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Behavior of the correction factor for aircraft noise façade measurements

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ABSTRACT

ISO 1996-2 standard has an appendix called Annex B which specifies the reference position of the microphone to undertake the measurement, and a simplified correction factor to use in case that the measurement must be located near a reflecting surface (3dB). Aircraft noise behaves as an extended noise source and its source-receiver geometry differs to that of other extended sources as it has an altitude. The altitude and the slant distance form a slant angle which modifies noise incidence on façade. Measurements in the reference and façade positions were performed in places with exposure to aircraft noise. Different slant angles were obtained with all aircraft noise events measured. The correction factor near a reflecting surface (3 dB) was tested through a model. With this model a relationship among the noise level in the reference position, the level in the façade position, the slant angle and the flight type was calculated. The model was tested for different scenarios and it was determined that the slant angle along with the flight type are variables that modify the ISO 1996-2's Annex B correction factor significantly.

Keywords: Aircraft Noise, Façade, Source-receiver geometry
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

Standard ISO 1996-2's Annex B states that a reference position is necessary in order to retrieve the sound pressure levels in free field conditions. However, in urban areas there are some elements present that do not allow performing the measurements without obstacles or reflecting surfaces. Hence, ISO 1996-2's Annex B proposes a correction factor of +3dB to standardize the measurements when a reflecting surface is present. Nevertheless, for aircraft noise there are factors of source-receiver geometry that modify wave incidence like the slant angle. With a greater altitude, the wave incidence changes, which could imply that the correction factor stated in ISO 1996-2's Annex B is not always +3dB. In this article it is intended to prove that the slant angle modifies the correction factor of +3 dB.

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2. METHODOLOGY

To verify the increasing value of +3dB for aircraft noise measurements performed near a reflecting surface, it was necessary to follow the procedure stated in the Annex B accordingly. This procedure states that the microphone must be placed 2m away from the reflecting surface at a height of 4m above ground. The microphone must be located far from the edges of the façade so that diffraction effects may be reduced. A reference position like the one mentioned on the Annex B was also placed in a location with a radius of 10m without obstacles to retrieve the sound field in free field conditions with a height of 6m above ground. Besides, the aircraft noise is complex as every flight path passes at a certain horizontal distance from the assessment point with a determined altitude. Therefore, in the same assessment point many different sound pressure levels may be obtained. In order to reduce the individual influence of each flight on the sound pressure levels measured on façade, a reference position is necessary. Hence, the events were measured simultaneously with two sound level meters with their respective half inch condenser microphones and their wind-screens in a configuration like the one shown seen on Figure 1.

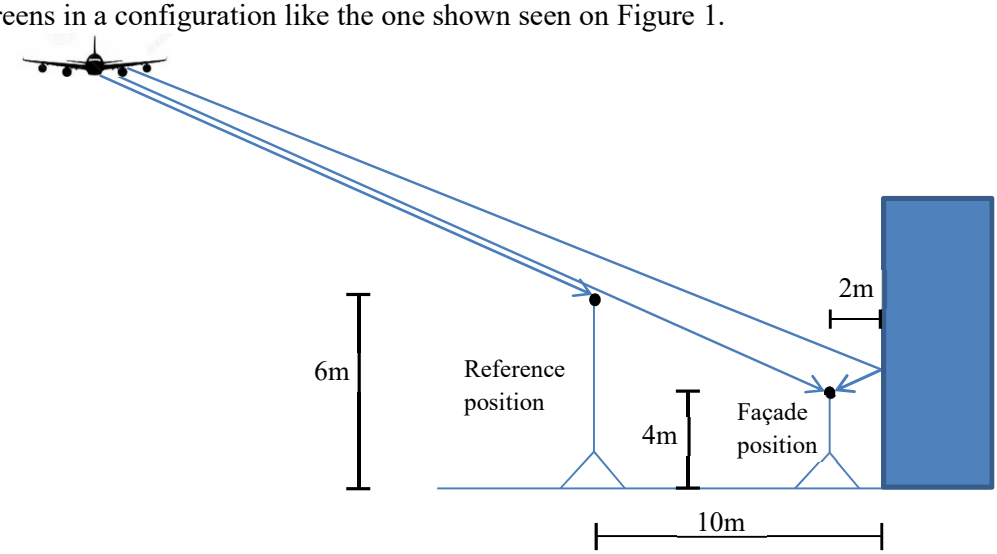

Figure 1. Configuration of reference and façade microphones for performing aircraft noise measurements.

