COMSOL CONFERENCE ROTTERDAM 2013

Loudspeaker Simulation Efficiency & Accuracy

using i) A Conventional Model, ii) The Near-To-Far-Field Transformation and iii) The Rayleigh Integral

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Agenda

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- Who We Are?

Loudspeaker simulations

- Simulation Objective
- Simulation Procedures
  - Conventional
  - Near-to-far-field (COMSOL)
  - Rayleigh integral (FEA2SCN+Klippel)
- Loudspeaker Cases
- Results
  - Pressure frequency responses
  - Time & Memory reductions
- Conclusions

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Who We Are?

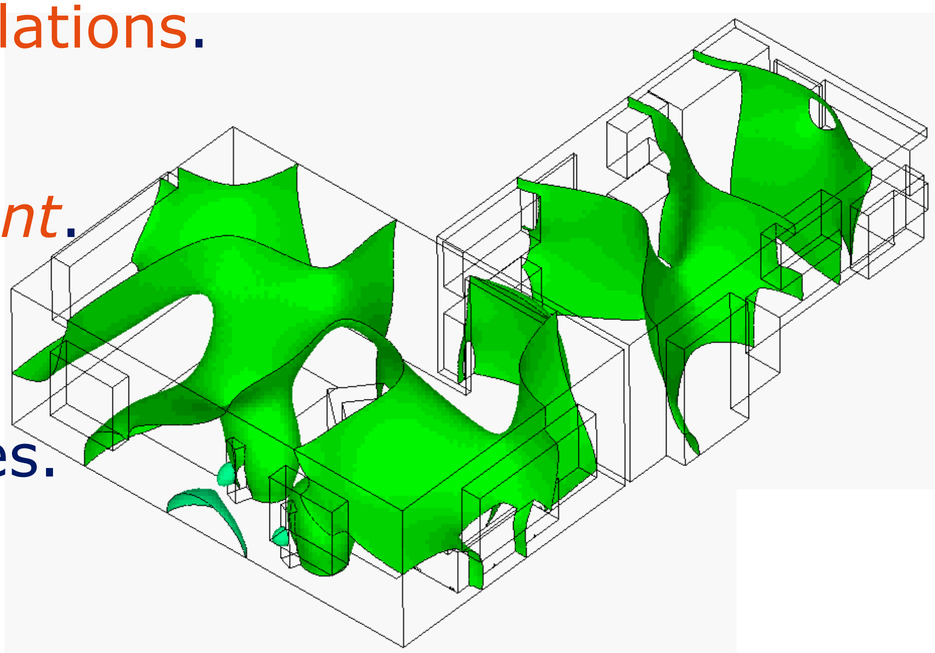
iCapture provides consulting, technology implementation and training in the field of multiphysics:

- Electromagnetic
- Vibroacoustic &
- Structural Dynamic

product development & simulations.

Since 2011 iCapture is a *Certified COMSOL Consultant*.

Work in loudspeaker, wind, medical and other industries.



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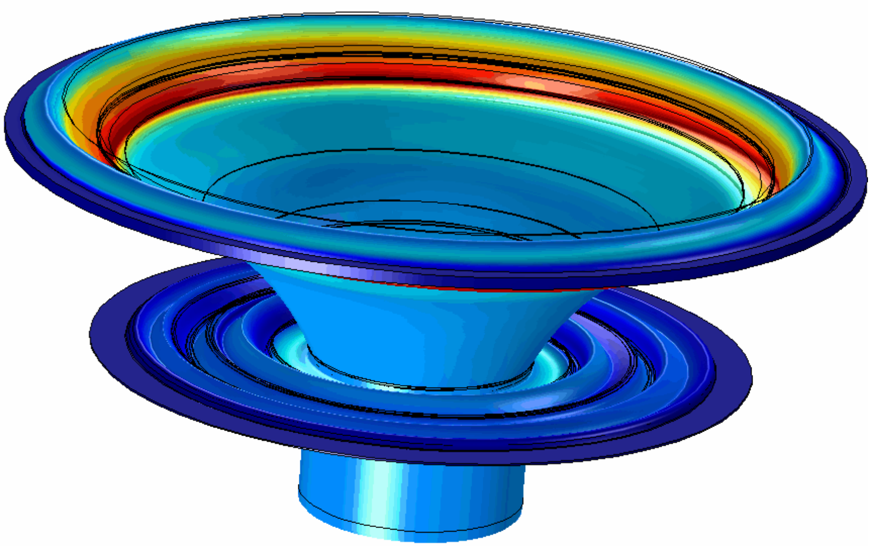
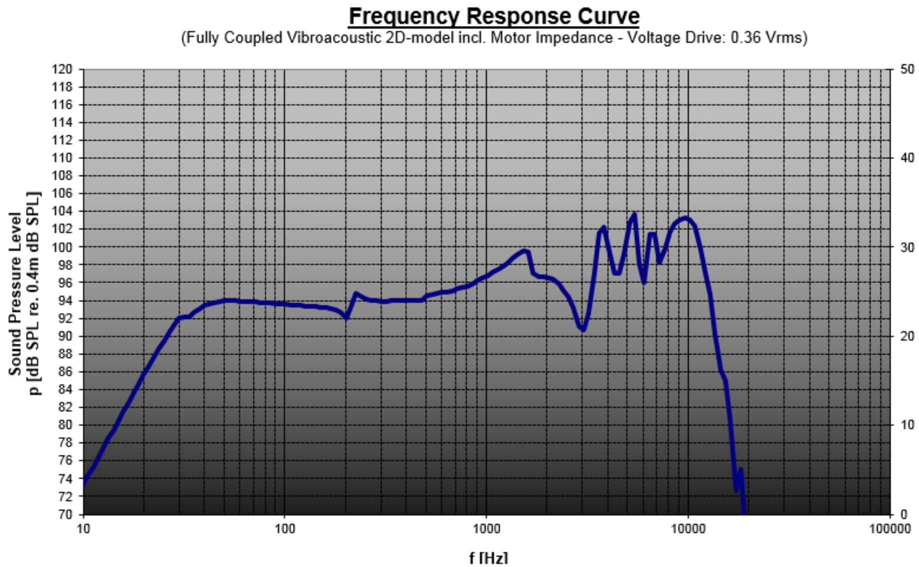
Simulation Objective

