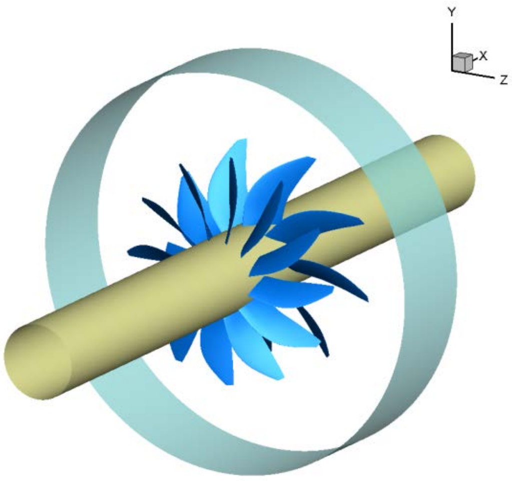
Comparaive analysis of counter-rotating propfans noise assessment methods in the case of open rotor with narrow cylindrical shield

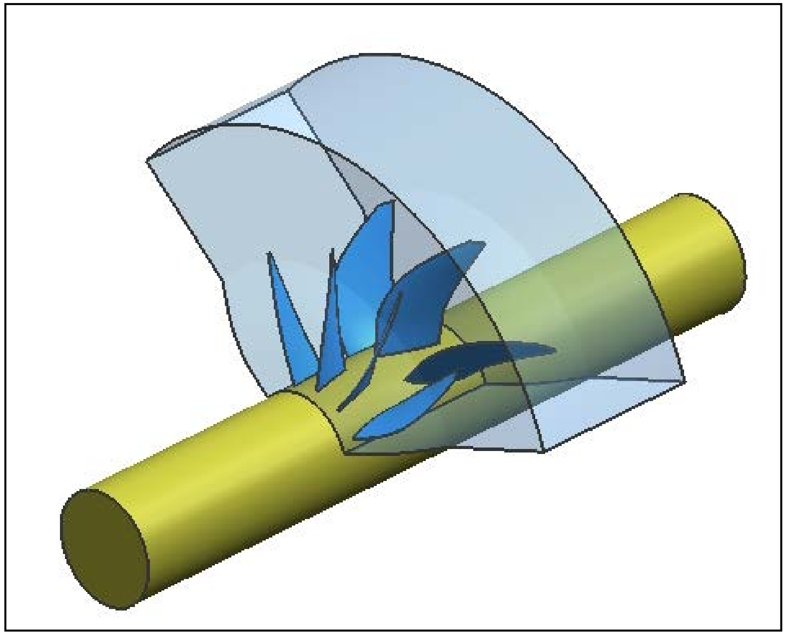


Authors:
K.S. Reent,
A.V. Gracheva,
V.A. Shorstov,
V.E. Makarov

22-26th September 2014, Svetlogorsk

Acoustic pressure in the far-field

Acostic potential in point $\vec{r}$ is defined as:



$$\phi \approx \frac{1}{4\pi a^2}\frac{e^{i\omega r}}{r}\int q(\overrightarrow{r_0})\, e^{-\frac{i\omega}{a}(\vec{e},\overrightarrow{r_0})}\, dr_0$$

$$\vec{e} = \frac{\vec{r}}{r}$$

$$p = \sum_i \sum_j p_{ij}(x,r) e^{-i\omega_{ij}t + i n_{ij}\varphi}$$

$$p_{ij} \sim \frac{1}{r} J_n(q)$$

$$\omega_{ij} = N_1\Omega_1 i + N_2\Omega_2 j$$

$$n_{ij} = N_1 i + N_2 j$$

$$q = \frac{\omega_{ij}}{a}\sin(\theta)\, r_1$$

where:

ω_{ij} – wave frequency, n_{ij} – angle mode number,
a – sonic speed,
θ - azimuth angle,
r_1 – radius of the ring of integration,
N_1 и N_2 – number of blades of the front and the aft props,
Ω_1 и Ω_2 – rotation frequency of the front and the aft props.

$i \neq 0, j = 0$ или $i = 0, j \neq 0$ – for the passing frequencies
$i \neq 0, j \neq 0$ – for the combined frequencies

From aerodynamic analysis to acoustical field

Unsteady aerodynamic calculation (Cobra)

URANS, Spalart-Allmaras model, 22 M cells, 12-14 revolutions

- Time-dependent data at Kirchoff's surface:
  - Static pressure **p**
  - velocity **(Vx,Vy,Vz)**

→

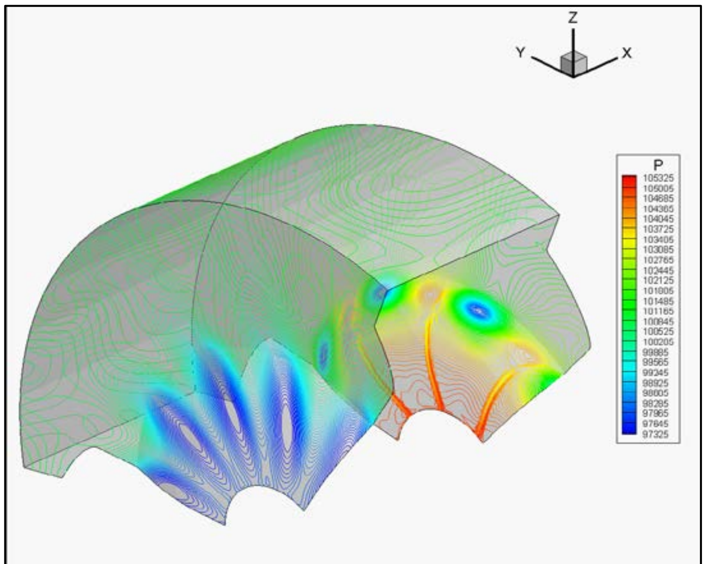
Fourie transformation of the data for each harmonic

