ASSESSMENT OF SOUND PROPAGATION FOR THE URBAN AIR MOBILITY

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ABSTRACT

The noise generated by vertical take-off and landing vehicles (VTOL) operating in urban environment is a determinant factor for the community acceptance. The ray tracing method often used for predicting road and railway noises in urban areas is applied to the Urban Air Mobility context. In densely populated urban area, the multipath of sound wave occurs due to numerous reflections on the building's walls. Such a configuration generates both constructive and destructive interferences, given rise to a complex shape of the spectra that can be difficult to explain. To assess ray tracing codes applied to the VTOL configurations, simple test cases such as a corner and a canyon based on image sources are proposed. The prediction is performed in octave bands in the frequency range 63 Hz to 8 000 Hz, including an acoustical source at high altitudes to account for the VTOL flight. On the whole, a good agreement is obtained between the reference solution derived from the image-source and the ray tracing technique. In particular, close to the corner an increase of about 8 decibels can be observed *vs* the free field. When both the source and the microphone are in the canyon, an increase up to 14 decibels is found.

Keywords: *drone, ray-method, urban area, corner, canyon.*

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1. INTRODUCTION

The use of VTOLs, including drones, is developing for various missions such as land use planning, prevention, natural risk management and surveillance of sensitive areas. In the future, drone hubs are also envisaged to serve cities. The objective here is to offer new services such as the transport of parcels to individuals, while improving the environmental footprint by reducing CO2 and replacing road vehicles by drones, with a payload of a few kilos to several hundred kilos. This development of drone traffic in urban areas is accompanied by the need for an analysis of acceptability with regard to the societal sphere, which depends on many factors, including the noise disturbance. It is therefore necessary to analyze acoustic propagation in urban areas, typically at the scale of a neighborhood. This communication presents cases of acoustic propagation based on simple academic configurations. This makes it possible to calculate multiple reflections on buildings and to determine the order of magnitude of spectral changes, relative to the free field. Through the comparison with the reference cases, we can also evaluate the ray tracing code, dedicated to road noise in urban areas and implemented with the noise sources of the VTOLs at high altitudes.

2. CONTEXT

To characterize the influence of buildings, among the various propagation methods (modal methods [1], BEM [2], Euler [3], LBM [4]), the rays method is chosen. The high-frequency approximation of the rays is legitimate here, where most of the acoustic wavelengths generated by the drone source are smaller than the typical dimensions of the buildings. However, for the lower frequencies less than a few tens of hertz, the ray tracing is no more valid and the acoustic wave propagation equation has to be solved.

Recently, ONERA [5] conducted an initial study to characterize acoustic propagation in urban areas using Mithra, a ray code developed by CSTB [6]. Like other commercial software, Mithra offers an efficient algorithm to quickly compute the numerous reflections of the rays in a complex 3D urban environment and a useful interface for modeling a realistic neighborhood. Propagation from a source at 500 feet above the Airbus Helicopters site in Marignane was determined. Figure 1 illustrates the spectra normalized by the free field plotted in decibels and determined in octave bands at two different locations in the Airbus Helicopters site. Far enough from the buildings (receiver MIC1), a standard pattern is observed with a destructive interference between incident and ground reflected fields, while closer to the walls (receiver MIC8), the shape of the spectrum is more complex to analyze.

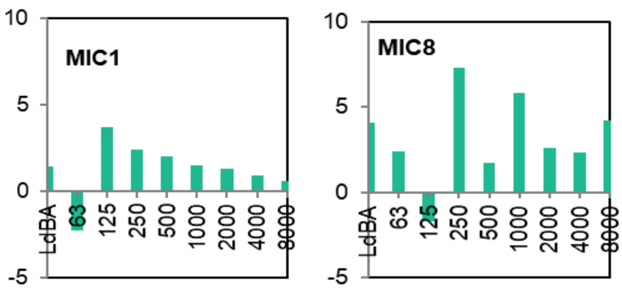


Figure 1. Spectra in octave bands normalized by the free field. Receivers placed on the Airbus Helicopter site [5].

3. POINT SOURCE ABOVE A CORNER

3.1 Reference case

For the reference case, the corner is built by the intersection of two infinite planes P1 and P2 (see Fig. 2). This configuration of propagation over a corner involves multiple reflections by the ground and the wall. The total pressure p_t comes from the contribution of four sources: the incident pressure p_i from the main source S and the three reflected pressures p_j from the image sources S_j, constructed by symmetries with respect to the planes P1 and P2.
The total pressure p_t is referenced by the incident pressure p_i and is plotted in decibels: we set $F(dB) = 20\log_{10}|p_t/p_i|$.
Figure 3a illustrates the complex pattern of interference generated with a pure frequencies emission (similar results are obtained using an approach based on the multipath from the wall reflections [8]). In Figure 3b, as expected, the octave bands emission smooths the interference pattern and significantly modifies the shape of the spectrum. As a result, only one destructive interference at 1 kHz remains in the octave bands spectrum, compared to the pure frequency one.

