

High resolution absorption mapping with a pu surface impedance method

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ABSTRACT

The *in-situ* surface impedance method with pressure-velocity probes is documented in many publications (see e.g. 1-6). The method is based on the measurement of sound pressure (p) and particle velocity (u) close to an acoustic absorbing material. A loudspeaker at a defined distance is used to generate a sound field with a known radiation impedance.

The impedance of a small area (a few square centimeters) with a known impedance is scanned with an ultra miniature pu probe very close to the surface. The area is made of steel with a cut-out, and behind this a material with a known impedance is placed.

In this paper the method is explained, the spatial accuracy of the measurement is examined and a visualization technique is presented with a display of the spatial distribution (2D picture) of the damping properties as function of frequency.

1. INTRODUCTION

The properties of many sound absorbing samples are not uniform. Often the material package itself is inconsistent, and adjacent structures influence the overall acoustic behavior. To get a better understanding of the mechanisms that create the absorption it is useful to have information about small material sections instead of one general absorption value of the entire structure.

The pu surface impedance method consists of measuring the impedance *in situ* close to the surface with a combined sound pressure and particle velocity sensor. From the impedance above the material also the material's surface impedance, reflection and absorption can be obtained.

In 2007 this method was used to measure a small area of a quarter lambda resonator sample (4). From multiple measurements close to the surface it could be shown that the resolution of the method is in the order of millimeters. By using spatial summation the average absorption of the whole sample could be obtained. Since then this method has been applied to measure small samples or areas (5, 6).

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In this paper the resolution of this method is studied even further. A sample of sheet metal with cavities is used. The cavities are filled with damping foam and thus the local absorption should depend on their shape.

2. DESCRIPTION OF THE MEASUREMENTS

The sample that is measured consists of a layer of sheet metal with a sophisticated μ -logo. Behind the logo there is a layer of acoustically damping foam. This sample is moved with an X-Y plotter, figure 1 left. At a distance of $\sim 1.5\text{mm}$ from the sample surface is measured with a miniature probe. A point like sound source is positioned at 23cm from the probe.

The X-Y plotter is moved in small steps (0.67mm). In an area of 12.3cm^2 (1.9 square inch) the sound pressure and particle velocity is measured on 2754 locations.

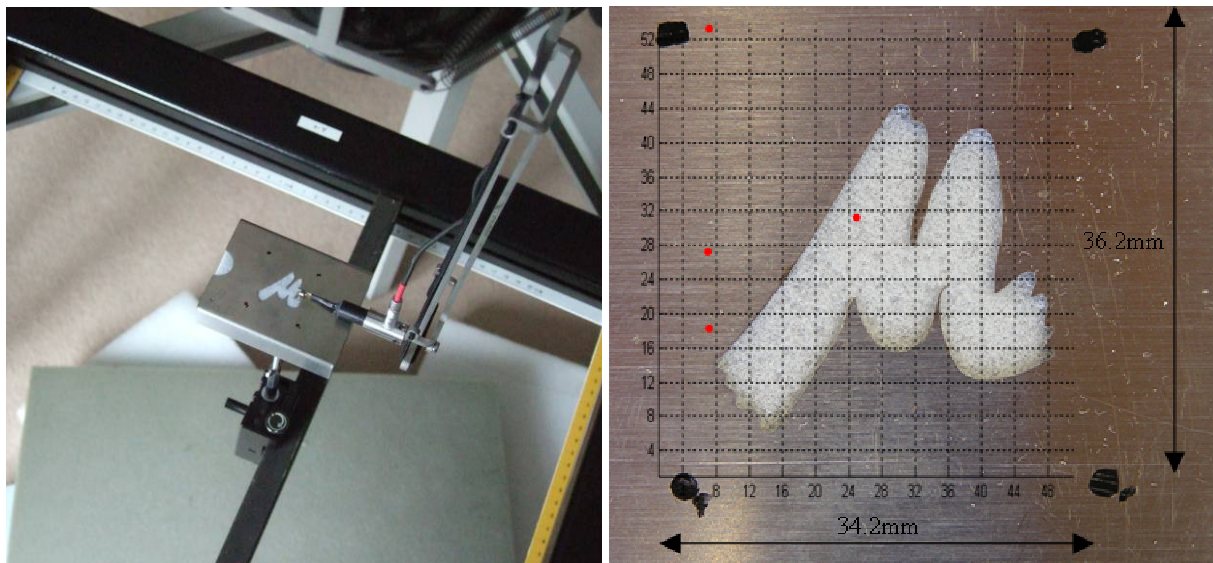


Figure 1: Left: the sample is moved with a X-Y plotter. Right: The sample is measured in 0.67mm steps.

3. MEASUREMENT RESULTS

In this section the measurement values at each location are displayed. First the pressure, velocity, impedance and absorption values are shown of 4 typical locations. Then various 2D and 3D contour and surface plots are shown to demonstrate the resolution of the measurements.

A. Spatial variation

The frequency responses of four locations are shown in figure 2-4. In the legend the measurement number is shown. Also their position above the sample is plotted with red dots in figure 1, right.

In figure 2 can be seen that the spatial variation of particle velocity (right) is much higher than the pressure (left). Up to 2kHz there is little difference between the situation where the pressure microphone is above the damping material or above the steel plate. It is therefore expected that the spatial variation of the impedance, reflection and absorption coefficients is more depending on the measured particle velocity than on the sound pressure. (figure 3-4).

