# CORRELATION MODEL FOR NOISE GENERATION BY LARGE VORTEX OSCILLATIONS IN TURBULENT JET

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***Summary*** The paper considers the mechanism of noise generation by turbulent jet related to the eigen-oscillations of large vortices. For this mechanism a correlation model is proposed similar to the earlier investigated models of noise by fine-scale turbulence. It enables a quantitative comparison of different noise radiation mechanisms. Noise prediction of the model is compared with the measurement data for jet with velocity V=120 m/s for different azimuthal modes. It is shown that the predicted far field spectra fit well with the experimental results for a wide frequency range. The proposed model can give a new insight on the well-known correlation models based on empirical modelling of the noise source correlation functions. It is shown that the main difference between the models is related not only with different multipole structures of the sources but also with different implicit conceptions of primary vortex formation adopted in the model.

## INTRODUCTION

One of the major research approaches to noise generation by turbulent jets is based on the application of correlation models for noise sources. The correlation models describe the sound source in the jet as a stationary stochastic process. The main features of the correlation functions are determined by the physics of noise generation process while the parameters can be adjusted to the experimental data or CFD results. An advantage of this approach is that it allows a prediction not only noise power but also its correlation characteristics, which may be necessary, for example, for aircraft interior noise calculations. Besides, the correlation function peculiarities can provide an opportunity for better insight into the physics of noise generation by turbulence.
Previously, the correlation models of noise sources in the turbulent jets were developed in [1,2], where monopole and dipole sources were considered. Then this approach was extended to quadrupole sources [3,4]. At present, there is no generally accepted opinion about the contribution of different ranges of turbulent pulsations in noise generation. In particular, fine-scale turbulence was considered as a source in [1-3,5]. At the same time, the contribution of large-scale pulsations was investigated [6-8]: instability waves [6,8], and eigen-oscillations of large-scale vortices in jet [7] (Fig.1).

Fig. 1. In the tone excited jet large vortex structures are identical to a vortex ring train (a), radiating mode of vortex ring accompanied by rotating deformation of vortex core (b).

Previously, it was shown that the large-scale vortex structures can participate in the noise generation process not directly (due to interaction of vortices or their passive convection), but by means of their eigen-oscillations (Fig.1b, [9]). The objective of the present work is a development of a correlation model for this mechanism of noise generation. This model should take into account, on the one hand, the deterministic character of the vortex eigen-oscillations, and, on the other hand, the randomness of the process of the large vortices formation in jet. The correlation model for eigen-oscillations of large-scale vortices enables quantitative prediction of spectral and correlation characteristics of jet noise and their comparison with the results of the other correlation models and experimental data.

## BASIC ASSUMPTIONS AND RESULTS

The correlation model of large vortex eigen-oscillations as a source of sound is based on the following assumptions:

1. The formation of the large-scale vortices takes place at the initial part of the jet as a result of the nonlinear stage of instability wave development.
2. The large-scale vortices are born to be disturbed.
3. The parameters of the large-scale vortices and their eigen-oscillations are determined by the mean-flow parameters in the point of vortex formation.
4. The oscillations of the large-scale vortices are a sound source of a quadrupole type in accordance with the results [7,9]

This conception is modeled with a pair of related stochastic processes, one of which describes the formation of the large-scale vortices and the other describes the evolution of noise sources. The obtained correlation model gives rise to a