- Pressure (and impedance) frequency response





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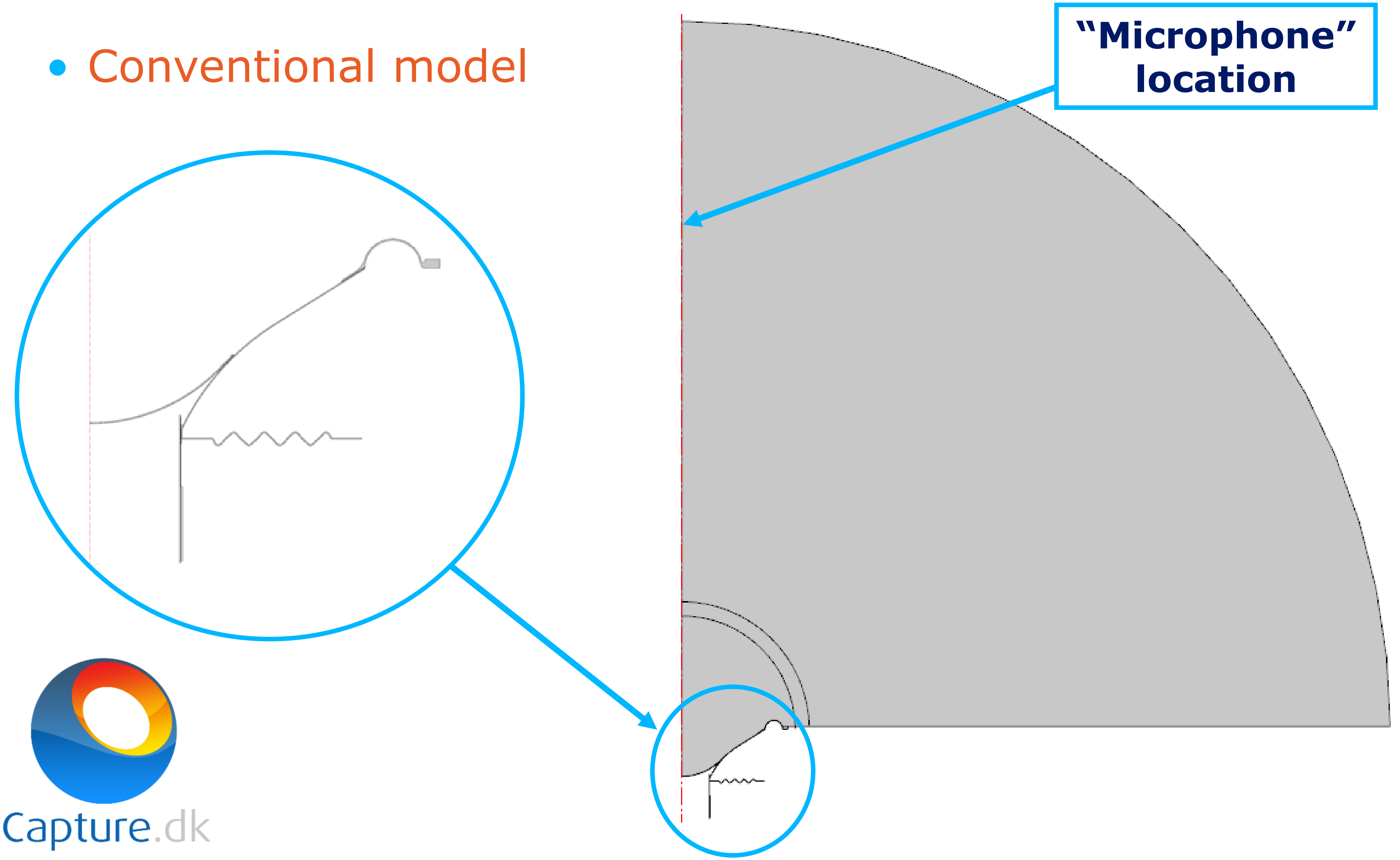
Simulation Procedures

- Conventional model



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Simulation Procedures

- Near-to-far-field transformation in COMSOL

$$C(P)p(P) = \int_S \left(i\rho\omega v_n(Q)G(r) + p(Q)\frac{\partial G(r)}{\partial n} \right) dS$$

- P indicates an observation point,
- Q is a point on the closed surface S
- $C(P)$ is the spatial angle in the measurement point, here 4π
- ρ is the density of the medium
- $v_n(Q)$ is the normal velocity in point Q with the normal denoted n, and
- the full space Green's function is defined:

$$G(r) = \frac{e^{-ikr}}{r}, \text{ where}$$

- r is the distance between points P and Q.