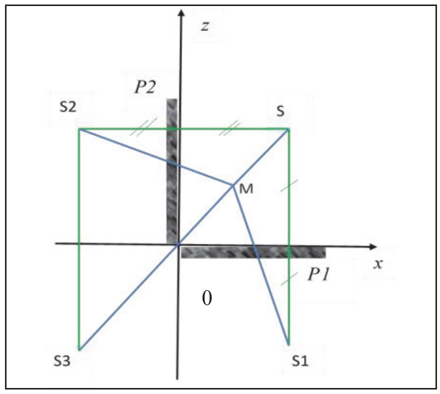
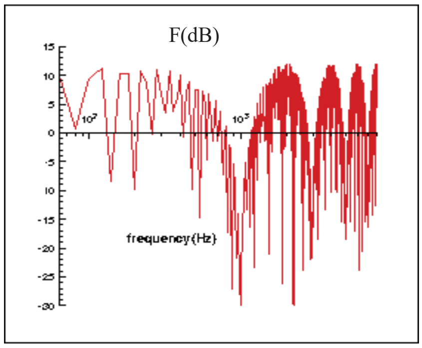
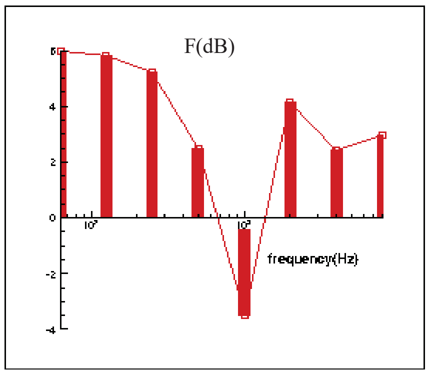


Figure 2. Modelling of the propagation in a corner. Main source S and image sources S1, S2, S3.



a) Pure frequencies emission [63 Hz – 8 kHz]



b) Octave bands emission [63 Hz – 8 kHz]

Figure 3. Propagation in a corner. Source (x = 700 m, y = 0, z = 30 m), receiver (x = 3 m, y = 0, z = 2 m).

3.2 Ray method

In the ray simulation, the corner is modelled by the intersection of a horizontal plane and a building with a height of 300 m, length of 800 m and width of 200 m (*i.e.*, large dimensions with respect to the wavelength and the source elevation). Figure 4 shows the local modification of the wave fronts close to the wall of the building.

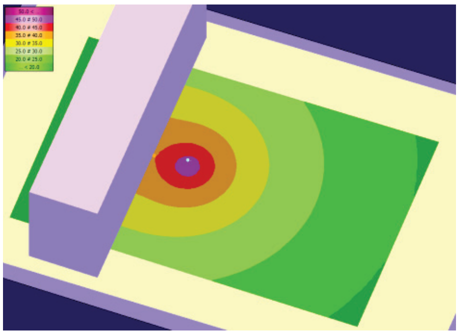
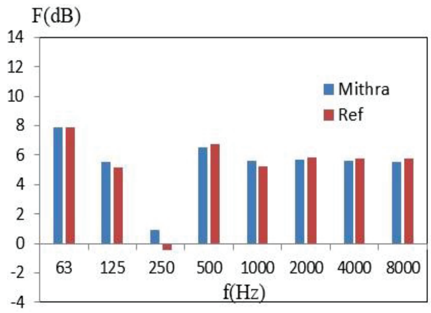


Figure 4. Pressure field in dBA above the ground in the vicinity of a corner. Source (x = 100 m, y = 0, z = 30 m).



Microphone (x = 4 m, y = 0, z = 1.20 m)

Figure 5. Propagation above a corner. Source (x = 100 m, y = 0, z = 30 m).

Figure 5, where the receiver is at z = 1.2 m above the ground and at a distance 4 m from the building, shows a good agreement between the reference and the ray method, with the appearance of a destructive interference at 250 Hz.

