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IDENTIFYING ACOUSTIC BRIDGES BY USING BEAMFORMING AND SOUND INTENSITY IN SITU MEASUREMENT TECHNIQUE

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Abstract
Performing building acoustic measurements to identify acoustic bridges are of the utmost importance as they can significantly affect the acoustic insulation behavior.

The authors of this paper will present sound intensity (based on P-P Intensity Probe) and beamforming as different techniques to assess the measurement of acoustic bridges. A case study will be presented comparing both methods and evaluating differences, advantages and disadvantages of each technique.

Keywords: Acoustic Bridges, Sound Intensity, P-P Intensity Probe, Beamforming.

1 Introduction

Acoustic bridges on acoustic insulation solution used in different applications (buildings, enclosures, etc) reduce drastically the efficiency of the acoustic treatment. These faults are really common and could appear during installation or manufacturing process.

To solve this problem, the location of the acoustic bridges must be very well defined to properly indentify the focus of the problem. This task can be really difficult, depending on the complexity of the acoustic insulation solution selected.

This paper presents two different sound measurement techniques of detecting acoustic bridges: the beamforming applied with a circular microphone array and the sound intensity measurements using a P-P Intensity Probe.

The first step to detect acoustic bridges must be to create a diffuse sound field in the enclosure. In such conditions, the sound pressure level will be the same at each point of the room and therefore, there will be the same incident sound energy in each point of the separation surface.

Any difference in the sound pressure level measured in the opposite side of the separation surface will be consequence of a local difference in the transmission lost of this surface. In this way, the weak zones of the separation surface, where the sound insulation will be smaller due to manufacturing or installation faults, will be detected.

Using beamforming technique, the sound pressure levels (SPL) on the opposite plane of the separation surface are obtained. As this color map performs relative SPL, different colors over a photography show the different SPL. The photography pixels that show the higher SPL values indicate where the acoustic bridges are located.

On the other hand, the sound intensity technique using a P-P probe makes possible to perform an acoustic map showing the sound intensity radiated by the separation surface. For this purpose, a measurement point mesh along this surface is defined to carry out the sound intensity measurements using the P-P probe.

The sound intensity average flowing through each grid-segment can be obtained using the sound intensity measurement system. Thus, the sound intensity emitted by each grid-segment will be calculated using the sound pressure average of the two pressure signals of the microphones and the particle velocity component in the direction of the axis of the probe, obtained by a finite-difference approximation to the pressure gradient in Euler's equation motion.

These results are performed over a photography using a color legend to distinguish the difference in the sound intensity levels along the surface to detect the acoustic bridges.

In this way, beamforming and sound intensity measurements are useful and powerful methods to detect acoustic bridges on acoustic insulation solutions. Thus, this paper compares both techniques showing the strong and weak points of each one.

2 Test description

2.1 Test stage description.

The emission room must to be approximate as a reverberant local. The walls are made up for gypsum except the surface of separation that is made up for two panels of methacrylate and a same material door. The floor is compound by floor tile and the ceiling by gypsum boards (Figure 1).

The sound emission system consists of a signal generator, an integrated amplifier and a loudspeaker with omnidirectional patron of radiation (Figure 1). The signal chosen was pink noise without filtering, in broad band (20 Hz – 20 kHz).

Figure 1 – Emission room with the sound system inside and the free space between the methacrylate door and the floor.

The main insulation problem of this room was known before doing the test. Visually, a free space was detected in the bottom of the door between the door and the floor (Figure 1).

Thus, this gap will cause losses in the acoustic insulation performance and will be one of the acoustic bridges that the acoustic study should detect.

2.2 Beamforming.

To perform beamforming measurements a circular 2-D microphone array was used. The time signals of the 48 microphones of the array were registered using a sampling frequency of 192 kHz to obtain the most accuracy results during the post-processing data.

The acquisition system was made up of a circular array with 48 microphones, a data recorder mc dRec and the NoiseImage software, all of them developed by GFai. Circular array was located 3,8 meters in front of the surface of separation (Figure 2).

Figure 3 shows the connection diagram to carry out the beamforming measurements.

Figure 2 – Acoustic antenna location in front of the room to a distance of 3,8 meters from the surface.