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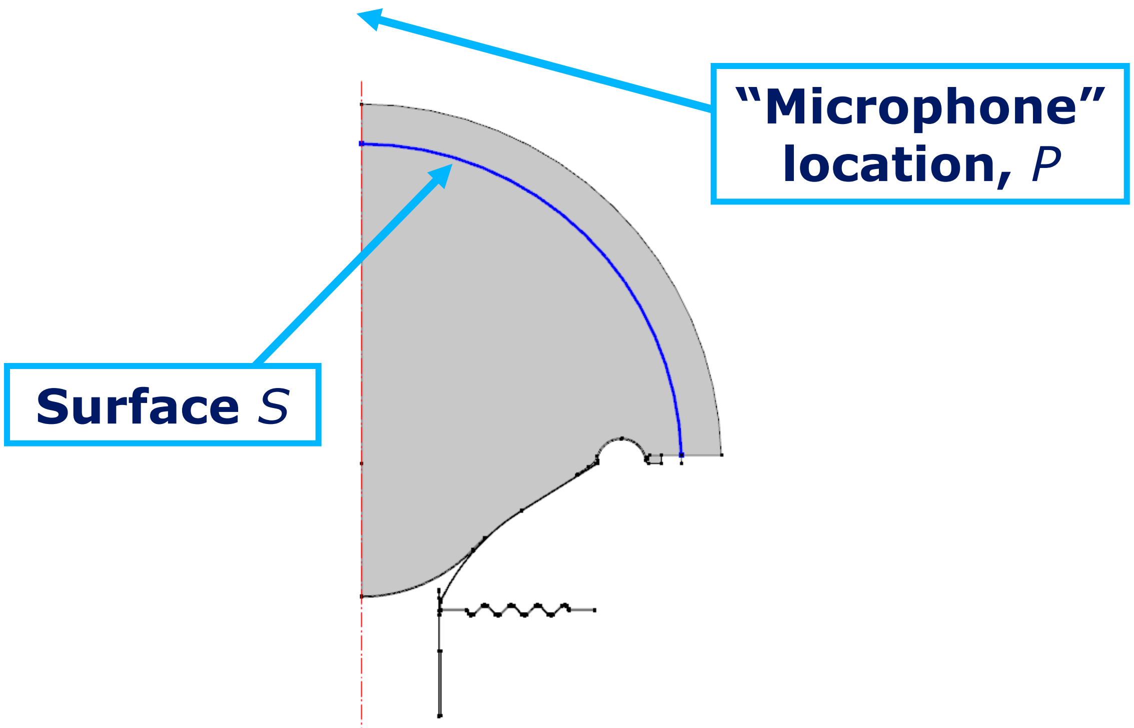
Simulation Procedures

- Near-to-far-field transformation in COMSOL

$$C(P)p(P) = \int_S \left(i\rho\omega v_n(Q)G(r) + p(Q)\frac{\partial G(r)}{\partial n} \right) dS$$



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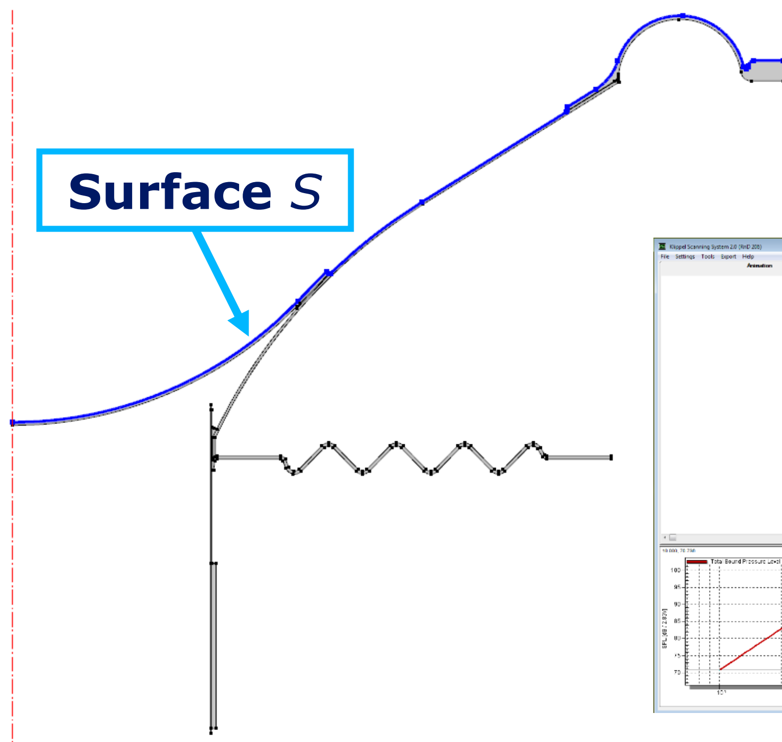
Simulation Procedures

