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The Acoustic Camera as a tool for machinery maintenance

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Abstract

MRO (maintenance, repair and operations) is an important topic in any industry and cost- and time-efficient maintenance and repair of machinery calls for efficient diagnostic tools. To better plan maintenance activities in terms of spare parts and personnel needed as well as production downtime, these tools need to provide reliable and accurate information on the machinery under investigation. There is a wide range of technologies available and using nondestructive testing equipment is certainly the widest spread approach. One of those tools is the Acoustic Camera – a sound localization system based on beamforming.

This paper will explore the possibilities of using the Acoustic Camera to detect faulty machinery parts. Furthermore, potential savings when using the Acoustic Camera as a diagnostic tool will be examined.

1. INTRODUCTION

The way MRO is handled in companies may differ but in the end the goal common to all companies is to prevent material failure and machinery down-times. Maintenance (whether planned or condition based) needs to be purposeful and efficient, ideally not intervening in the regular production process. Having a tool that helps to quickly and reliably identify faulty parts in large and complex machinery facilitates the engineer's job and opens up further potential for savings.

Sound localization systems based on beamforming were originally developed as R&D tools for the aerospace industry. The Acoustic Camera, launched in 2001, was at first used to analyze the acoustic properties of car-engines and quickly became a common tool for several NVH tasks in automotive and other mechanical engineering. The Acoustic Camera was quickly identified as a valuable tool for numerous applications and over the years these fields of application have grown even more. The electrical sector and white goods producers were next to recognize the potential of the Acoustic Camera for their purposes, followed soon by environmental measurements. For a long time the Acoustic Camera was used mainly for R&D purposes but the idea for employing it in wind power plant maintenance gave way to a general push into the field of machinery maintenance.

Besides R&D departments, beamforming systems are used in environmental acoustics, health & safety, maintenance and repair and condition monitoring.

A common set up for environmental acoustics are measurements on all kinds of industrial complexes whenever they are close to residential areas. A measurement with a beamforming system will help to specify the hot spots of acoustic emission, as a first step to eliminate them.

In health and safety the focus is on the worker in a loud working environment. Beamforming systems can help to decide which measures will help to improve the working situation. A common method to improve the acoustic field around machines is to encase them but in many cases these extensive methods are distended and less expensive measures (uncovered by using the Acoustic Camera) help.

In many cases sound is a clear indicator for a modification inside a machine. These modifications are usually a sign of wear in components, for example gears. Being able to localize such modifications is, in many cases, the key to quickly repair or exchange the faulty component before it breaks and causes machinery down-time. Especially with big machines or entire production lines, which are hard to access, the advantages of assessing wear and tear with a beamforming system are explicit. Additionally, there is the huge benefit of being able to do the measurement during operation of the machines.

Condition monitoring with a beamforming system is a comparable task. As soon as the emissions of a machine or production line, in normal course of operation, are recorded it can be compared to subsequent measurements. Variations can be visualized and will give fundamental indications of the origin of noises.

The aim of this work is to show the use of the Acoustic Camera in plant maintenance and identify possible savings enabled by the use of this tool.

2. MEASUREMENTS

The example at hand is taken from a press plant for auto body parts. The machinery in focus is a plate press line where workers remarked on a change in the noise emitted by the machinery and sensors showed some peculiarities.

2.1 General information

In this press plant that uses the Acoustic Camera as a condition monitoring system, auto-body parts are processed. The first processing step is the cutting of stored metal materials. At this point the material already passed through several machines to produce the desired cutout.

The next step is the pressing of those cutouts to their final states. This takes several steps and the parts run through different presses.

The last step in this plant is the assembly of the body parts.

There is also different machinery for additional tasks like pressing discarded metal or varnishing.

In general, there is a wide range of different machines to perform various tasks. To survey them, different sensors are in use. The Acoustic Camera was acquired in an aim to lift MRO tools to the next level. It comes in operation whenever there is an audible change in one of those machines or when one of the additional sensors implicates that there is an anomaly.

2.2 Measurement object

The measurement example this work focuses on is a plate press line. Technicians working on the press noticed a change in the sound coming from the machine so they informed the technical engineering team. If the technical engineers were not able to track down the reason for the modification during operation it would be necessary to stop the press which effectively means stopping production.

