inter•noise 96
25th Anniversary Congress – Liverpool
INCE: 66.1

AN ACOUSTICAL COMFORT CHART: A SIMPLE WAY OF EVALUATING THE SPEECH INTELLIGIBILITY INSIDE URBAN TRANSPORT VEHICLES

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In this work we're going to suggest an acoustical comfort chart. This chart describes the intelligibility degree and, consequently, the acoustical comfort, inside urban transport vehicles as a function of a few parameters depending on the noise spectrum shape and on the A-weighted noise level. In this chart a transition region separates two areas in which a state of absolute comfort or discomfort has been outlined. Within the transition region the acoustical comfort depends on the above mentioned parameters under the same speech level.
A series of subjectives tests has been performed in order to verify the theoretical curves plotted in the Chart.

1.INTRODUCTION

In a previous work about comfort [4] inside railway carriages, a relationship between the comfort level and some objective physical parameters, noise spectrum dependent, was analyzed. In particular, in order to provide an acoustical comfort expecting method, a spectrum model, similar to a low-pass filter transfer function, with a fixed cut-off frequency and slope, was adopted. In getting deeper the knowledge of the problem, a procedure, cut-off frequency and slope dependent, has been outlined with a view to extend this modelling to speech intelligibility evaluation inside the most important transport vehicles (railway carriages, buses, trams, cars).

2. CHART DESCRIPTION

The evaluation method suggested and its relative comfort chart arise from the observation that the noise spectrum produced by urban transport vehicles has a shape similar to a low-pass filter transfer function [2,4,5].

Therefore, the spectrum can be easily described by means of two parameters: the cut-off frequency and the slope. In the analyzed noise context, the cut-off frequency varies in the range between 250 Hz and 1 kHz and the slope varies in the range between 5 to 14 dB/octave.
Assuming the upper limit of 1 kHz as a reference cut-off frequency we plotted a curve providing the A-weighted noise level, slope dependent, corresponding to an assigned Articulation Index (AI), under the same speech level equal to 75 dB_{lin} (high speech level at a distance of 0.5 m).
Changing the AI value, a family of curves can be plotted (see Fig. 1b). For different cut-off frequency values, curves with the same trend but with different absolute A-weighted noise levels can be obtained. So, in order to consider as representative the above mentioned family of curves, we have to take into account the offsets existing between such representative curves and the curves with a different cut-off frequency.
Consequently, the correct sound pressure level (called "Effective noise Level") corresponding to a particular Articulation Index can be evaluated introducing a correction factor. This factor provides the offset between the reference curves and the curves relative to different cut-off frequencies as a function of the slope. The offset to be added to the measured noise level can be inferred from the curves of Fig.1a relative to the ten cut-off frequencies (125-1kHz) as a function of the slope.
Therefore, on the X-axis of the lower diagram of the Chart (see Fig.1b) appears the slope (dB/octave) and on the Y-axis appears the effective noise level (i.e., the A-weighted noise level + offset), whereas the cut-off frequency constitues a parameter in the upper diagram describing the offset as a function of the slope (see Fig.1a).
As the main purpose of this chart is to describe the rate of comfort inside urban transport vehicles, we are not really interested in furnishing an exact numerical evaluation of the Articulation Index, even though the error made in this evaluation is less than 5%. At the contrary, we are interested on a characterization of the Chart by means of regions corresponding to different degree of comfort, in terms of intelligibility. Since the index AI= 0.3 fixes the boundaries of speech intelligibility, the AI= 0.3 curve on the chart separates the region of complete acoustical discomfort from a critical region that reaches the AI= 0.5 curve, corresponding to a speech intelligibility equal to 95%. This value can be reasonably considered as the threshold of comfort. The absolute comfort can be obtained for AI values equal or greater than 0.8 corresponding to the maximum intelligibility (100%) [1].

3.DESCRIPTION OF THE METHOD

The comfort degree evaluation can be done executing a spectral analysis and infering from the noise spectrum the descriptive parameters of the chart: the effective A-weighted sound pressure level, the cut-off frequency and the slope.