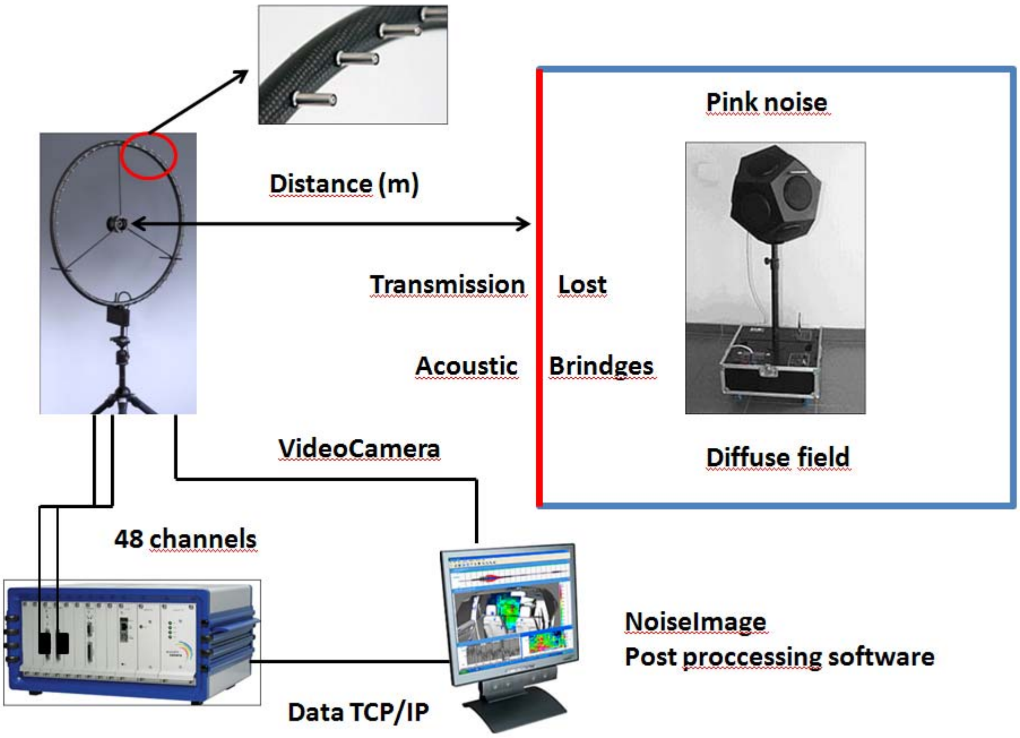

Figure 3 – Connection Diagram to carry out the beamforming measurements.

2.3 Sound Intensity using a P-P Probe.

For the sound intensity measurements, a grid with 46 points was defined. This grid is not a regular one, because a higher density of measurement points were defined in the zones where a higher acoustic power values was expected to have or, e.g. the zones where acoustic insulation problems are expected.

The separation between the intensity probe and the surface of separation was 12 cm and the direction of measurement was normal to the surface for all the measurement points.

The measurement was carried out according to the International Standard ISO 9614-1 [5] and a combination of two microphones of ½" and a 12 mm spacer was selected to carry out the measurements to minimize errors.

Before starting the measurements, an intensity probe phase calibration and Pressure Residual Intensity Index calibration (PRII) were performed using the G.R.A.S. intensity probe calibrator model 51AB.

Figure 4 shows the connection diagram to carry out the sound intensity measurements and figure 5 shows a sound intensity measurement.