The source-receiver geometry of aircraft noise differs from that of traffic noise as each flight path has a determined altitude and slant distance. These change the wave incidence on façade and originate another variable of source receiver geometry called the slant angle. As seen on Figure 2, the slant angle γ is formed by the shortest perpendicular distance or slant distance from the assessment point to the flight path and its altitude.

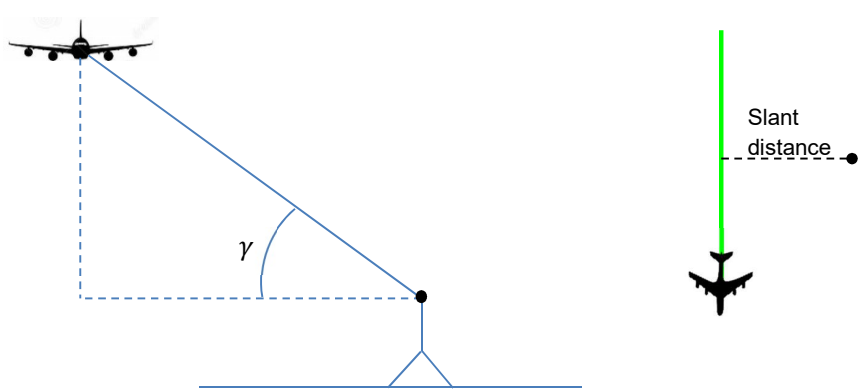

Figure 2. Slant angle

For an adequate analysis of the slant angle's influence on aircraft noise propagation it was necessary to perform the measurements in places with exposure to aircraft noise. Adolfo Suárez Madrid Barajas and Galileo Galilei airports are two international airports with daily traffic that results in aircraft noise exposure in their surroundings. With information of Madrid's strategic noise map it was determined that Mejorada del Campo, San Sebastián de los Reyes and Algete are cities that report sound pressure levels greater than 60 dBA. Pisa is another city in which aircraft noise is present in locations nearby as the airport Galileo Galilei has daily traffic. The ideal reference position for retrieving the sound pressure levels in reference position was the rooftop of the building in which the assessment point was located. However, for safety regulations, the personnel of the premises in which the measurements were performed did not always allow placing the reference position in the rooftop. The only location in which it was possible to place the microphone in the rooftop was Pisa. On Figures 3 and 4, the main flight paths around Adolfo Suárez Madrid Barajas and Galileo Galilei airports are shown in Madrid and Pisa respectively.

