УДК 534.8

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EXPERIMENTAL MEASUREMENTS AND USING THE ACOUSTIC CAMERA IN INDUSTRY

The Acoustic Camera was the first commercially viable system using beamforming to visually localize acoustic emissions. The tool is now used in a variety of industries and has a growing customer base worldwide. This article describes some field experience on the use and measurement results and procedures of the Acoustic Camera. By the use of Acoustic Camera in measurements it is possible to differentiate and localize different sources. Acoustic emission monitoring is getting increasingly important with engineering product design. An acoustic camera was recently developed as a new measuring device and constitutes a strong innovation made for localizing noise emissions.

Key words: *Acoustic camera, visualization, acoustic picture, frequency spectrum*

1. INTRODUCTION

A digital camera is taking an image of the noise emitting object. At the same time an exactly computed array of microphones acquires and records the sound waves emitted by the object. A special developed software calculates a sound map and combines the acoustical and the optical images of the sound source. The Acoustic Camera can extend the time and frequency selectivity and add a location-selective component. With this method the sound signal is shown and also a sequence of acoustic images can be acquired – acoustic films are generated. Nevertheless the Acoustic Camera comprises traditional analysis methods as well, like A-weighting, one-third octave band and narrow band analysis.

With the Acoustic Camera it can be precisely analyzed when, where and which part is occurring the sound emission. The so far used analyses do have an important disadvantage as the location of the emission is limited or not possible. If the sound from several spots of an appliance is to be acquired simultaneously, individual microphones are required for each reading point, and they must be placed very close to the object – a time consuming and costly method.

The whole measurement and subsequent analyses are characterized by:

- high accuracy,
- high speed,
- dynamic operational mode,
- high effectiveness,
- transparent result processing (coloured acoustic maps, movies, records).

The Acoustic Camera is based on beam forming of a conventional delay-and-sum beamforming in the time domain.

$$\hat{f}(X,t)=\frac{1}{M}\sum_{i=1}^{M} w_i f_i\left(X,\left(t-\Delta_i\right)\right) \tag{1}$$

Delay-and-sum beam forming can be performed in either the time or the frequency domain, whereby time domain delay-and-sum is done by separately delaying each microphone signal, making them align before summation and normalization. Acoustic Camera currently uses the time domain delay-and-sum mainly because of the faster processing speed and new signal processing algorithms. [1]

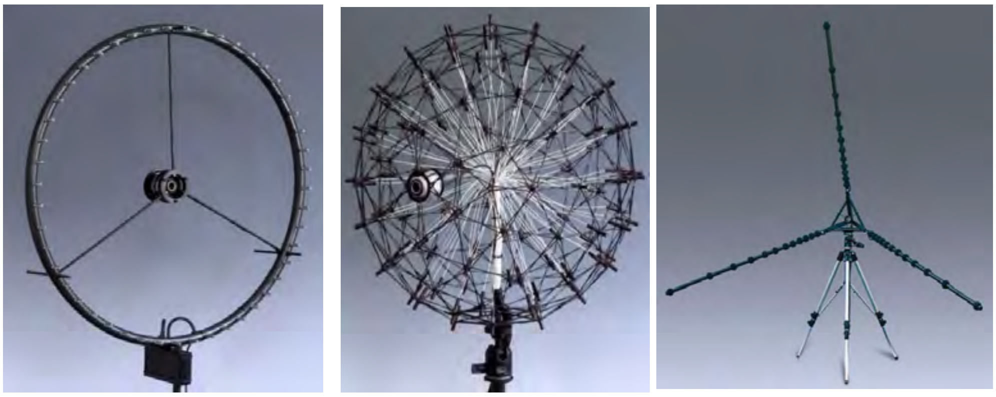

Fig. 1 Microphone Arrays (Ring, Star and Sphere)

The use of microphone arrays and multi channel data recorders in connection with software for a fast visualization results an Acoustic Camera. Such a device has become popular for the localization of sound sources of machinery and equipment of any kind. An overlay of an optical photo gives the user a fast overview of the dominant noise sources emitted by the device under test.