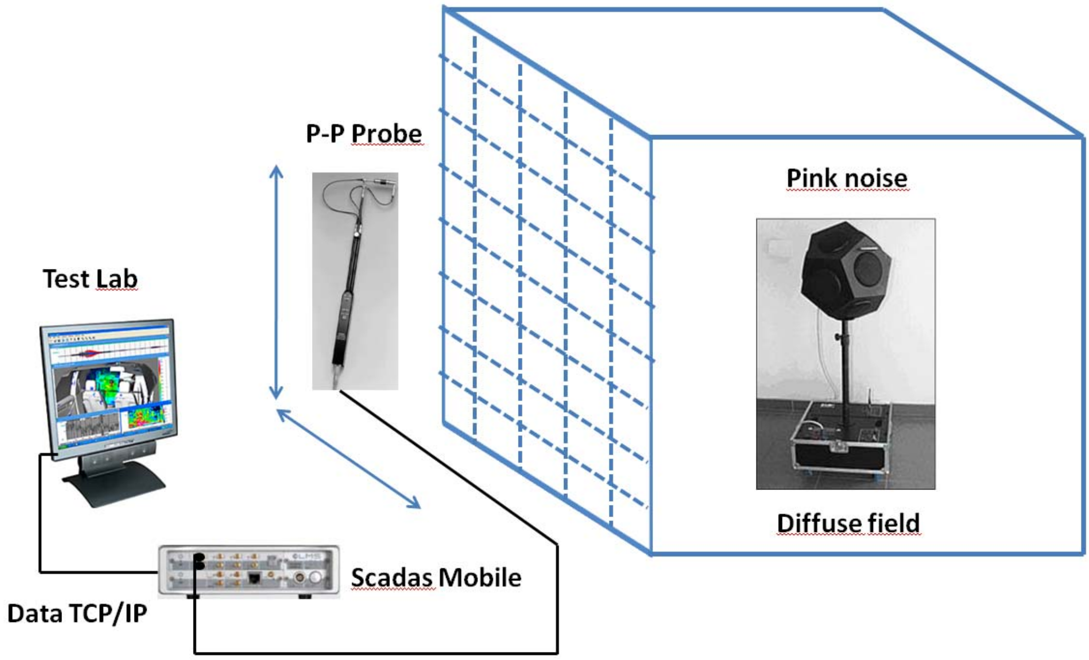

Figure 4 – Connection Diagram to carry out the sound intensity measurements.

Figure 5 – Performing a sound intensity measurement.

3 Test results.

3.1 Beamforming.

The results obtained by beamforming measurements were filtered through a band-pass filter between 1000 Hz and 10000 Hz to delete the low frequencies. From the results, it is possible to state that this method has a bad resolution at low frequencies.

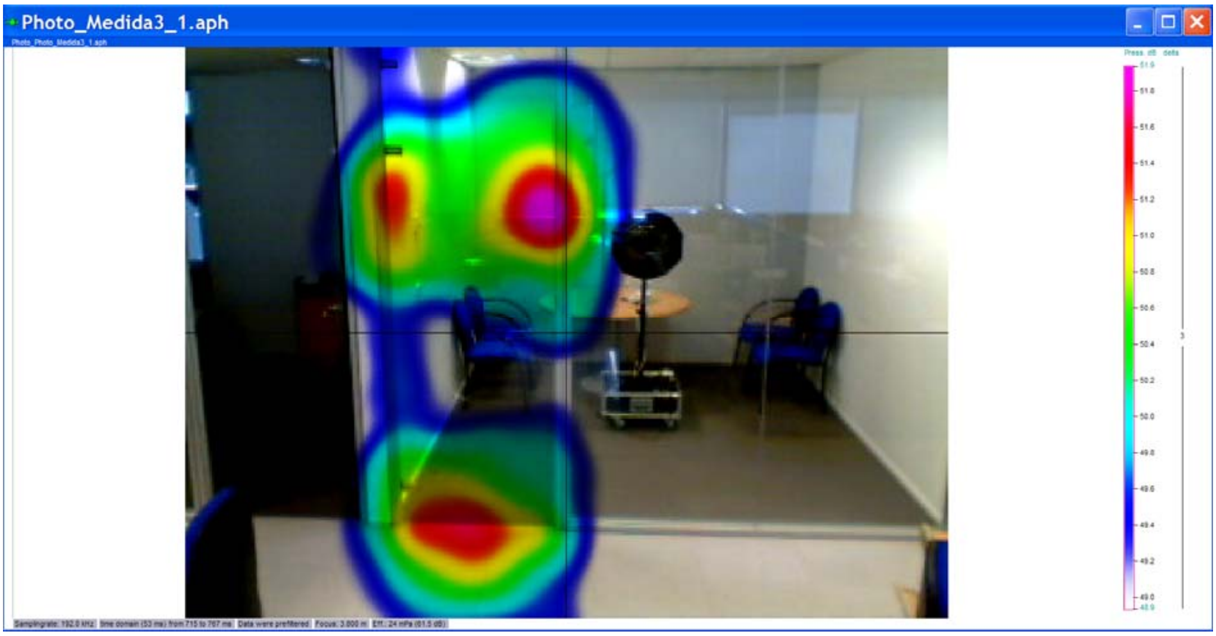

Figure 6 – Acoustic map. Sound pressure average level at 3.8 meters from the source plane. From 914.10 Hz to 9263.97 Hz. Signal time processing: 53 msec. Scaling range: 3 dB.

