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The influence of source position and orientation on speech intelligibility in school environments

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ABSTRACT

In school environments, the teacher's position can change during lessons. Consequently, also the directivity of the sound source (i.e., the teachers' head), as well as its position, can vary, for example when standing, sitting, walking, using blackboard or speaking directly to one receiver. If the directivity varies significantly so does the speech intelligibility and this may affect students' comprehension and interfere with lessons, especially in case of volumes with poor acoustics.
In this study, an experimental STI measurement campaign was delivered in a classroom measuring the sound pressure levels in several fixed positions. Results clearly indicate how the source orientation and position affect the intelligibility of the speech at receivers' locations with sensible variations from one configuration to another.

Keywords: Speech transmission index, Indoor acoustic field, Intelligibility
I-INCE Classification of Subject Number: 25

1. INTRODUCTION

The uniformity and the quality of the acoustic field within school classrooms are of paramount importance [1]. Indeed, the students' learning process depends also on how much acoustic energy is available to the receivers [2] and whether it conveys a clear sound signal without overlaps given by the reverberation [3] or disturbances from the background noise.

As a matter of fact, during a lesson, the teacher (i.e., the sound source) has to deal with the features of the space in which he is located, and is often asked to raise the volume of his/her voice [4] because the indoor acoustic field is not optimal for the sound transmission.

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In addition, the speaker changes very often his/her head's direction and position of the emission as he/she moves from the desk to the blackboard or across the classroom. Therefore, because of the natural movement of the body during a lesson, the teacher can change the directionality of the sound emission many times, and, as a consequence, the acoustic field inside the classroom related to the sound pressure may change as well.

The aim of this work is to investigate how the position and variation of the directivity of the sound source (i.e., the teacher) can influence the behavior of the acoustic field inside a classroom, through the objective measurement of the STI and L_{Aeq} parameters in different fixed positions.

2. MATERIALS AND METHODS

A university classroom was chosen as a case study, as it represents a type of closed location for which it has been demonstrated in the literature that a good internal acoustic field has a significant influence on the students' ability to learn [5]-[7].

The class is part of the Living Lab spaces within the facilities of the Free University of Bozen-Bolzano. The room is box-shaped, 7.3 m x 7.6 m x 3.6 m, for a volume of 196 m^3. It is characterized by flat surfaces with untreated concrete ceiling, linoleum floor and painted plasterboard walls; in addition, one of the side walls is composed of furniture presenting MDF panels with holes, without sound absorbing materials.

STI tests were carried out using a B&K 4720 source while a model B&K 2270 sound level meter analyzer connected to a sound card controlled by the B&K Dirac 6.0 software was used as a receiver. The receptors were placed at 1.4 m from the ground and nine positions were chosen according to the class furnishings (Figure 1), while the source positions were placed at 1.4 m (position 1) and 1.7 m (position 2).

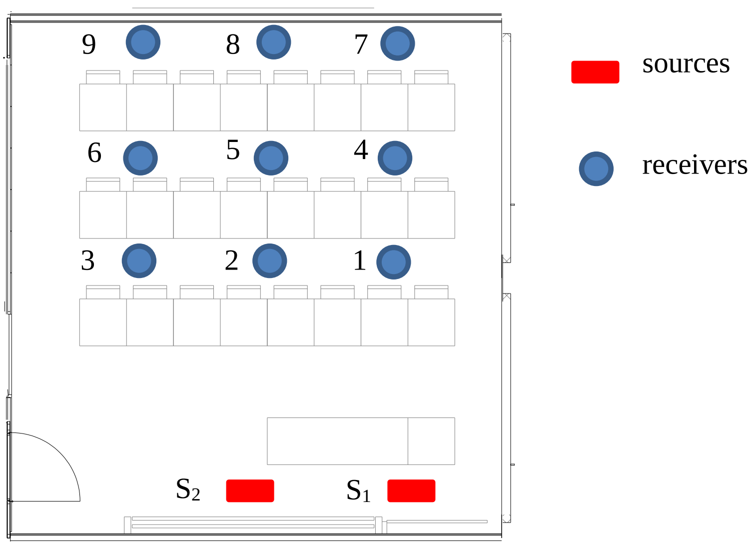

Figure 1 - Classroom layout: positions of the speech and noise sources (S1 and S2) and positions of the receivers. Usual locations of students close to the measurement points are depicted by chair occupancy.