- Rayleigh integral via FEA2SCN and Klippel Scanner

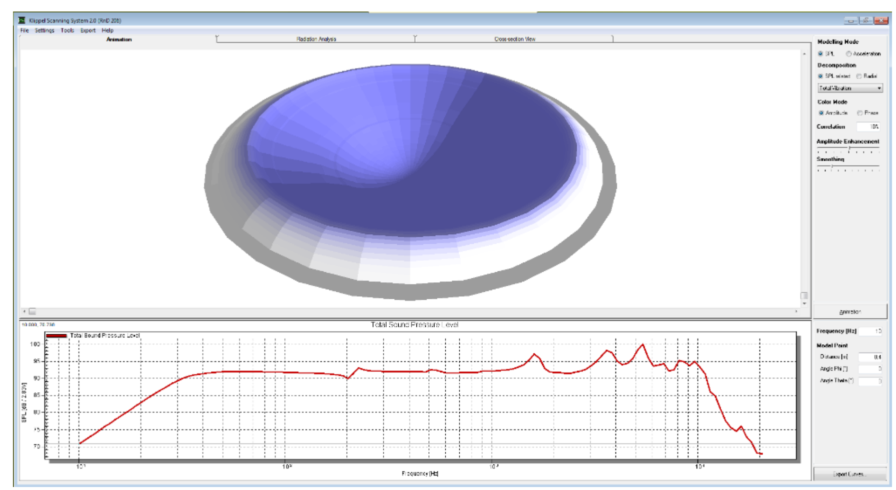
Assumption:

Flat geometry in baffle

$$p(P)=\int_S \frac{i\rho\omega v_n(Q)}{2\pi}G(r)dS$$



FEA2SCN



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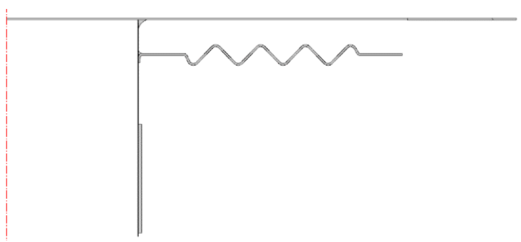
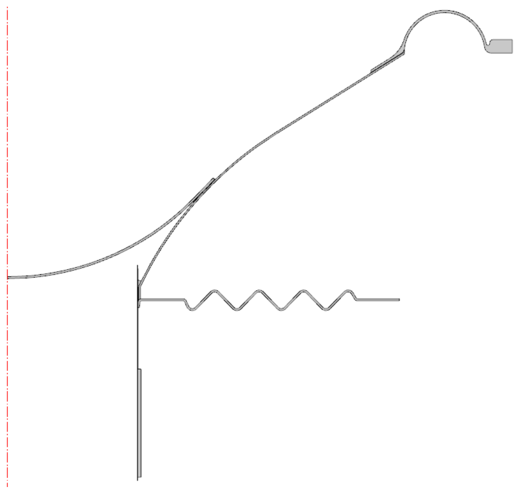
Loudspeaker Cases

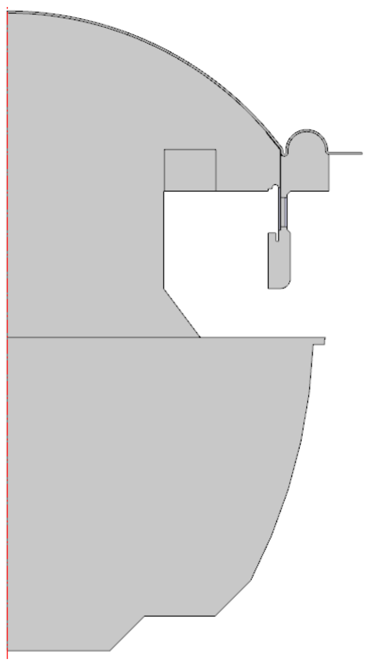
Totally Flat 6”



Convex Cone 6”



Concave Dome 3”



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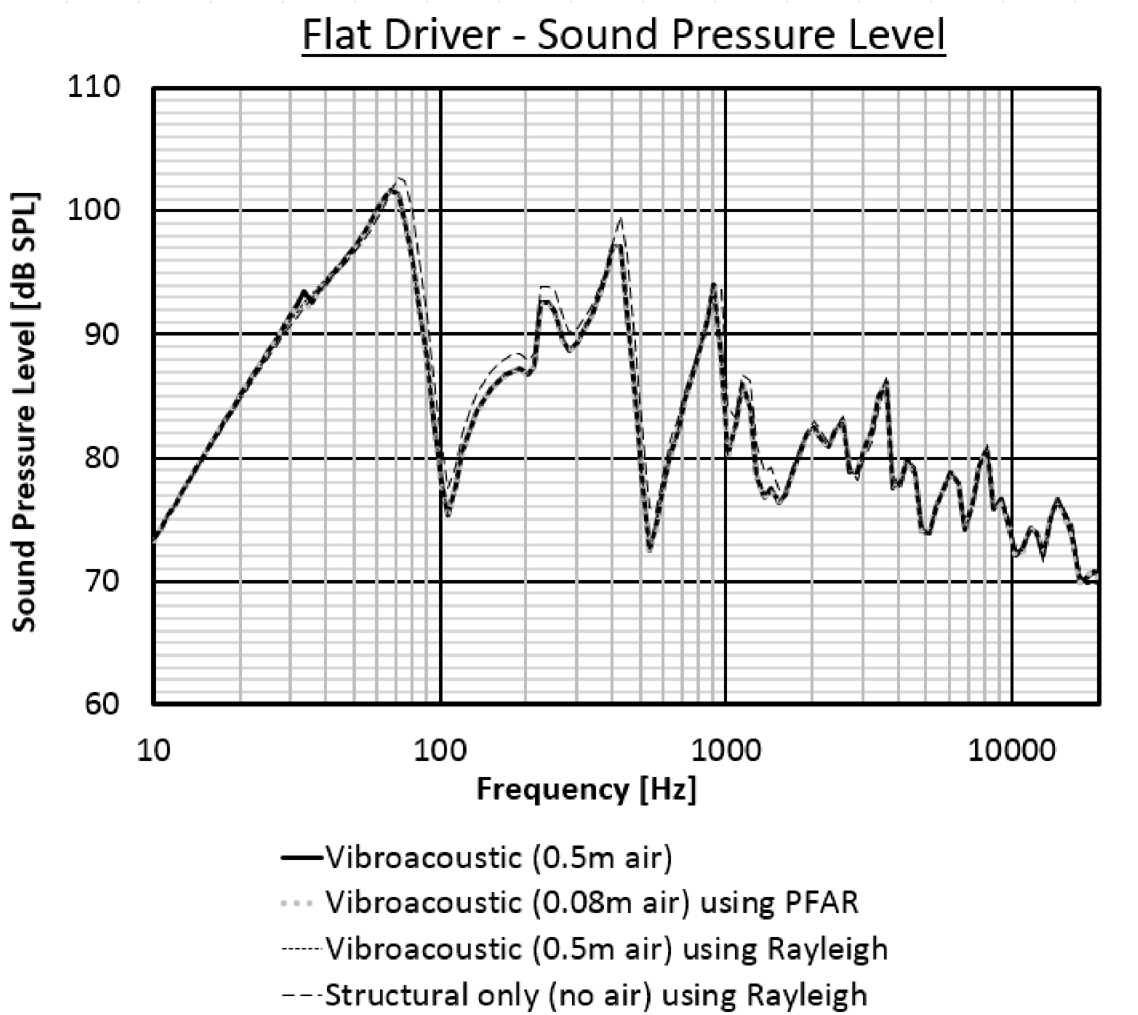
Results