The higher SPL values are located along the doorframe and, above all, in the free space between the door and the floor. It is noteworthy that the differences in the SPL values shown in this figure are covered between 3 dB.

Figure 7 shows the analysis that was made only for high frequencies between 3000 Hz and 10000 Hz. A better resolution is obtained but we conclusions are the same.

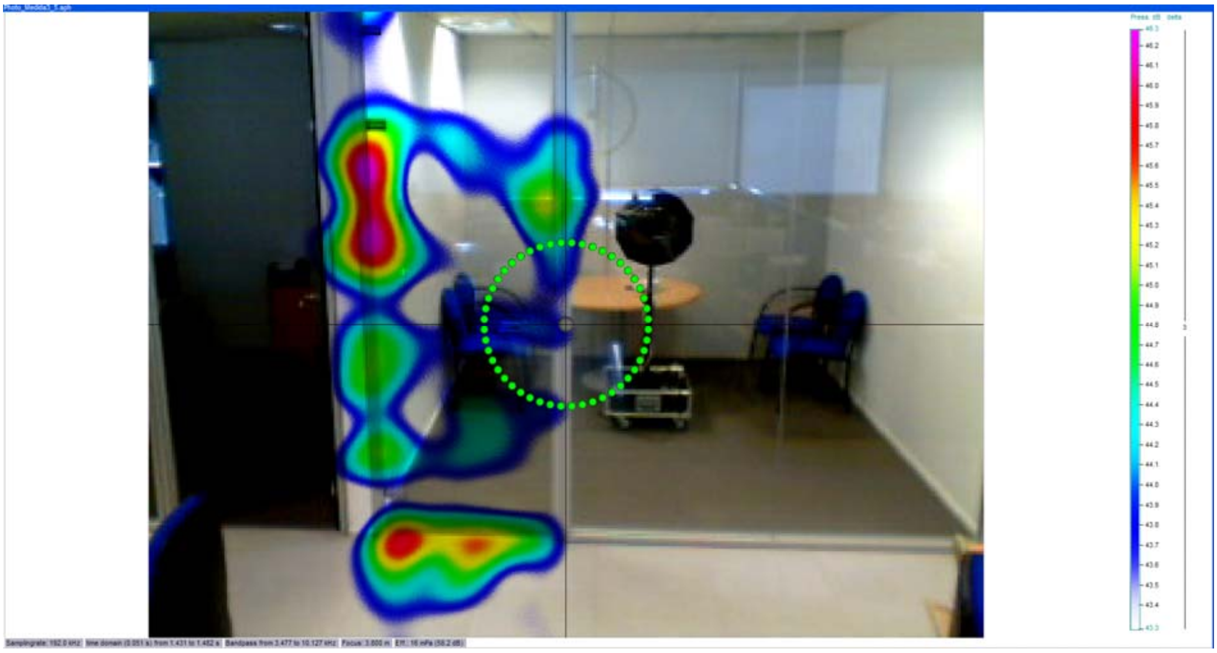

Figure 7 – Acoustic map. Sound pressure average level at 3.8 meters from the source plane. From 3.477 kHz to 10.127 kHz. Signal time processing: 51 msec. Scaling range: 3 dB.

Figure 8 shows the calculations for the YZ and the XY plane. The XY plane shows the sound waves reflection on the floor outside the room.