For the measurement of the sound pressure level inside the classroom, 9 fixed omnidirectional microphones model ECM ½" 999 were used, hung on the roof of the classroom by means of a fixing system and controlled by a sound card Zoom F8. The positions are depicted in figure 1 and they are positioned at 2 meters height. The measurement chain is completed by the Multican acquisition software by MateriAcustica srl. This instrumentation was installed in the room to acquire the sound pressure levels 24 hours a day, both when in use and when there are no sources inside. This allows to understand how the internal acoustic field is modified, when the sound source (i.e., the teacher) moves, or how the background noise varies while the source is off or not present. In order to take the source movement into account, the directional noise source was first located in position S_1 (desk) and directed (i) towards the students' desks, then (ii) towards the front door and finally (ii) towards the blackboard. Then, the source was moved to the S_2 position where the three directions of emission were repeated. This will allow to measure 6 different type of emission within the classroom, simulating the teachers movements.

Figure 2 – Fixed microphones positions.

The directional source has been equipped with a male voice signal that emulates the directivity of the human mouth, using a signal with a standard level of 60 dB(A) at 1 m, which corresponds to a vocal effort considered normal [8]. This procedure will provide a repeatable and reproducible sound source.

3. RESULTS AND DISCUSSION

The STI results for source 1 are depicted in Figure 3, while table 1 shows the results by receiver.

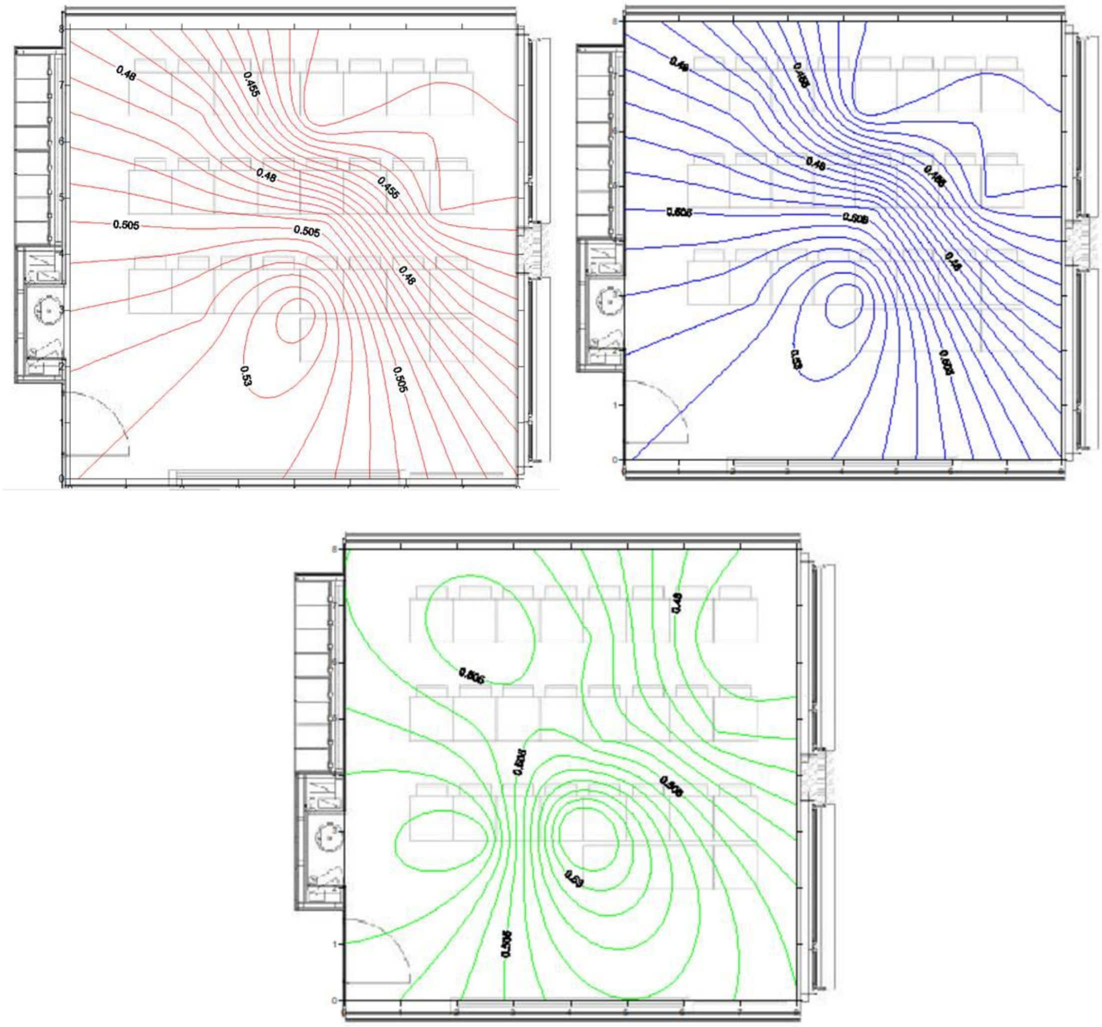

Figure 3 – STI results for different kind of source position and direction. "Student" direction in red, "door" direction in blue and "blackboard" direction in green