At the time of the alert the press was still running without limitation so the intention was to find the problem without stopping the press.

Accelerometers that had been placed in neuralgic positions showed some peculiarities: There were bursts in the spectra which indicated an abnormality. Still it was not possible to point out what exactly the problem was, or where it came from. To correctly locate the origin of this sound the MRO team was called in and decided to employ the Acoustic Camera in this localization task.

2.3 Equipment used

For the measurement a Ring48-75 microphone array and a data recorder mcdRec721 were used. The ring array is designed for high spatial resolution, covers a wide range of applications and will give the exact position of sound sources. It is specified for a frequency range of 400Hz – 20kHz and can be used starting at 0,75m distance to the object. This array geometry is not very sensitive to wrong foci and is lightweight and easy to use. Therefore, the MRO team at the plant is employing only this array for all their measurement tasks.

2.4 The measurement

The best position for the measurement was on the upper part of the press. It is possible to open the machine to allow a view inside. Measuring around the press and from a distance is not constructive as the machine is encased by thick walls and the beamforming technology is not able to penetrate these walls (Figure 1).

The microphone array and the data recorder were lifted up on top of the press and the measurement was conducted during operation and without interrupting the production process.

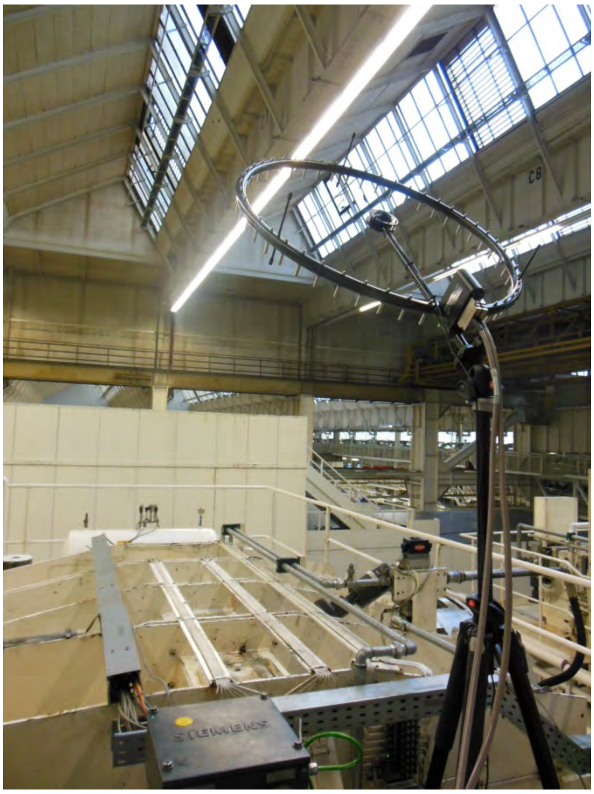

Figure 1: left – overview of the plate press line; right – set-up of the Acoustic Camera on top of the plate press

3. RESULTS

The first step in post-processing was the frequency-based analysis of the recorded data. Looking at the spectrogram, the process of pressing is distinctively visible in the channel-/time-data as well as the spectrogram (Figure 2 between 2.000 and 3.000ms)