- Totally Flat 6”



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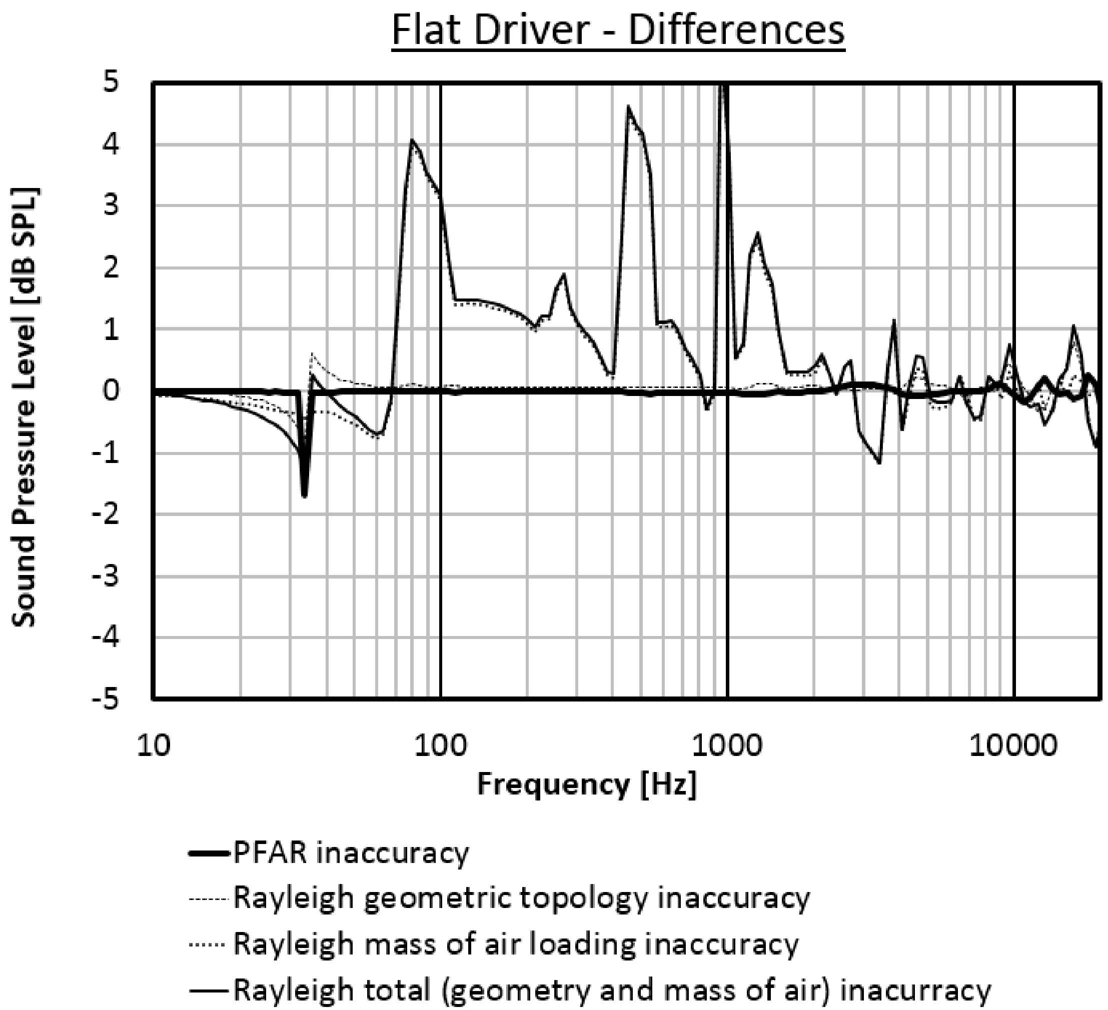
Results

- Totally Flat 6"