Table 1 – STI results for source 1

	Direction 1	Direction 2	Direction 3
Receiver	STI		
1	0.52	0.52	0.48
2	0.54	0.54	0.55
3	0.47	0.47	0.5
4	0.5	0.5	0.5
5	0.5	0.5	0.5
6	0.44	0.44	0.48
7	0.48	0.48	0.51
8	0.43	0.43	0.5
9	0.44	0.44	0.47

It is clear how, by changing the direction of the source, the intelligibility of speech changes in the various positions, even if in those near the source it remains "fair"; on the other hand for more distant positions, only the "blackboard" direction is able to maintain an acceptable degree of speech intelligibility.

As regard for the results provided by sound pressure measurements with fixed microphone stations, Figure 4 reports the three-dimensional trends of the L_{Aeq} parameter for the source S_1, calculated as the total energy produced by the male voice and measured position by position. It can be noticed that the internal acoustic field is highly not homogeneous and the change of direction of the source causes a variation in terms of sound pressure present at the receiver. In the case of the "student" direction, sudden drops in energy occur at positions 6 and 9, with differences of even more than 2 dB(A), with respect to the nearest positions. By changing the direction of emission of the source, this problem extends to position 5; negligible differences are present as regards the other positions. This shows how the directivity of the source plays a very important role in the distribution of the internal sound field and therefore also on the speech intelligibility. In Figure 5 the three-dimensional trends of the L_{Aeq} parameter for the source S_2 are reported. It is noticeable that in position 2 the level is higher due to the proximity of the sound emission point.

From the comparison between figures 4 and 5, it can be observed that the displacement of the source from the desk to the blackboard and its elevation (standing position) involves a substantial change in the acoustic field within the classroom. In particular, for positions 6 and 9 there is a considerable increase in the sound pressure level for the "student" direction and for the "blackboard" direction.

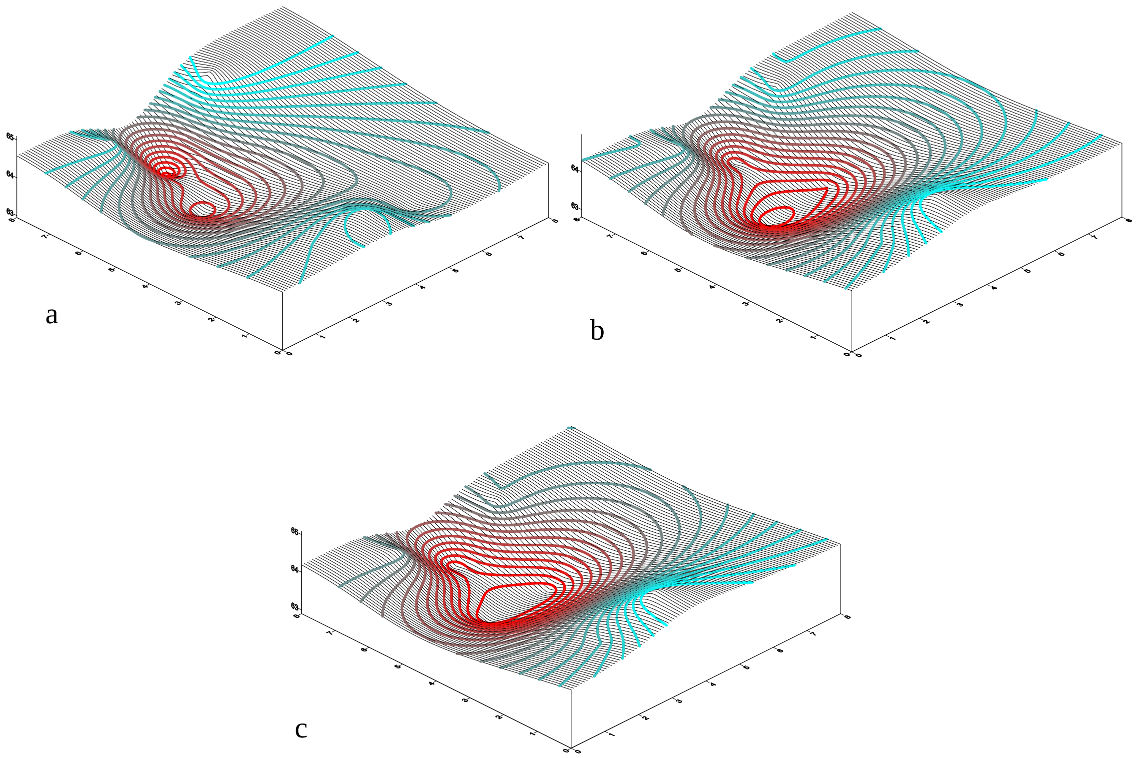

Figure 4 – Three dimensional plot of the L_{Aeq} parameter measured in every fixed microphones position for source position S_1. a) “student” direction, b) “door” direction and c) blackboard direction

