DESIGN AND TESTING OF AN ANTENNA ARRAY FOR SOUND-SOURCE LOCALIZATION

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1. INTRODUCTION

This paper describes the adaptation of an existing 'eye-array' antenna [1], based on a time-delay-of-arrival algorithm, to use a beam-forming algorithm, for application to the localization of noise sources in industrial workshops and in turbulent airflows (e.g. jets), and its preliminary testing. Full details can be foound in [2].

2. ANTENNA CONFIGURATION

The antenna consists of a hemispherical array of 26 electret microphones equally spaced over a 34-cm-diameter hemisphere, with a 27th microphone at its centre, and an associated 27-channel data-acquisition system (Figure 1).

Figure 1. Antenna and DAQ system in anechoic chamber.

3. SIGNAL PROCESSING

The original antenna achieved sound-source localization based on a time-delay-of arrival (TDOA) algorithm [3]. This was tested in an anechoic chamber, and found to perform well with a single source; however, the extension of the algorithm to multiple source was considered too complicated.

Thus, a new localization algorithm was developed based on delay-and-sum beam-forming methods [3], and its performance tested.

4. EXPERIMENTATION

The antenna array, hardware and new beam-forming algorithm were tested in an anechoic chamber (see Figure 1), with one or more real sources (omnidirectional points, diameters <5 cm, radiating broadband noise) located 1-2 m from the antenna, and virtual 'image' sources created by introducing reflecting surfaces, as well as in a reverberant room (a small, empty office with dimensions 5.6 m x 4.2 m x 2.7-m high and acoustically-hard surfaces) with a single real source at various distances from the array.

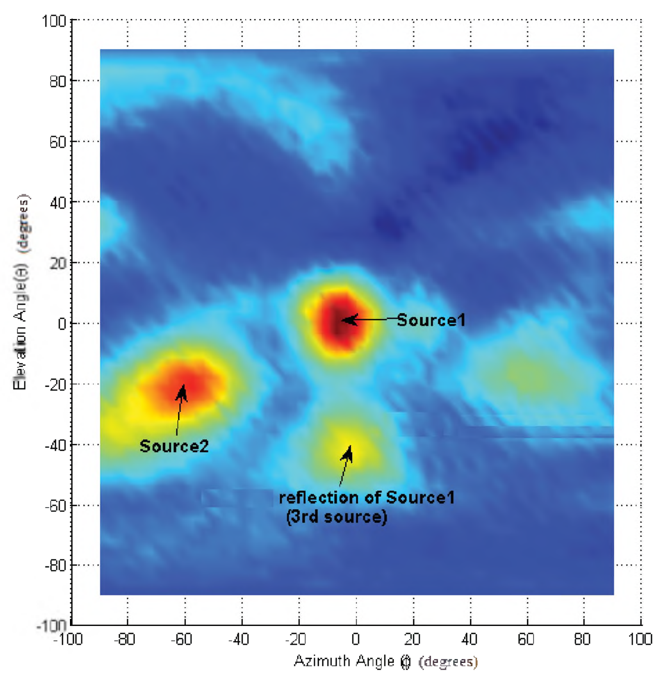

Figure 2. Directivity diagram for beamforming with two real point sources and a virtual source (reflecting surface).

5. RESULTS

Figures 2 to 4 show test results in terms of 'directivity diagrams' generated by the system. These show the distribution of sound intensity incident on the antenna over the hemisphere towards which it is pointing.

Figure 2 shows the directivity diagram for delay-and-sum beam-forming with two real sources and a virtual source (reflecting surface). The directions of the three sources are accurately localized.

Figure 3 shows the directivity diagram of the delay-and-sum beam-former with a source at a distance of 4.2 m (i.e., in the reverberant field) in the reverberant room. The directions of the real source, and of the virtual sources corresponding to first-order images in the reflecting surfaces, are well identified. Note the wrapping of the side-wall reflection

Figure 4 shows the directivity diagram of the delay-and-sum beam-former with the source in the reverberant room, and one wall covered by absorbing material. Energy arriving from the direction of the image source in the treated surface, which is now much lower, is no longer evident.

6. CONCLUSION

An existing microphone-array antenna has been adapted for sound-source localization, with new hardware, and software based on a beam-forming algorithm. The array has been tested in an anechoic chamber and in a reverberant room with one or multiple real and virtual sources. It performed well and was able to identify all sources; it displayed an angular resolution of 3-4°

Future work will improve the resolution by implementing a CLEAN or similar algorithm [3], and will adapt the system to localizing 3-D source positions. It will then be used to localize noise sources in industrial workshops and in turbulent airflows, as in jets.

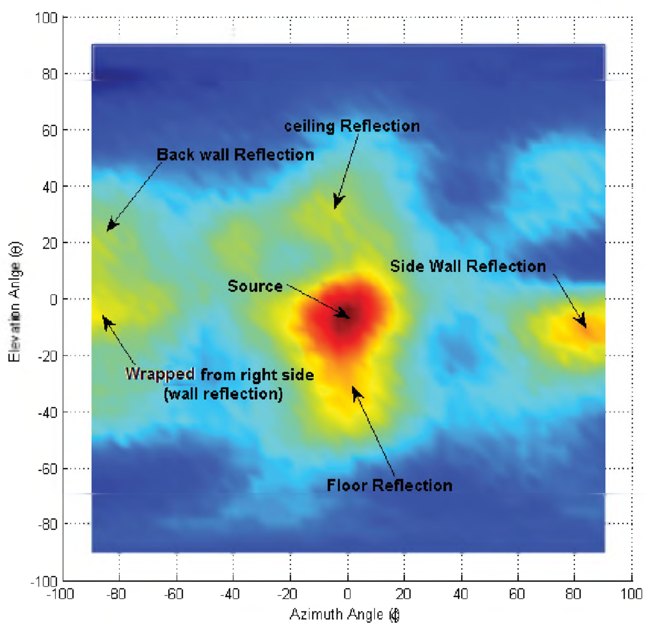

Figure 3. The directivity diagram of the beam-former with a point source in a reverberant room.

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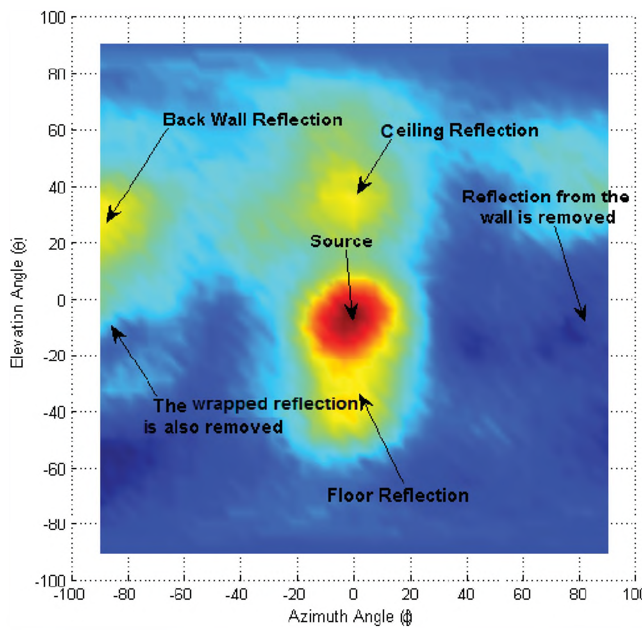

Figure 4. The directivity diagram of the beam-former with a point source in a reverberant room with one wall covered by absorbing material.