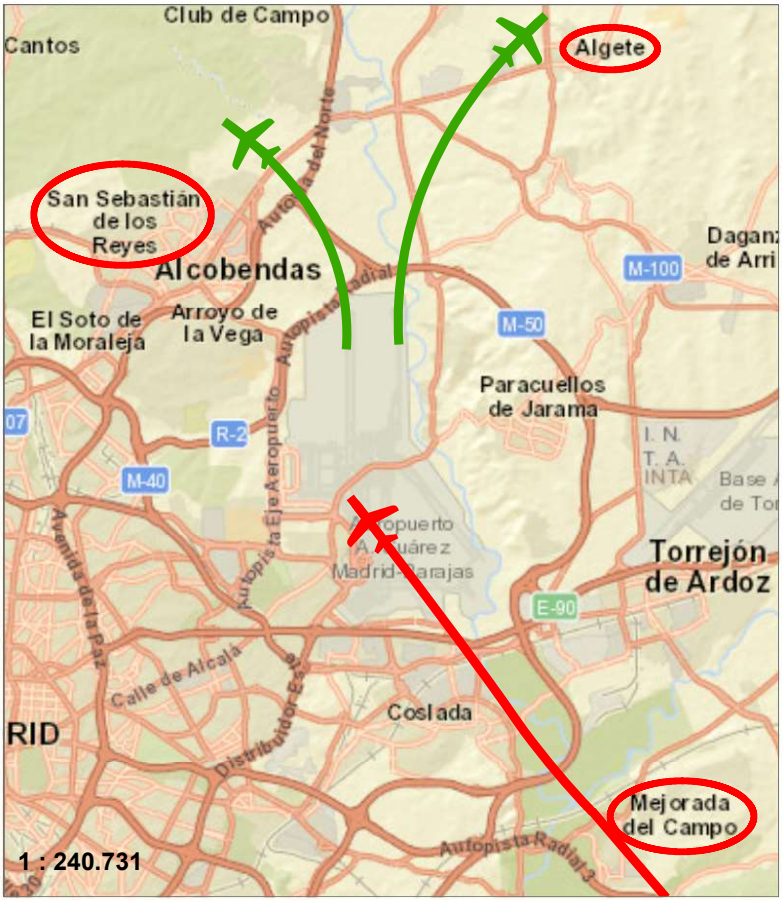

Figure 3. Main flight paths of Adolfo Suárez Madrid Barajas airport

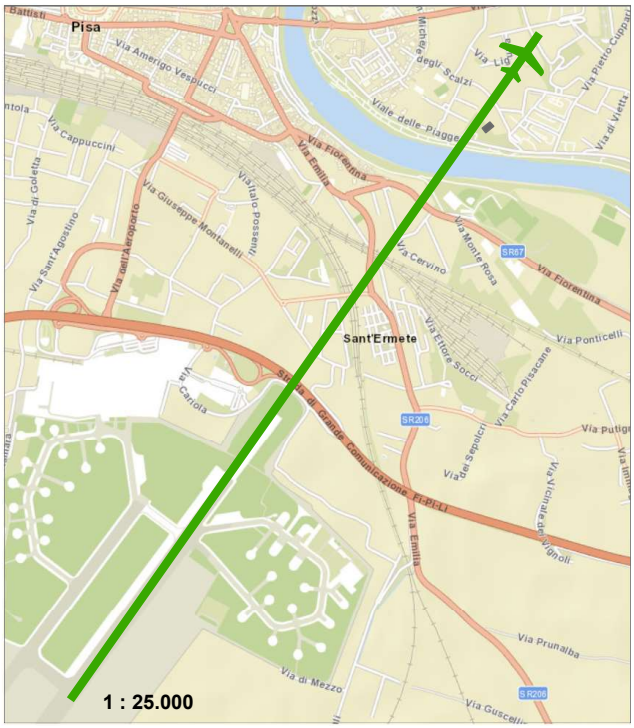

Figure 4. Main flight paths of Galileo Galilei airport at Pisa

The assessment points were chosen according to the criteria stated in ISO 1996-2's Annex B. The façades were required to have a minimum line of sight angle of 60º to the flight paths and the events were obtained in different assessment points to gather as many slant angles as possible. The main flight paths and assessment points in which the measurements were performed for each city are shown on Figures 5-8, the reference position is shown as a blue star and the façade positions are shown as red stars, whereas the takeoffs and landings are depicted as green and red lines, respectively.

