ACTRAN TM cross-validation versus ACTRAN DGM: a 2D numerical study

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Contents

- Introduction
- Motivation of Actran/TM versus /DGM cross-validation;
  focus on turbine noise radiation through engine exhaust
- Steps for Actran simulation
- Specification of the numerical model
- Results
- Conclusions

Introduction

- MTU Aero Engines develops and produces sub-systems (e.g. compressors, turbines) of jet engines. MTU is world's leading independent MRO provider.

- From an engineering prospective:

  Growing demand of low noise aircrafts brings out technical challenges which requires more and more accurate aero-acoustic computation methods.

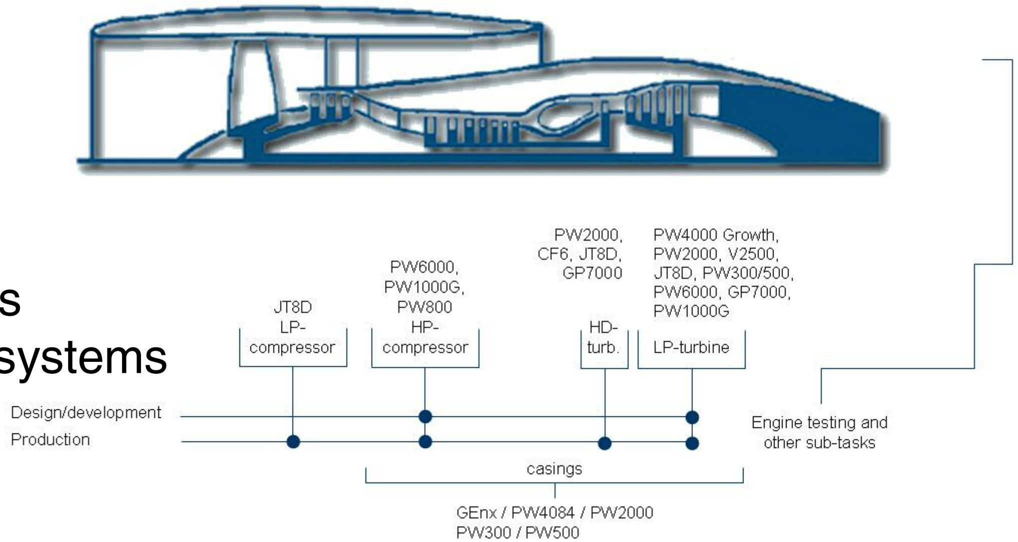
- Turbine noise radiation through engine exhaust is of particular interest:

  The design-process demands an turbine noise evaluation for both operating conditions, landing (Approach) and take-off (e.g. Flyover-Cutback).

Introduction

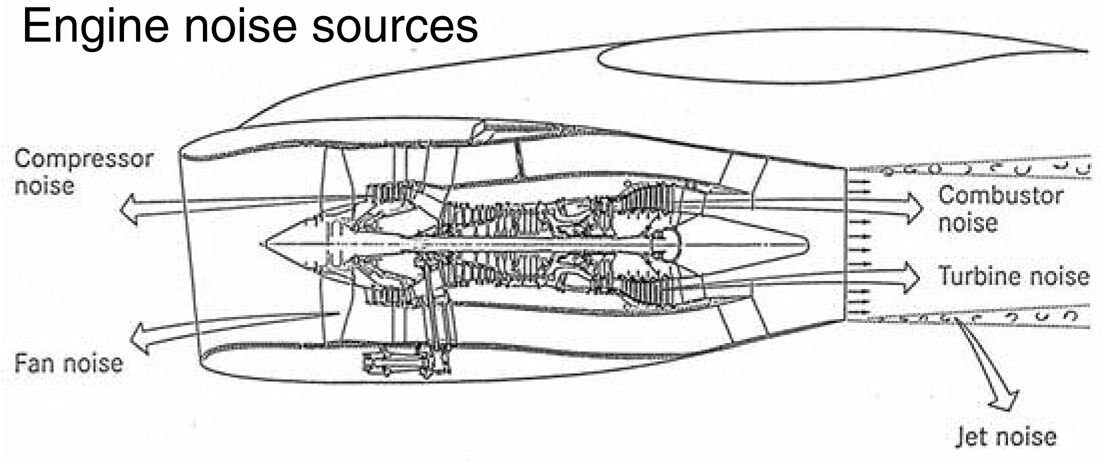
MTU Aero Engines, Munich
Companies headquarters