- Extraction of main and spurious modes for each harmonic form 0 to 15

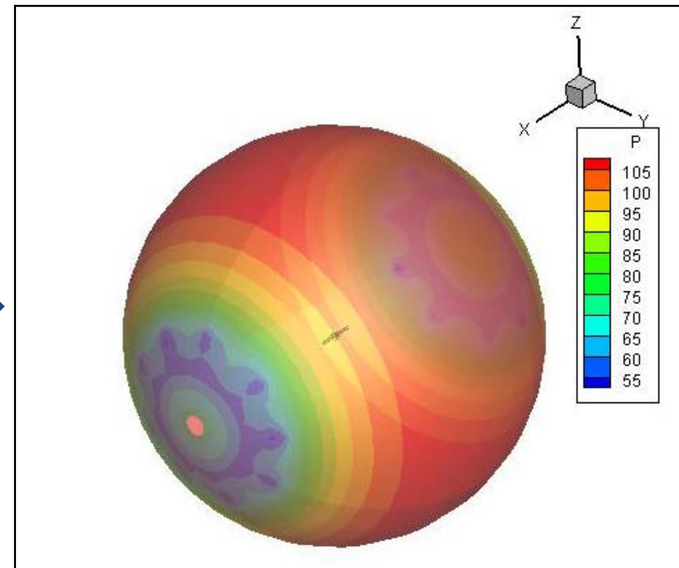
→

Ffowcs-Williams Hawkings method

- Pressure perturbation analysis at the far-field (50 metres)