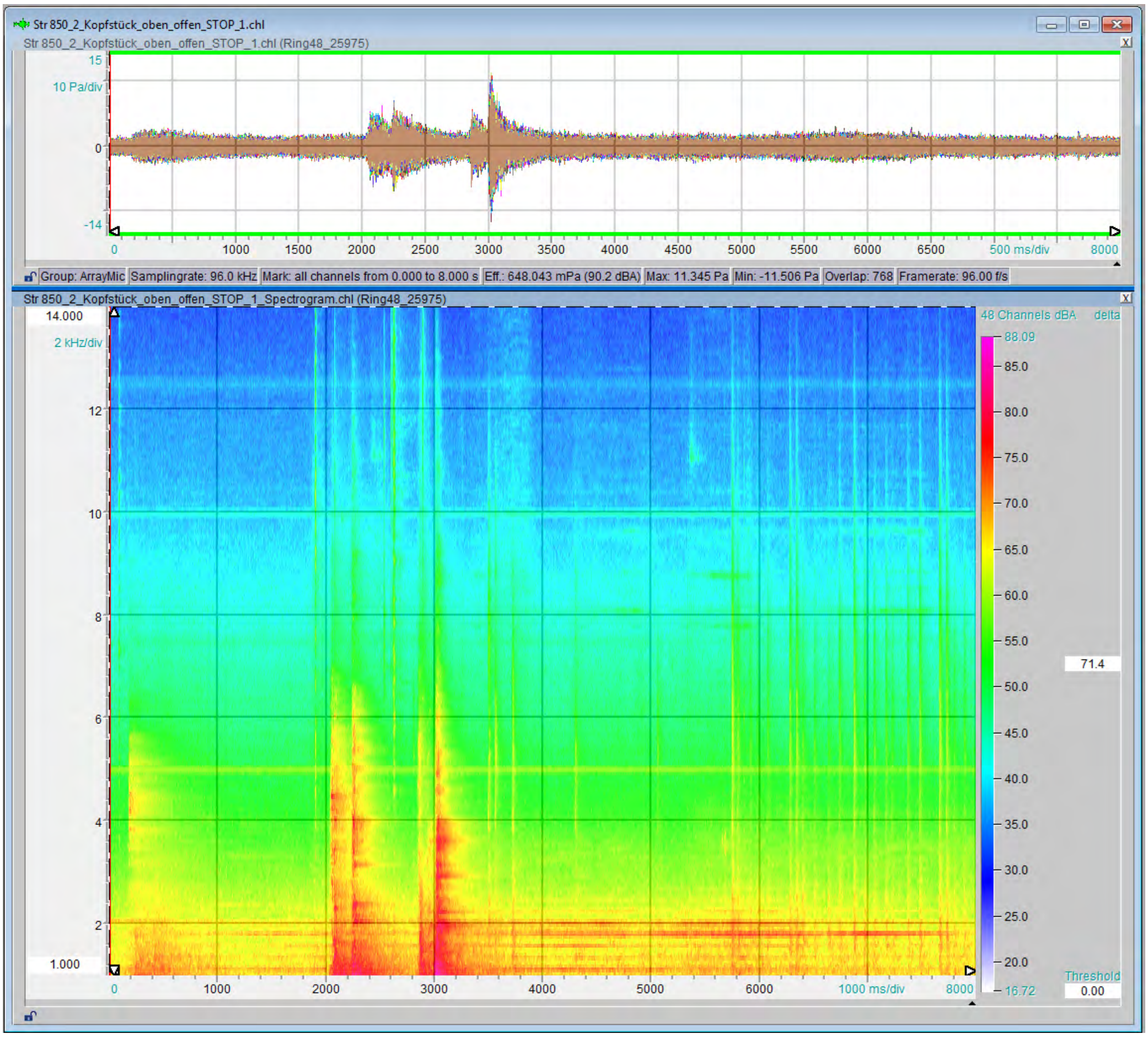

Figure 2: channel-/time-data (top) and spectrogram (bottom) of an 8s recording

The pressing cycles themselves are not important for this analysis so the focus was set on the timeframe from 4 to 8s (Figure 3) which represents a gap between two pressing cycles. Irregularities are clearly visible from 5.500 – 8.000s: Under normal conditions the time after pressing should not contain such peaks in the spectrogram. Thus, the spectrogram hints at a defect and these peaks are further analyzed to locate the origin of this source.

