using timedomain beamforming
- Mapping onto 2D optical photo or 3D-CAD-model of the measured object
- High resolution acoustic map (more than 20MPixel)
- Location selective listening into the acoustic map
- Frequency selective Acoustic Photo using band filter
- Frequency and time selective Acoustic Photo directly from selected region in the spectrogram
- Adjustable contrast of Acoustic Photos (colour palette and pressure- or dB-range)
- Export of Acoustic Photos to Text, JPG, PNG or BMP-format

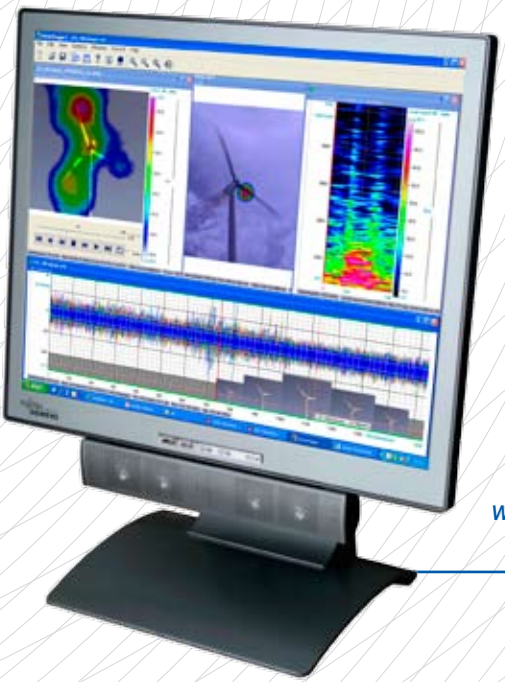
ACOUSTIC MOVIE 2D

- High time resolution, acoustic ultra slow motion up to several thousand acoustic frames per second
- Mapping of acoustic frames onto the recorded optical video (movie on movie-function)
- Location selective listening into the acoustic movies
- Adjustable contrast of Acoustic Movies (colour palette and pressure- or dB-range)
- Export of the complete Acoustic Movie to AVI-format in slow motion (without sound) and in realtime (including sound)
- Export of individual frames from the Acoustic Movie to Text, JPG, PNG or BMP-format

SPECTRAL PHOTO 2D

- Manual selection of a frequency band and immediate update of Photo2D
- Easy manipulation of the width of the selected frequency band using the mouse
- Continuous shifting of individually marked frequency band
- View of frequency and amplitude axis in linear as well as in logarithmic scalings
- Simple and fast visual evaluation of third octave bands
- Sound pressure level display for individual third octave bands
- Export of the Acoustic Photo to Text, JPG, PNG or BMP-format

Acoustic Photo 3D and spectral analysis of a Mercedes Benz B-Class on a four poster shaker Source is a key in the ignition lock



Acoustic Movie of a wind turbine including spectral analysis

COMPANY PROFILE

The Society for the Promotion of Applied Computer Science (GFaI), in which the Acoustic Camera was designed, was founded in 1990 with its headquarter in Berlin. The institution offers custom R&D services. The list of references of successful projects ranges from small and medium sized enterprises to research establishments and major corporations. The gfai tech GmbH is a wholly owned subsidiary of the GFaI and is responsible for the production process and marketing of the GFaI product line. A solutions driven approach guides our team through the understanding of our customers' needs and goals. Our team of experts is committed to world-class service and quality. The production and technical support staff guarantee innovation, immediate action and customer driven customization. The sales team ensures flexibility and collaboration in order to deliver the utmost value to our clients.

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acoustic camera

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