Pressure field at Kirchoff's surface extracted around CROR 9x12

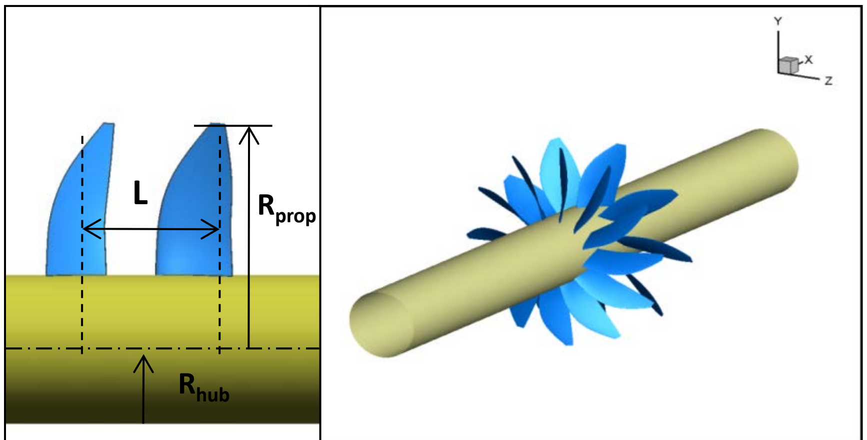


Pressure field distribution in dB in the far field: R = 50 m

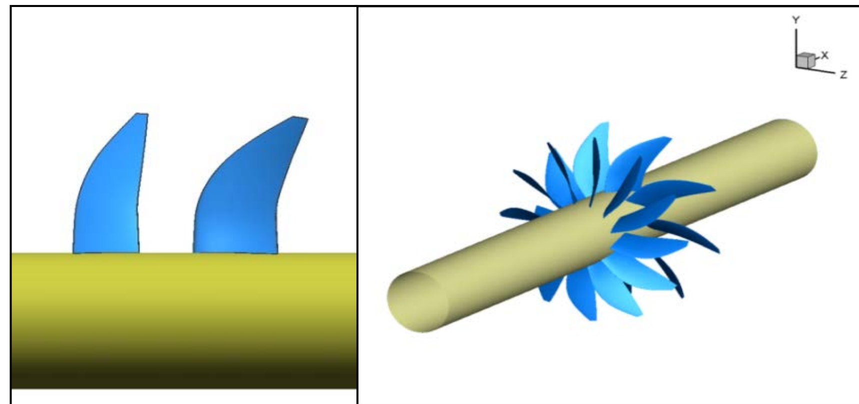
Open rotor tested

<u>CROR 12 x 9 based on SR-7:</u>

R_{prop} = 1.35 m
R_{hub} = 0.45 m
L = 0.7 m

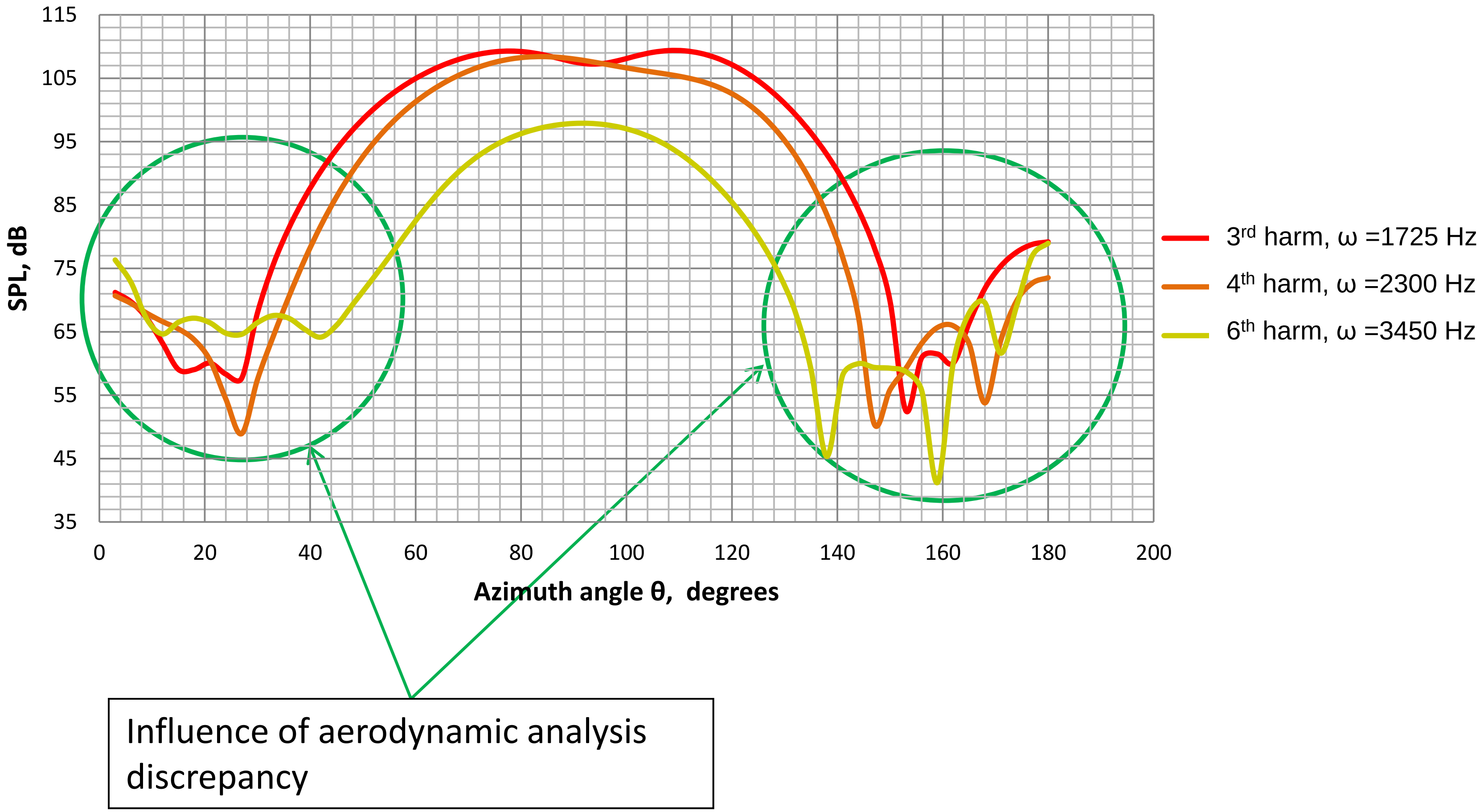


CROR12/9: initial geometry



CROR 12/9: enlarged sweep
of aft blade: 11.5°

Azimuth distribution of pressure amplitudes for some dominate harmonics of tonal noise at 50 m (for CROR 12/9)

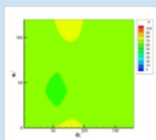
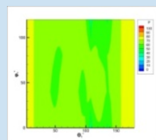
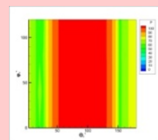
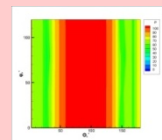
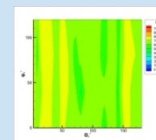
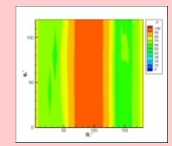
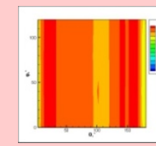
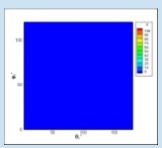
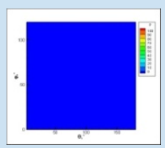
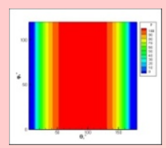
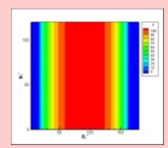
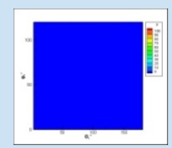
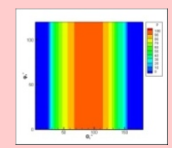
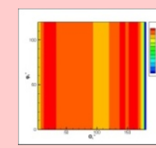
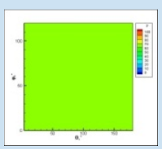
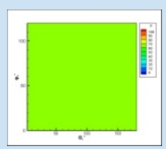
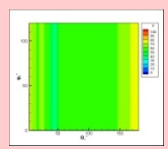
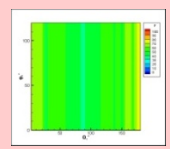
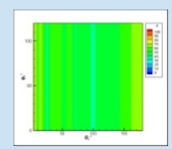
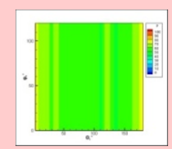
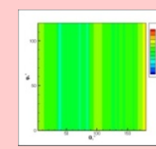