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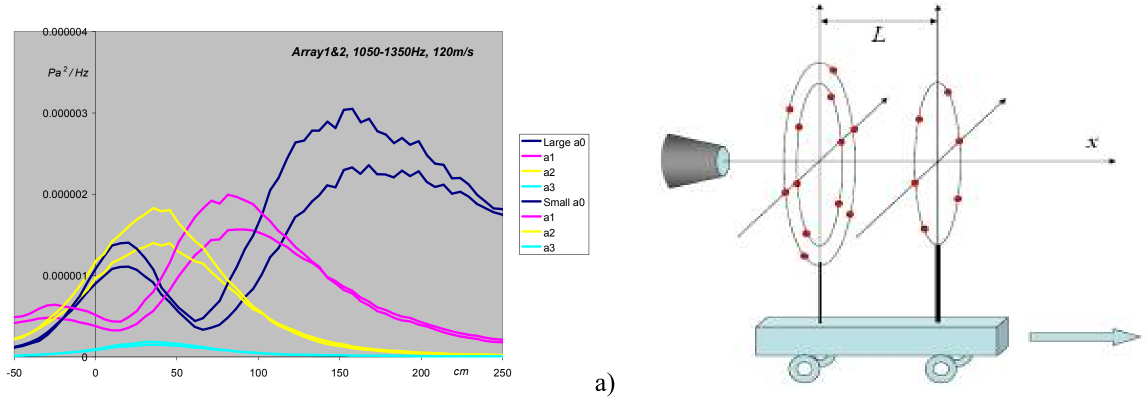
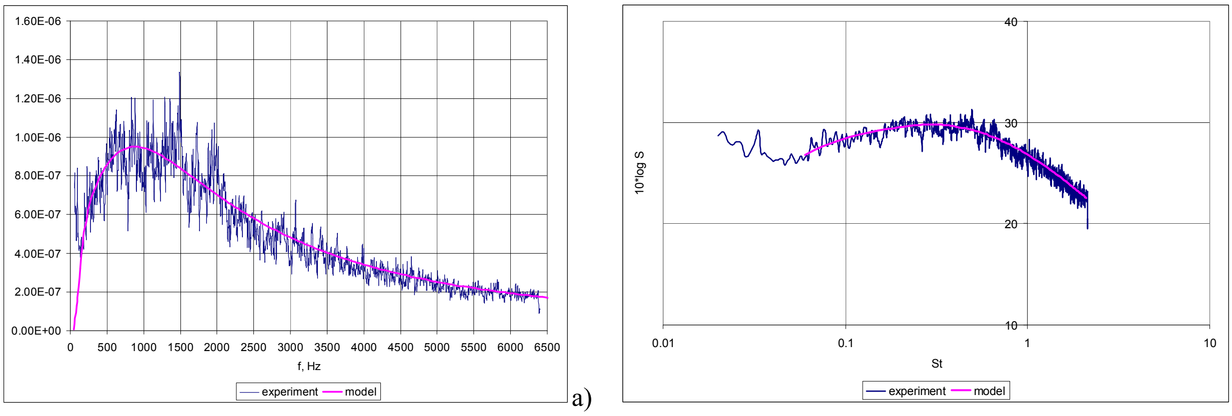
qudrupole-type radiation for every azimuthal mode, which agrees with the results obtained with the azimuthal decomposition technique (Fig. 2a, [10]). The predicted noise spectrum in the far field is in a good agreement with the experimental data for the jet under consideration (V=120 m/s, Fig. 3).




a) b)

Fig. 2. Noise directivity patterns for $n$=0,1,2 azimuthal modes (a), measured by two coaxial arrays (b)




a) b)

Fig. 3. Comparison of predicted far-field spectrum of noise generated by large vortex oscillations with measurement data for $U_{jet} = 120 m/s$, $D = 0.04m$, $\theta = 90^0$, axisymmetrical (n=0) azimuthal harmonic, a) normal and b) logarithmic scales.

## CONCLUSIONS

The obtained results translate the ideas on noise due to large-scale vortices into the language of correlation functions, analogous to the earlier developed models of noise by fine-scale turbulence [1-3]. It enables a quantitative comparison of different mechanisms of the jet noise generation. The proposed model is shown to predict the noise spectra in the far field as good as the models for fine-scale turbulence. This means that the question remains open as to the contribution of different turbulent pulsation ranges into jet noise. To solve this question, a comparison of more subtle characteristics of the competitive models seems necessary.

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