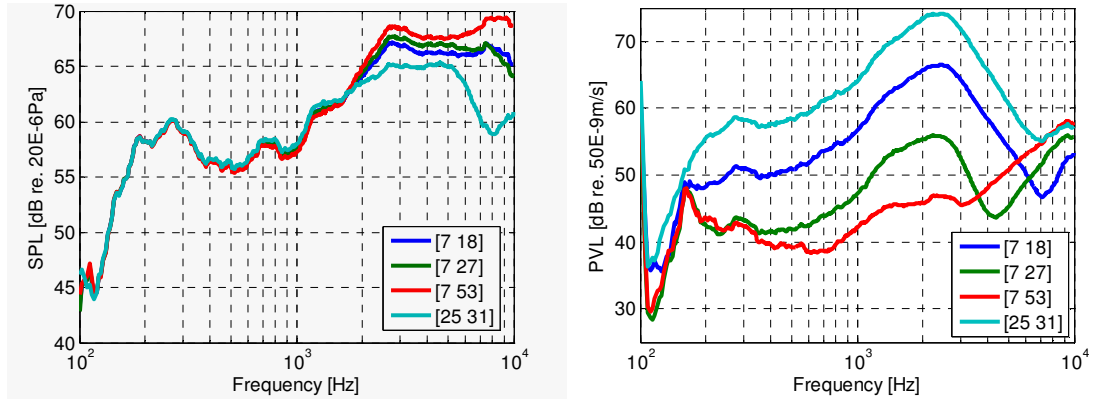


Figure 2: Measurement result on 4 positions. Left: Sound pressure level. Right: Particle velocity level

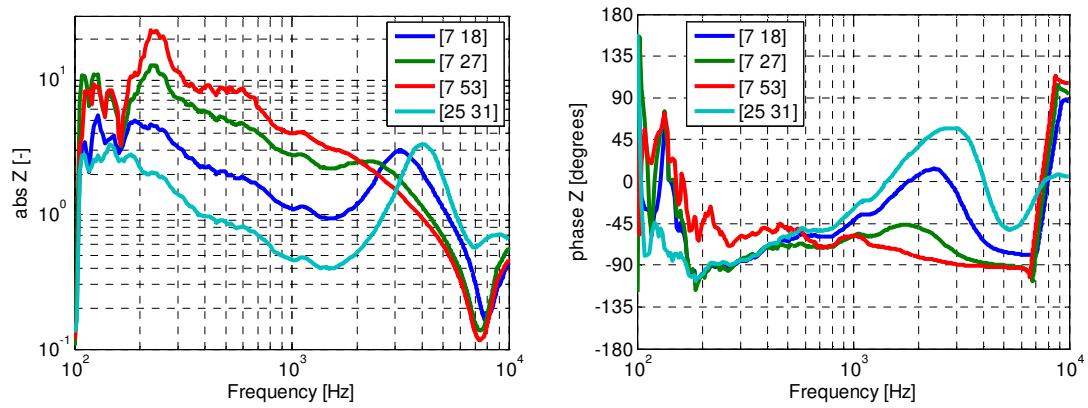


Figure 3: Impedance normalized to air on 4 positions. Left: absolute value. Right: phase

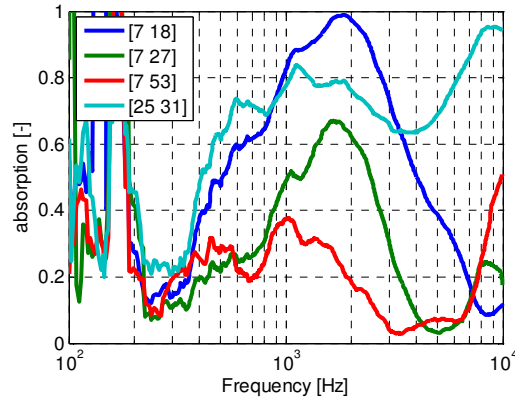


Figure 4: Local absorption at 4 positions

B. Contour plot of velocity compared with logo image

In order to get an understanding of the measurements resolution the velocity level at each location is displayed as a contour plot. This image is that plotted on top of the actual image of the μ -logo, see figure 5. It can be seen that the logo contours are quite nicely followed.

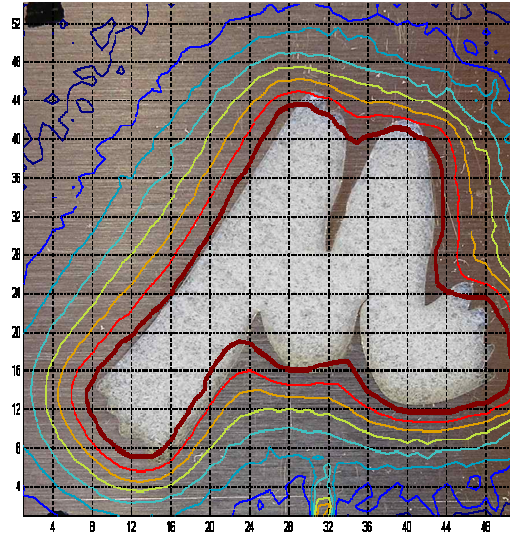


Figure 5: An overlap of a velocity contour plot at 2253Hz on top of the logo image

C. Spatial distribution visualized by surface plots

In figure 6 to 22 the results are visualized as 2D and 3D surface plots. In section 3A was already mentioned that the sound pressure variation is small compared to the velocity variation. In figure 6 can be seen that also the logo is less clearly visible from the sound pressure representation. Left the frequency with the best result is shown (2733 Hz). At higher frequencies the shape of the logo is almost not recognizable.