Influence of aerodynamic analysis discrepances

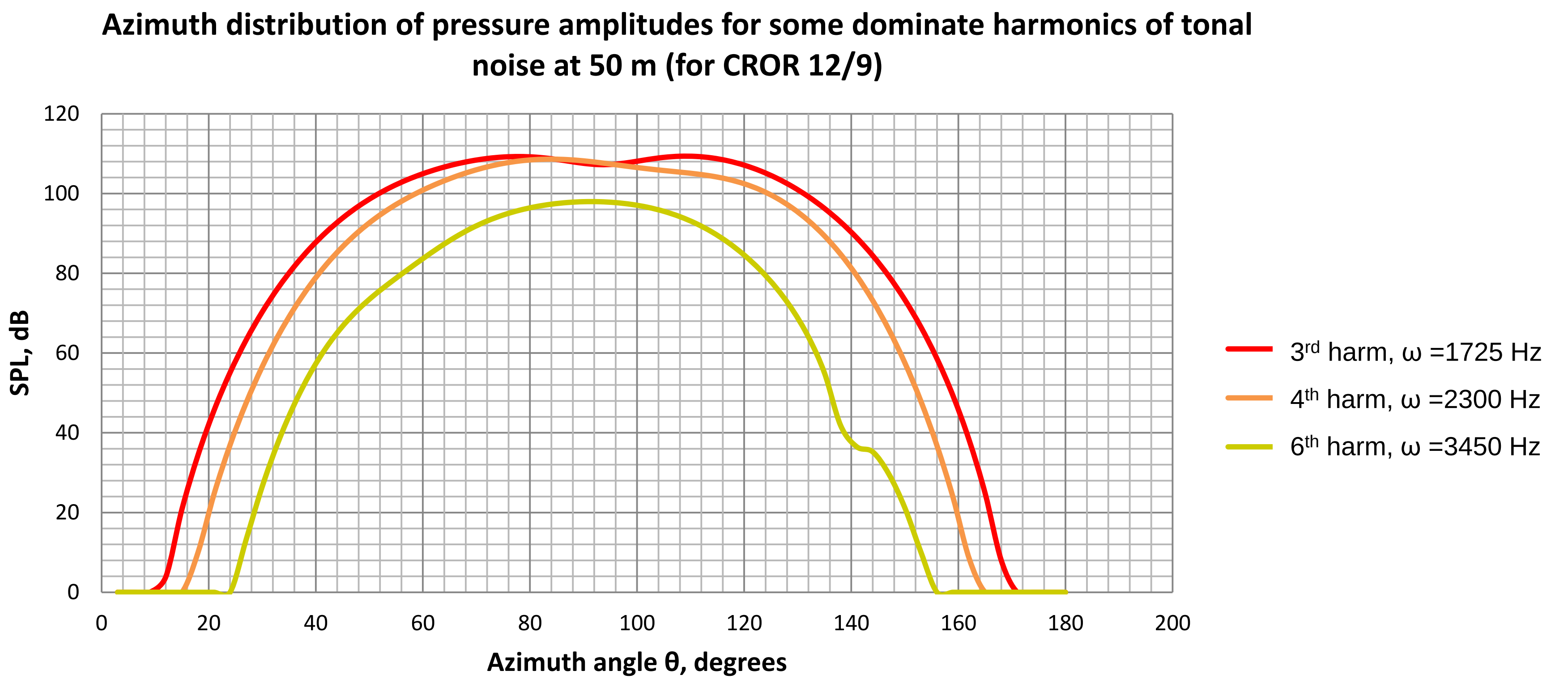
A “zero” mode: $n_{ij} = N_1 i + N_2 j = 0$

(where $\omega_{ij} = N_1 \Omega_1 i + N_2 \Omega_2 j$)

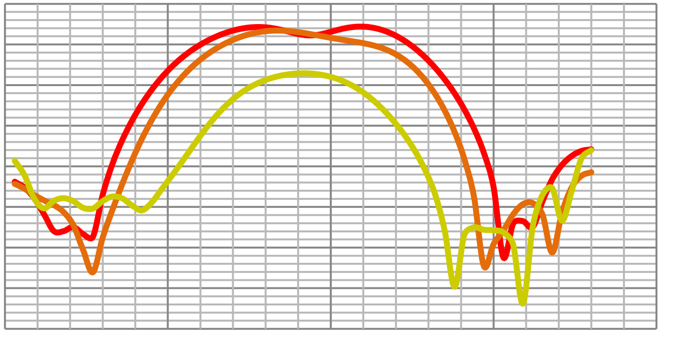
Influence of “zero” mode on different harmonics

№ of harmonic	1	2	3	4	5	6	7
All modes							
Main mode							
“Zero mode” (n_{ij}=0)							

Azimuth distribution for main modes of some harmonics



Instead of:

