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Influence of artificial mouth's directivity in determining Speech Transmission Index

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ABSTRACT

In room acoustics, one of the most used parameters for evaluating the speech intelligibility is the Speech Transmission Index (STI). The experimental evaluation of this STI generally employs an artificial speaker (binaural head) and listener (artificial mouth). In this study, the influence on the measurements of the emission directivity of the artificial mouth was investigated for different acoustic environments and we have found that, in many cases (i.e. big rooms or systems of telecommunications) the results is not sensitive to modifications of the directivity; on the contrary, inside cars, the shape of the whole balloon of directivity is important for determining correct and comparable values and the different mouth studied gives really different results in the same situation.

1. INTRODUCTION

The optimal listening conditions are very important in assessing the "comfort" of a space: intelligibility is certainly the most important when verbal communication becomes central. For example in a classroom, listening correctly to the teacher is the basic acoustical requirement.

The parameter that is able to consider all these effects is the Speech Transmission Index: the methods for determining it, exposed in the IEC standard n.60268-16:2003 [1], are based on the reduction of the modulation index of a test signal simulating the speech characteristic of a real talker, when emitted in an acoustic environment.

The test signal consists of a noise carrier with a speech-spread frequency spectrum and a sinusoidal intensity modulation at frequency F (see Figure 1), it is transmitted by a sound source situated at the talker's position to a binaural dummy head at any listener's position.

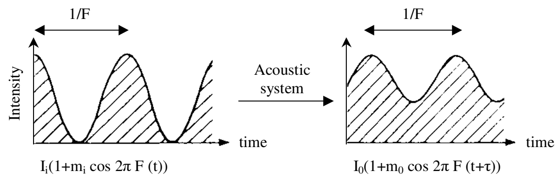

Figure 1 - Modulated signal emitted by the artificial mouth (left) and received at the listener position (right), showing a smaller modulation at the receiver.

The reduction in the modulation index is quantified by the modulation transfer function m(F) which is determined by :

$$m(F) = \frac{m_o}{m_i} \qquad (1)$$

The STI is derived from these modulation transfer functions, taking in account auditory masking, absolute hearing threshold, and the octave weighting factors given in [1]. STI goes from 1.0, when the intelligibility is optimal, to 0.0 when it's not possible to understand anything.

This kind of measurement, in some uses, is connected to the directivity of the artificial mouth, which is employed. In this study, the influence on the measurements of the emission directivity of the artificial mouth was investigated for different acoustic environments.

2. MEASUREMENTS

2.1. Artificial Mouths

We have considered different artificial speakers and tested them in the anechoic room for evaluating their directivity.

We have evaluated these three sources:
1) Brüel & Kjær mouth simulator type 4230;
2) small loudspeaker built by Boston mounted on an artificial torso;
3) wooden head built by Parma's University.

Figure 2 - Brüel & Kjær mouth simulator type 4230.

Figure 3 - Small loudspeaker built by Boston mounted on an artificial torso.

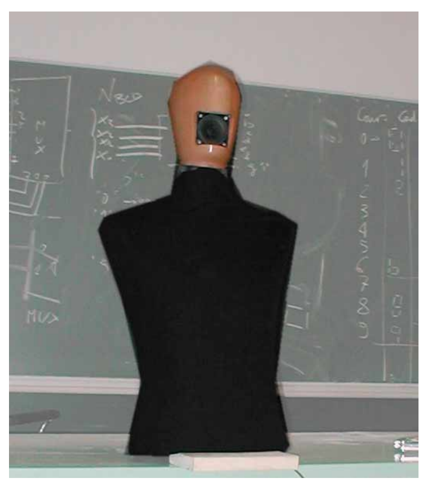

Figure 4 - Wooden head built by Parma's University.

Inside an anechoic room we have employed MLS-based impulse response, which was repeated hundredths of times, rotating the transducer by means of an automated turning table. It has been exposed in [2].

The results can be easily transformed in frequency response spectra by means of an FFT: consequently, it is possible to get the frequency response for any angle of emission or listening, and to plot polar pictures of the response in a given frequency band.

All these sources fit ITU recommendations [3], that define directivity only in few frontal positions. When comparing the directivity measurements obtained with the artificial mouth to the actual directivities of humans [4], big discrepancies were highlighted, especially in the back locations.

Here we report average directivities of real speaker and artificial ones in horizontal plane at various frequencies.

Finally all these sources have been calibrated in anechoic room so that the spectrum generated in front of the artificial mouth, at 1m distance, complies with the specification of the IEC 60268-16 code,[3].