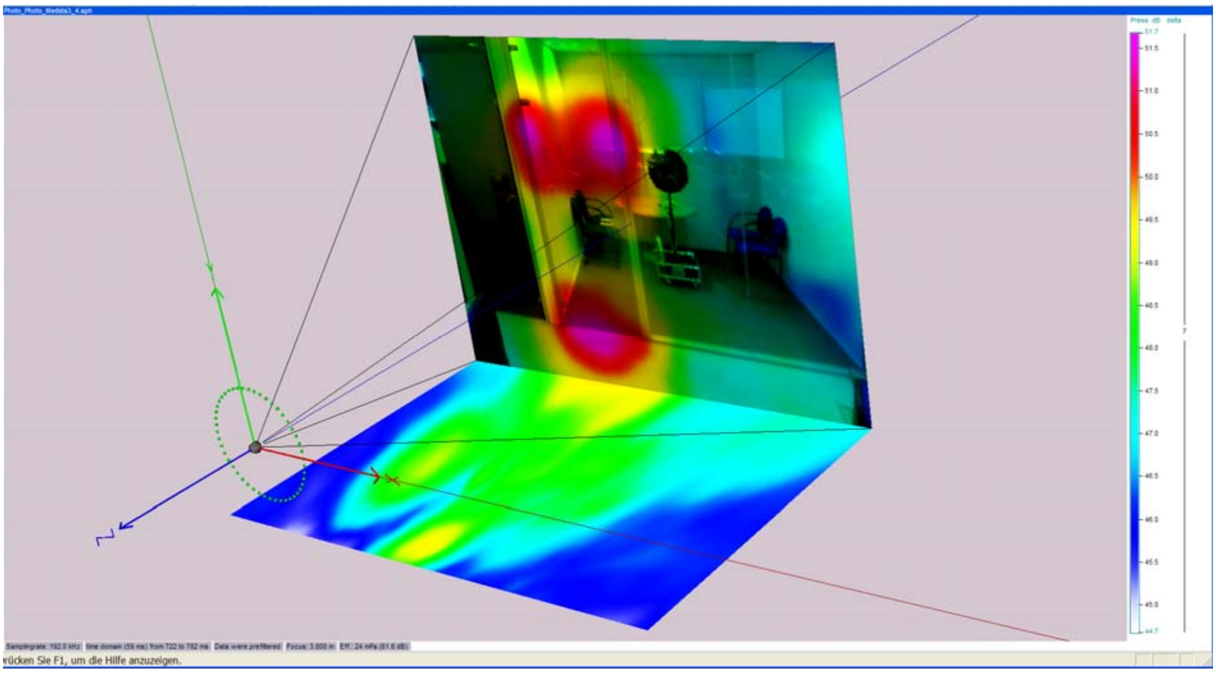

Figure 8 – Acoustic map including the XY plane. Sound pressure average level at 3.8 meters from the source plane. From 3.477 kHz to 10.127 kHz. Signal time processing: 51 msec. Scaling range: 5 dB.

3.2 Sound Intensity using P-P probe.

In this section, a color map is performing from the interpolation of the sound intensity levels measured in each grid points defined. A photography was added on the background to identify where these values is arising from.

Figure 9 shows sound intensity average levels for different frequencies. On the left of each figure a sound intensity legend appears relating the colors to the sound intensity levels. On the top-right corner of each figure axis reference is shown.