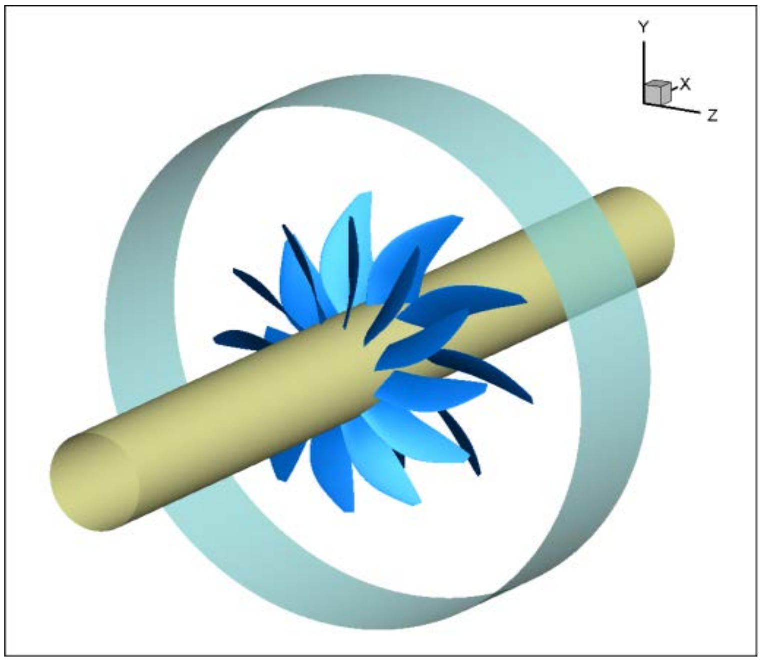


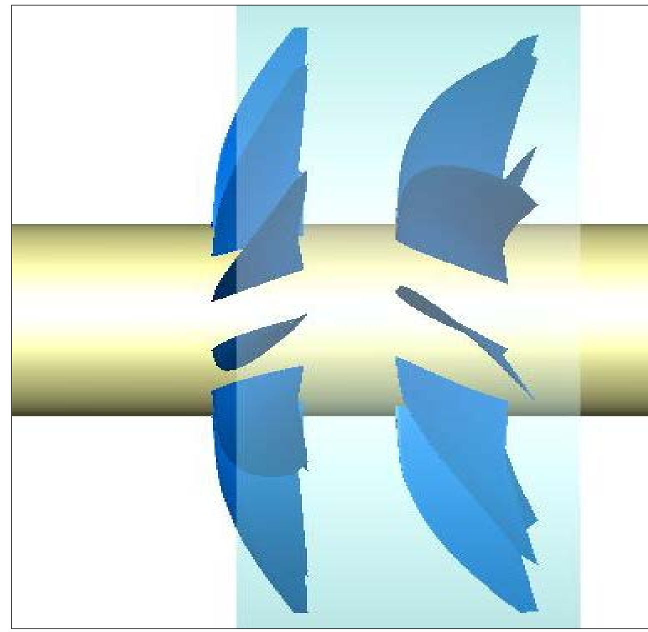
Максимумы амплитуд давления				
№	max1, dB	Θ1,deg.	max2, dB	Θ2,deg.
3	109	78	109	108
4	108	87		
6	98	93		

