

Acoustics in Education: Paper ICA2016-817**Speech transmission index variation due to ventilation and air-conditioning system in university classrooms**

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Abstract

A major factor to be considered in the study of teaching-learning process based on spoken communication is sound field. Excessive background noise levels or reverberation time values inside a classroom interfere with oral communication, creating an acoustic barrier to the teaching-learning process. In previous work, reverberation time was measured in a sample of university classrooms in the City of Córdoba, observing that such parameter has tripled the value recommended by international literature. Furthermore, background noise level was measured in two different conditions: heating, ventilation and air-conditioning system turned on and off. Then, these levels were evaluated according to NC and RC criteria established by IRAM 4070, where more than 50 % of the population under study complied with the NC criteria, and none with the RC criteria. Moreover, spectrum of heating, ventilation and air-conditioning system noise was observed to significantly interfere with the frequency range with greater contribution to speech intelligibility. In this paper, results of speech transmission index (STI) measurements for both conditions of heating, ventilation and air-conditioning system are presented. Such measurements were performed by the impulse response method according to IEC 60268-16, with head and torso simulator as source. Results of STI and signal-to-noise ratio obtained in both conditions are compared. Variations of up to twelve times the just-noticeable difference of STI were found.

Keywords: speech transmission index, speech-to-noise ratio, classroom acoustics

Speech transmission index variation due to ventilation and air-conditioning system in university classrooms

1 Introduction

A major factor to be considered in the study of teaching-learning process based on spoken communication is sound field. Excessive background noise levels (BNL) or reverberation time (T_{30}) values inside a classroom interfere with oral communication, creating an acoustic barrier to the teaching-learning process.

In our country, classrooms and small auditoriums that are intended for the teaching-learning process have usually been built not in accordance with acoustics guidelines, prevailing inside high sound reflection index surfaces. In previous work, T_{30} was measured in a sample of university classrooms in the City of Córdoba, observing that such parameter has tripled the value recommended by international literature [1]. Furthermore, background noise level was measured in two different conditions: heating, ventilation and air-conditioning system (HVACS) turned on and off [2]. Then, these levels were evaluated according to NC and RC criteria established by IRAM 4070, where more than 50 % of the population under study met the NC criteria, and none the RC criteria. Moreover, spectrum of HVACS noise was observed to significantly interfere with the frequency range with greater contribution to speech intelligibility.

This paper presents the results of speech transmission index (STI) and signal-to-noise ratio (SNR) measurements for both conditions of HVACS. Such measurements were performed by the impulse response method according to IEC 60268-16 [3], with head and torso simulator as source. The results of both conditions are then compared to determine the classroom sound field effects of HVACS.

2 Method

The STI and SNR measurements were performed in four university classrooms in the city of Córdoba, Argentina, where T_{30} and BNL measurements were previously made [1, 4, 2]. STI measurements were made in accordance with IEC 60268-16. The impulse response method was employed, using a Maximum Length Sequences (MLS) signal. The STI male was measured, using the MLS excitation signal with a standard male voice frequency spectrum, obtained by filtering the source signal with a male filter. Similarly, the STI female was measured, using a female filter.

The equipment used was the same as used in previous work to measure T_{30} [1, 4], except for the source. In this work, the mouth simulator included in the head and torso simulator B&K Type 4128-C was employed as the signal source. Figure 1 shows the acoustical measurement system employed.

A detailed description of the rooms under study was carried out by Cravero et al [4]. The measurement condition was: unoccupied room, doors and windows closed, and with curtains (if exist). Measurements were made one time with HVACS turned off (HVACS OFF) and then with

HVACS turned on at its maximum power (HVACS ON). In each classroom 2 source positions and 6 microphone positions were used [4], thus obtaining 48 STI values and 48 SNR values per room, 24 in each condition under study. Finally, averaging of the 24 STI values was performed for each measurement condition in each room, and similarly for SNR.