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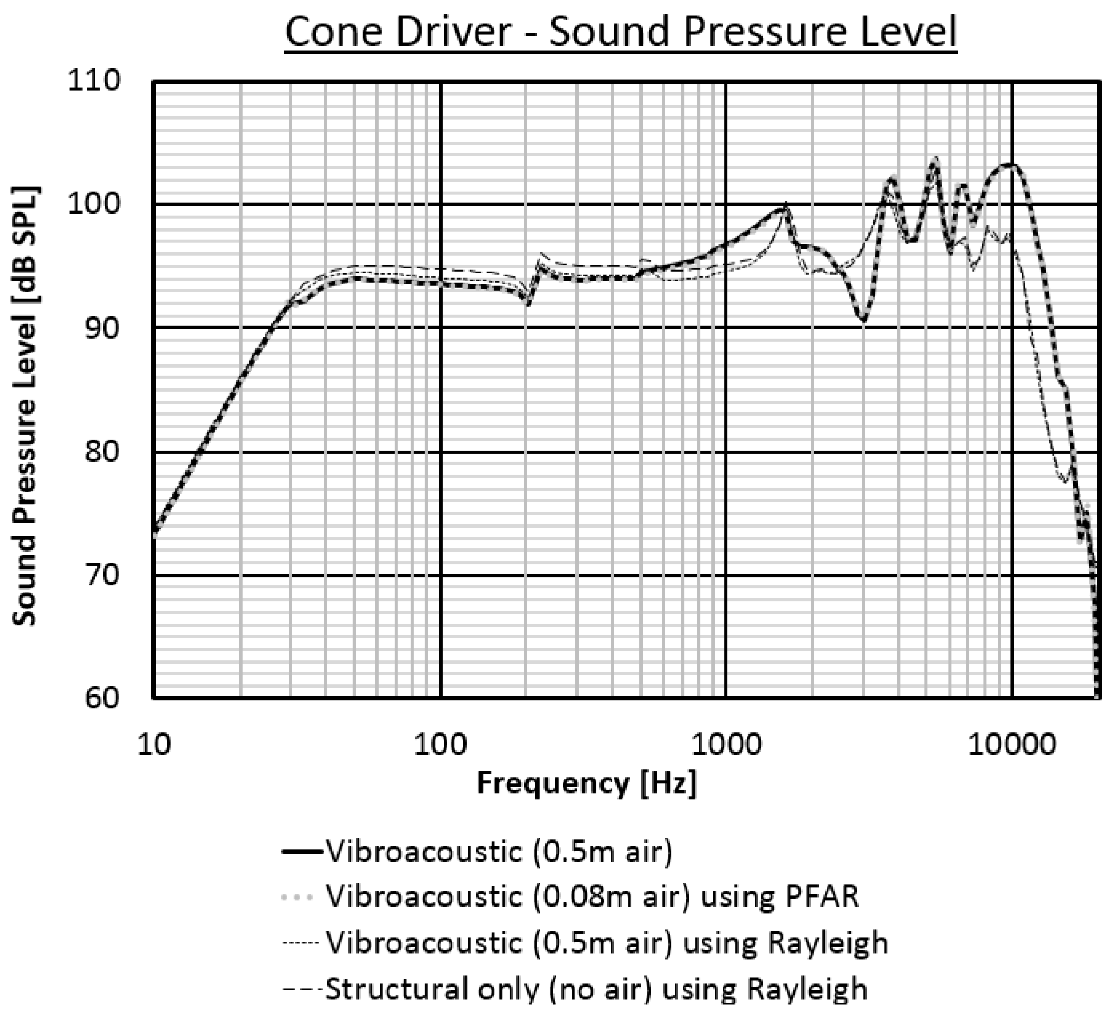
Results

- Concave Cone 6”



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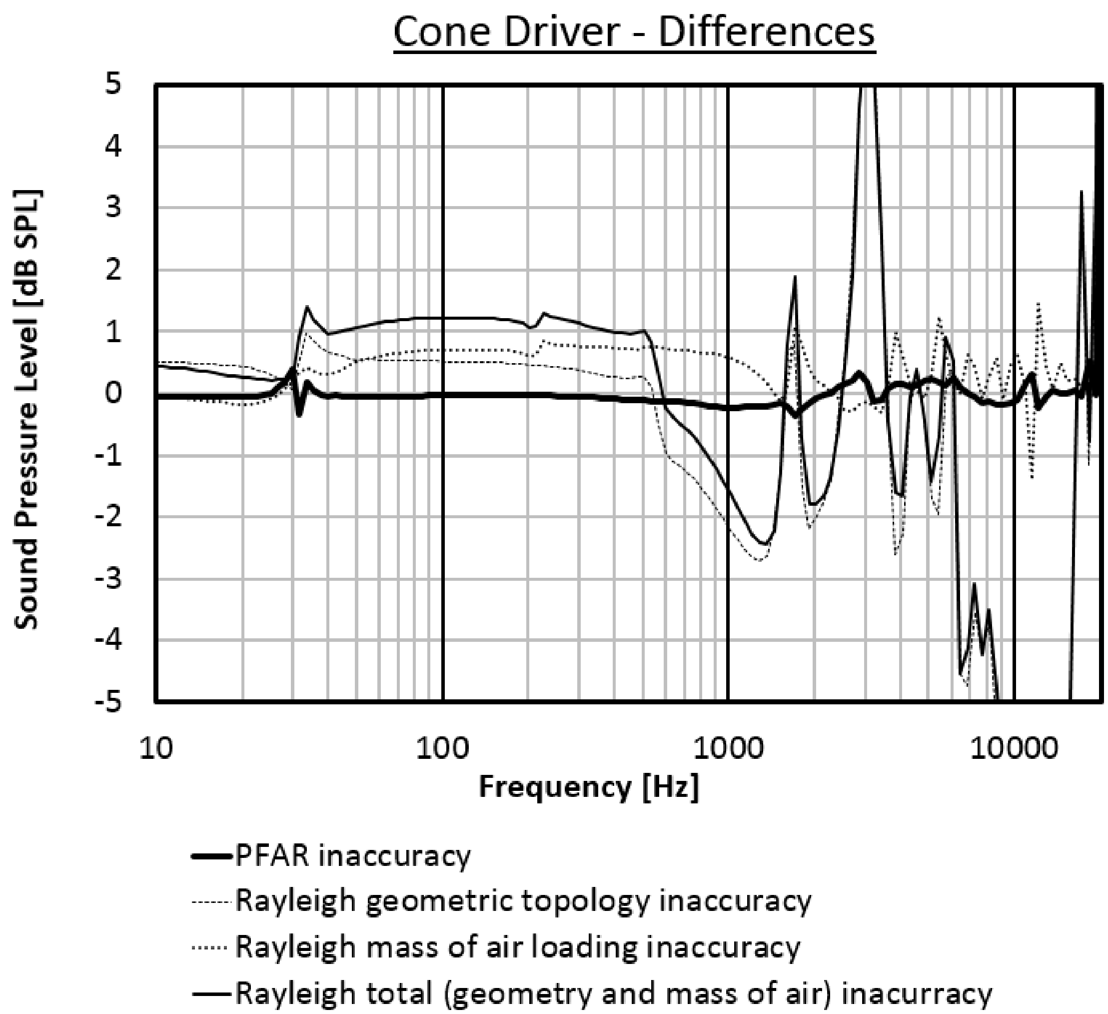
Results