<u>Narrow shield:</u>

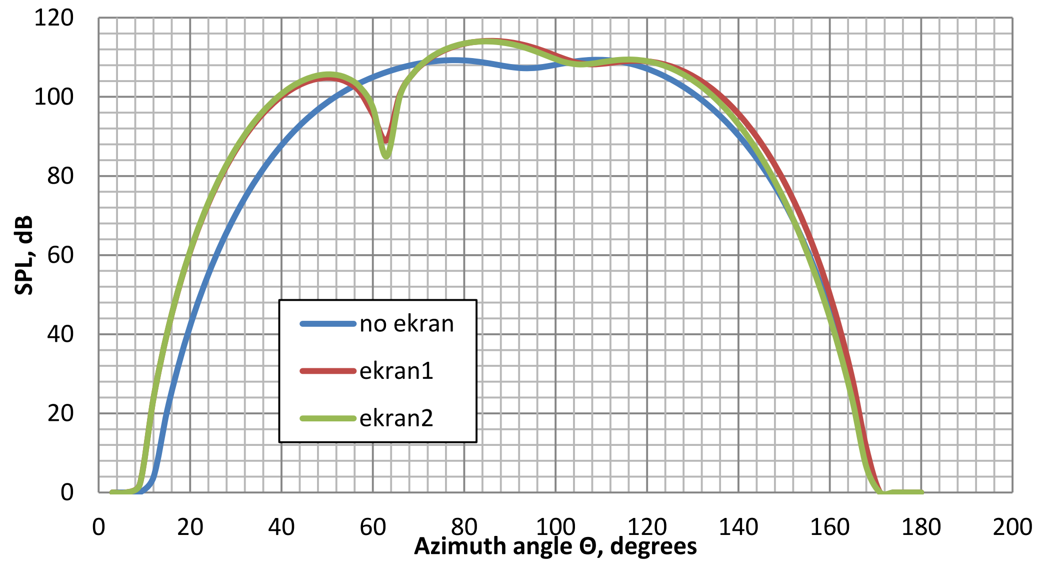
R_{shield} = 2.36 m

dl_{shield} = 1.0 m

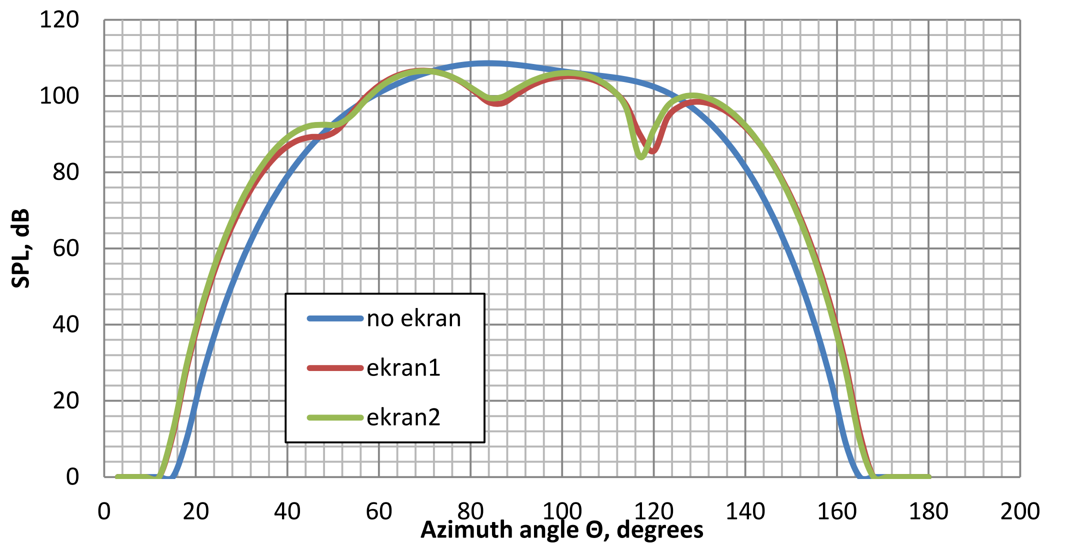




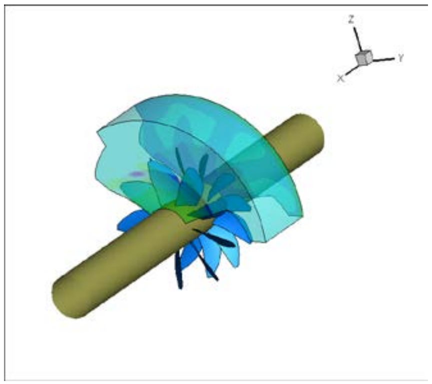
Azimuth distribution of pressure amplitude for the 3th harmonic
ω = 1725 Hz

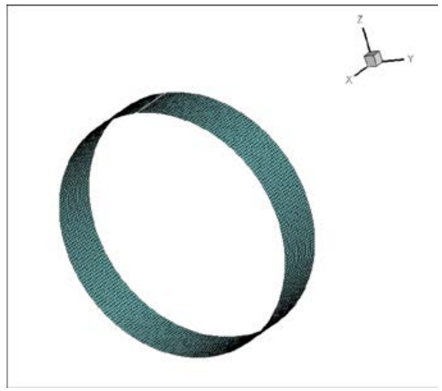


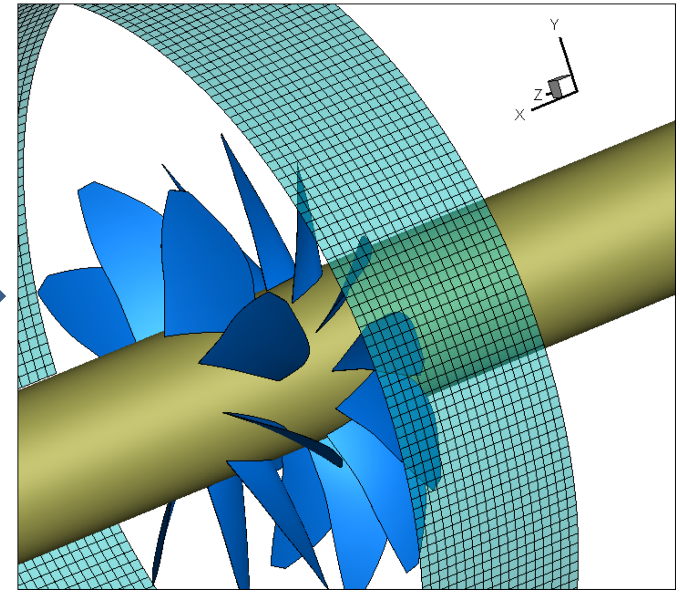
Azimuth distribution of pressure amplitude for the 4th harmonic
ω = 2300 Hz



Artificial shield (based on horseshoe method)







$$v_n = \left(\vec{V} \cdot \vec{n}\right) = 0$$

Flow tangency condition at the new shield:

