Auralization of aircraft noise in an urban environment

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Summary

Aircraft noise can cause annoyance and sleep disturbance. In order to obtain a good impression of annoyance one should predict the audible aircraft sound and determine the impact of the sound on people.

The goal of this project is to develop a tool for the auralization of aircraft noise in an urban environment where reflections and shielding can play an important role.

Introduction

Aircraft noise can cause annoyance and sleep disturbance. Currently, annoyance and sleep disturbance are predicted using indicators based on time-averaged sound pressure levels. To obtain a better representation of annoyance the audible aircraft sound should be predicted in order to determine the impact of the sound on people.

Figure 1: Aircraft taking off from Zurich airport.

Auralization is a technique to artificially create the aural aspects of an object or surrounding. Auralization can therefore be used to create audible aircraft sounds that can be used in listening tests to determine the impact of aircraft noise on people.

Goal and methods

The goal of this project is to develop a tool for the auralization of aircraft noise in an urban environment. The tool should provide plausible auralizations of aircraft noise for typical urban situations where reflections and shielding can play an important role.

The project is divided into three phases:

1. Development of a sound generator to **synthesise aircraft noise** audio signals;
2. Design of a time-varying digital filter to **model sound propagation** in an urban environment for highly elevated and distant sources;
3. Development of an Ambisonics **sound reproduction** system suitable for aircraft noise.

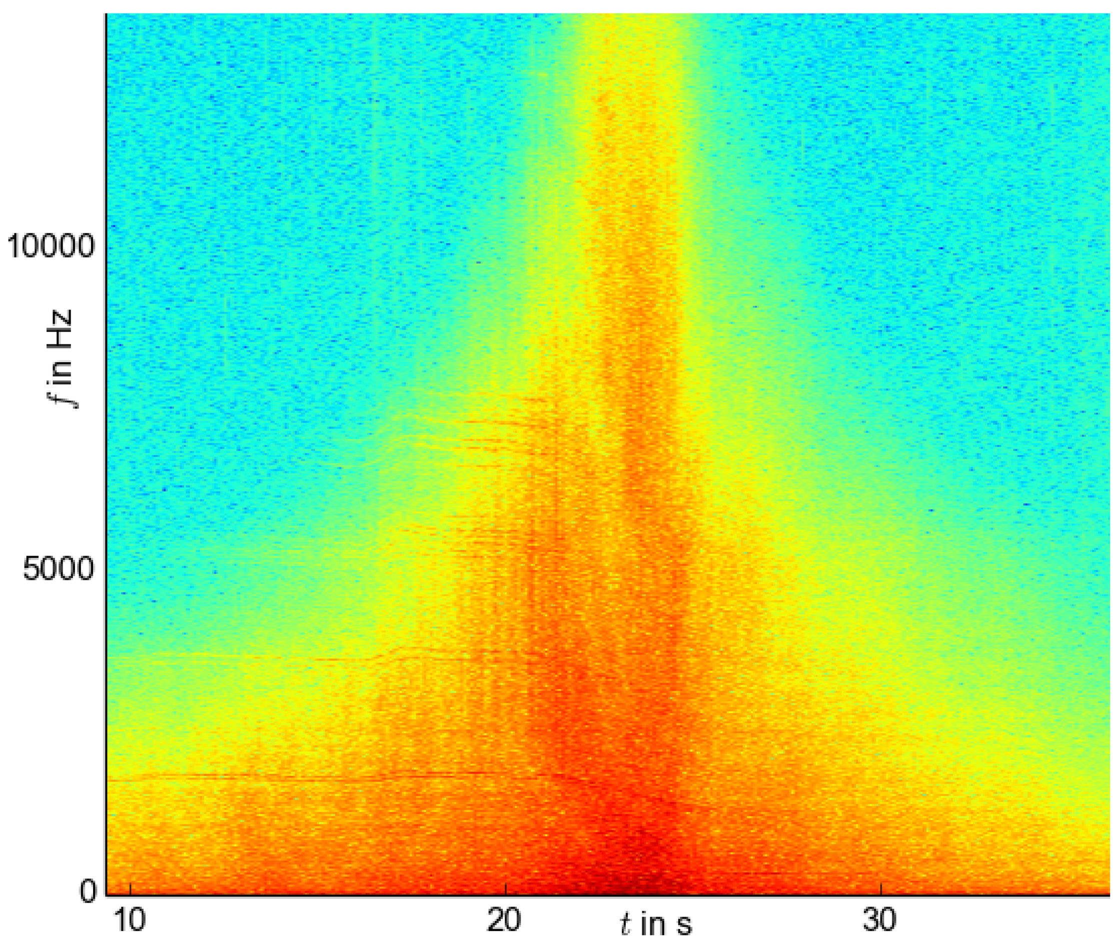

Figure 2: Spectrogram showing the sound pressure level as function of time and frequency.