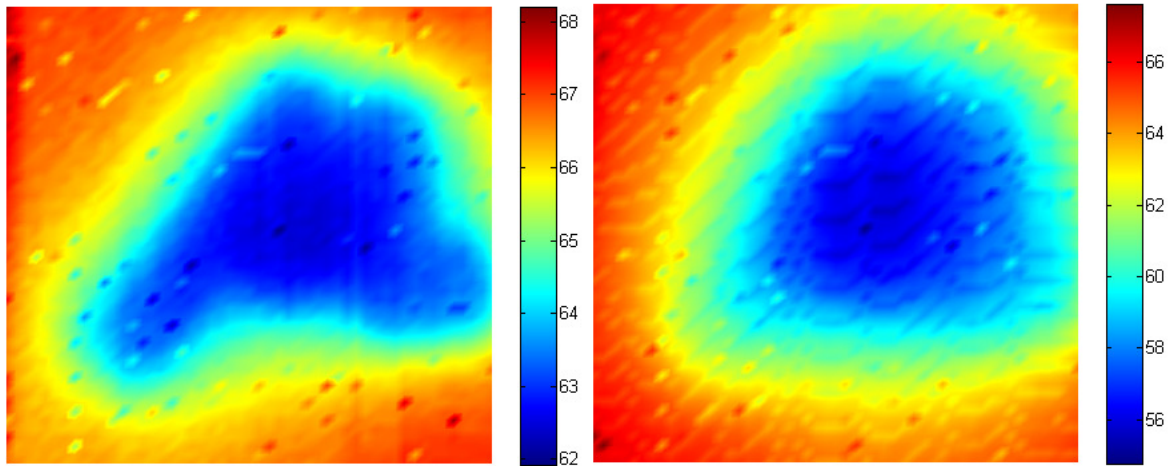


Figure 6: 2D surface plots of the sound pressure level (dB re. 20E-6Pa). Left 2733Hz. Right 7195Hz

At certain positions the stepper engine of the Y axis of the XY robot vibrated. Therefore at lower frequencies the measurement is much affected, see figure 7. Despite the vibrations the μ logo shape is already visible at 220Hz (1.5 meter wavelength). Above 900Hz the pattern of the μ logo is clearly visible and the influence of the vibration of the scanner is negligible. This is because at higher frequencies the vibration of the XY plotter are weaker and the signals from the speaker are higher.

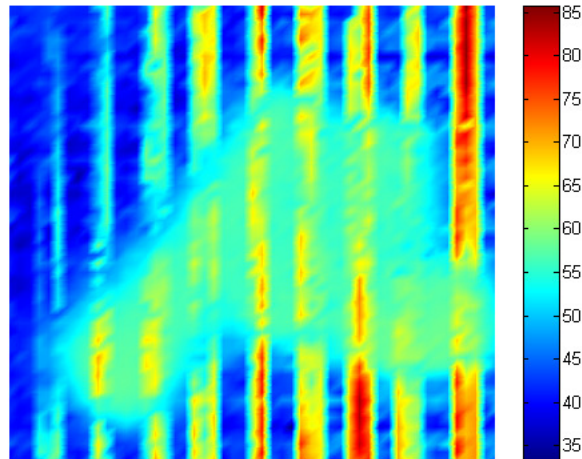


Figure 7: 2D velocity surface plot of 220Hz. The vibration of the XY scanner affects certain columns.