COMFORT CHART

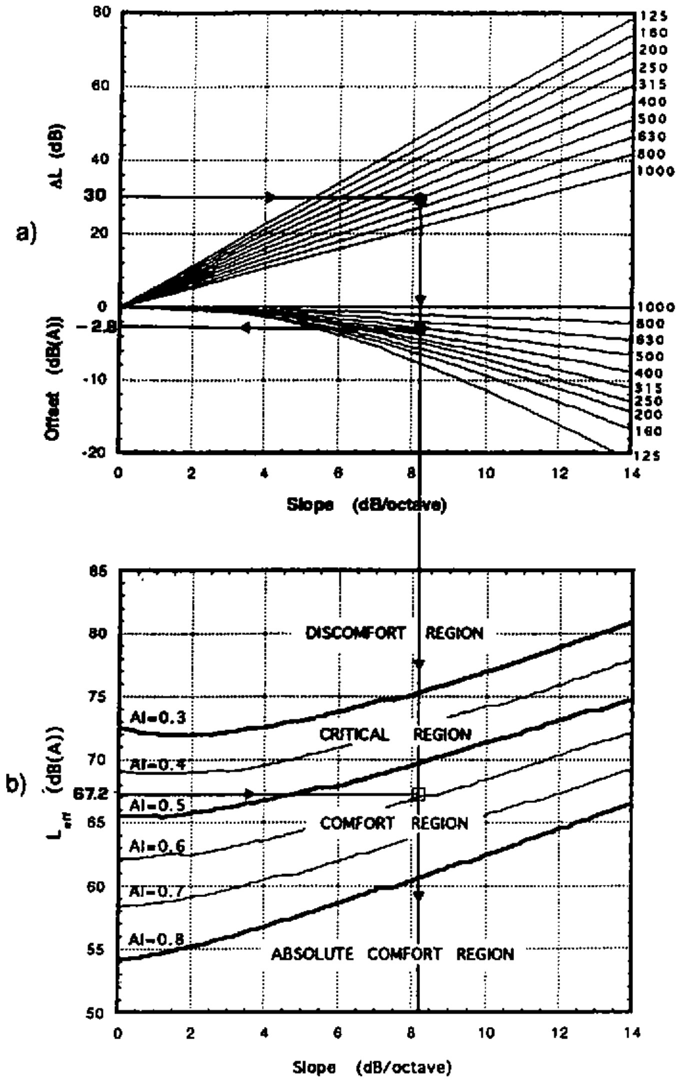

Fig.1 - a) The upper diagram provides the offset value as a function of ΔL and locates the slope value on the X-axis corresponding to an assigned cut-off frequency . b) The lower diagram represents the Comfort Chart and it provides the comfort degree as a function of the slope and of the effective overall A-weighted noise level.

The effective A-weighted level can be obtained by adding to the A-weigthed noise level an offset value, that can be deduced from the offset diagram as a function of the slope and the cut-off frequency. The cut-off frequency can be got by spectrum inspection. The slope can be simply calculated using this expression:

$$Slope = (L_{cf} - L_{6.3k}) / C_{cf}$$

where L_{cf} is the level corresponding to the cut-off frequency and $L_{6.3k}$ is the level correspondind to the 6.3 kHz one third octave band. C_{cf} is a constant depending on the cut-off frequency and reporting the number of octave bands between the cut-off frequency and the 6.3 kHz one-third-octave band. Also the slope can be rapidly evaluated by the use of a diagram that provides the slope as a function of the levels difference $\Delta L = L_{cf} - L_{6.3k}$ (see fig.1a). For example, as it can be seen by inspection of Fig. 1 , if we have a cut-off frequency equal to 500 Hz and ΔL = 30 dB, the correspondig slope is equal to 8.2 dB/octave, whereas the offset value is equal to -2.8. Now, if we imagine an A-weighted noise level of 70 dB(A), the effective A-weighted noise level becomes equal to 67.2 dB(A). This level implies an Articulation Index of about 0.6 that places the representative point in a transition region below the comfort threshold, but above the curve relative to the absolute comfort.

4.CONCLUSIONS

The results obtained using the Comfort Chart have been confirmed by experimental checking based on subjective tests [3]. The use simplicity and swiftness of the Chart make it an useful instrument to evaluate the acoustical comfort inside urban transport vehicles. Since the comfort degree depends also on absolute noise levels, we are going to correlate our Chart to this other variable too.

References

[1] I.Barducci-G.Ibba, Criteri di valutazione dei rumori (Fondazione U.Bordoni, Roma, 1970).

[2] C.M.Harris, Handbook of noise control (McGraw-Hill,1979).

[3] G.Ibba-F.Bianchi, Studio preliminare per l'adattamento alla lingua italiana del metodo delle parole rimate, Note recensioni e notizie, Anno XX N.3, 367 (1971).

[4] P.Bellucci-M.Coppi-S.Santoboni, Acoustical comfort evaluation inside urban railway carriages, 18th AICB Congress, 11-13 September 1995.

[5] J. Kaku and M.Yamashita, Impact noise from Railroads, J. Sound Vib., 120, (2), 333, 1988.

(*) This work was partially supported by ENEA (Italy).