Source model

The source model describes the emission of the aircraft. Major noise contributors when considering aircraft noise are the fan, turbine, jet, combustion chamber and the airframe [1].

The aircraft will be modelled as one or multiple point sources. The emission of each point source will be modelled as bandpass filtered noise and tones. Each of these spectral components can have a unique directivity pattern.

The source model will be an empirical model based on sound recordings of aircraft fly-overs. An inverse propagation model shall be used to obtain a better estimation of the emission.

Propagation model

The propagation model describes the propagation of the sound from source to receiver. The propagation model currently supports:

- **spherical spreading** resulting in a decrease in sound pressure with increase in source-receiver distance;
- **Doppler shift** due to relative motion between the moving aircraft and the non-moving receiver;
- **atmospheric absorption** due to relaxation processes;
- **reflections** at the ground and façades due to a sudden change in impedance.
- **modulations and decorrelation** due to fluctuations in the effective soundspeed caused by atmospheric turbulence.

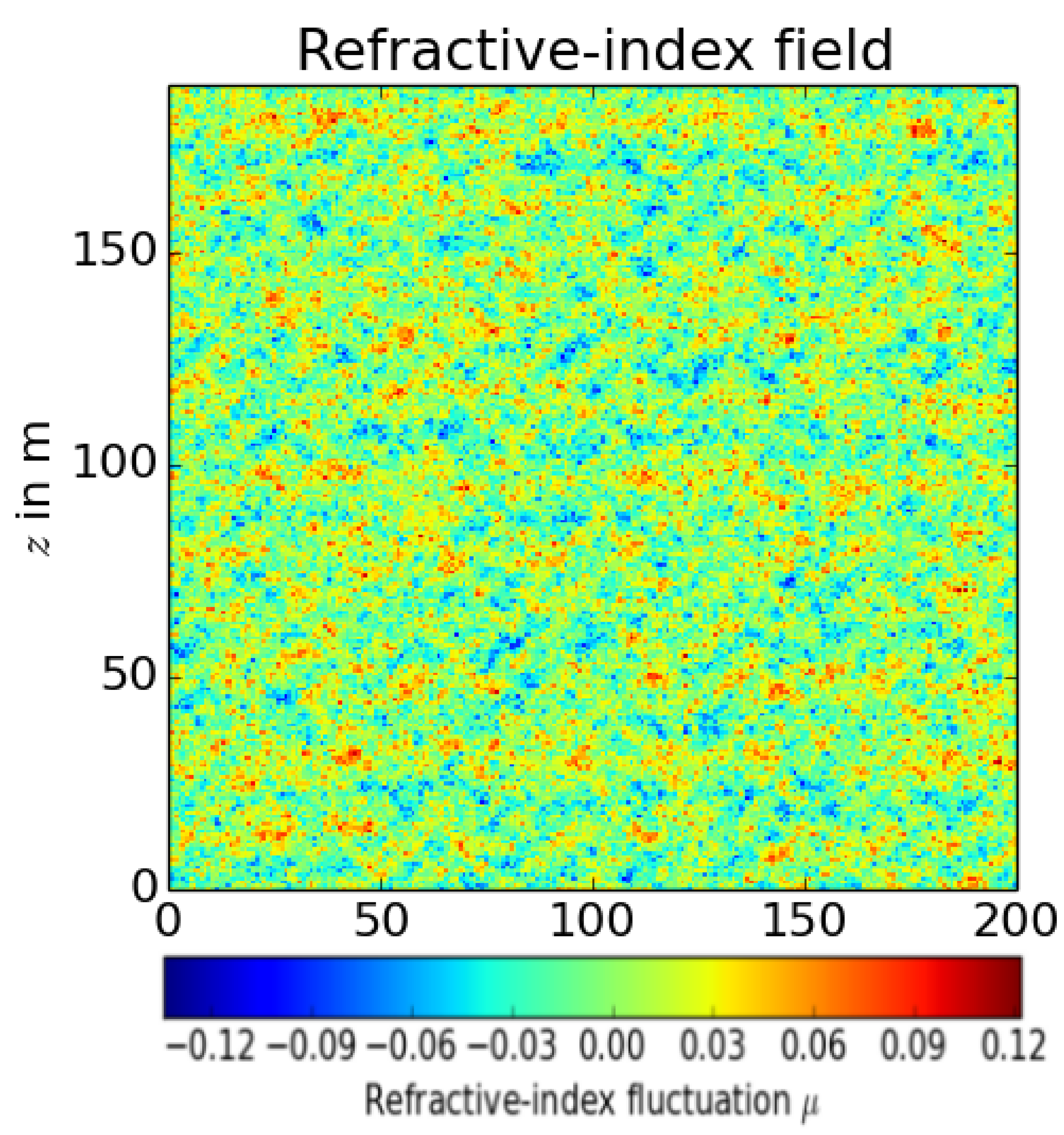

Figure 3: The refractive-index as function of position. This field is generated using a statistical description of atmospheric turbulence.

A theoretical model was developed that allows generating time series of amplitude and phase fluctuations due to turbulence. This model has been included as a *turbulence filter* in the propagation model.

References

[1] Oleksandr Zaporozhets, Vadim Tokarev, and Keith Attenborough. Aircraft Noise: Assessment, prediction and Control, May 2011.

[2] Makoto Tabei, T Douglas Mast, and Robert C Waag. A k-space method for coupled first-order acoustic propagation equations. *The Journal of the Acoustical Society of America*, 111(1 Pt 1):53–63, January 2002.

Reproduction

In order to determine the impact of aircraft noise on people listening tests have to be performed. A reproduction setup has to be developed in order to perform these tests.

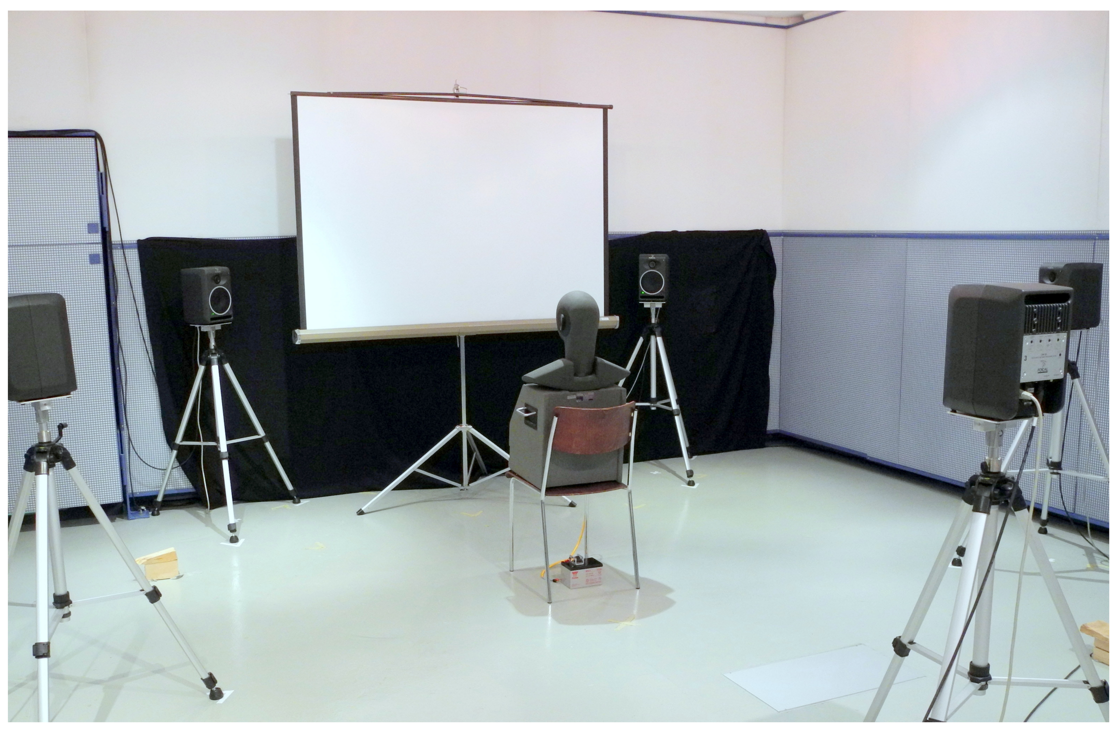

Figure 4: Sound reproduction setup of a previous experiment at Empa. The setup was used in an experiment to determine what Ambisonics decoding strategy to use considering how the head of the listener perturbs the sound field.