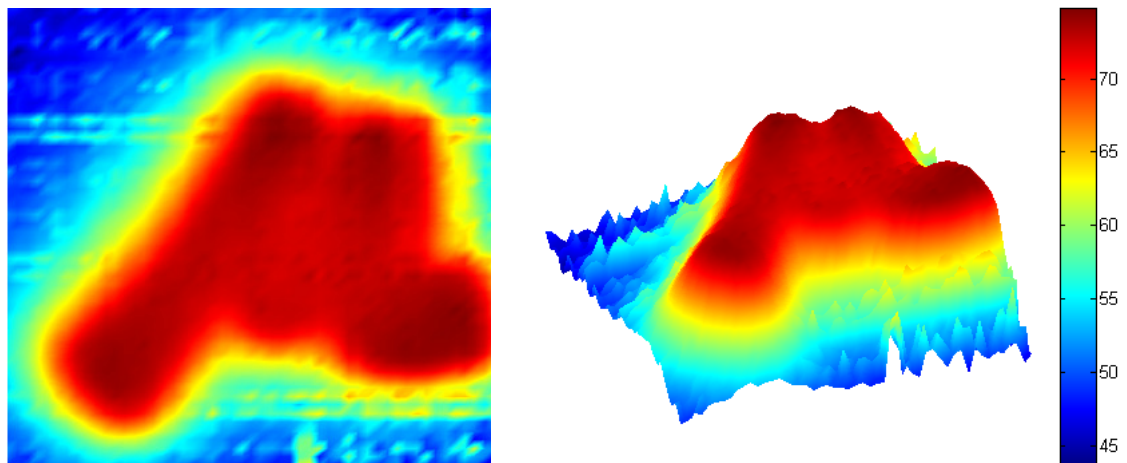


Figure 8: Velocity surface plot of 1857Hz. Left 2D, right 3D representation

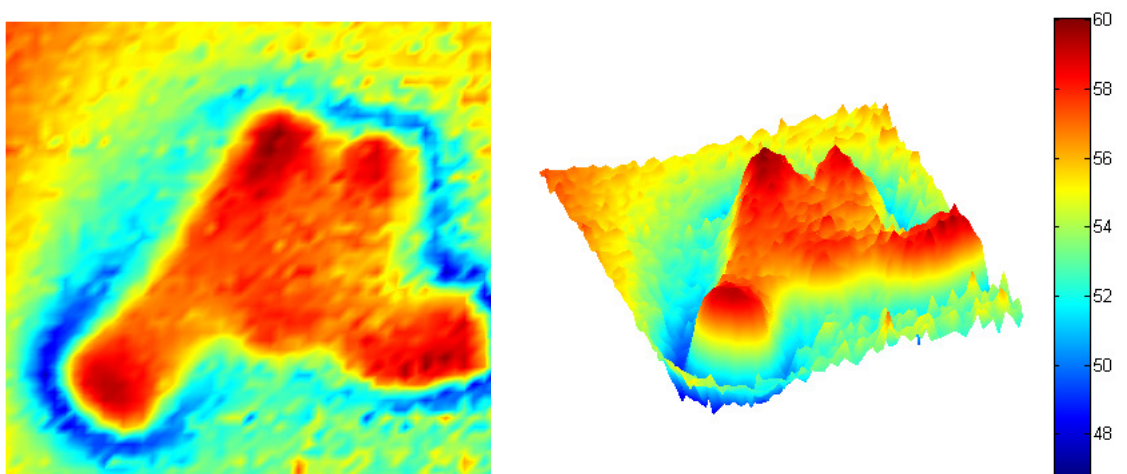


Figure 9: Velocity surface plot of 7371Hz. Left 2D, right 3D representation

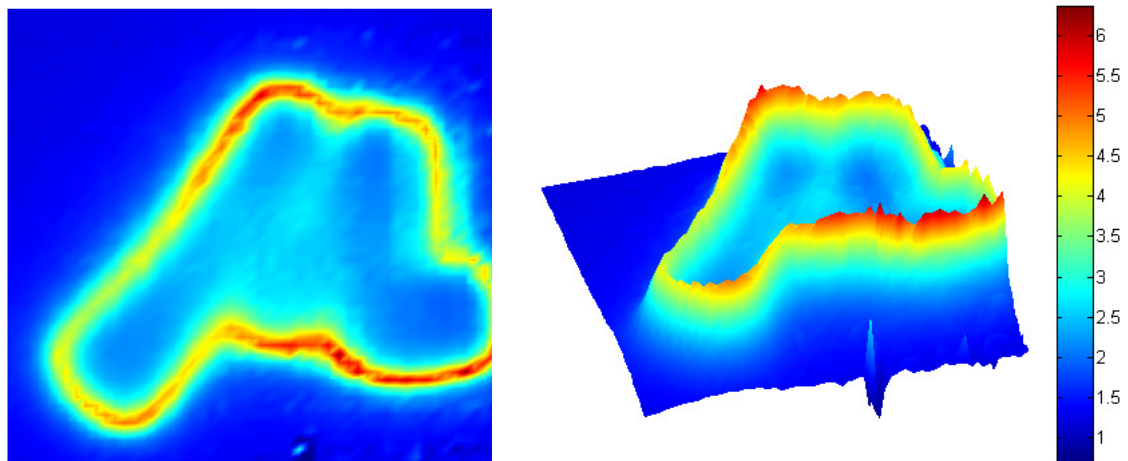


Figure 10: Impedance surface plot of 3457Hz (absolute value). Left 2D, right 3D representation

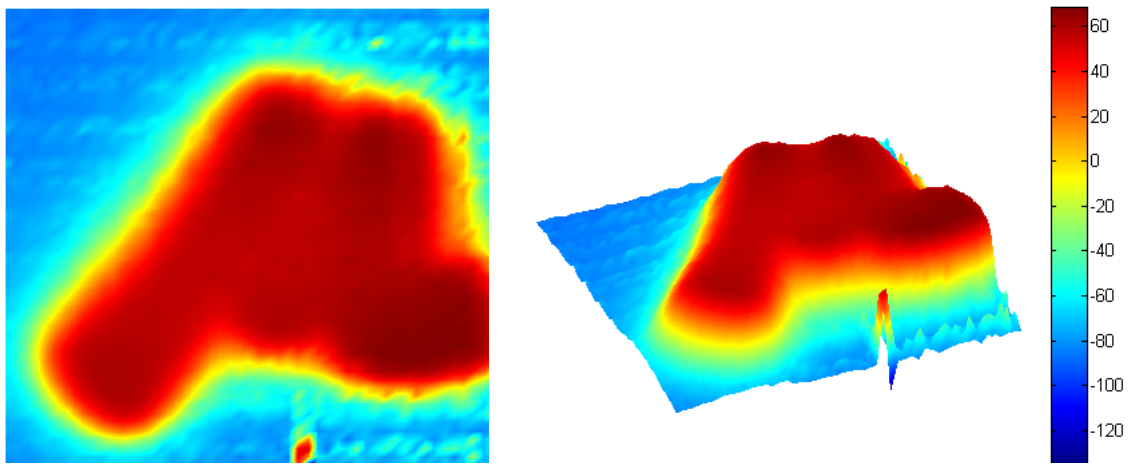


Figure 11: Impedance surface plot of 2631Hz (phase). Left 2D, right 3D representation

