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Measurement of Active Speech Level inside cars using throat-activated microphone

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ABSTRACT
One of the most used intelligibility's parameters is Speech Transmission Index : the techniques for determining it employ an artificial speaker and listener. When signal to noise ratio is particularly low, for example inside cars, the value of STI is mainly influenced by this ratio and measuring the emission level of real speakers is the only way for driving correctly the artificial mouth. We have implemented a technique that is based on a throat-activated microphone and it is able to find the effective level of a real speaker's voice inside a noisy space in realistic conditions. We have studied especially the speech level inside cars and we have discovered how the value defined by IEC/ITU standards may be extremely different from real one. In this way, we were able to produce test signals at a more appropriate emission level.

1. INTRODUCTION

The optimal listening conditions inside a car compartment are of paramount importance for carmakers, as this is one of the most relevant points in assessing the "comfort" of the car. Typically, "sound quality" methods were used for assessing the perceived noisiness and harshness of the background noise without taking into account the effects of internal reflections, echoes and resonances inside the cavity. The parameter that is able to consider all these effects is the Speech Transmission Index: the methods for determining it, exposed in IEC standard n.60268-16 [1], are based on the reduction of the modulation index m_o of a test signal simulating the speech characteristic of a real talker, when emitted in an acoustic environment.

The problem with this standard is that it specifies an emission level of the speech-like test signal of 68 dB(A) at 1m from the talker's lips, which appears to be an unrealistically low value for representing the effective vocal effort of real takers inside a noisy car compartment.

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

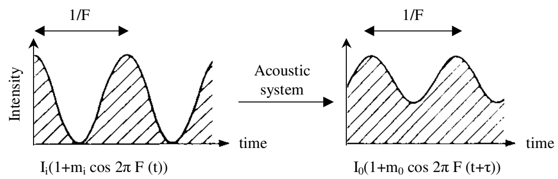

Figure 1 Modulated signal emitted by the artificial mouth (left) and received at the listener position (right), showing a smaller modulation at the receiver.

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

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

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 real m(F) can be derived calculating the modulation transfer functions m'(F) from the noise free IR, and taking into account for the effect of the background noise with the following expression:

$$m(F) = m'(F) \cdot \frac{1}{1+10^{\left(\frac{L_{noise}-L_{signal}}{10}\right)}} \qquad (2)$$

Inside cars, where background noise level is comparable to artificial mouth level, STI is highly influenced by the signal level. The IEC standard [1] fixes the signal level at 68 dB(A) at 1 meter from the lips of the artificial mouth. Using this level of the test signal we have found really low values of STI inside cars: some results are shown in the table below.

car speed (km/h)	STI
70 km/h	0.518
90 km/h	0.437
110 km/h	0.355

Table 1 STI in a D-segment five-door vehicle with the listener in the driving position and the speaker in the rear seat exactly behind the driver.

These results are badly correlated with the subjective experience of the driver, who doesn't find so hard to listen while the car is moving.

We explained this fact with the hypothesis that the real emission level of a talker inside a car is much higher than 68 dB(A) at 1m. Of consequence, we decided to study the real level of the speech in the operative conditions and to use this as the proper level of the test signal for determining a new "raised-voice" value of STI.

2. THE TECHNIQUE BASED ON THROAT-ACTIVATED MICROPHONE

With the goal of measuring the true level of the emitted speech inside a car at different speeds, we have implemented a new technique, based on the use of a throat microphone, which makes it possible to record a speech signal almost immune from the environmental noise.

The IEC standard [1] fixes an emission level of 68 dB(A) at 1 meter from the lips but it's not clear how this value is connected with the real "running" speech level: it seems reasonable to correlate it with the "Active Speech Level" of a normal conversation in a noiseless room. The following results will show that this kind of supposition is correct.

Active Speech Level is defined by ITU – T Recommendation P.56 [3]: it is measured by integrating a quantity proportional to instantaneous power over the aggregate of time during witch the speech in question is present (called the active time), and then expressing the quotient, proportional to total energy divided by active time, in decibels relative to appropriate reference. Ideally, the criterion should indicate the presence of the speech for the same proportion of time as it appears to be present to a human listener, including those brief period of low or zero power that are not perceived as interruptions in the flow of speech.

