CONTRAST IMPROVEMENT OF ACOUSTIC MAPS BY SUCCESSIVE DELETION OF THE MAIN SOURCES

Dirk Döbler, Ralf Schröder

[1]Society for the promotion of applied computer science (GFaI e.V.)
{doebler@gfai.de, schroeder@gfai.de}
Rudower Chaussee 30, 12489 Berlin

ABSTRACT

Beamforming for acoustic imaging is a well established, fast and practical method for acoustic source localization. A disadvantage of the method is the still relatively low image contrast due to sidelobes in the map. Weaker sources may be masked by stronger ones. Therefore, algorithmic contrast improvements in acoustic maps are an ongoing topic of research. Many algorithms developed for this purpose are computationally very expensive.

The paper presents a simple and fast time domain method which successively deletes the dominant sources in the beamforming map and hence uncovers weaker sound sources. The contrast improvements are partially very dramatic and they offer the advantage of an interactive analysis of the acoustic emissions nearly in real time. The properties of the algorithm are discussed, and application examples and simulations are shown.

1 INTRODUCTION

The low contrast of standard beamforming [1] is a limiting factor for the application of the technique. If the differences between the sound levels of sources in an acoustic scene are greater than the maximum contrast of the used microphone arrays (the level distance between main lobe and sidelobes), weaker sources are masked by the sidelobes of the stronger sources. A typical example is illustrated in fig. 1. It shows an acoustic photo of five uncorrelated noise sources (frequency domain 100 Hz - 20 kHz) with the levels s1(90 dB), s2(80dB), s3(70 dB), s4(60 dB), and s5(50 dB). The maximum contrast of the array (ring array, 48 channels, sampling rate 48 kHz) for this broadband signal is 12 dB. Therefore the source s2(80 dB) is still visible in the mapping, whereas all other sources are masked. A separation in the frequency domain is not possible, due to the broadband emission of the sources. For that reason, in [2] and [3] main sources are eliminated by correlative methods and the contrast of the mapping is improved.

This article points out that all hidden sources from fig.1 can be mapped by pure subtractive decomposition of the signal.

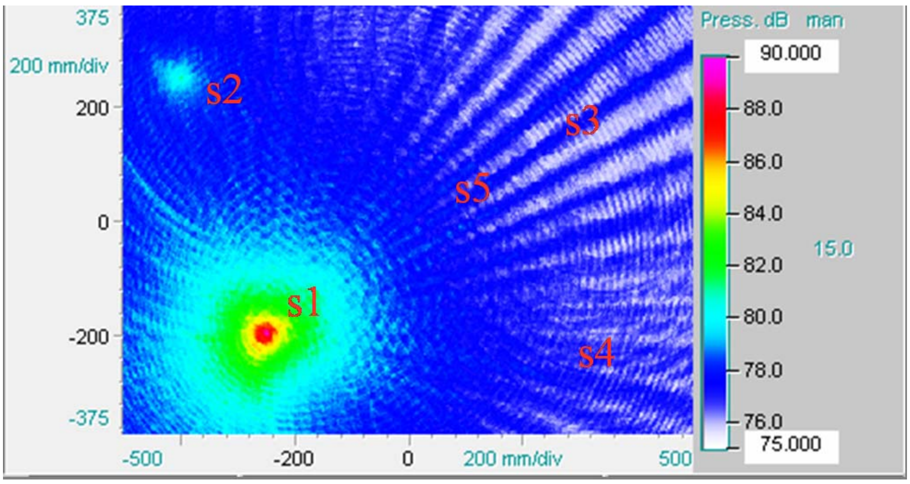

Fig.1: Acoustic photo of 5 noise sources (90dB, 80dB, 70dB, 60dB, 50dB)

2 SUBTRACTIVE SIGNAL DECOMPOSITION IN THE TIME DOMAIN

Therefore the signal of the strongest source s1 is reconstructed according to equation 1.

$$\boxed{\hat{f}(s_1,t)=\frac{1}{M}\sum_{i=1}^{M} w_i\, f_i\big(s_1,(t-\Delta_i)\big)} \qquad \text{Eq. 1}$$

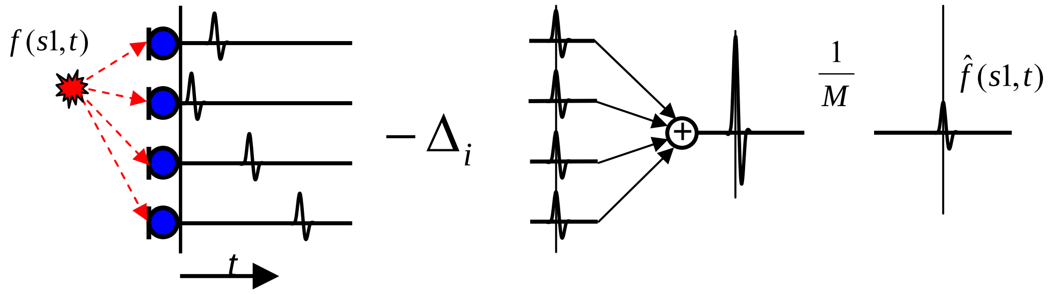

Fig. 2 Signal reconstruction of source s1

Now, this time function is translated by +Δi and subtracted from all microphone channels.