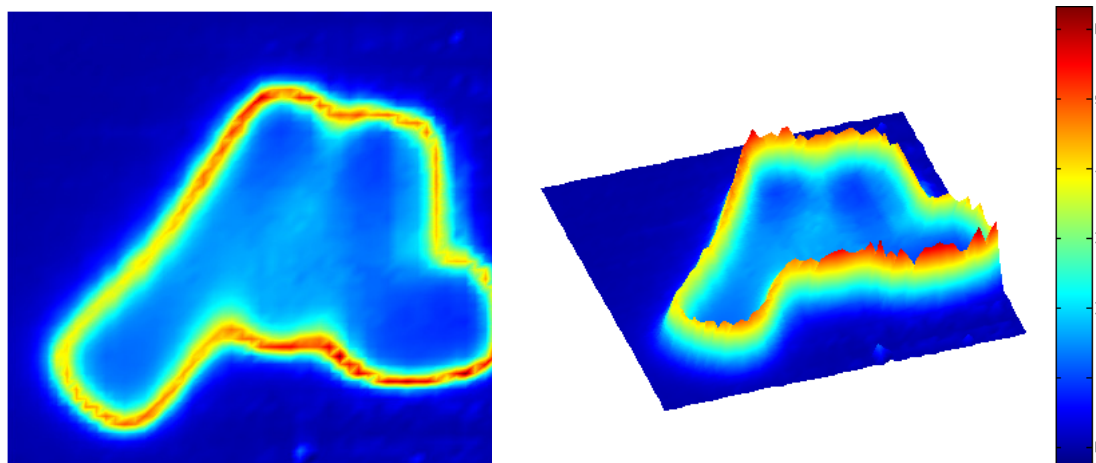


Figure 12: Impedance surface plot of 3457Hz (real part). Left 2D, right 3D representation

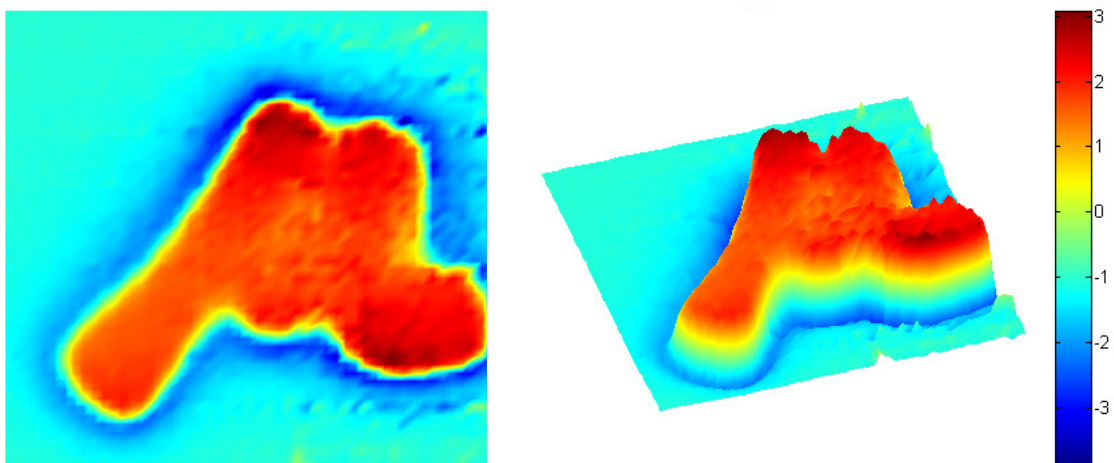


Figure 13: Impedance surface plot of 3727Hz (imaginary part). Left 2D, right 3D representation

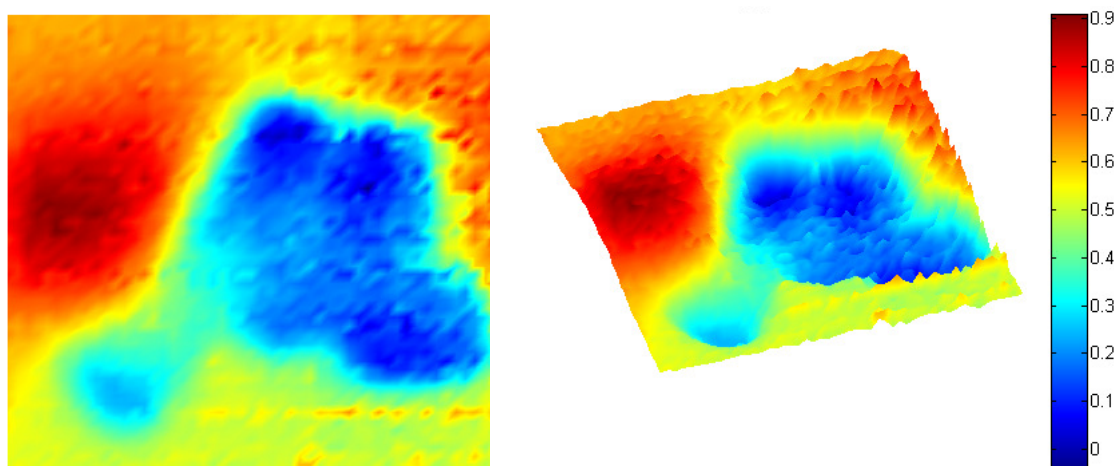


Figure 14: Impedance surface plot of 9999Hz (imaginary part). Left 2D, right 3D representation

