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Directivity balloons of real and artificial mouth simulators for measurement of the Speech Transmission Index

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ABSTRACT

One of the most used intelligibility's parameters is Speech Transmission Index: the technique for determining it employs an artificial speaker and listener. In many cases (i.e. big rooms or system of telecommunications) the precision of directivity of the artificial mouth doesn't influence too much the result; on the contrary inside cars, but also in other cases, the shape of the whole balloon of directivity is important for determining correct and comparable values, and different mouths give really different results in the same situation. Moreover there isn't a current standard that fixes the whole balloon of directivity of artificial mouths, but it defines only limits for some frontal position. For this reasons we have measured, in an anechoic room, the directivities of a real speaker and some artificial mouths and finally we have compared them for underlying the need of a more precise standard in this field.

1. INTRODUCTION

The optimal listening conditions inside a car compartment are of paramount importance for car makers, as this is one of the most relevant point in assessing the "comfort" of the car. One of the intelligibility's parameters that revealed to be more sensitive inside cars is Speech Transmission Index: STI, as exposed in IEC standard n.60268-16 [1], is 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 is transmitted by a sound source situated at the talker's position to a microphone at any listener's position and it consists of a noise carrier with a speech-spread frequency spectrum and a sinusoidal intensity modulation at a precise frequency. The STI is got from the reductions of modulations, taking in account auditory masking and absolute hearing threshold, and with proper octave weighting factors.

Fig. 1 – measure of STI inside a car using artificial mouth in the back seat and artificial listener in driving position

This kind of measure, in many uses, is not so strictly connected with the directivity of the artificial mouth employed: in room acoustics, because of the distance between speaker and receiver and the big amount of reflections, the precision of directivity of artificial mouth doesn't influence too much the results; 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 distance between speaker and receiver are less than 2 meters but more than few centimeters, only few image sources are considerable and sometimes (for example when the talker is in the driver position and the listener is in a rear seat) the signal coming from the back of the speaker is as important as the signal from the front; for all these reasons, the whole balloon of directivity of the artificial mouth is important for the measurement of STI inside vehicles. Otherwise there are no recent publications about real speaker's directivity and there are no norms that define it on all the directions.

2. MEASUREMENT OF ARTIFICIAL MOUTHS

The first step of this work has bean measuring the directivity of a commercial artificial mouth (Brüel & Kjær mouth simulator type 4128) and of one made by Parma University according to ITU recommendations [2] as shown in [3]. Inside an anechoic room we have employed an MLS-based impulse response measurement system [4], repeating the measurement hundredths of times, rotating the transducer by means of an automated turning table.
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.

Fig. 2 – Parma University's artificial mouth inside the anechoic chamber on a computer-controlled rotating table

Fig. 3 – Brüel & Kjær mouth simulator type 4128 on the rotating table

3. MEASUREMENT OF REAL SPEAKER

We have made use of an actor because he is able to repeat the same sentence for thousands of times without changing too much intonation, speed of speech and intensity. He has bean put inside an anechoic room, he stood up in a relaxed position and, fixing in front of him, he has repeated an Italian sentence of about 30 words paying attention to speaking without affectation. While he was speaking, two omnidirectional microphones connected to a computer measured the sound pressure level: one microphone was the reference and it was set horizontally in front of the speaker at 1 meter from the center of his head, the other one was moved all around at the same distance.

Fig. 4 – real speaker in anechoic room with two microphones for determining his voice's directivity

The directivity can be easily obtained with the difference between the equivalent sound pressure levels of the two microphones, it has been done for all the octaves where signal was present. We have measured in the horizontal plane moving the microphone with step of 10 degrees and in the other planes (30 degrees over and 30 degrees under horizontal) with step of 30 degrees, as the distance between testing positions was smaller. Finally we have considered the vertical directivity exactly over the head.

4. RESULTS

At this point of our work, we have considered the directivities in the horizontal plane only, and mainly at the octaves of 250 Hz, 500Hz, 1000Hz and 2000Hz since speech is especially present in this range. We have noticed that, even if both B&K Artificial Mouth and Parma's one fits ITU recommendations, the differences with the real speaker in some directions exceeds 5 dB, mainly in the back of the head, probably because artificial heads are made of materials with a density definitely lower than real body's one.

It's clear that there are also differences of about 5 dB between the two artificial mouths; these are due to loudspeakers and shape of the mouths.