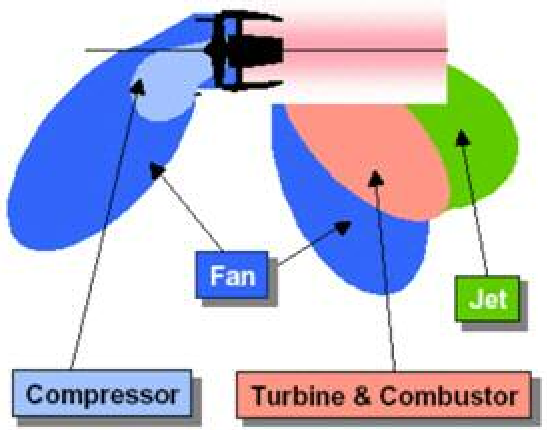
MTU's activities
related to sub-systems



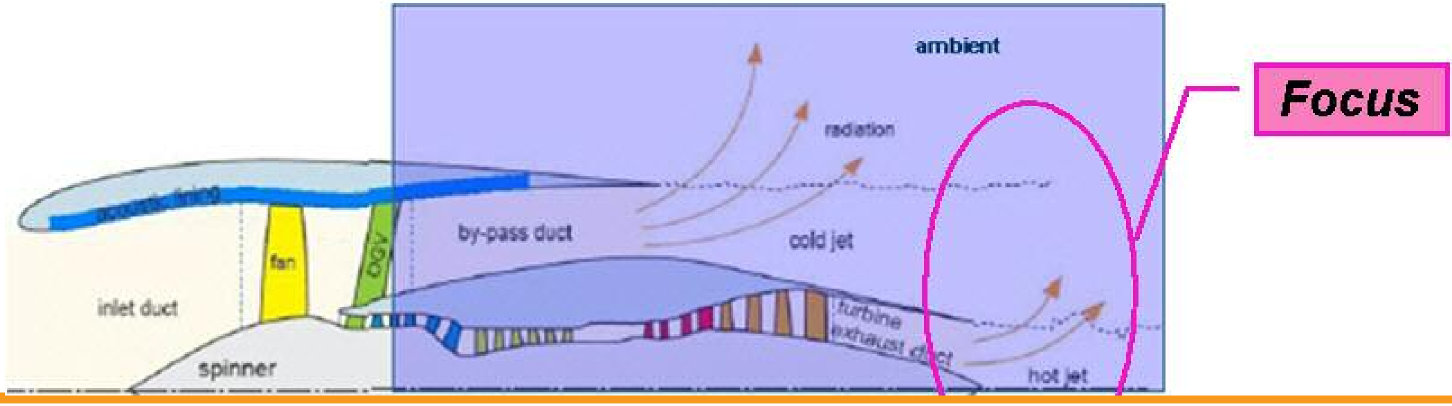
Introduction

Engine noise sources





Numerical study focus on turbine noise radiation problem



Motivation of Actran cross-validation

- Since the release 2009, Actran/TM has the "Moehring" operator available:
  A propagation operator allowing to perform acoustic computations in both non-uniform flow and temperature fields.

- A single paper deals with the validation of the "Moehring" method, but only for flows of low (< 0.1) Mach-no..

- In view of practical application:
  How useful is the "Moehring" approach to model the propagation through strong shear layers of high gradients in Mach no. and temperatures.

- Actran/DGM is validated within the MESSIAEN, TURNEX projects;
  thus the comparison of Actran/TM results with Actran/DGM is self-evident

Steps for Actran simulation

Applying Moehring operator

1. Model specification (database for meshing and aero-acoustic computation)

2. Flow computation (RANS) based on CFD-mesh

3. Flow field, interpolated on Acoustic-mesh by using Actran/CFD interface
   - Velocity field represented by FLOW data block
   - Pressure and density field represented by ACOUSTIC_HETEROGEINITY data block

4. Actran set up (acoustic mesh, interpol. flow field, boundary conditions etc.)

5. Actran computation and post-processing (near and far field simulation)

Model Specification

Overview:

- Geometry and dimensions:

  - exhaust configuration based on a full scale geometry of a modern turbofan engine
  - 2D axi-symmetric model