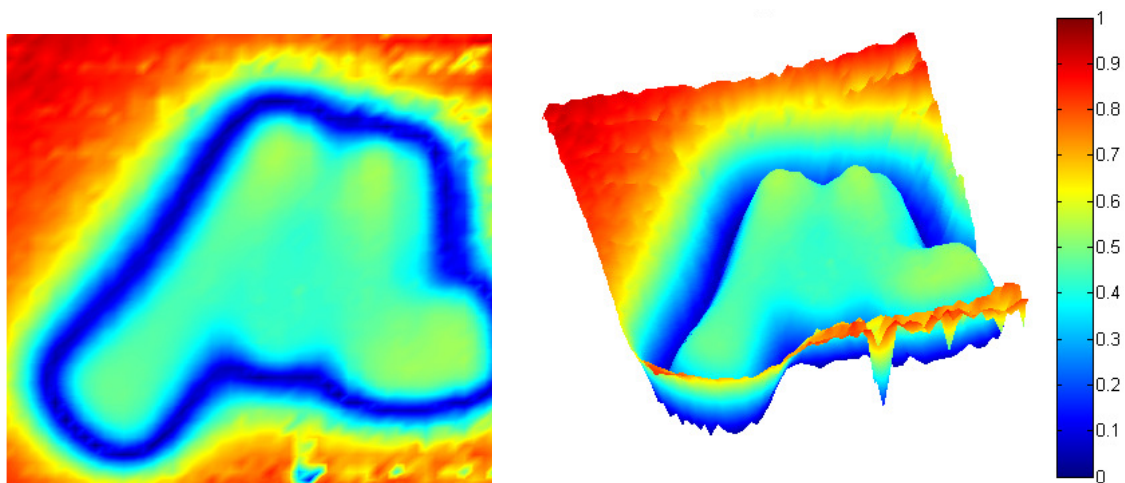


Figure 15: Reflection surface plot of 1878Hz (absolute value). Left 2D, right 3D representation

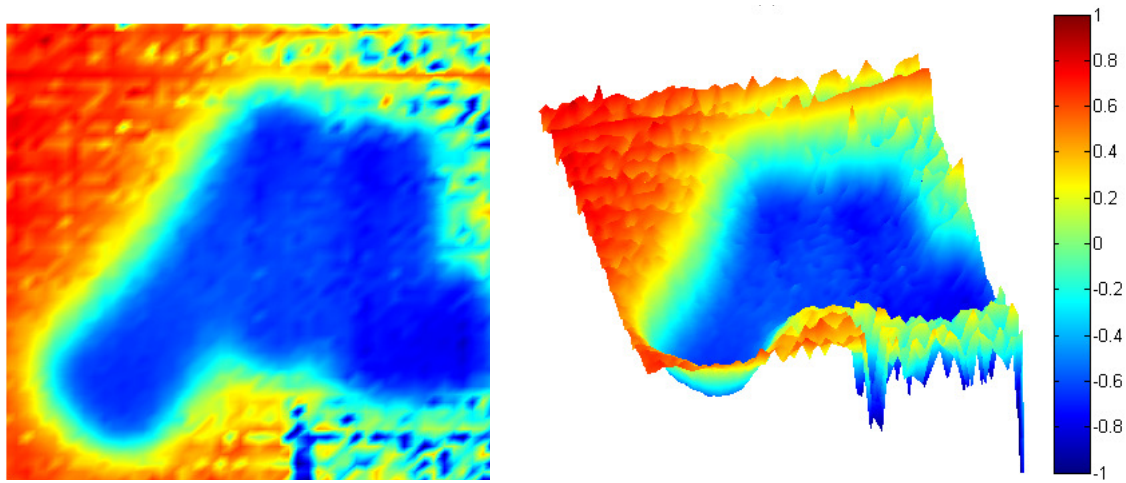


Figure 16: Reflection surface plot of 938Hz (real part). Left 2D, right 3D representation