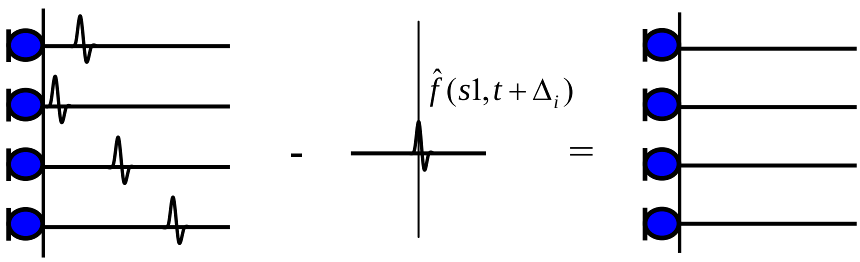

Fig. 3 Subtracting the reconstructed signal of source s1 from all microphone

In the best of cases source s1 is completely removed from the original signal (fig. 3). From this modified original signal a new acoustic photo is calculated, which does not contain the source s1 and all its related sidelobes (fig. 4). Thereby further weaker sources become visible, fig. 4 now shows source s3. By recursively proceeding the method (up to an appropriate recursion depth as stop criterion), all 5 sources can be detected successively (fig. 5 - fig. 7).

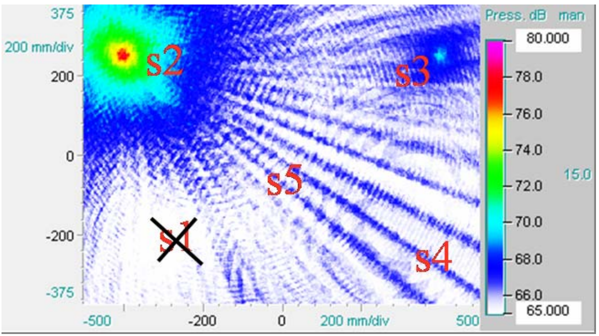

Fig. 4

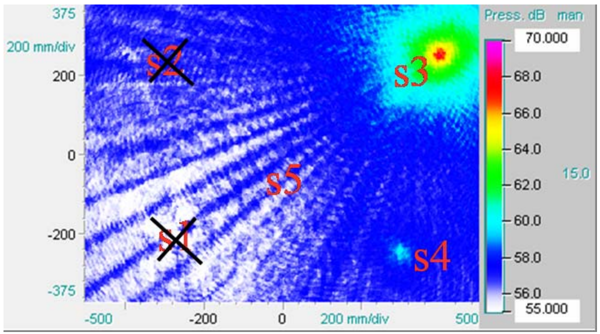

Fig. 5

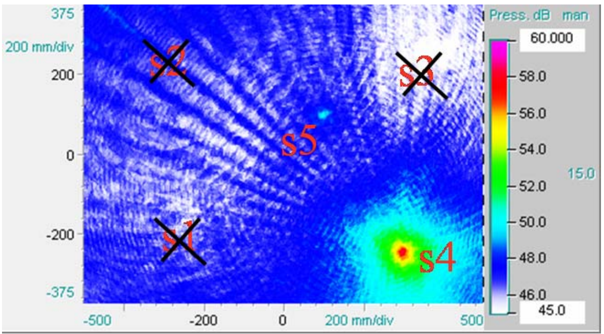

Fig. 6

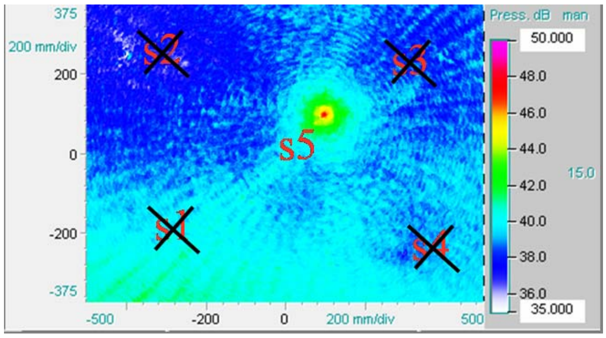

Fig. 7

The reconstructed time function for a source is not completely identical to the original function of that source. The acoustic photo has a discrete resolution, so that the point for the maximum of a source can not be determined with full accuracy. Furthermore, the reconstructed time function also contains signal parts from other sources in the photo. So, after the subtraction, signal artefacts of the deleted sources remain in the time functions of the microphone channels. With increasing level reduction during the progress of the method, this results in a reappearance of already deleted sources. With repeated appliance of the method on these artefact sources, the signal parts of the sources can be removed almost completely. Finally, by merging all partial mappings, all sources can be depicted in one mapping. As a typical example of use, fig. 8 and fig. 9 show a measurement of an automobile inside a wind tunnel. Here, the strongest sources always appear around the wheel cases and the vehicle floor, because the strongest turbulences can be found there. The maximum contrast in fig. 8 is only 5 dB. After deleting the main sources (six iterations) several other emission can be detected. The available contrast increases to 13 dB.

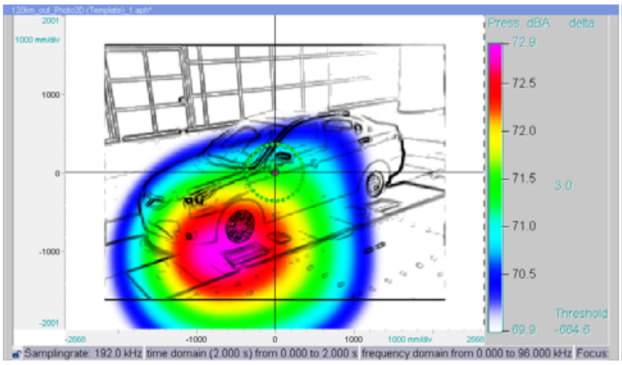

Fig.8 Automobile in wind tunnel. Main sources wheel cases and vehicle floor

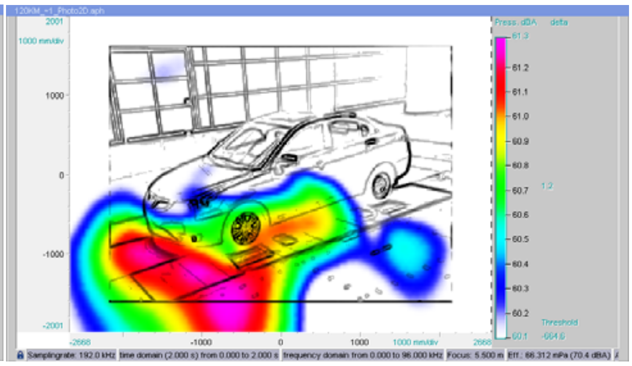

Fig.9 After deletion of the main sources several other sources become visible