- Operating points, frequencies, sound modes

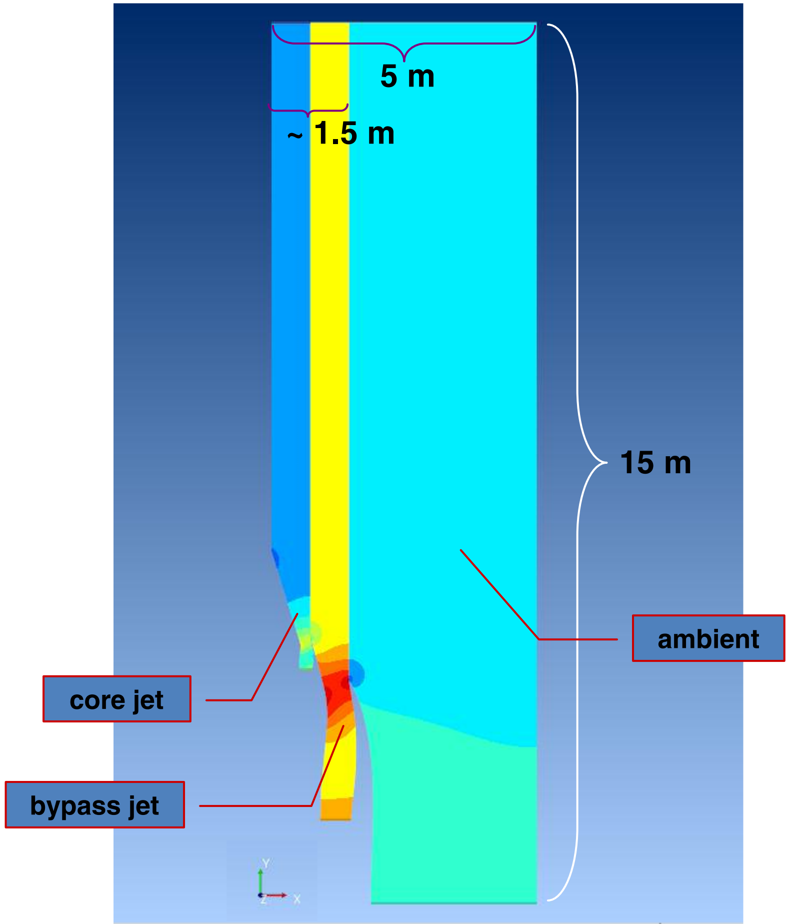
  - realistic conditions as specified for Approach and Take-off Flyover (Cutback)
  - sound modes of interest which belong to the blade passing frequency (BPF), generated by the last turbine rotor

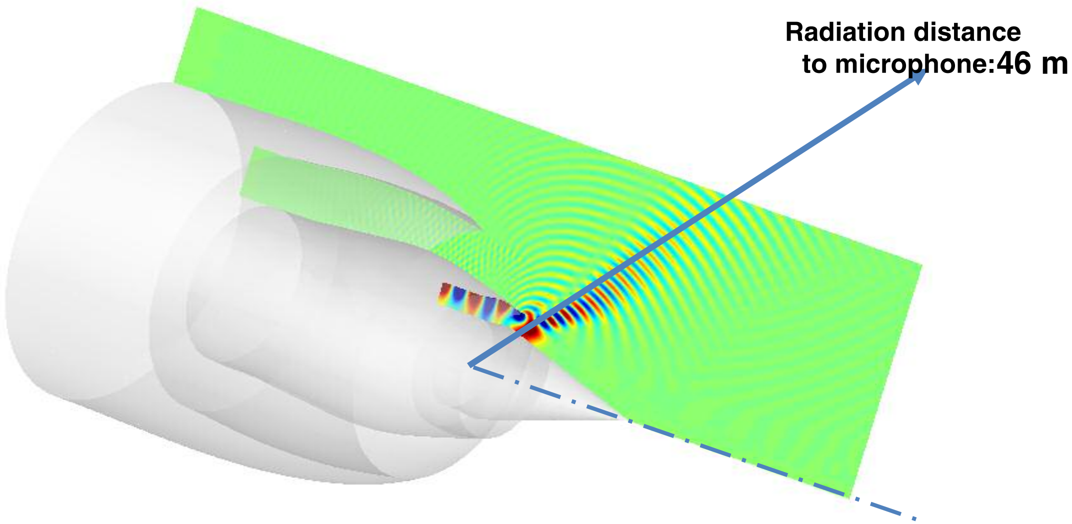
- Mean flow properties
  - based on RANS computations i.e. non-uniform, irrotational mean flow assumed

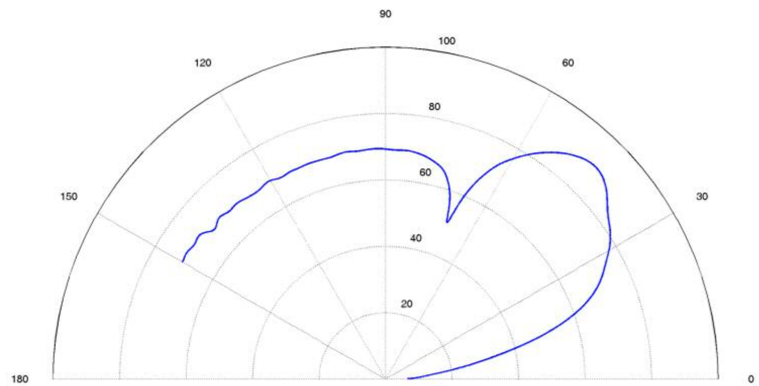
- Mesh parameters

Model Specification

Geometry and dimensions







Model Specification

Operating points, frequencies, sound modes

Cut-On Sound Modes	
Approach BPF at 2575 Hz (kR~25)	**Cutback** BPF at 3683 Hz (kR~35)
|m|= 3 n= 1, 2, 3 |m|=10 n= 1, 2, 3 |m|=16 n= 1, 2 Specified for cross validation	|m|= 3 n= 1, 2, 3, 4, 5 |m|=10 n= 1, 2, 3, 4 |m|=16 n= 1, 2, 3, 4 |m|=23 n= 1, 2, 3 |m|=29 n= 1