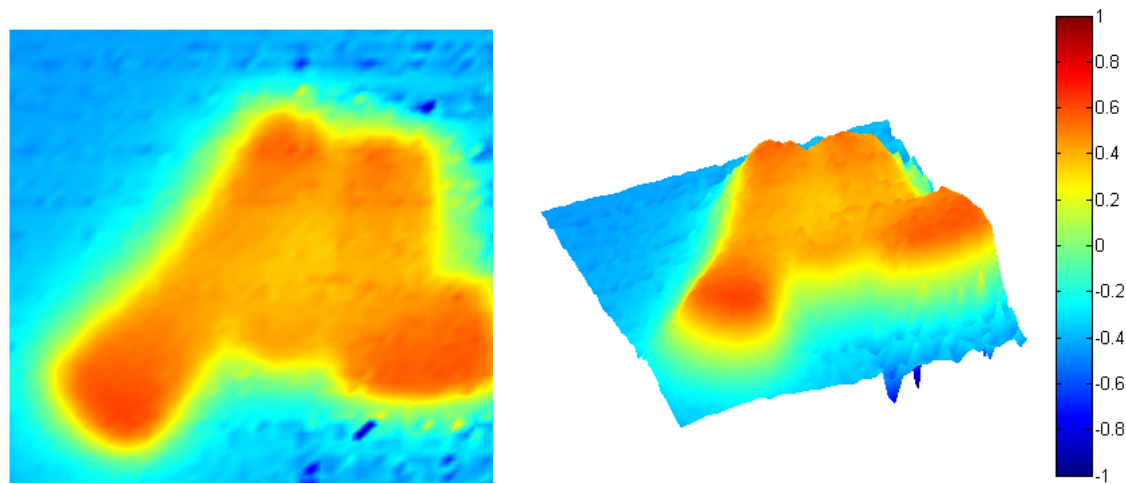


Figure 17: Reflection surface plot of 4740Hz (real part). Left 2D, right 3D representation

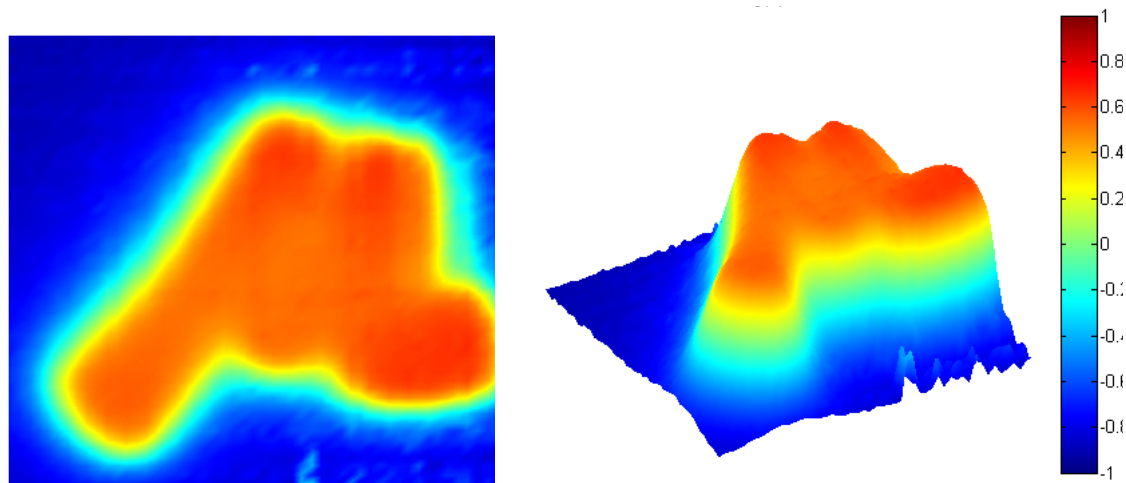


Figure 18: Reflection surface plot of 2921Hz (imaginary part). Left 2D, right 3D representation

The resolution appears to be best in the mid frequency range (1.5kHz – 5kHz), and is worse at lower and higher frequencies (figure 19 to 22).