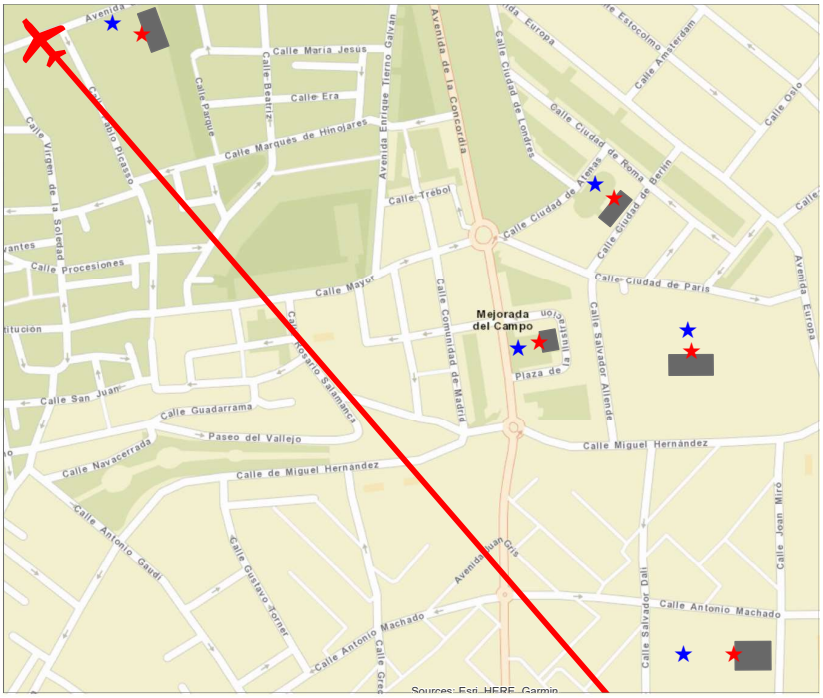

Figure 5. Most common flight paths and assessment points on Mejorada del Campo

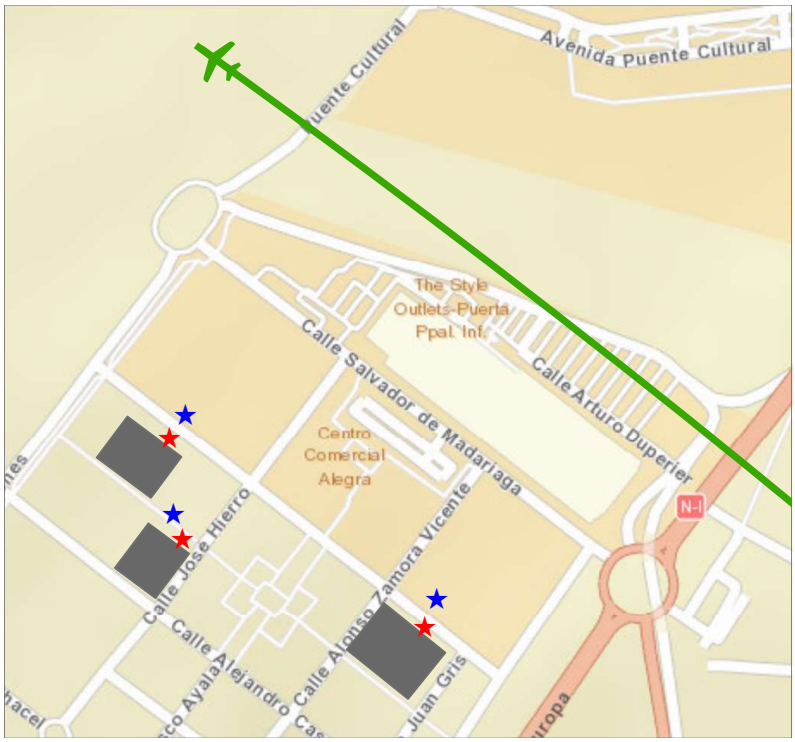

Figure 6. Most common flight paths and assessment points on San Sebastián de los Reyes