4. POINT SOURCE IN A CANYON

4.1 Reference case

The canyon configuration can be encountered in urban site when two buildings are close from each side of a street. The reference solution is represented by a source and a receiver placed above the ground between two parallel planes P1 and P2. The walls of the buildings are supposed to be perfectly reflective and of infinite dimension. Figure 6 shows the section of the canyon in the $(0, y, z)$ plane. The length of the canyon along the axis ox is assumed to be infinite. Again, the total field p_t is determined by the contribution of successive image sources between the two planes P1 and P2, and by the symmetry with the ground, according to nr the order of assumed reflections. Finally, $ns = 2(nr + 1)$ sources are considered.

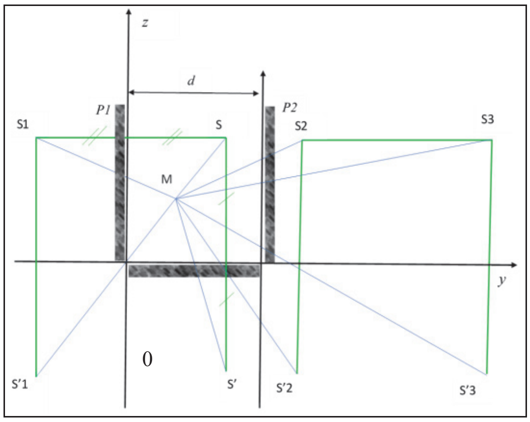


Figure 6. Propagation in the canyon by construction of image sources with respect to P1, P2 and the ground.

4.2 Ray method

For the modelling of the canyon above the horizontal plane, two parallel buildings of height 300 m, length 300 m, width 50 m and distant d = 30 m are considered. Figure 7 shows the calculation in the presence of the canyon.

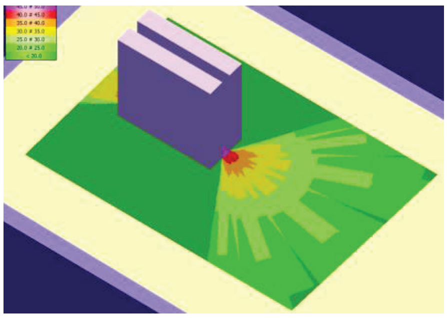
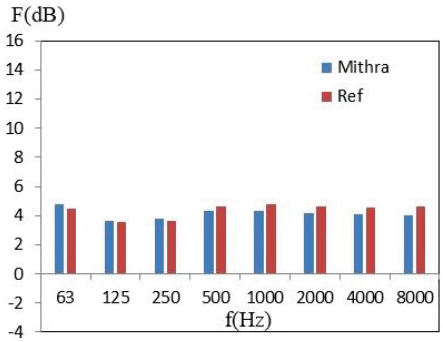
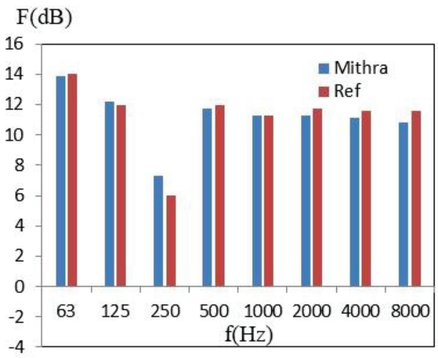


Figure 7. Pressure field in dBA above the ground radiated by a canyon. Source (x = 0, y = 20 m, z = 30 m).

It is observed that the acoustic field propagates in the canyon via the creation of a channel and then radiates by the two open ends, with pronounced diffraction effects by the edges of the walls.



a) Source (x = 0, y = 20 m, z = 10 m), microphone (x = 0, y = 10 m, z = 1.2 m)



b) Source (x = 50, y = 20 m, z = 10 m), microphone (x = -50, y = 10 m, z = 1.2 m)

Figure 8. Sound pressure in the canyon.

Figure 8 shows a very satisfactory comparison between the the reference case and the ray solution, where both the source and the receiver are placed inside the canyon. One notes a significant increase in the effect of the acoustic channel, reaching here 14 decibels when receiver and source are distant from 100 m (Fig. 8b), compared to 4 decibels when they are both in the same plane $x = 0$, in the middle of the buildings (Fig. 8a).

5. CONCLUSION

Simple reference cases based on image sources, including multiple acoustic reflections and a source at high elevation, were presented. The results allow us to appreciate the order of magnitude of the changes generated by the urban environment relative to the free field configuration. An overall good agreement is obtained between the ray method and the reference cases. The acoustic propagation applied to Urban Air Mobility is a very complex problem where additional steps are required. First to validate the ray-method with buildings of finite heights and less than the source elevation, then to examine the case of acoustic sources in motion, and to model the aerology for the ray propagation, to accurately take into account the wind and temperature gradients around the buildings.

6. REFERENCES

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