The underlying common principle of those systems in the far field approach is the delay-and-sum beam forming method. That technique use special time delay sets for the incoming signals to focus the microphone array on a spatial location. The correct delay set results in a coherent overlay by adding up all microphone signals. With that special time delay the region emitting the strongest sound pressure can be found. [2]

The transformation between two acoustic camera images can be calculated by putting one image into the coordinate system where the image is on the xy-plane with the positive y-axis along the center line of the image and the center of the arc at the origin (fig. 2).

Applying that beamforming technique for each pixel in a measurement plane generates a sound pressure image (fig. 3).

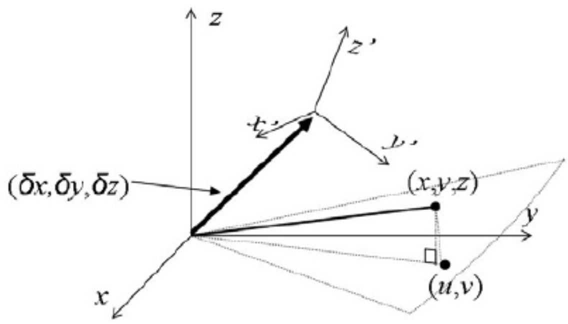

Fig. 2 The imaging geometry of an acoustic camera

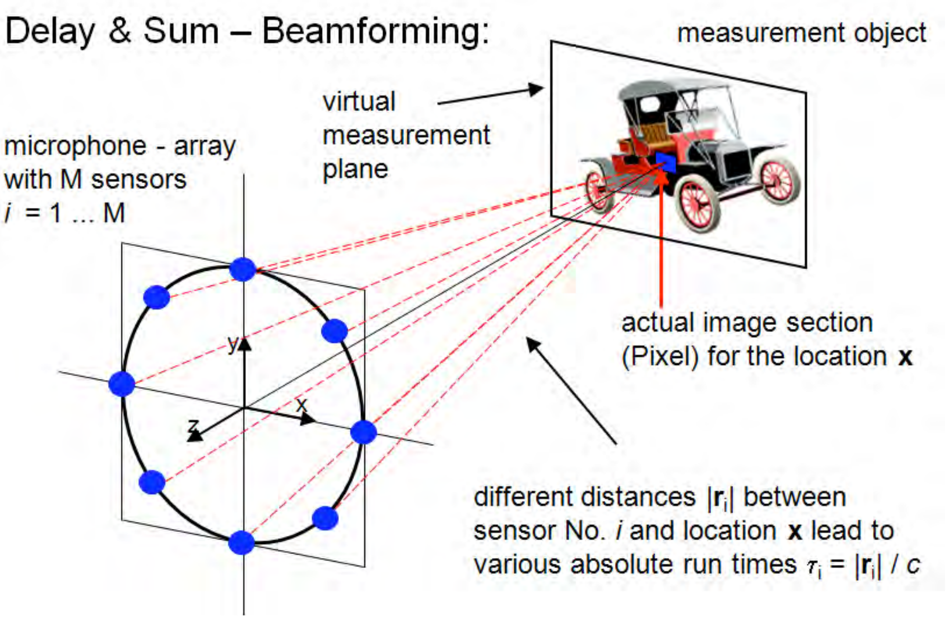

Fig. 3 Delay-sum beamforming and the acoustic camera

2. SIGNAL PROCESSING IN THE PROGRAM "NOISEIMAGE"

For working with the software „NoiseImage" a complex but easy to operate intuitive concept of interactions between space, time and frequency has been developed. In order to avoid model assumptions about emitter characteristics, only the equivalent sound pressure level is mapped, i.e. in the acoustic image the value is colour coded that would be generated by a point source in a nonreflexive room at the same distance. [1]

The recorded time functions can be evaluated according to A-, B- or C-weighting. A universal filter bank allows spectral generalisations. In the spectrogram view, noticeable emissions can be marked temporally and spectrally simply by a mouse move and can instantaneously be shown as acoustic photo or movie to identify the related sound source.