Figure 7. Most common flight paths and assessment points on Algete

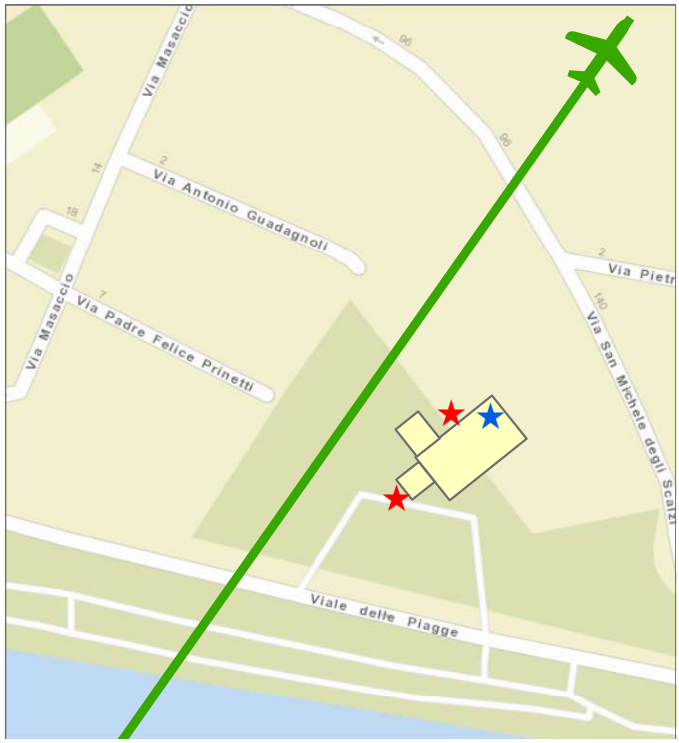

Figure 8. Most common flight paths and assessment points on Pisa

It was necessary that the events could be distinguishable from the background noise so that the influence of other noise sources could be isolated. Once the data was gathered, it was processed in compliance with the criteria stated in ISO 20906 which remarks that aircraft noise events must be discriminated from the background noise with a difference of 10 dB from the peak level of the event. Notes were taken while performing the measurements so that the noise produced by other unwanted sources could be removed. The information of the flight paths like the altitude and the slant distance was obtained with the aid of Bruel & Kjaer's Webtrak for Madrid and the information of the flight paths at Pisa was obtained with the aid of the ADS-B signals retrieved from the transponder. These data allowed obtaining the slant angle and all events were arranged in a database with the sound exposure levels (SEL) of the events measured in the reference and façade positions with their respective slant angles, and flight types (takeoff/landing). All events were analysed with a multiple linear regression test. In which the sound exposure level measured in façade was the dependent variable, and the sound exposure level in the reference position, the slant angle and the flight type, were independent variables with the goal of obtaining a model like the one shown in the Equation 1.

$$L_{EA\,façadei} = L_{EA\,referencei} + \varepsilon_{\gamma} + \varepsilon_{ft} \quad \text{Equation 1}$$

$L_{EA\,façadei}$ represents the sound exposure levels of the -ith aircraft noise event measured on façade and it is the dependent variable. $L_{EA\,referencei}$ represents the sound exposure level of the -ith aircraft noise event measured on the reference position, ε_{γ} and ε_{ft} represent the effects of the slant angle and the flight type respectively. All

variables are quantitative, except for the flight type, which is a dummy variable (takeoff-0, landing-1).

3. RESULTS

With a total number of 942 events, the linear regression analysis was performed. The assumptions of linear regression were tested and the model fulfilled all of them. All the variables considered proved to be significant in this analysis for aircraft noise propagation, the residuals followed a normal distribution and homoscedasticity was present. Besides, a linear relationship was shown when plotting the sound exposure levels on the reference position vs the sound exposure levels on the façade position as seen on Figure 9. This means that the sound exposure levels in the reference position increased when increasing the sound exposure levels in the façade position.

