

USING A SPHERICAL MICROPHONE ARRAY FOR IDENTIFICATION OF AIRBORNE SOUND TRANSMISSION PATHS

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1. INTRODUCTION

Assessment of the sound insulation properties of building partitions (e.g., walls, floors) is usually conducted according to standard procedures. ASTM E90 and E336 and ISO 140-3 and 140-4 provide means of rating the sound insulation performance of partitions in the laboratory or in the field. The results of these tests do not necessarily indicate whether an otherwise highly-insulating partition contains weak spots or leaks, other than a lowered overall rating. This paper presents the results of some initial efforts using a highly directional microphone array measurement system for identification of such weak spots.

Major weak spots such as holes may be obvious, but even subtle ones may be of importance. Recent work has shown that, particularly near the threshold of intelligibility, a slight increase in speech signal level can lead to a large increase in intelligibility [1]. This may have important implications on rating the “speech security” level of a meeting room, for instance. In these cases, finding even minor weak spots in the room boundaries may be of interest.

2. MICROPHONE ARRAY SYSTEM

A spherical array measurement system has been previously developed for assessment of directional variation of sound within rooms [2,3]. By measuring the impulse response at each array microphone, then beamforming, a directional impulse response due to sound arriving from within the array aperture is obtained. This is simultaneously computed for steering directions distributed over all 3D angles. Analysis of this set of directional impulse responses allows determination of the temporal and angular variations of arriving sound at the array position.

Two free-field arrays of 32 omnidirectional electret microphones, differing only in diameter, were constructed. The layout of the array microphones is shown in Fig. 1(a). Filter-and-sum beamforming is used with each array to generate a narrow beam over a different frequency range. The beampattern of the 48 cm-diameter array in the 800 Hz 1/3-octave band, and that of the 16 cm-diameter array in the 2500 Hz 1/3-octave band are shown in Fig 1(b). The 3-dB beamwidth of each pattern is only 28 degrees; the directivity index is over 14 dB.

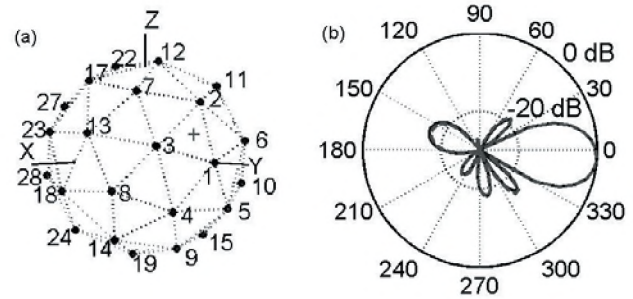


Figure 1 (a) Layout of microphones in 32-element spherical array, (b) beampattern in 1/3-octave bands: 800 Hz (48 cm array) and 2500 Hz (16 cm array). The are two curves, nearly coincident.

3. MEASUREMENTS

A 2.44-by-3.66 m test wall was constructed between two reverberation chambers at NRC. The wall had a single row of 90 mm wood studs (610 mm on centre), with a single layer of 16 mm drywall directly attached to the studs on one side, and a single layer of 16 mm drywall mounted on 13 mm resilient channels (610 mm on centre) on the other side. The cavity was completely filled with glass fibre batts. A standard ASTM E90 test was performed and the wall was found to have an STC rating of 52. Array measurements were subsequently made with the array 0.8 m from the centre of the wall in one chamber, and an omnidirectional loudspeaker 2.3 m from the wall in the other chamber. The room containing the array had a 1/3-octave band reverberation time of 4.3 s in the 800 Hz band, and 3.0 s in the 2500 Hz band. To more accurately represent typical office and residential rooms, all measurements were also made with absorptive material in the chamber containing the array. With the absorption present, the 1/3-octave band reverberation time was lowered at 800 Hz to 0.65 s, and at 2500 Hz to 0.60 s.

3.1 Partial Slit in Test Wall

A seam between two sheets of drywall on the side facing the array (the layer mounted on resilient channels) was intentionally widened to 5 mm. Such a “slit” could arise from improper cutting or installation of drywall, for instance. After this modification, the STC of the wall was measured to be 50. A directional measurement made with the absorption in the room with the array is presented in

Fig. 2. Panel (a) shows the geometry of the setup, indicating the wall and the slit with heavy lines. Panels (b) and (c) show a plot of the sound energy arriving during the first 35 ms of the response, viewed from above. The arrow indicates the expected direction of sound incidence from the slit. The shape of the surface indicates that the sound transmission through the slit is detected in both the 800 Hz and 2500 Hz 1/3-octave bands.