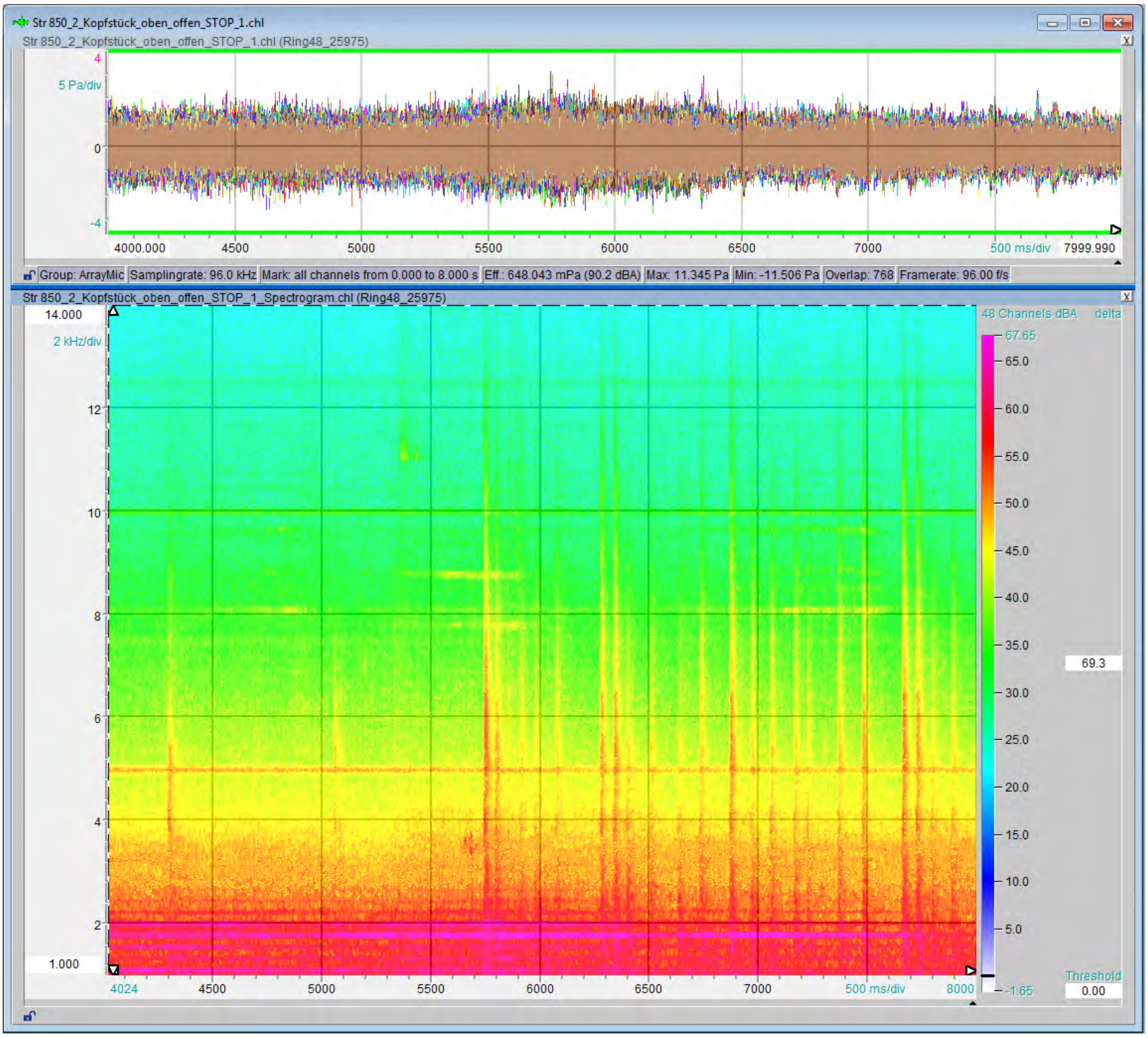

Figure 3: channel-/time-data (top) and spectrogram (bottom) of a 4–8s interval of the entire recording

Several of those peaks in the range of 2,3 – 4,8kHz are marked and an Acoustic Photo is generated (Figure 4).

The photo clearly shows that the emitted frequencies are originating from a distinctive area. Upon closer investigation of the machinery itself it becomes clear that this press contains several gears and according to the area indicated it is easy to quickly identify the faulty gear.

A new gear (Figure 5) was ordered to replace the old/ faulty one.