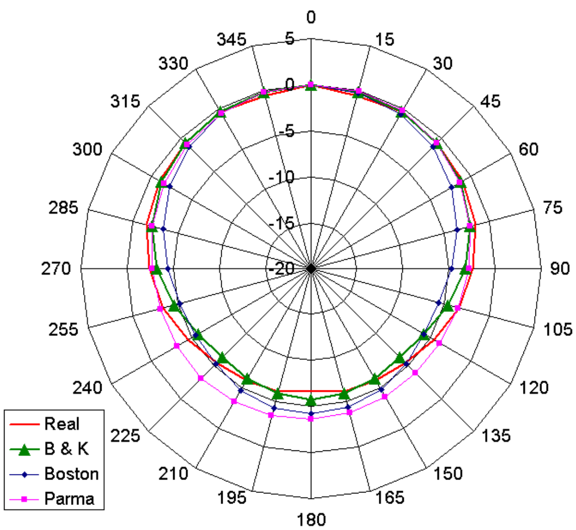

Figure 5 - Directivities of real speaker and artificial mouths at 500 Hz, horizontal plane.

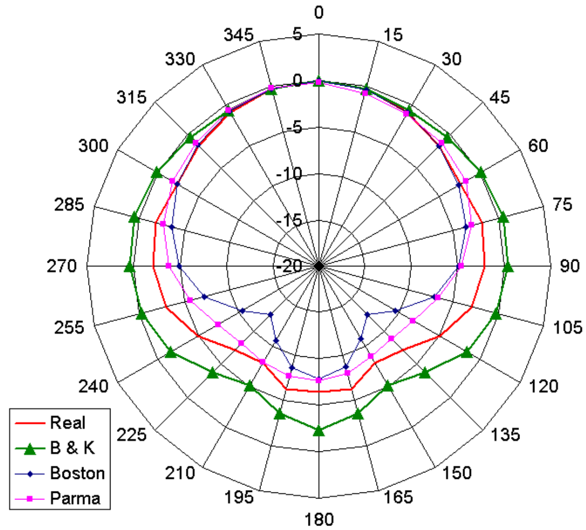

Figure 6 - directivities of real speaker and artificial mouths at 1000 Hz, horizontal plane.

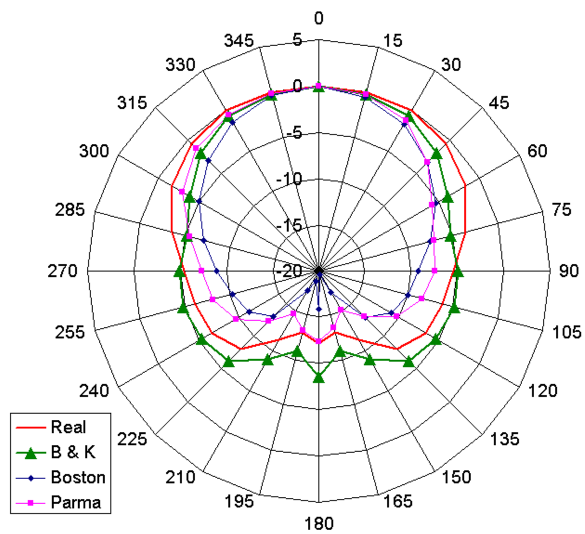

Figure 7 - directivities of real speaker and artificial mouths at 2000 Hz, horizontal plane.

2.2. Environments

We have used the three different mouths for determining the STI in three different condition:

A) a big classroom of 300 seats, with the speaker placed in teacher's position and listener in the middle of the room;

B) a small classroom of 60 seats, with the speaker placed in teacher's position and listener in the middle of the room;

C) a D-segment three-door vehicle at 90 km/h, with the speaker in the driver positions and listener in the left back seat.

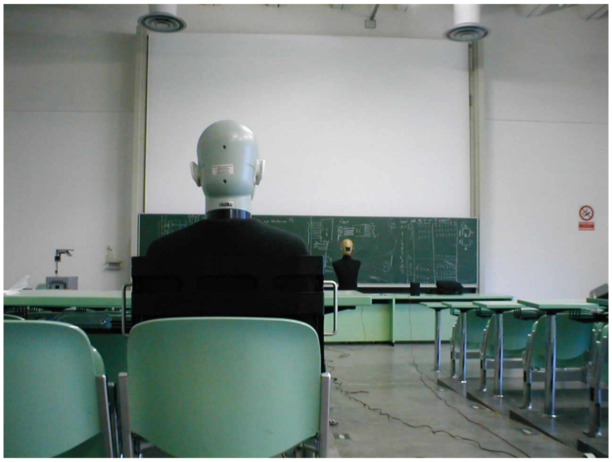

Figure 8 – Big classroom.