In photos and movies, the reconstructed time function of every location can be saved as wav-file, it can also be displayed as spectrum (fig. 4) or spectrogram (fig. 5). All images can be exported as Bitmaps or JPEGs, movies can be saved as AVI. Spectra can be shown in third octave bands. Listening to the time functions of photos and movies is possible by moving the mouse over the picture. This allows to individually recall recordings even many years old. When a film is saved as AVI, the stereo sound from the recorded time functions or alternatively the reconstructed time function of a chosen location in the image can be integrated into the exported movie. The according location is then marked by a microphone icon. For the analysis of stationary emissions, the so called „spectral frames" (a type of spectrally sensitive photo) are an additional tool for interactions between image and spectrum. A mouse click into the picture will immediately show the corresponding spectrum of that location, and vice versa selecting a spectral band from the spectrum will show the related acoustic image covering only those selected spectral components.

The spectrogram and frequency spectrum is used to generate acoustic photos by studying tonal frequencies and to easily do filtering including playback of selected area, so that the display/generation of the acoustic photo is optimized.

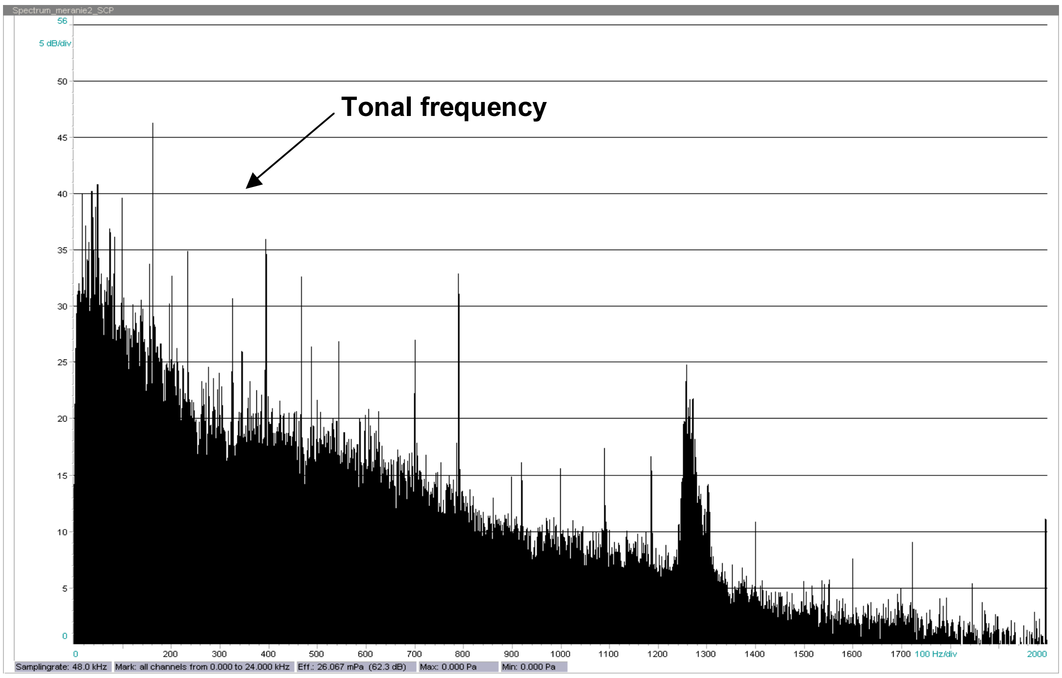

Fig. 4 Frequency spectrum of measuring data

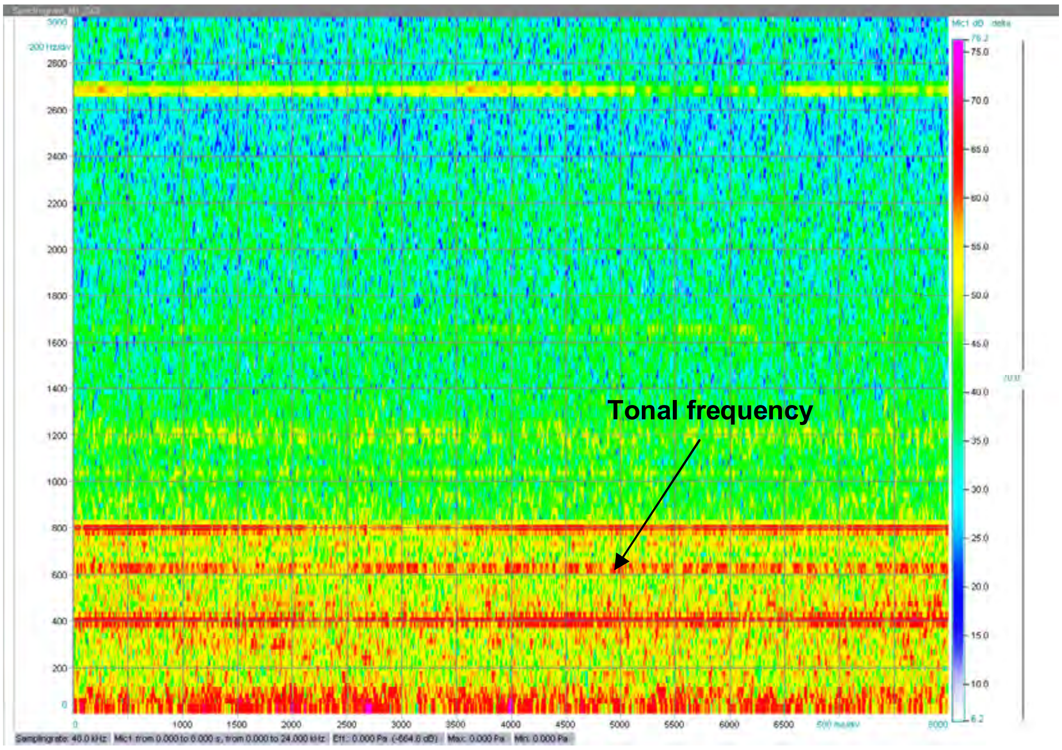

Fig. 5 Spektrogram of measuring data

EXPERIMENTAL MEASUREMENTS IN PRAXIS

In figure 6 is the location of the acoustic camera for the measurement of exhaust plant. In figure 7 is shown acoustic picture of exhaust plant.