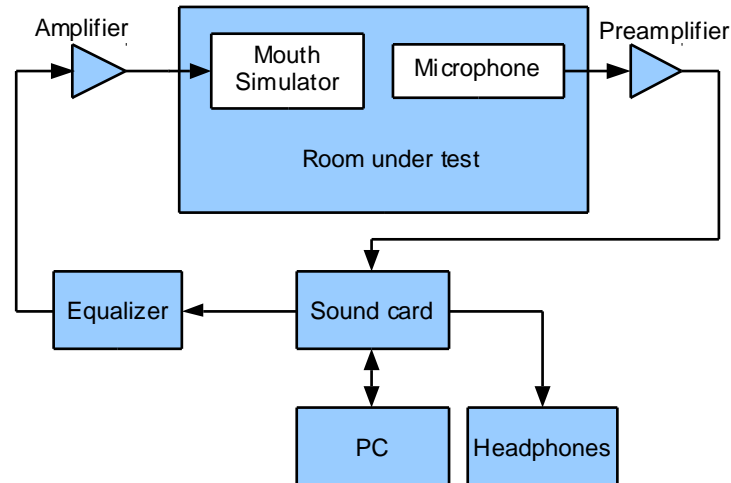


Figure 1: The acoustical measurement system

3 Results and discussions

3.1 Speech Transmission Index (STI)

Table 1 shows the STI values in each room for both HVACS conditions, the corresponding Nominal Qualification Band (NQB) value for STI [3] and the variation of the STI values obtained in both HVACS conditions, which are expressed in terms of JND, that in STI is 0,03 [5]. The IEC-60268-16 standard recommends for classrooms a NQB category D as minimum target values, which means STI values greater than 0,60. Table 1 shows that only AU011 in HVACS OFF condition complies with that recommendation.

Table 1: STI measurement results

Classroom	HVACS OFF		HVACS ON		Variation JND
	STI	NQB	STI	NQB	
AU011	0,68	B	0,51	G	6
AU154	0,57	E	0,48	G	3
AU405	0,41	I	0,13	U	9
AU608	0,43	I	0,08	U	12

The differences found between STI values measured in each condition were 3 JND in AU154, being this the classroom with minor difference, 6 JND in AU011, 9 JND in AU405 and 12 JND in AU608.

3.2 Signal Noise Ratio (SNR)

Figure 2 shows the variation of SNR in octave bands for each classroom. As shown in Table 1, classrooms most affected by HVACs are AU405 and AU608.

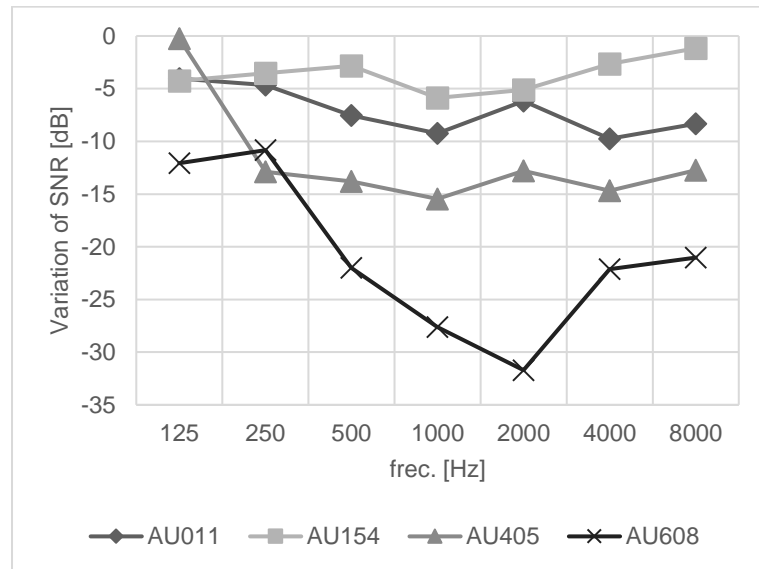


Figure 2: Variation of the SNR for both HVACs conditions.

Table 2 shows SNR measurement results for both HVACs conditions along with the SNR difference expressed in JND, taking as reference the JND in speech-to-noise ratio which is 3 dB [6]. Again, it is noted that the classrooms most affected by the HVACs operation are AU405 with a 4 JND variation and AU608 with 7 JND.

Table 2: SNR measurement results

Classroom	HVACS OFF [dB]	HVACS ON [dB]	Variation JND
AU011	12	5	2
AU154	6	2	1
AU405	6	-6	4
AU608	12	-9	7

4 Conclusions

In this work, the effects of HVACs on the objective parameters STI and SNR of the sound field in four university classrooms were analyzed. In the HVACs OFF condition only one classroom complies with the STI values recommended by IEC-60268-16 while in the HVACs ON condition no one does the same. Classrooms most affected by the operation of HVACs are AU405 with variations of 9 JND in STI and 4 JND in SNR and AU608 with 12 JND in STI and 7 JND in SNR.

Acknowledgments

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