- Concave Cone 6"



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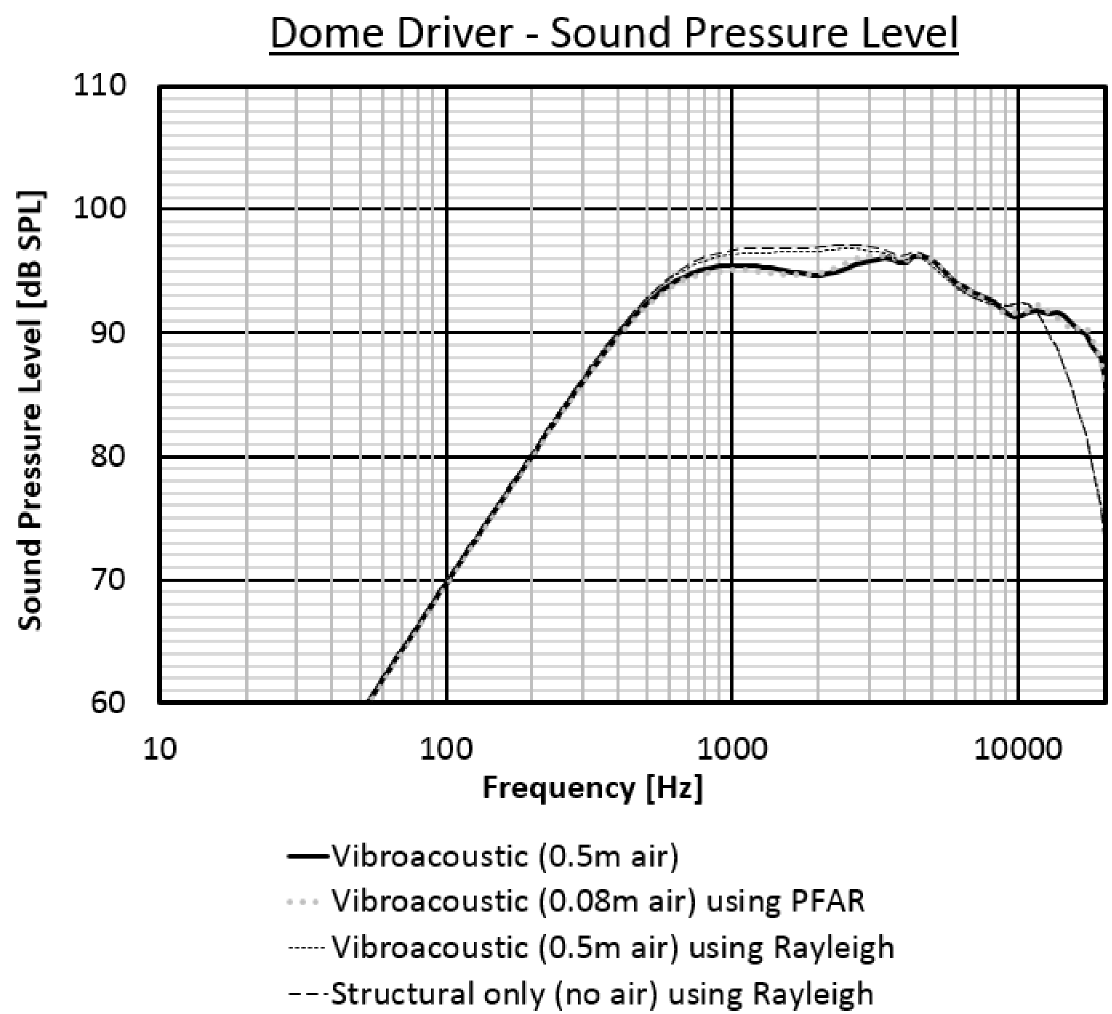
Results