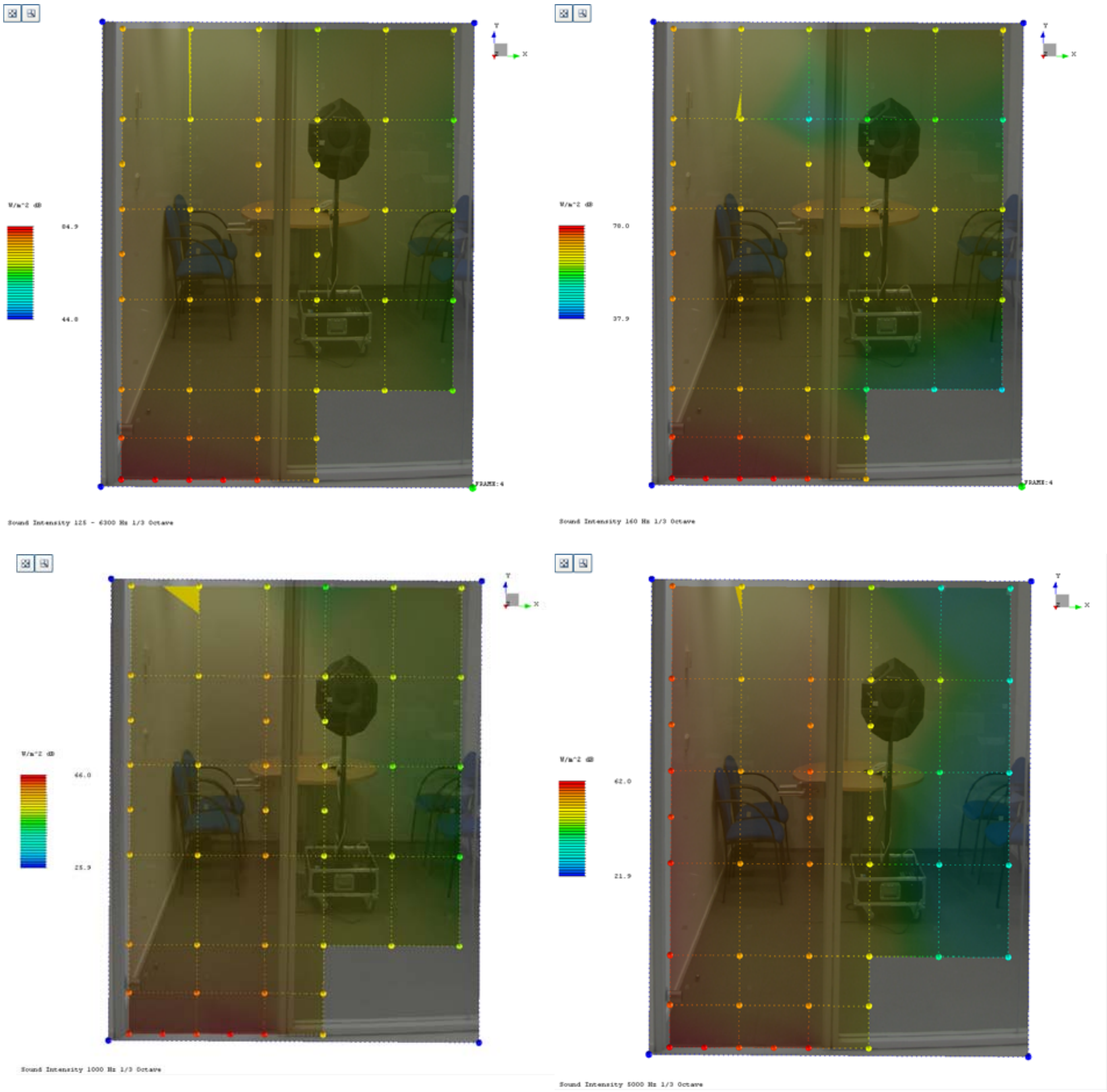

Figure 9 - Color maps showing Sound Intensity Levels. Top/Left - Sound intensity average level from 125 Hz to 6300 Hz (1/3 octaves). Top/Right - Sound Intensity Level in the 1/3 octave band of 160 Hz. Down/Left - Sound Intensity Level in the 1/3 octave band of 1000 Hz. Down/Right - Sound Intensity Level in the 1/3 octave band of 5000 Hz.

The results obtained in the third octave for low frequencies (160 Hz) show the sound escape for the bottom of the door where there is a great space free but not for any place more. This space is big enough for the low frequencies sound waves propagation outside by diffraction.

On the other hand, for middle and high frequencies, the sound escapes also trough the doorframe and the hinges due to the free spaces in these locations is big enough compare with the wavelength.

4 Conclusions

Both beamforming and sound intensity measurements allow the detection of acoustic bridges on sound isolation solutions, even when the faults are not visible for the human eye. In the test results chapter, where the results are shown, this affirmation is corroborating: the acoustic bridge are located by beamforming and by sound intensity measurement as well. Thus, both methods are adequate for this propose.

Beamforming has the limitation at low frequencies due to its bad resolution. In this case, the sound source location cannot be achieved by this technique. However, sound intensity measurements have not such a type of limitation if appropriate spacers are used. In this case of study, low frequencies are not necessary to be analyzed to locate the acoustic bridges.

The time necessary to carry out the measurements and the post-processing using beamforming is only a few minutes. On the contrary, just the sound intensity measurements using sound intensity technique, without the post-processing, need at least two hours to be completed. The time saving make most advisable the use of beamforming than sound intensity measurements for acoustic bridge detections. An exception of this affirmation appears if a detail analysis at low frequencies is necessary. In this case, beamforming is not useful and so, sound intensity measurements will be the most appropriate option.

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