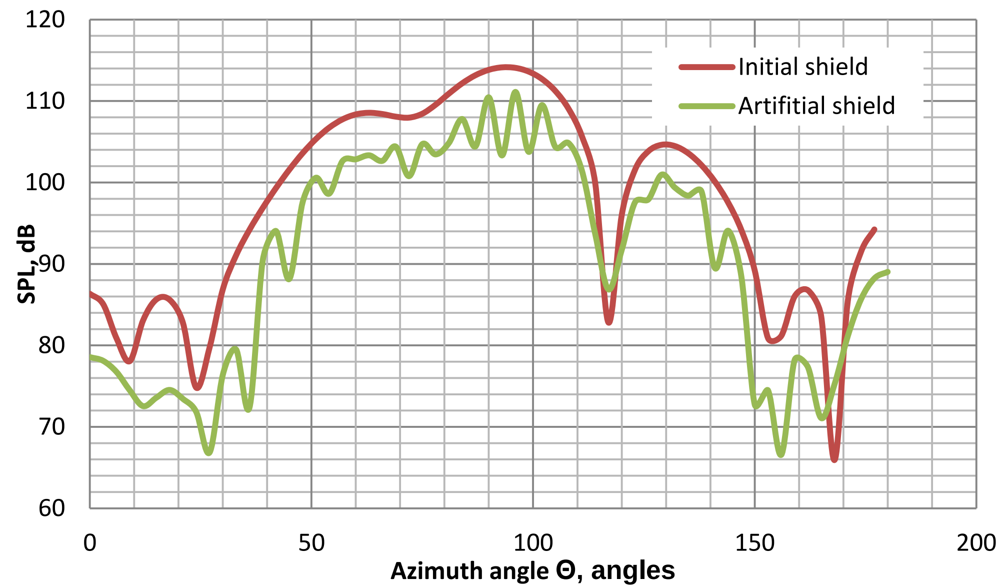
$$\boldsymbol{v_n = \iint_{S_{shield}} Q_D(\vec{r}_0)\frac{\partial^2 G(\vec{r}-\vec{r}_0)}{\partial n_0 \partial n} dS_0 + \iint_{S_{Kirchoff}} \left(\frac{p(\vec{r}_0)}{i\omega r}\frac{\partial^2 G(\vec{r}-\vec{r}_0)}{\partial n_0 \partial n} - \frac{\partial G}{\partial n} v_n(\vec{r}_0)\right) dS_0 = 0}$$

Shield dipoles contribution

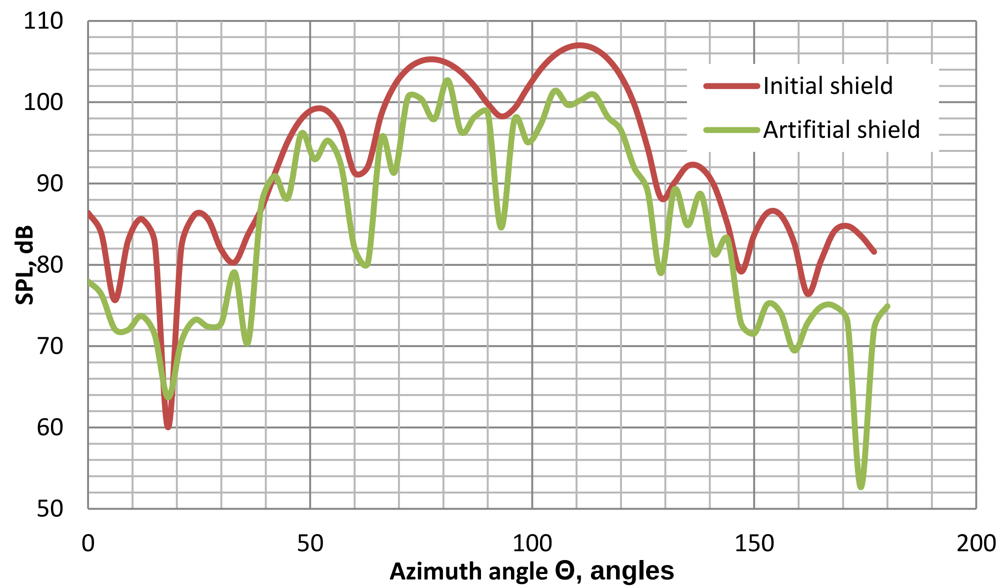
Unsteady field contribution

Shielding by a narrow noise

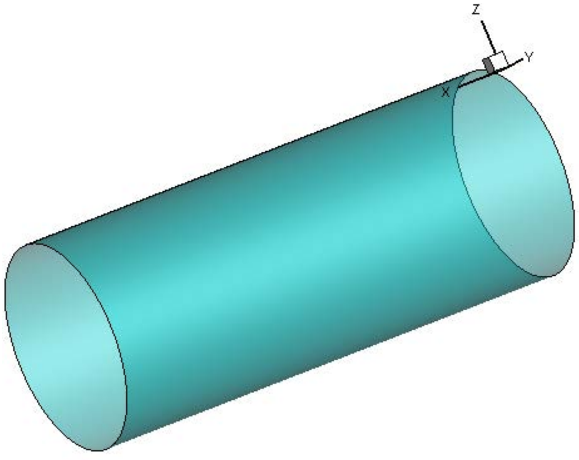
Azimuth distribution of pressure amplitude for the 3th harmonic
ω = 1725 Hz