Fig. 6 Installed acoustic camera by exhaust plant

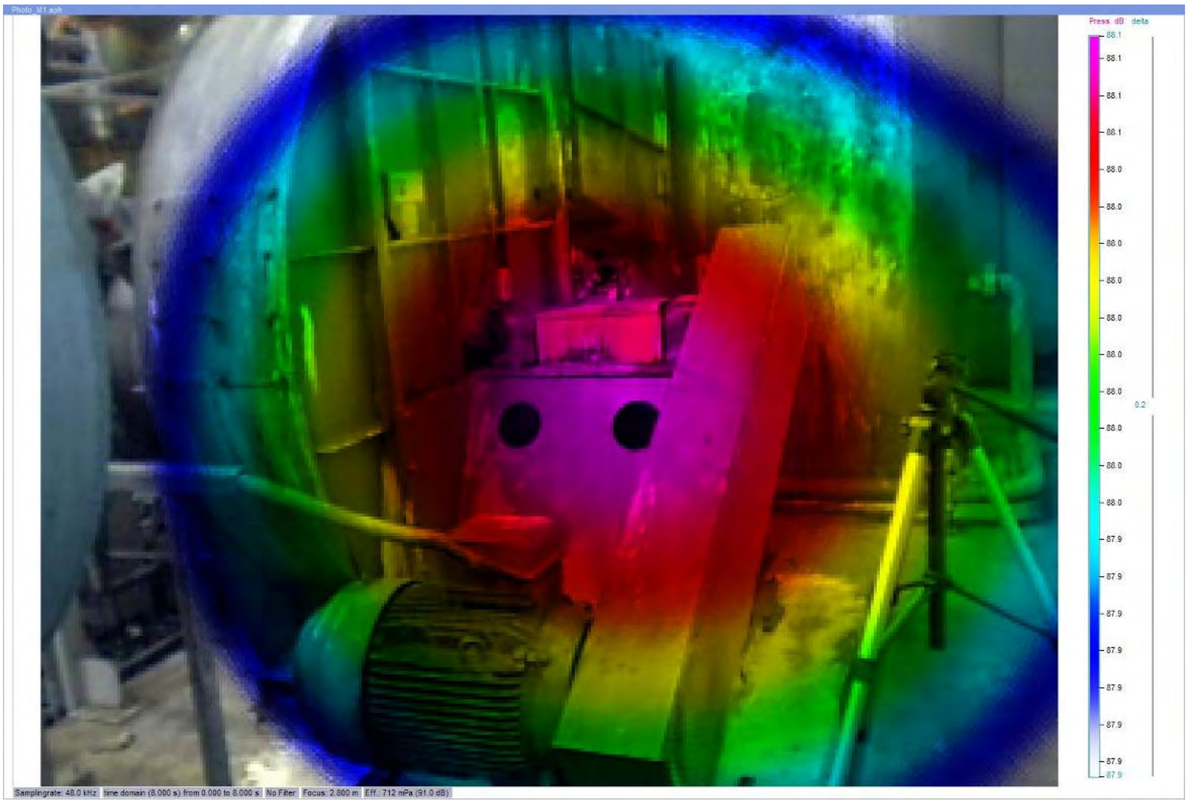

Fig. 7 Acoustic picture of exhaust plant

In figure 8 is the location of the acoustic camera for the measurement of tanks in stone guarry. In figure 9 is shown acoustic picture of tanks in stone guarry.

Fig. 8 Instaled acoustic camera by tanks in stone guarry

Fig. 9 Acoustic picture of tanks in stone guarry

In the Acoustic Photo each of the pixels have a corresponding spectra, it is therefore possible to display the spectra for every pixel in the photo. Vice versa another useful post-processing algorithm is the "Spectral Frames", where it is possible to do the opposite. For every part in the frequency spectra it is possible to mark an area and then to display the corresponding location for this part.

In figure 10 is shown acoustic picture of plant for paper processing. The cause of the spread of noise over longer distances are noise sources that are located on the building's roof (chimneys, air vents, exhausters, etc.). They are mainly those which have a low frequency characteristics of the noise.