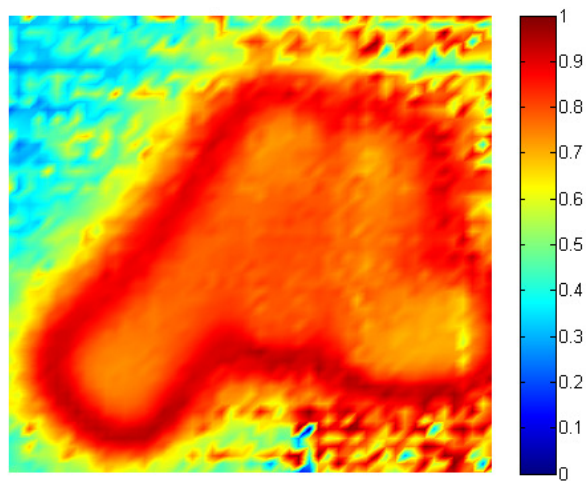


Figure 19: Absorption 1110Hz

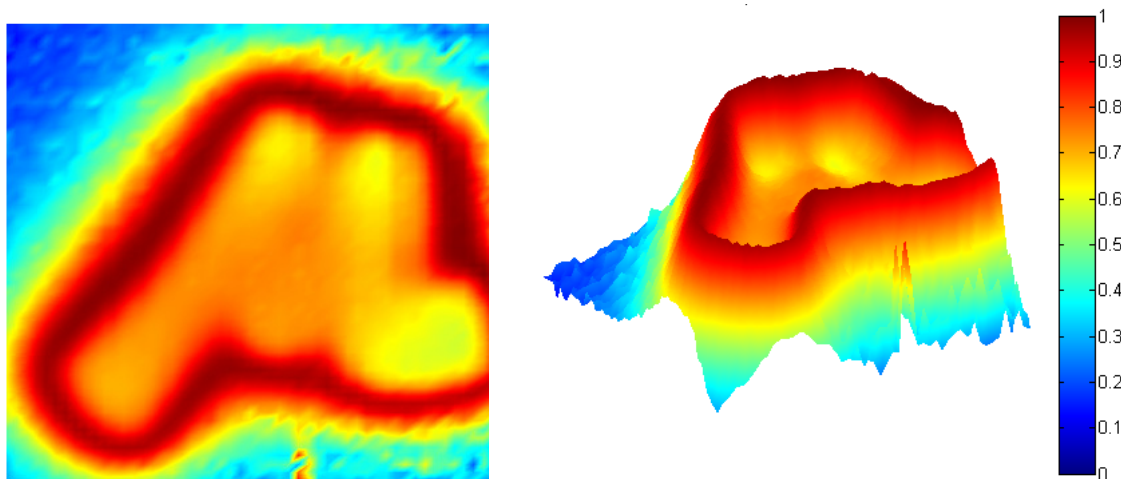


Figure 20: Absorption 2133Hz

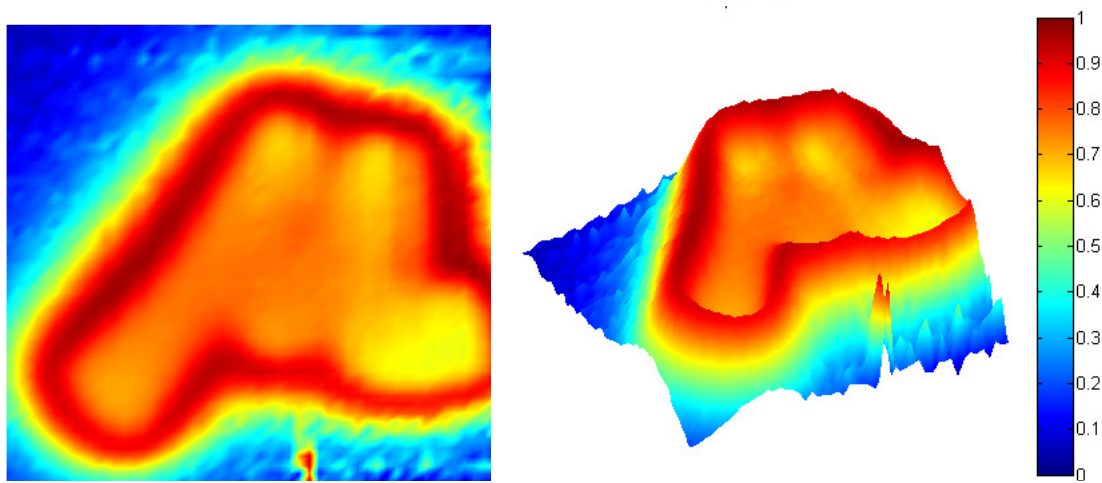


Figure 21: Absorption 2367Hz

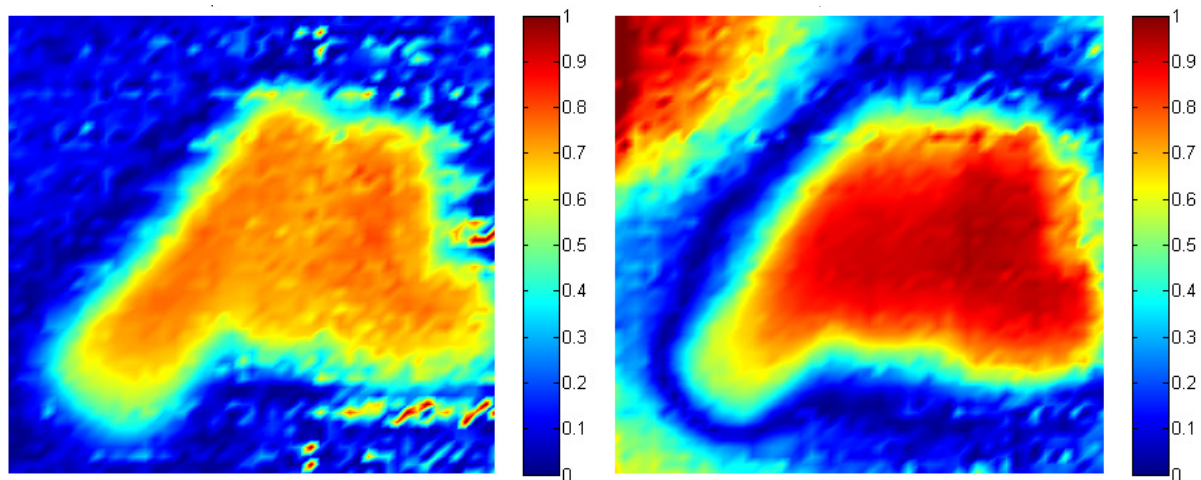


Figure 22: Absorption 5490Hz, Absorption 9895Hz

4. CONCLUSIONS

The surface of a sample is scanned with a miniature pressure-velocity probe with high spatial resolution. The velocity and pressure are measured at 2754 locations in a 12.3cm^2 area. The contour of the foam behind the cut-out in the sample is recognizable in a broad band (220Hz – 9.9kHz), but is most clearly visible in the mid-frequency range (1.5 to 5kHz). The spatial variation of sound pressure, which has an omni directional sensitivity, is lower than the spatial variation of particle velocity, which has a figure of eight shape sensitivity.

Because many of the fine details on the company logo are visible in the impedance and absorption plots it can be concluded that the spatial resolution is in the order of a millimeter.

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