Model Specification

Mean flow properties, mesh parameters (basics)

Mean Flow Properties (at the nozzle ducts' inlet)		
Parameter	**Approach**	**Cutback**
M_∞ (ambient)	0.230	0.278
M_{fan} (bypass)	0.395	0.677
M_{turb} (core)	0.183	0.328
c_∞ [m/s]	346.0	344.9
c_{fan}	350.3	349.2
c_{turb}	510.0	526.8
ρ_∞ [kg/m^3]	1.167	1.147
ρ_{fan}	1.226	1.393
ρ_{turb}	0.550	0.526

Mesh Parameters (basics)	
Discretization:	unstructured
Element shape:	Triangle
Topology:	Tria6 interpolation order 2 (quadratic)
Fineness:	≥ 4 elements per wavelength*

*) Doppler corrected

Results

Actran/TM (Moehring) versus Actran/DGM

1. Flow field, based on RANS computation, interpolated on Acoustic mesh

2. Sound field:

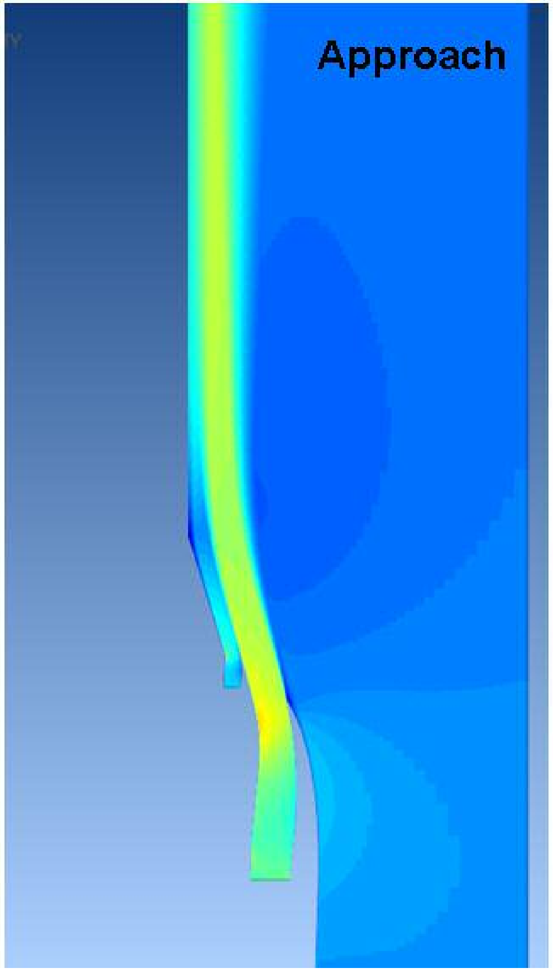
Single modes of order (m,n):

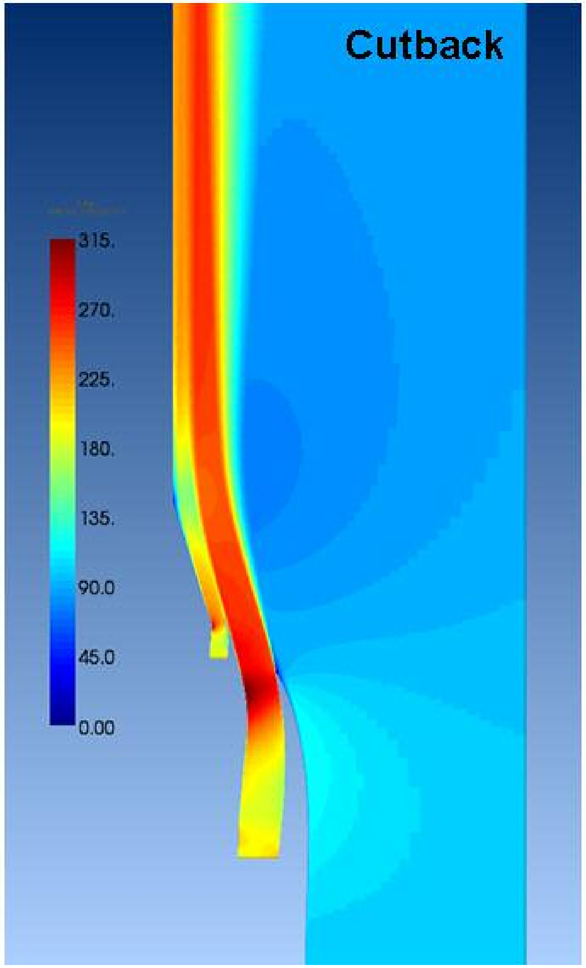
- Near field color map (sound pressure)
- Far field directivity (SPL_dB at arc 46m field points)