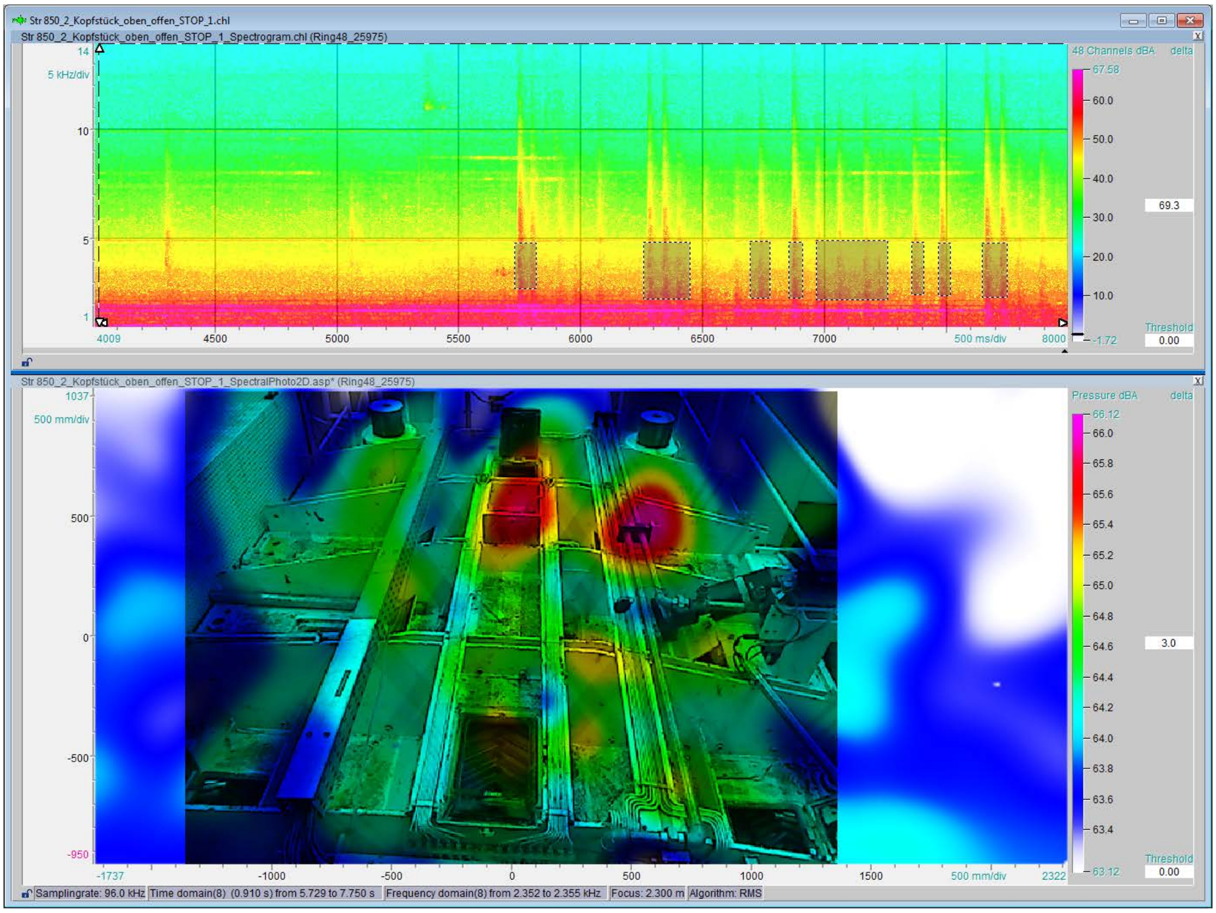

Figure 4: spectrogram with marked peaks (top) and acoustic photo of sources for these peaks (bottom)

Figure 5: new and old gears

Analyzing the spectrogram of a second measurement (after the exchange) clearly shows that the peaks were eliminated by replacing the previously identified gear (Figure 6).