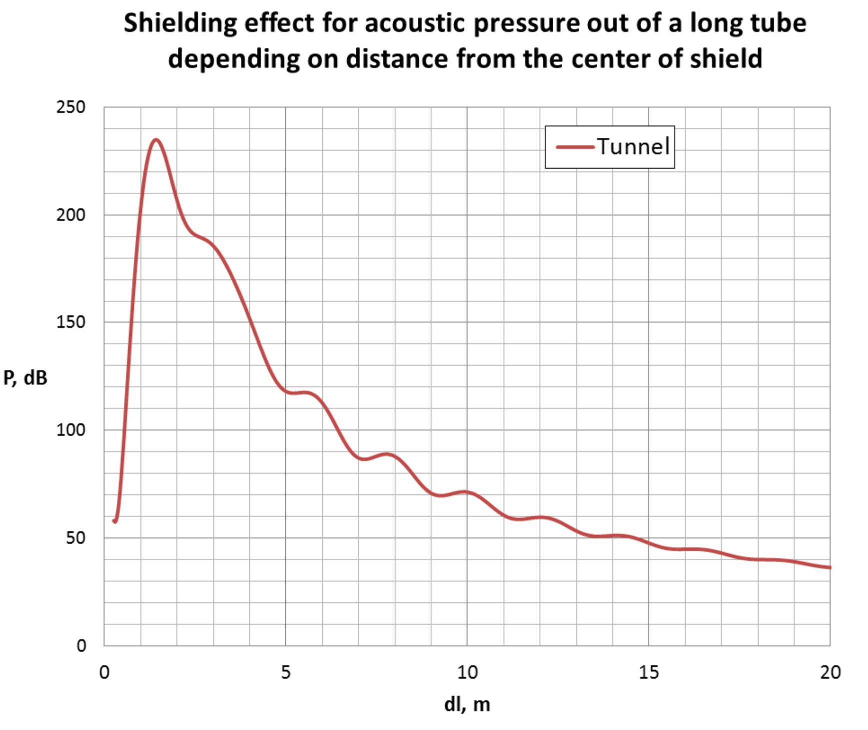
Azimuth distribution of pressure amplitude for the 4th harmonic
ω = 2300 Гц



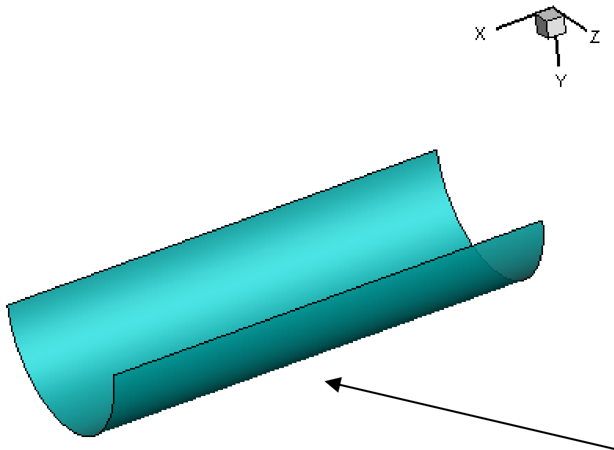
Test problem: long tube around a 8/8 open rotor



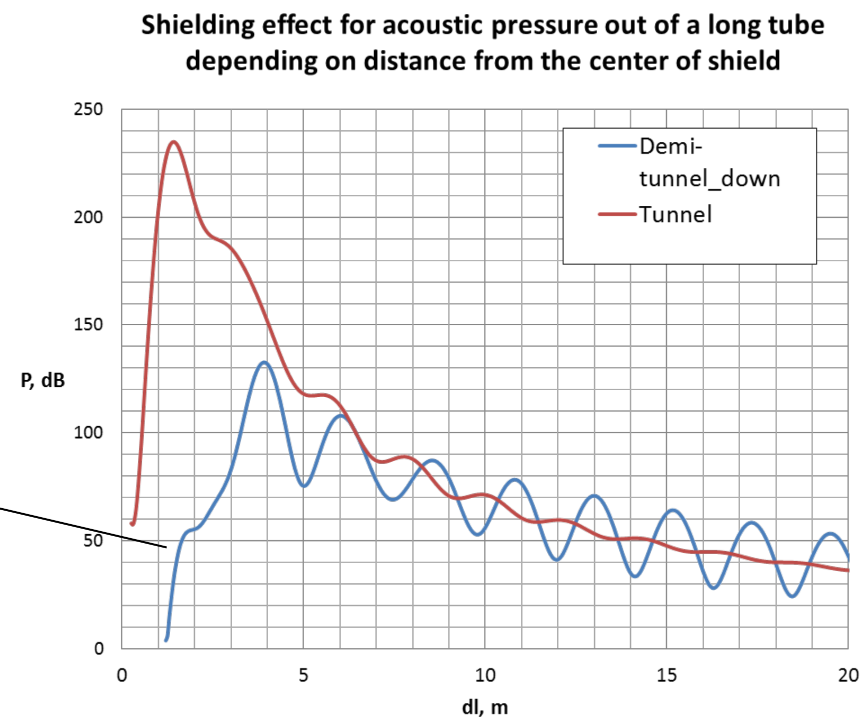
Artificial dipoles intensity distribution over a long tube shield (L=8m) for the first harmonic for a 8/8 open rotor, ω=1600 Hz



Test problem: long tube around a 8/8 open rotor



Artificial dipoles intensity distribution over a long demi-tube shield (L=8m) for the first harmonic for a 8/8 open rotor, ω=1600 Hz



A hybrid method with introduction of artificial screen was supposed to be appropriate for fast acoustic analysis

An artificial shield can be used for qualitative analysis of shielding effect

Hybrid FWH and artificial screen based on horseshoe method allow fast shielding effect estimation

In plans: accurate verification with more unsteady aerodynamic analysis and inclusion of airframe model