Sound reproduction will likely be done using an Ambisonics surround sound setup. Ambisonics is a surround sound technique that in addition to the horizontal plane allows sound sources above and below the listener. One important question to answer is whether and how Ambisonics can provide a plausible correct reproduction of over-head information.

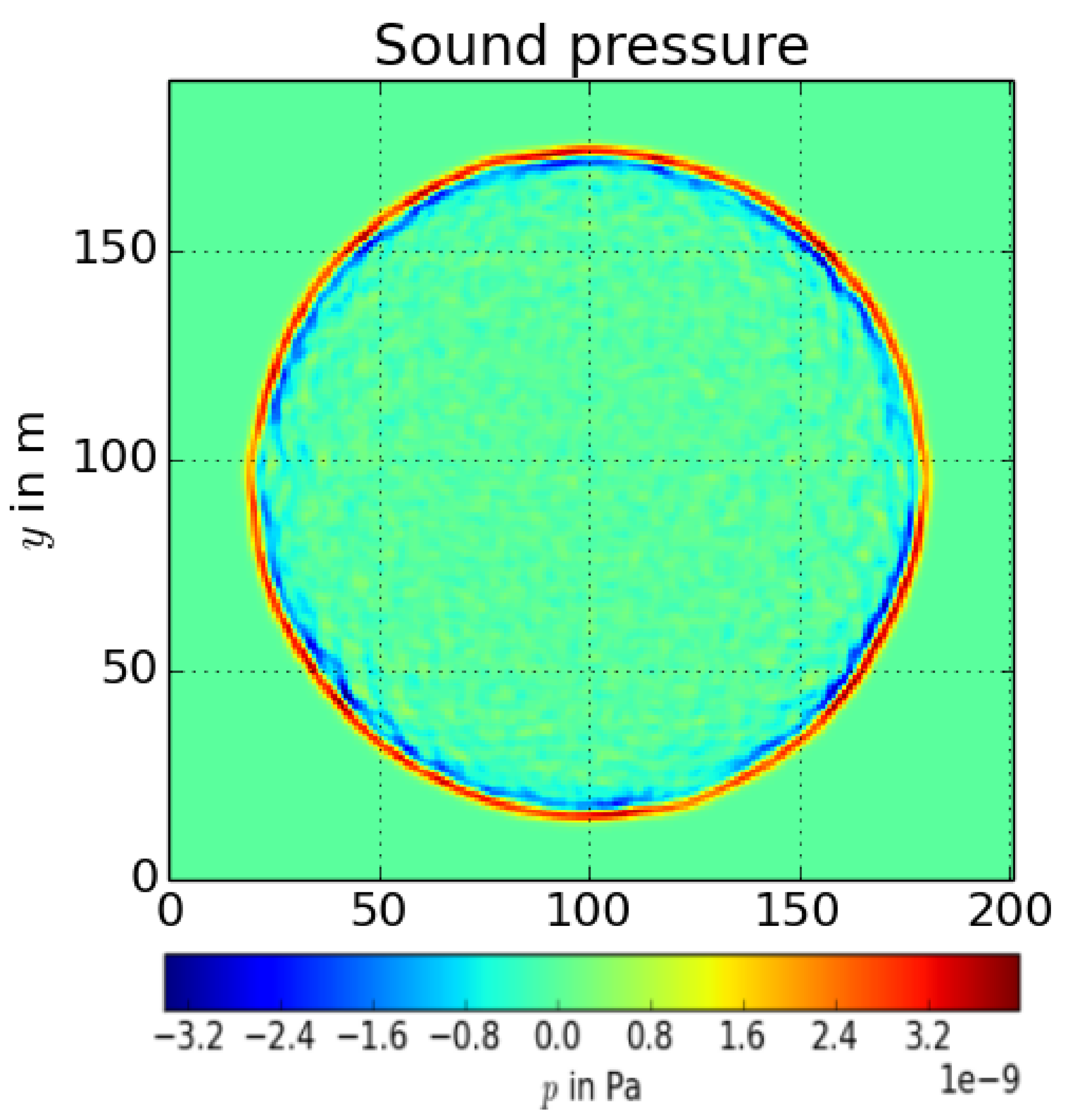

Figure 5: Sound propagation through an turbulent atmosphere. The turbulence clearly distorts the spreading of the sound wave. The sound propagation was modelled using the *k*-space pseudospectral time-domain method [2].

Acknowledgements

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