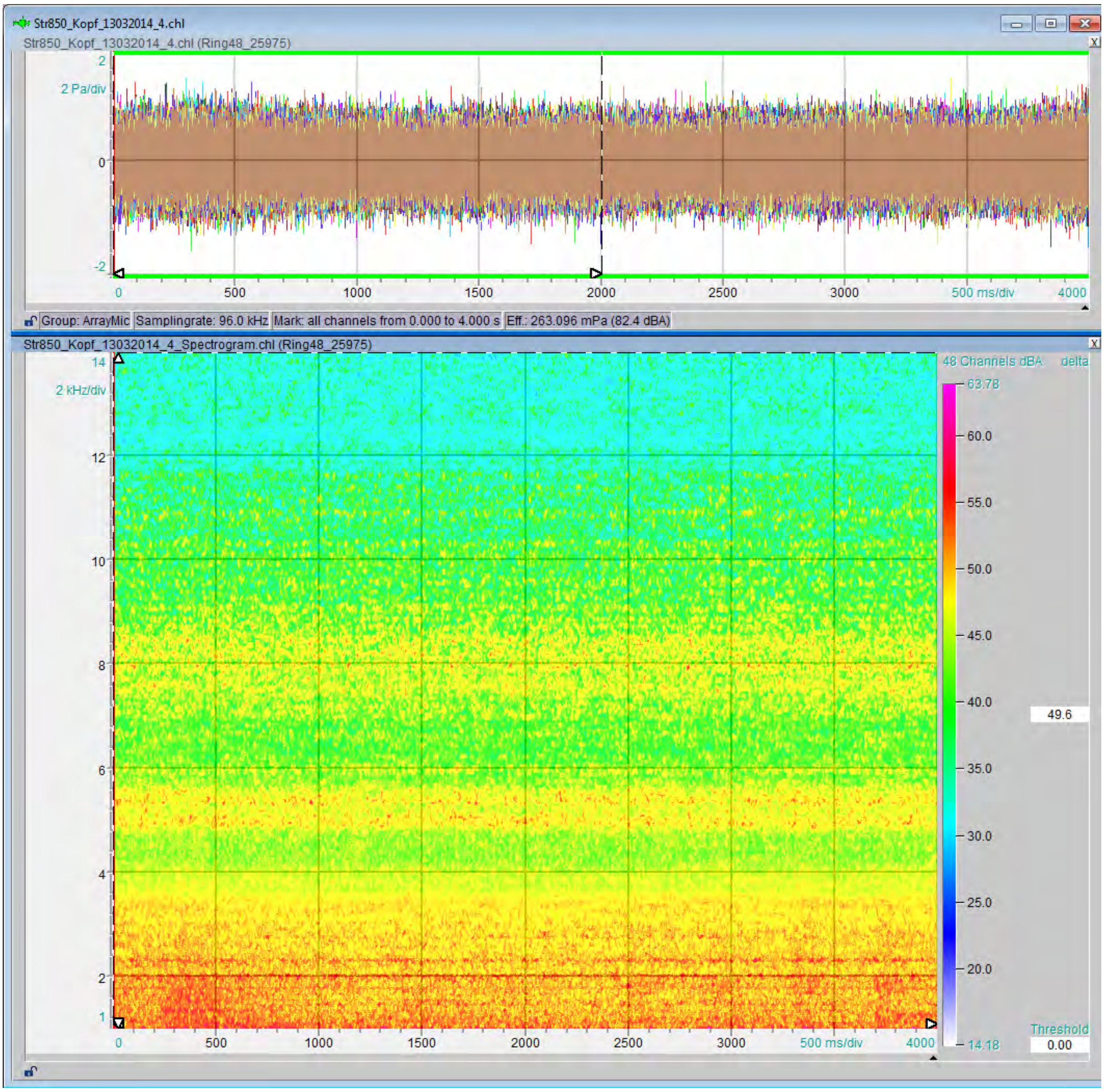

Figure 6: 4s measurement (channel-/time-data on top, spectrogram on bottom) after the gear was exchanged

4. CONCLUSION

The advantages of using the Acoustic Camera for machinery maintenance are obvious: it is an easy to use system that can be set up quickly and is operable within a few minutes. It is not necessary (or even desired) to stop machinery or the whole production process. Down-times are avoided and the plant is fully operational at all times.

Previous maintenance at the press plant required holding various costly replacement materials available and exchanging several parts until – by trial-and-error – the actually faulty part was identified. This process clearly is time consuming and cost-intensive. For the case at hand the savings in using the Acoustic Camera for identifying the damaged gear amounted to about € 250.000.

The Acoustic Camera proved itself as an invaluable tool in MRO and its use will certainly be extended further in the future. There is potential to develop the system to allow for more portability and implement a simplified user interface that enables engineers to use the software without extensive training. These points will be addressed over the next few months.

REFERENCES

1. Investigation of the depth of field in acoustic maps and its relation between focal distance and array design
   Döbler D. et al., Internoise 2008
2. A New Method for the Acoustic Analysis of Noise Sources in Industry Halls.
   Jaruszewska K. et al., Euronoise 2012
3. Exploring the limitations and expectations of sound source localization and visualization techniques.
   Heilmann G et al., Internoise 2014
4. Evaluation of beamforming systems
   Schröder R. & Jaeckel O., BeBeC 2012
5. Ein Beitrag zur Erweiterung von Beamforming-Methoden
   Kern M., PhD thesis 2008