3.2 Partial Holes in Test Wall

After the slit was caulked and taped, two 8-by-10 cm holes were cut in the drywall, one on either side of the wall. The holes did not line up, and were cut through one layer of drywall only, the glass fibre batts were left intact. The STC of the wall in this state was still 52. A directional measurement made without the absorption in the room with the array is presented in Fig. 3. Panel (a) again shows the geometry, indicating the holes in the wall. Panels (b) and (c) show a plot of the sound energy arriving during the first 35 ms of the response, viewed from above. The arrows indicate the expected directions of sound incidence from the holes. The shape of the surface indicates that the sound transmission through the holes is detected in the 800 Hz 1/3-octave band, but not in the 2500 Hz 1/3-octave band. This is presumably due to the fact that less sound power is transmitted at 2500 Hz. The difference in level arriving

from the two holes is likely due to the difference in distance of each from the array.

4. CONCLUSIONS

A spherical array measurement system has been employed to locate weak spots in a wall. In conditions where the “defects” in the wall were minor enough to cause no, or only a slight, reduction in STC, they were localized accurately. The technique was effective even under conditions of high reverberation, and showed that the “detectability” of the defects varied with frequency. These initial investigations indicate that the present approach seems capable of identifying weak spots in a reliable and effective manner.

REFERENCES

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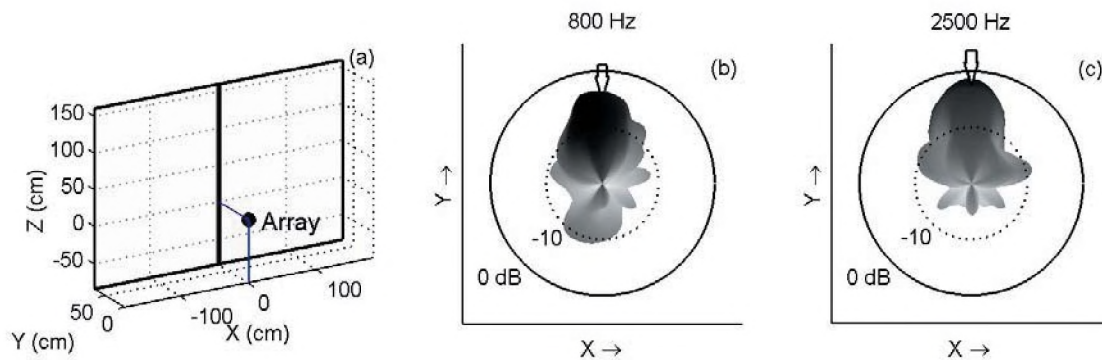


Figure 2 Measurement with slit in one side of test wall: (a) geometry of setup. Energy arriving at array during first 35 ms of impulse response is shown in (b) 800 Hz and (c) 2500 Hz 1/3-octave band.

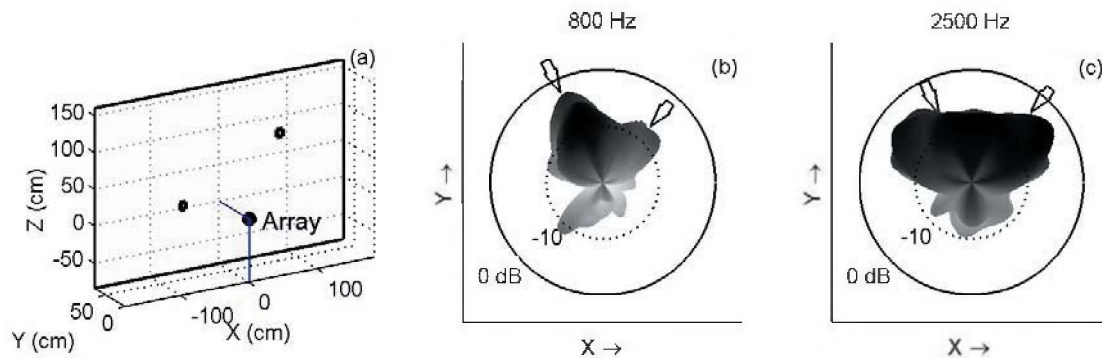


Figure 3 Measurement with two partial holes in test wall: (a) geometry of setup. Energy arriving at array during first 35 ms of impulse response is shown in (b) 800 Hz and (c) 2500 Hz 1/3-octave band