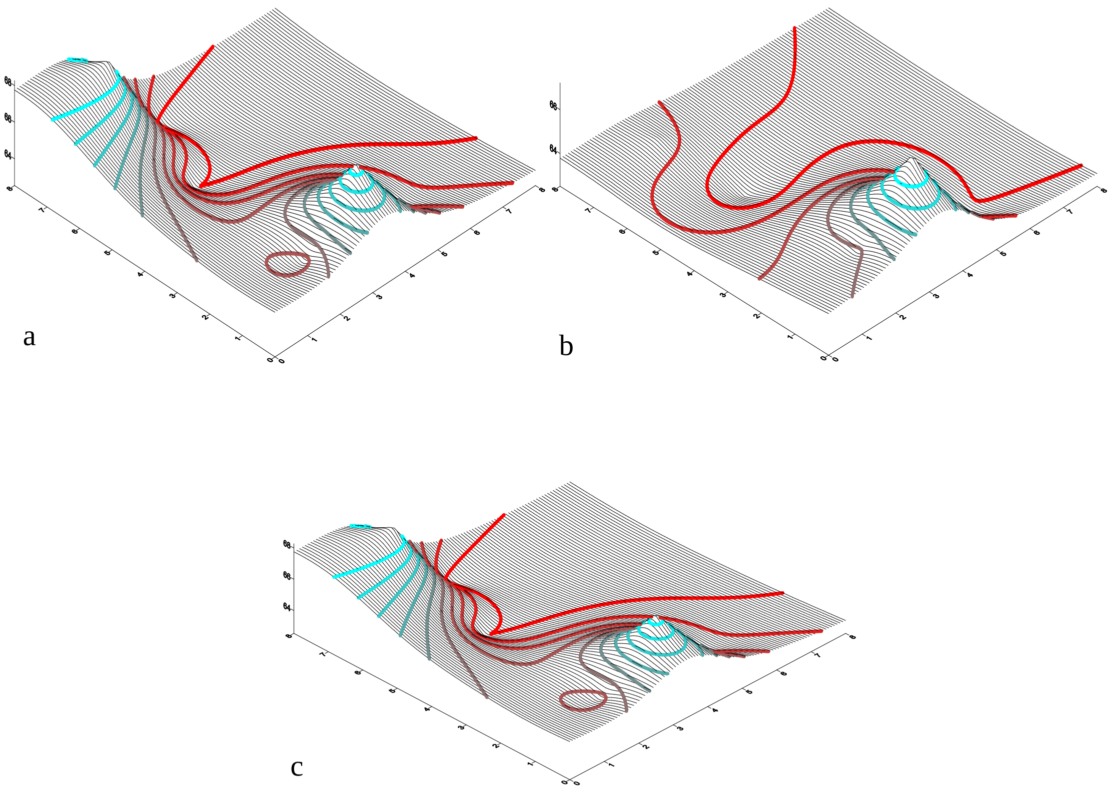

Figure 5 – Three dimensional plot of the L_{Aeq} parameter measured in every fixed microphones position for source position S_2. a) "student" direction, b) "door" direction and c) blackboard direction

A further difference is related to levels measured at positions close or adjacent to the source. Indeed, for S_1 there is no marked difference between receptor 1, 2, 3 or 4, while for position S_2 there is a substantial discontinuity between receptor 2 and the others.

Another important difference is the unevenness of the acoustic field between the different positions of the receptors. In fact, for source S_1, figure 4 shows continuous changes in levels while for position S_2 (figure 5) these changes are exclusively related to position 2 (adjacent to the sound emission) and the two directions ("student" and "blackboard") for position 8. This shows a greater homogeneity in the distribution of sound energy within the class.

4. CONCLUSIONS

In this study, the results of an experimental campaign carried out at the Living Lab of the Free University of Bozen-Bolzano were presented, focusing on the study of the influence of directivity and the position of the sound source (i.e., the teacher) in a classroom.

The final values show that both the position and the directivity influence significantly the acoustic field within the room by modifying the values of the STI parameter as well as the sound pressure level present in the various positions. These variations may even exceed 2 dB(A) from one position to the nearest one and, thus, could negative influence the speech intelligibility in the classroom.

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