Superposition of numerical modes:

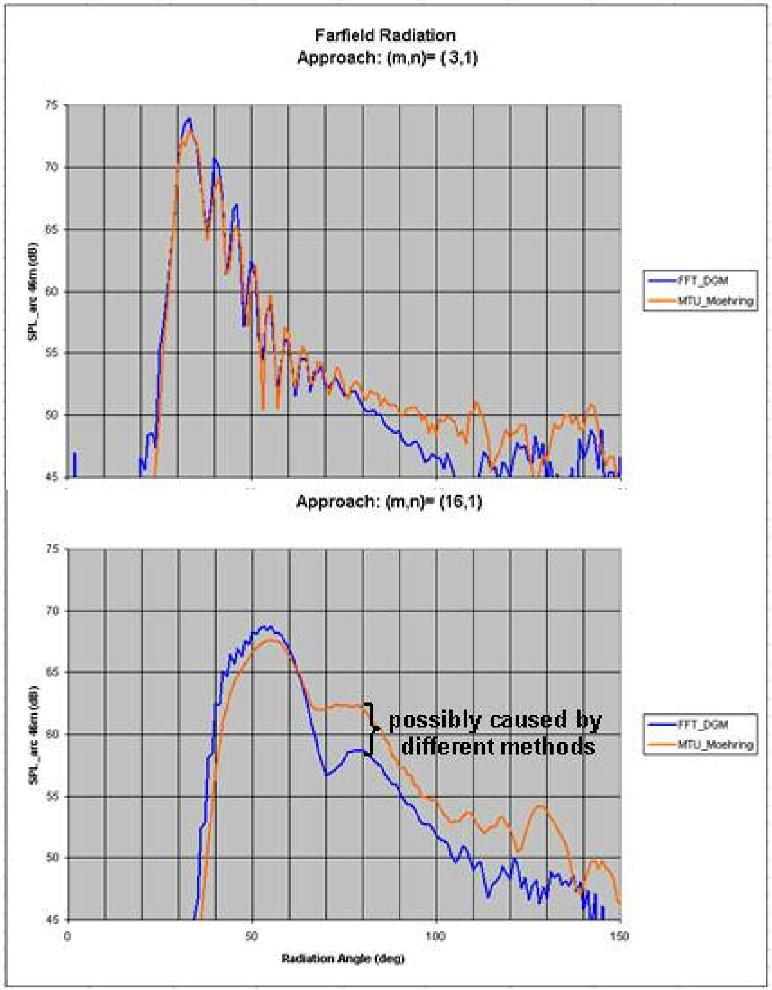
- Far field directivity (SPL_dB at arc 46m field points)

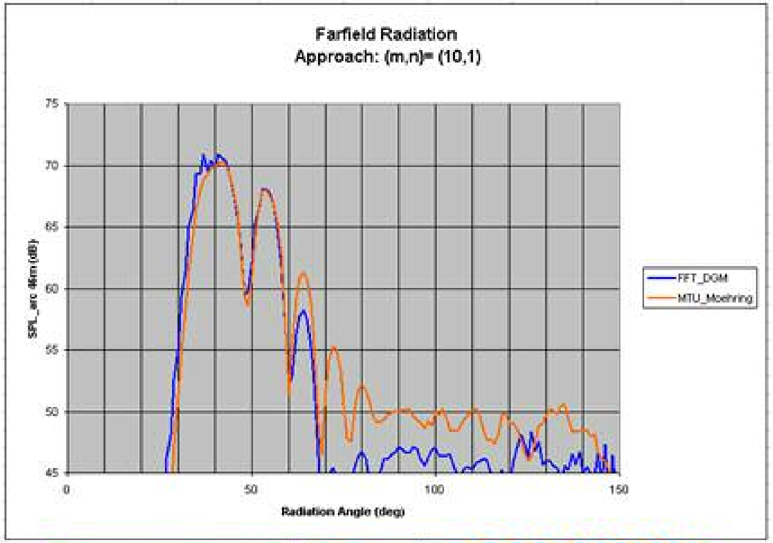
Results:
Interpolated flow field (e.g. mean velocity)