2.1. Calibration of the throat microphone

Inside an anechoic room, we have fixed the throat-sensitive microphone, with a lot of adhesive tape, on the neck of a person and we have put a microphone in front of him at 1 meter from the mouth. Later we have asked him to speak with different voice intensities and we recorded, the two signals (traditional microphone and throat–activated one) using a PC equipped with a professional Digigram sound card and with Adobe Audition software.

We have chosen a sentence to be repeated: in this case it was the Italian maxim *"Tanto va la gatta al lardo che ci rimette lo zampino"* repeated three times: this phrase is long enough and well balanced in frequency content.

Because of the big discrepancy between the frequency response of the two tracks, we have calculated an equalization filter simply making the dB-difference of the two average spectrums (when speaking at normal loudness) on the entire sentence from 80 Hz to 5kHz.

Figure 2 The speaker during the calibration procedure with a throttle-activated microphone and a classical one in front of him.

At the end we have filtered the signal of throttle activated microphone with this filter, applied the A-weighting, and, using a Matlab program, we have computeded the Active Speech Level in dB(A) of the two signals.

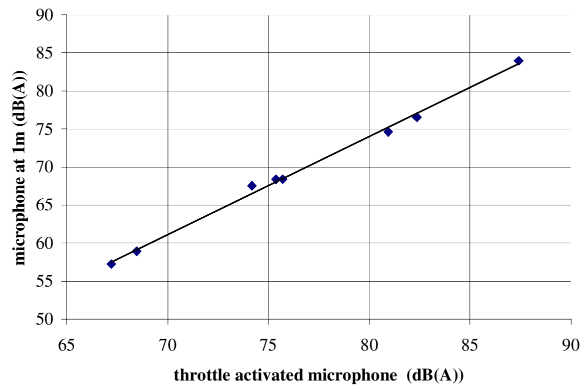

Figure 3 Active speech level of the microphone at 1m in function of active speech level of throttle-activated microphone.

It's clear from figure 3 that there is a perfectly linear dependence between the two parameters and that this chain of measurement has an error of about ±1 dB(A) .

Looking at table 2 it is clear how poor is the speaker's control of loudness of his own voice. At the same time we notice that the average level, when a normal voice level is asked, is about the 68 dB(A) required in STI norm.

voice level asked	**active speech level obtained (dB(A))**
Low	58.9 – 57.3
Normal	66.5 – 68.5 – 69.3
High	74.3 – 77.2 – 75.3
Very High	84.2 – 83.5

Table 2 Active speech level measured at 1 meter from the mouth in an anechoic room, while different levels are asked to the speaker.

3. RESULTS

Before using this technique on cars we have tested it with the same calibration (and with proper equalization filter on the throat-activated microphone) but using different sentences.

The error introduced is less than 1 dB(A) and it is comparable to the error of the chain determined before: in this way the speaker inside the car has just to speak naturally to the driver (no need to employ again the "fixed" sentence employed for the calibration).

For testing how much this system in insensible to background noise, we made a recording inside the car while the speaker wasn't talking and we have post processed it. With a background noise of 76.0 dB(A) we have found an active speech of 43.2 dB(A): there is an headroom of about 33 dB(A) that permits to use this method also inside noisy environments.

At the end, employing the throat microphone, we have measured the active speech level inside a D-segment three-door vehicle car at a speed of 110 km/h. The same subject already employed for the anechoic tests was employed, and he was asked to speak "normally" with the driver, while being seated behind him.

The measured Active Speech Level is about 75 dB(A), significantly higher than the 68 dB(A) fixed by the IEC standard.

This higher level for the speech explains why the communication inside the car is much better than what could be estimated looking at the "standard" STI values reported in table 1.If we calculate STI at 110 km/h with a signal of 75 dB(A), we find 0.57 instead of 0.36 as we have shown in Table 1.

4. CONCLUSION AND FURTHER WORK

We have implemented a technique based on a throat activated microphone, that is able to determine active speech level at 1 m from the mouths in every kind of situation. It's useful because we can use spontaneous speech in the real environments without problems of reverberation or background noise.

We have tested the system inside a car at 110 km/h and we have found an active speech level of 75 dB(A), 7 dB(A) higher than 68 dB(A) prescribed by the IEC standard.

The next step will be testing different cars at different speeds, for finding how much the speech level varies, and checking if the values of STI, determined with a source with these new levels, is able to better describe the car compartment.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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