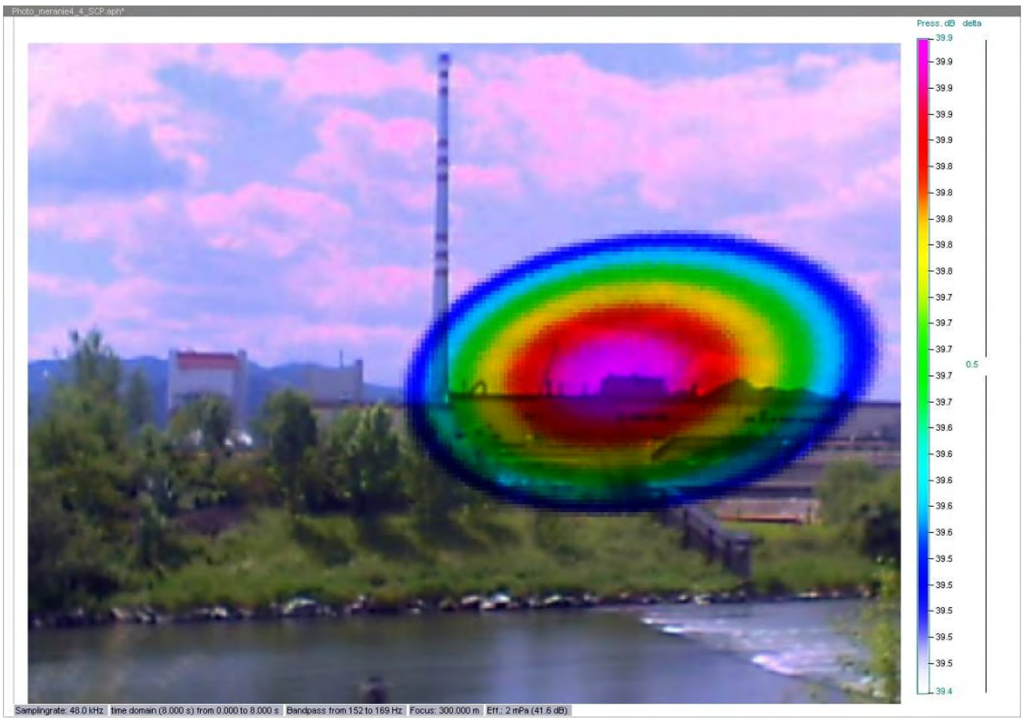

Fig. 10 Acoustic picture of plant for paper processing

4. CONCLUSIONS

By the use of acoustic camera in field measurements it is possible to localize different sources, even with other dominating sources present. It is possible to cover a large number of measurements per day if one makes proper preparations. The measurements results from the acoustic camera shows good correlation with sound level meter measurements, after applying correction. By the use of the various new evaluation possibilities such as acoustic picture, acoustic movie and spectral frames it is quite possible to localize noise sources, also when these do not really dominate the overall levels.

References

[1] DÖBLER, D., Time-Domain beamforming using zero-padding, Berlin Beamforming Conference (BeBeC), 2008.

[2] JAECKEL, O. – SCHRÖDER, R.: Beamforming - Zeitbereich versus Frequenzbereich, Gesellschaft zur Förderung angewandter Informatik e.V. (GFaI e.V.), Berlin.

[3] MORAVEC, M. - LIPTAI, P.: Aplikácia akustickej kamery pri riešení problematiky priemyselného hluku. In: Novus scientia 2007, 10. celoštátna konferencia doktorandov strojníckych fakúlt technických univerzít a vysokých škôl s medzinárodnou účasťou, Košice, SjF TU, 2007, s. 401-405, ISBN 978-80-8073-922-5.

[4] Steinebrunner, C. - Stirnemann A.: Schallquellenlokalisierung mit einem Reihenrichtmikro-fonsystem in SPARSE-Technik, DAGA 97, Seite 279, März 1997.

[5] Steinebrunner, C. – Schmid, A. – Zeman, J.: Akustische Kamera mit eindimensionaler Auflö-sung in Echtzeit, Sulzer INNOTEC AG, Fachhochschule Winterthur.

[6] Ulf, M.: Akustische Antennen vermessen den Schall. DLR-Nachrichten Nr. 92, 1999.

[7] Zogg, H, - Steinebrunner, C.: Sparse Microphone Array for Identification of Sound Sources on moving and Non-Moving Objects, Inter-Noise 97, Page 1489, August 1997.

[8] FELLNER, W.: Umweltmessung mit der Akustischen Kamera. Der Fellner - Newsletter für professionelle Schall und Schwingmesstechnik, 2/2005.

[9] LIPTAI, P. a kol.: Dynamická vizualizácia emisií hluku pomocou akustickej kamery. In: Environmentálne inžinierstvo a manažérstvo : 4. medzinárodná konferencia EIaM 2007, Zborník príspevkov, Košice 2007, s. 269-276, ISBN 978-80-8073-894-5.

Acknowledgements

The contribution was prepared in the frame of solving of grant scientific project Park TECHNICOM – ITMS 26220220182.