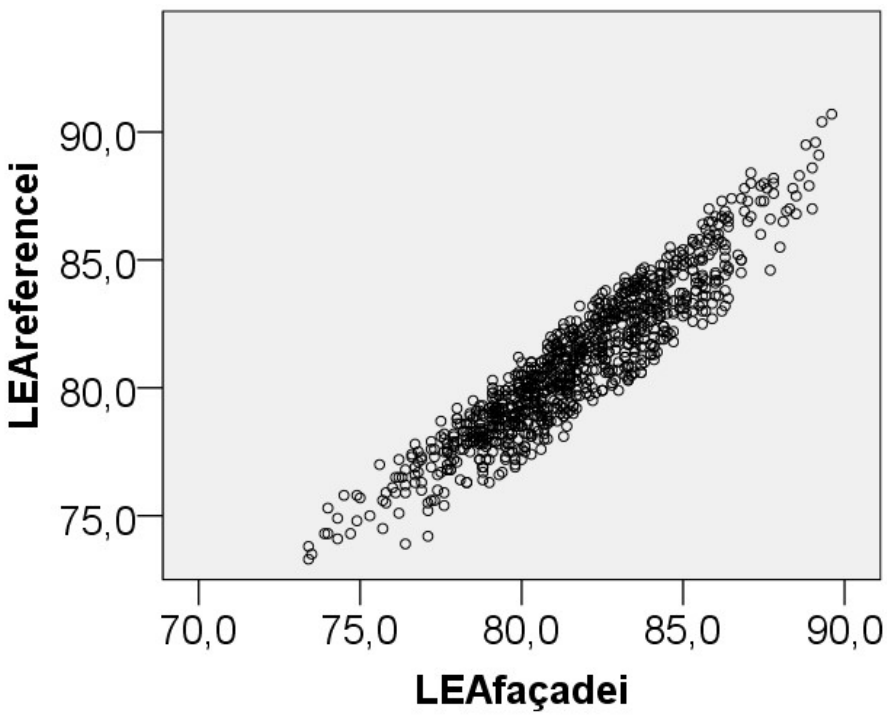

Figure 9. $L_{EA\,referencei}$ *vs* $L_{EA\,façadei}$

The model obtained is shown on Equation 2

$$L_{EA\,façadei} = 0{,}972 L_{EA\,referencei} - 0{,}017\gamma - 0{,}898 ft + 4{,}465$$

Equation 2

The variable γ represents the slant angle and the variable ft represents the flight type. The adjusted coefficient of determination $\overline{R^2}$ 0,92 which means that this model explains 92% of the variance. Therefore, this model provides enough information to explain the behavior of aircraft noise on façade regarding the slant angle and the flight type. When the slant angle increases, the correction factor decreases,

particularly when the slant angle gets close to 90º. Whereas when the slant angle decreases to values within the range of [20º-50º] the correction factor reaches greater values up to 4 dB. This happens because when increasing the altitude of the flight paths, the wave incidence is modified and reflections on façade are barely produced. On the other hand, when the slant angle decreases, more reflections are produced resulting in an increase of the sound exposure levels produced on façade.

4. CONCLUSIONS

Aircraft noise propagation differs from that of other sources as the elevated source changes wave incidence resulting in different sound exposure levels produced on façade. Particularly the flight path slant angle is a parameter of source receiver geometry that influences the wave incidence directly. The correction factor of +3 dB stated on ISO 1996-2's Annex B is intended to be used for standardizing the measurements with respect to the values obtained in the reference position. However, there are other variables present in urban environments and in the source-receiver geometry that do not allow obtaining an increase of +3 dB in the values of sound pressure levels measured in reference conditions. The variable flight type is a simplification of the types of aircraft operations that are present in an airport's daily movements. If this variable is removed from the analysis, the coefficient of determination does not decrease substantially. However, it was proved to be a significant factor in the analysis performed. Therefore, it could be used whenever takeoffs and landings are found on the same assessment point. The model presented here could be a useful tool for acoustic technicians performing measurements in field work as it is based on statistical samples and average values that could result in a reasonable approximation to the values obtained in free field conditions.

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