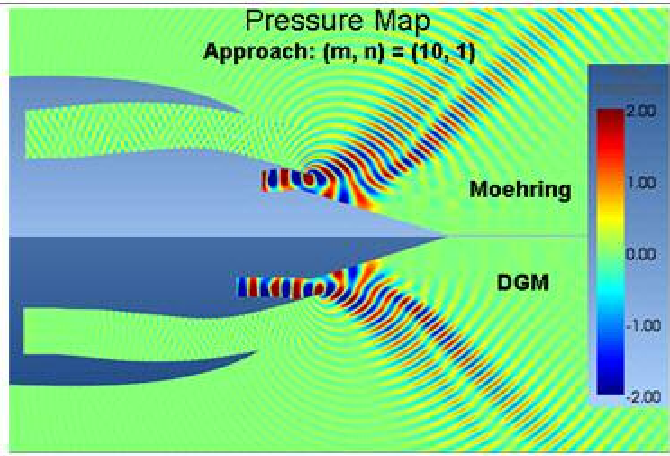




Results: Single Modes, Approach
Actran TM(Moehring) versus DGM

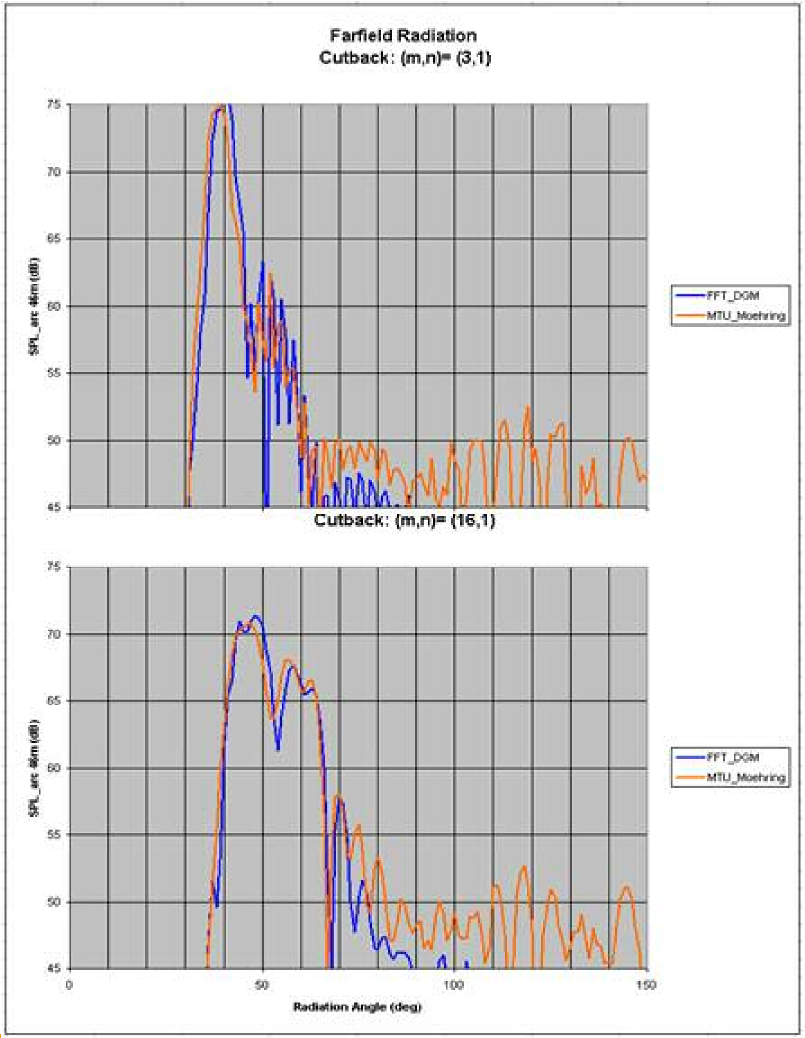


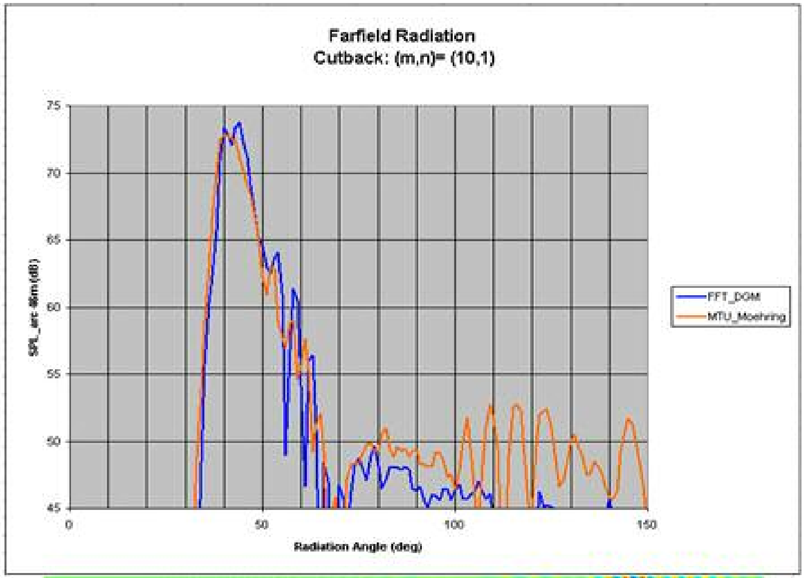


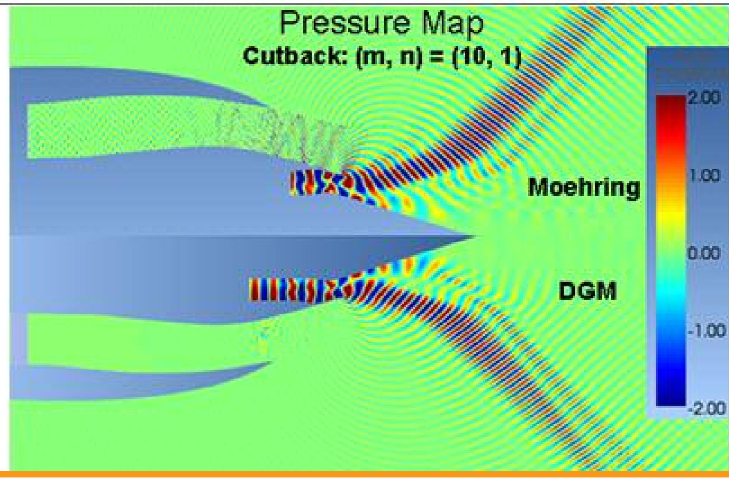


Results: Single Modes, Cutback

Actran TM(Moehring) versus DGM

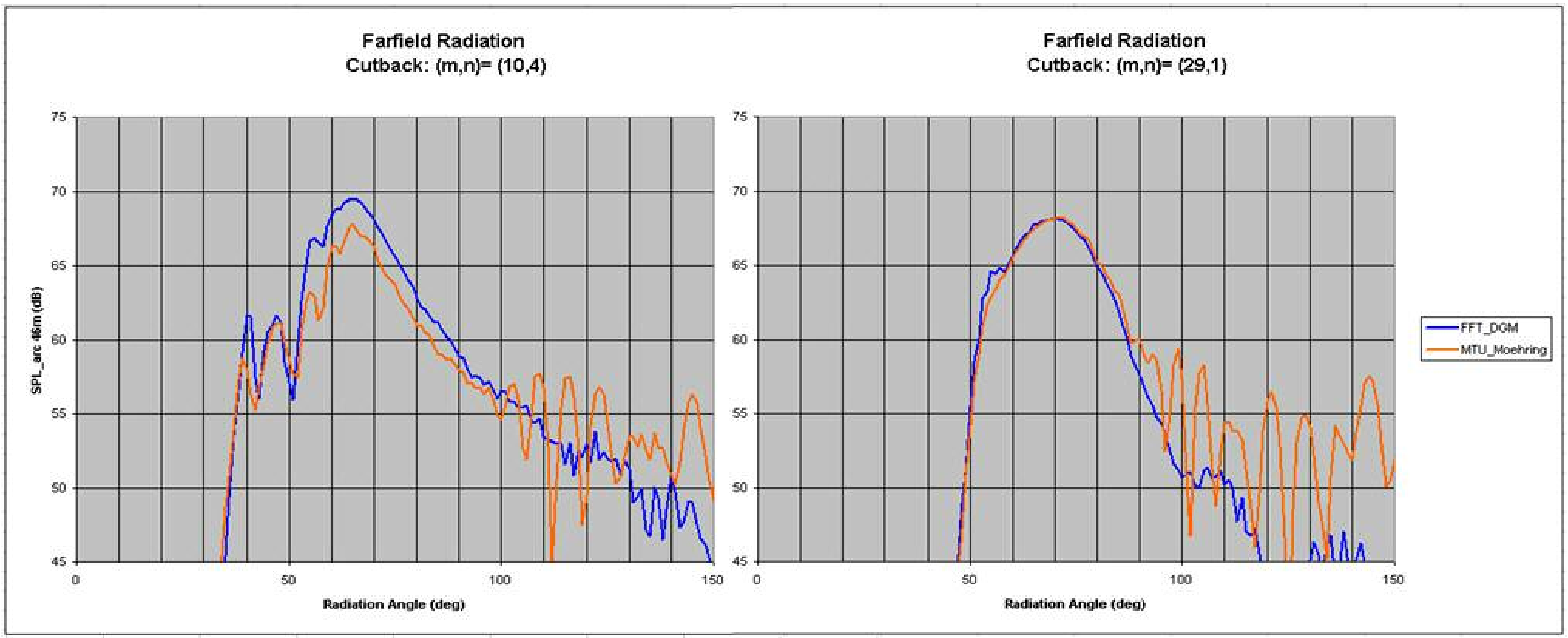






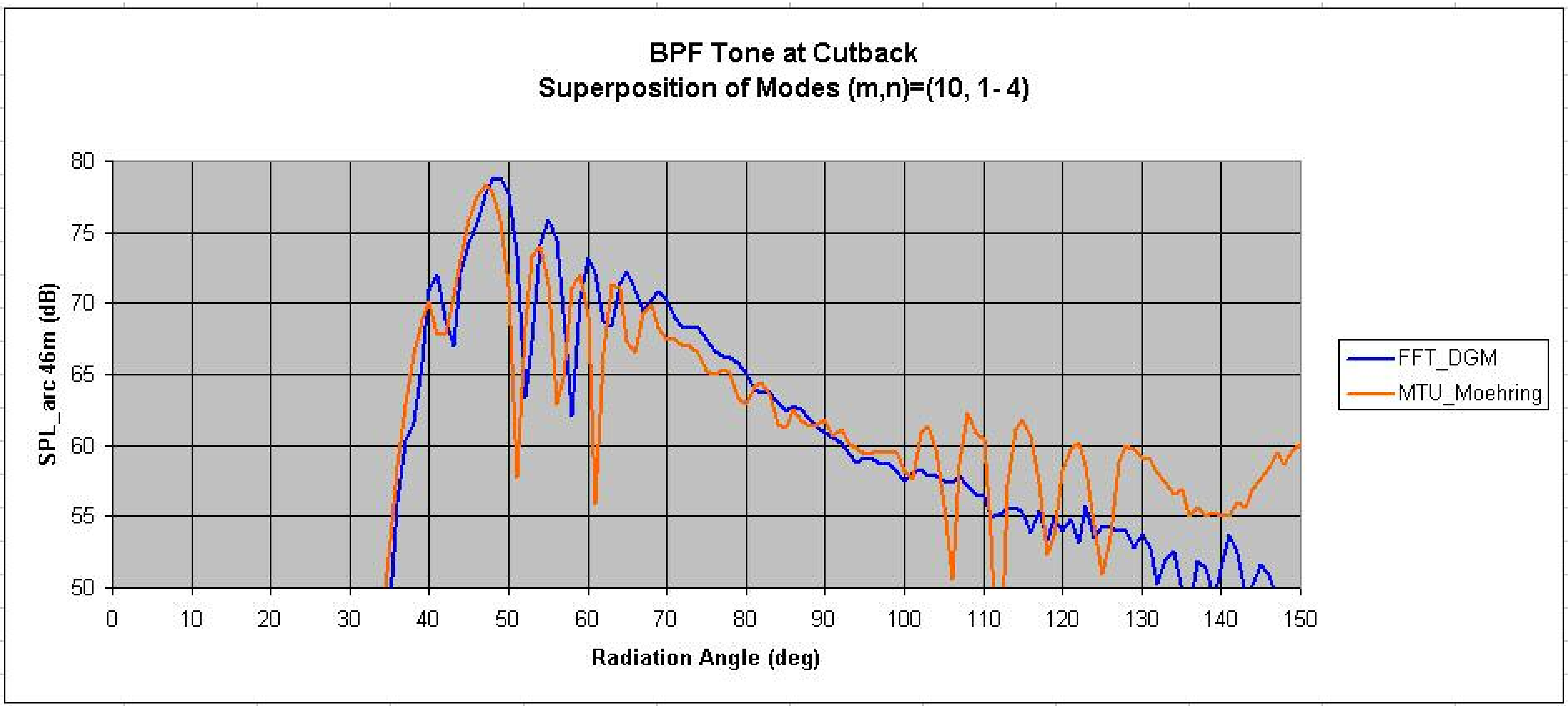
Results: Single Modes, Cutback

Modes of high radial or azimuthal order



Results:

Superposition of modes of order (10, 1-4)



Conclusions

- Actran/TM(Moehring) method has been successfully validated with Actran/DGM; the numerical results reproduce the main expected features.

- TM/Moehring method has been proved to be a valuable tool for the analysis of the exhaust noise radiation problem even for engine configurations and flow properties close to reality.

- TM/Moehring is well suited to improve the (acoustic) design process: it models the physics with acceptable assumptions within reasonable computing times.

Acknowledgements

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  MAssive **S**challpegel **S**enkung **I**m **F**lugverkehr – **Effek**tive **T**riebwerkslärmminderung

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Thank you
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Merci