- Convex Dome 6”



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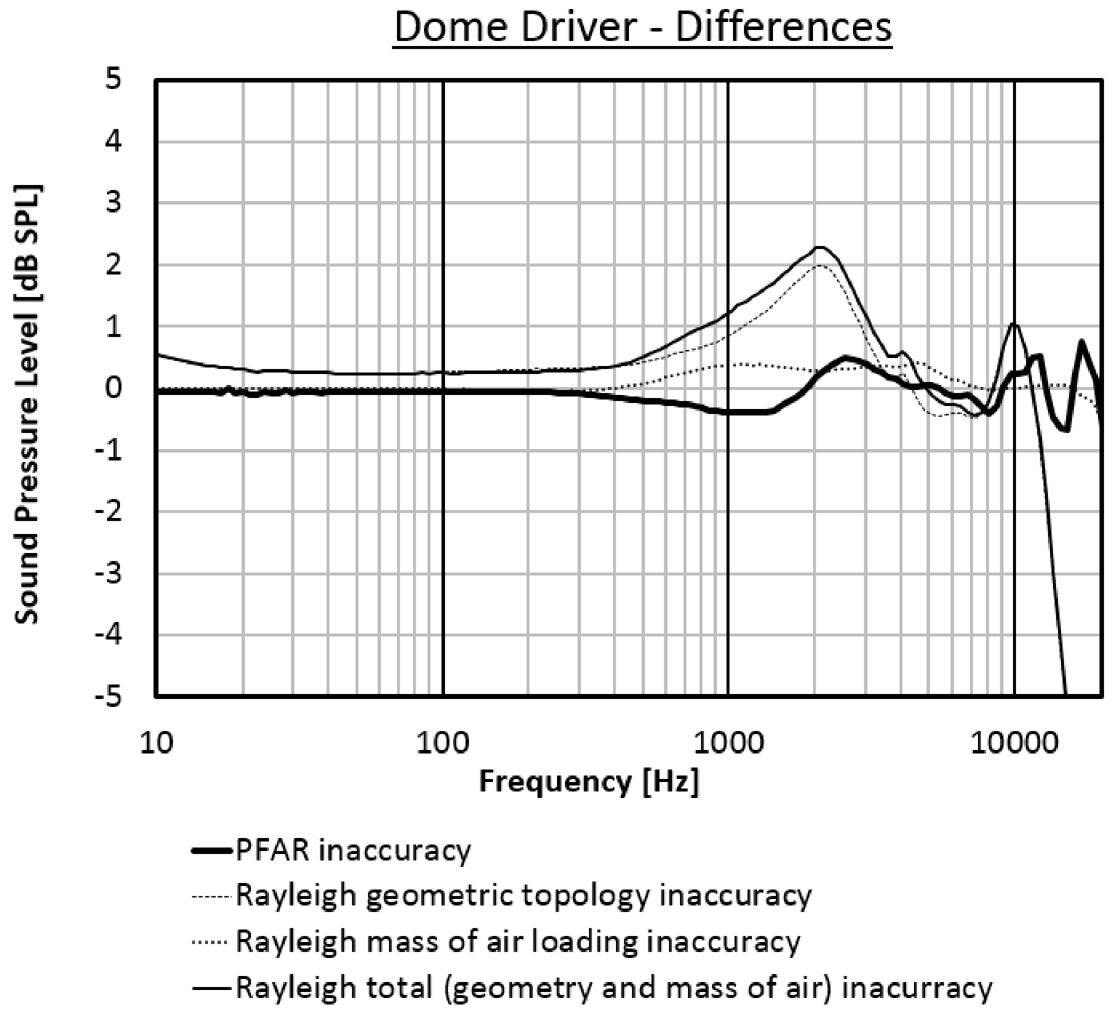
Results

- Convex Dome 6”



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Results

Simulation	DOFs	FEA time [s]	FEA2SCN time [s]	Memory [GB]
Flat Full VA (0.5m air)	192,873 ***100%***	386 ***100%***	36	1.2
Flat VA+PFAR (0.08m air)	54,750 ***28%***	126 ***33%***	-	0.80
Flat Rayleigh (no air)	41,988 ***22%***	100 ***26%***	36	0.75
Cone Full VA (0.5m air)	211,916 ***100%***	434 ***100%***	37	1.2
Cone VA+PFAR (0.08m air)	74,118 ***35%***	171 ***39%***	-	0.83
Cone Rayleigh (no air)	59,114 ***28%***	140 ***32%***	37	0.84
Dome Full VA (0.5m air)	246,899 ***100%***	635 ***100%***	18	1.8
Dome VA+PFAR (0.08m air)	109,712 ***44%***	325 ***51%***	-	1.4
Dome Rayleigh (no air)	98,002 ***40%***	306 ***48%***	18	1.3

Table 1 Simulation statistics for 133 frequencies solved with 8 cores 3.9GHz Xeon processors having 1333MHz RAM modules (index numbers in italic)

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Conclusion

It is possible to do reduced vibroacoustic models via both the near-to-far-field transformation and the Rayleigh integral methods reducing the calculation time by 50-70 % (for 3D the reduction is up to 75-85 % via FEA2SCN).

With the near-to-far-field method accurate results are obtained for all loudspeaker cases.

With the Rayleigh integral method accurate results are obtained for the flat loudspeaker case. For the convex cone and the concave dome speaker cases the results deviate ±5.0 dB due to the curved (non-flat) geometries.

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