3 ADVANTAGES AND LIMITATIONS

The advantages in comparison to correlative techniques in the frequency domain mainly result from the simplicity of the method:

- Fast. If the resolution of the acoustic photo is not too high (up to 1500 points), it is possible to 'erase' in real-time. This allows interactive working with the acoustic material and a better understanding of the source mechanisms.
- No additional reference channel is required. The signal of a reference microphone can however be used instead of the reconstructed time function.
- No falsification by windowing or averaging errors, which may result from the application of the cross-correlation procedure in the spectral domain.
- Up to 50 dB contrast improvement (depends on environmental conditions).

Disadvantages

- Correlated sources (reflections, spatially differentiated sources with common stimulation) are not deleted.
- For main sources outside the image field the method can not be applied.

4 SUMMARY

The described technique allows for an improvement of the contrast in acoustic mappings by means of a purely subtractive signal decomposition. The method works very fast in the time domain and it avoids the windowing and averaging errors that can result from the cross-correlation calculations in the frequency domain. Under ideal conditions (anechoic room, point sound sources) contrast improvements up to 50 dB can be achieved. The low resource requirements allow for interactive working on acoustic mappings, just like an 'Acoustic Eraser'. However, the correlated signal parts of a sound source, that are spatially separated in the mapping (reflections, sources with common stimulation), can not be removed with the proposed technique.

REFERENCES

[1] D.H.Johnson, D.E Dudgeon : Array Signal Processing. Concepts and Techniques, PTR Prentice Hall, 1993

[2] Sandro Guidati, Verfahren und Vorrichtung zur bildgebenden Darstellung von akustischen Objekten, Offenlegungsschrift DE102008026657A1 Deutsches Patent- und Markenamt

[3] Marcus Kern, Ein Beitrag zur Erweiterung von Beamfoming-Methoden, Dissertation TU Berlin 2008

[4] R. P. Dougherty: Advanced Time-domain Beamforming Techniques. AIAA-Paper 2004-2955, Proc. of 10th AIAA/CEAS Aeroacoustics Conference, Manchester, UK, May 2004.