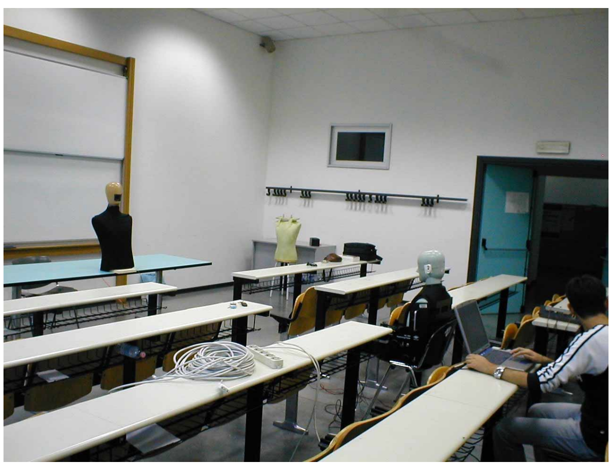

Figure 9 – Small classroom.

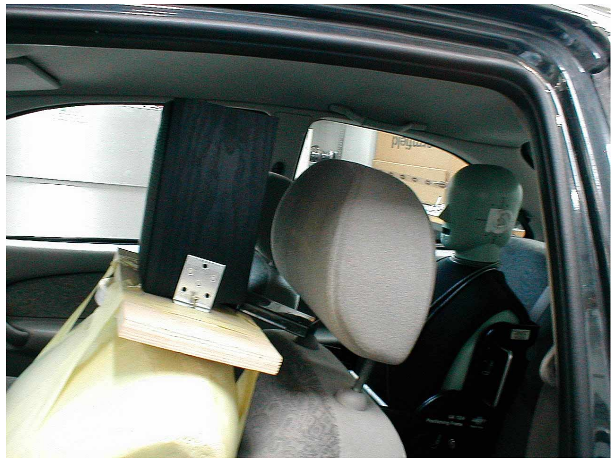

Figure 10 – D-segment three-door car.

2.3. STI

To obtain the actual STI value, we have developed a method, fully explained in [2], based on measuring the Impulse Response in absence of background noise, making use of special techniques (for example MLS or Sweep signal) for maximizing signal to noise ratio.

The STI are evaluated in the three situations with background noise. In rooms background noise has been recorded during a university lesson.

In figure 11 the results are shown.

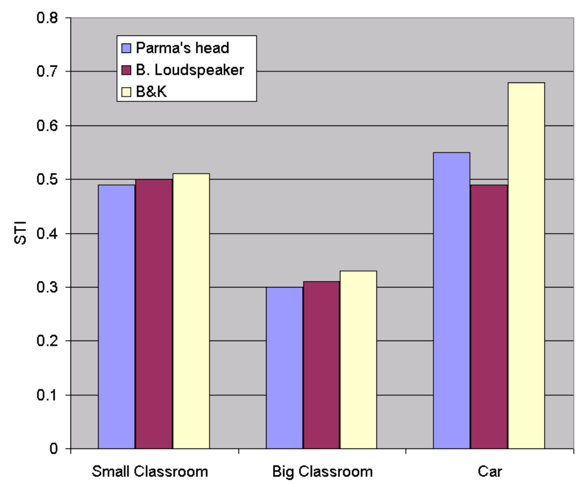

Figure 11 – STI values obtained in the three situations at the right ear.

3. CONCLUSIONS

We have found that the measurement of STI, in many uses, is not strongly connected to the directivity of the artificial mouth, which is employed. For room acoustics applications, because of the substantial distance between speaker and receiver and the numerous reflections, the directivity of the artificial mouth doesn't influence too much the result; in fact in classrooms the STI varies of only 3% using different sources.

Equally, in telecommunication acoustics, the receiver microphone is so close to the mouth that only the frontal near field affects the global intelligibility.

On the contrary, inside cars, the order of magnitude of the distance between the speaker and the listener is round one meter. Thus, only a small number of image sources are considerable and the signal emitted by the back of the speaker is as important as the signal stemming from the front; for all these reasons the whole balloon of directivity of the artificial mouth is important for a reliable assessment of the STI in the automotive field. We have noticed a STI variation of 40% changing sources.

The key point is that there are no norms that define human directivity in all directions and it produces problems of reliability in using STI in Automotive applications.

4. ACKNOWLEDGEMENTS

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