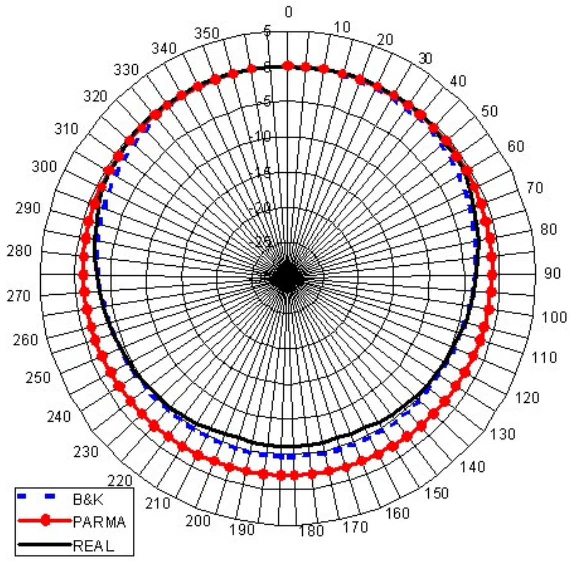

Fig. 5 – directivities of B&K mouth, Parma University mouth and real speaker at 250 Hz octave

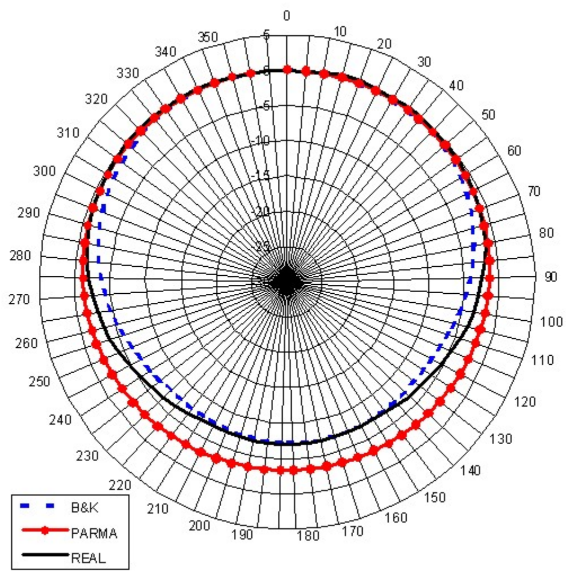

Fig. 6 – directivities of B&K mouth, Parma University mouth and real speaker at 500 Hz octave

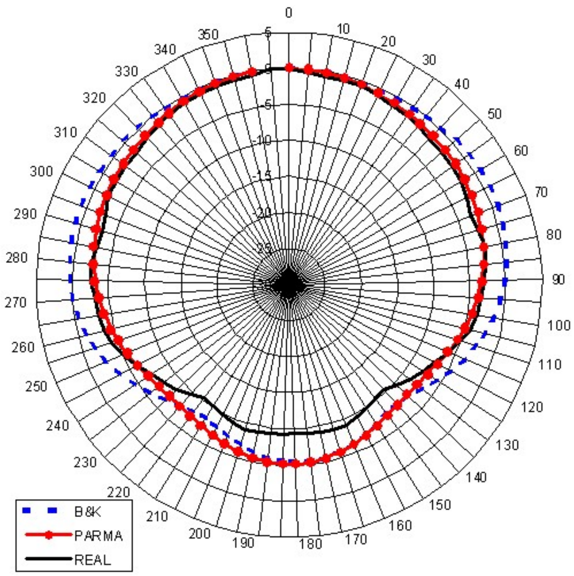

Fig. 7 – directivities of B&K mouth, Parma University mouth and real speaker at 1000 Hz octave

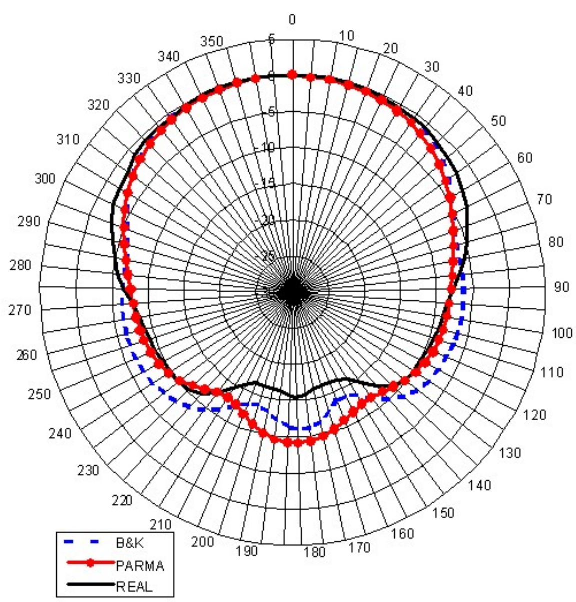

Fig. 8 – directivities of B&K mouth, Parma University mouth and real speaker at 2000 Hz octave

5. CONCLUSIONS AND FUTURE WORK

With this study we have underlined that the lack of a standard about artificial mouth's complete directivity balloon allows for sources with different behavior: in some cases this can produce different values of Speech Transmission Index, especially when the mouth's lateral and rear emission are more important than the frontal one for transferring signal from speaker to listener. We have analyzed one real speaker and in the future we have planned to study the directivities of several more real speakers in many configurations. Afterwards we'll study how much the differences between artificial mouths influence the STI measurement, employing different artificial mouths (all according to ITU recommendations), in some critical cases, for example inside cars, with speaker in the driving position and listener in the back seat.

6. ACKNOWLEDGMENT

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7. REFERENCES

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