# Contributions to the experimental characterisation of fan noise radiation

**PhD supervision :** Christophe Bailly (Pr ECL) & Antonio Pereira (IR)
**Technical monitor - Safran Aircraft Engines :** Josselin Régnard
**Founding :** Industrail chair ARENA (Aeroacoustics of New Engine Architectures in Aeronautics)

**To apply :** christophe.bailly@ec-lyon.fr
**Web site :** http://acoustique.ec-lyon.fr

The noise generated by a turbojet fan now represents a large part of the total noise emitted by an aircraft. New designs of high-by-pass-ratio engines tend to further increase this contribution. This is partly due to the increase in fan diameter, associated with a reduction in rotor rotation speed and a shorter nacelle. New acoustic treatment technologies and the modification of structural elements such as rotor and stator blades are currently being studied to reduce noise.

The validation of these new technologies by experiments on a reduced scale, but in a controlled environment, is a crucial step. This task, however, becomes very complex when a local modification (*e.g.* the leading edge of stator blades) is evalluated under realistic fan operating conditions. It is well known that many noise generation mechanisms are involved, including rotor-stator interaction noise, rotor noise, and also interaction noise between the turbulent boundary layer and the rotor. The assessment of the effective noise reduction gain of a given technology can therefore be strongly masked by other physical mechanisms, which are not necessarily related to the change made.

There is therefore a real interest in discriminating the different components of the noise radiated by the rotor/stator stage of a fan. This is one of the objectives of this research work : to measure the global acoustic field emitted by a rotating machine and be able to extract the contribution of each sub-component. The noise measurement associated with each component separately[4–6] is briefly illustrated in figure 1. However, this direct experimental approach is difficult to apply in practice, and is also costly with the need of isolating each sub-component.

Alternative approaches will have to be explored in this thesis to overcome these difficulties. Some possible ideas are mentioned here,

- the use of reference sensors in the vicinity of each noise generation mechanism, noting that different physical quantities may be considered (*e.g.* wall pressure, velocity, far-field pressure) ;
- the use of numerical simulations to properly isolate each physical mechanism, and the use of recent theories in dictionary learning to find optimized bases for representation for each phenomenon ;
- for signal processing purposes, the characterization of statistical properties related to the different mechanisms could also facilitate their identification. In particular, the use of the different orders of cyclo-stationarity[7] allows already the separation between deterministic and random parts of a signal taken from rotating machine.

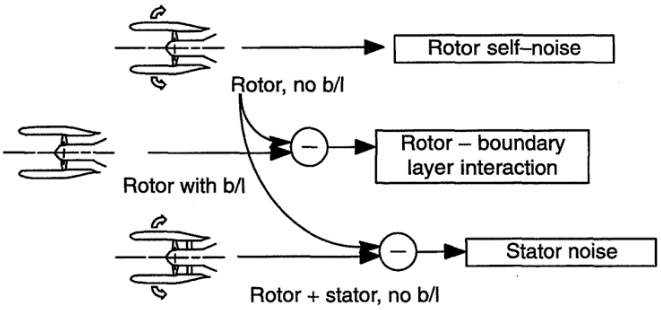


Figure 1 – As an illustration, experimental protocol for the extraction of the noise associated with different sub-components of a rotating machine, from Ganz *et al.*[4]

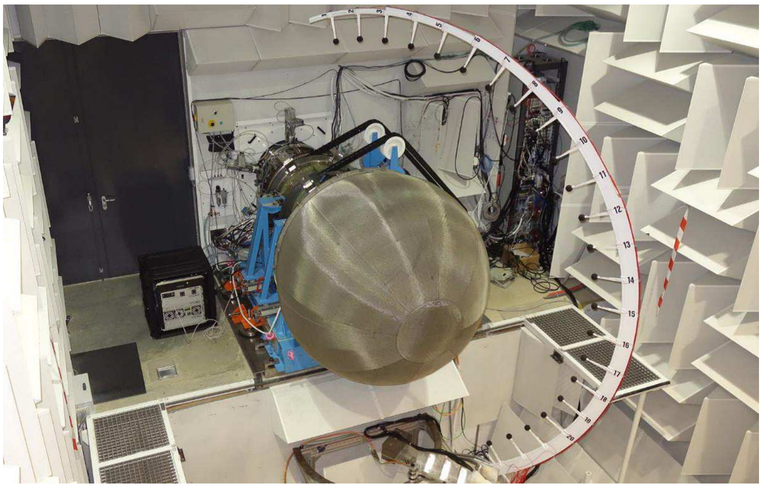

Figure 2 – Characterization of fan noise in the ECL-B3 facility (1/3 scale of a real engine) at Ecole Centrale de Lyon.

A second axis of research will focus on the experimental characterization of fan noise radiation. On the one hand, we will revisit methods for estimating the modal content inside the ducted fan from far-field pressure measurements.[1,2,8] In addition, the prediction of far-field acoustic radiation associated with each noise generation mechanism will be examined, by extrapolating the acoustic field measured inside the duct to the far field. In order to go further to the state-of-the-art, the challenge is to take into both the presence of the flow as well as realistic nacelle geometries. This will be done using analytical radiation models, but also numerical models to include specific air inlet sleeves for instance.

The different methods discussed below can be tested on a modular installation (LP3 bench, see *Centre for Acoustic Research* website), before being implemented on the ECL-B3 bench, refer to figure 2.

Depending on the candidate's skills, the work may focus more on modelling, both analytical and numerical, or signal processing. For the first point,[3,10] the use of commercial software based on on finite elements (*e.g.* ACTRAN software) will be privileged. Knowledge of advanced signal processing will allow you to investigate the resolution of inverse problems.

## References

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