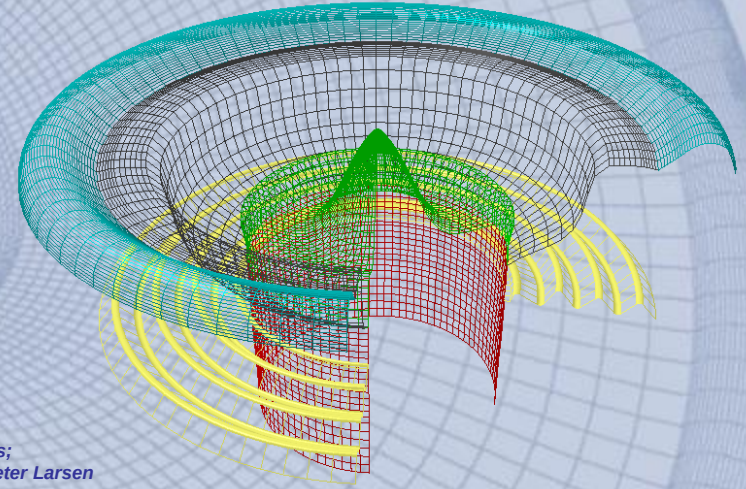
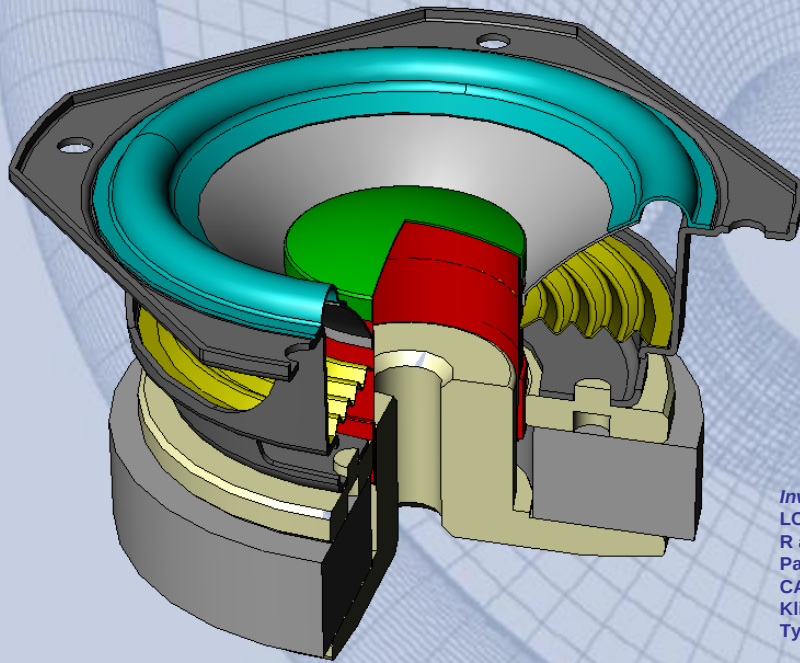


AES 126th Loudspeaker FEA/BEM Workshop

Panelist: Peter Larsen LOUDSOFT

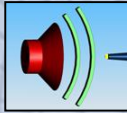


Invited Participant Companies;
LOUDSOFT loudsoft.com - Peter Larsen
R and D Team randteam.de - Joerg Panzer
Pafec vibroacoustics.co.uk - Patrick Macey
CAPA Wisoft.de - Hermann Landes
Klippel klippel.net - Wolfgang Klippel
Tymphany Tymphany.com - Richard Little

Loudspeaker FE/BE Modeling Workshop:

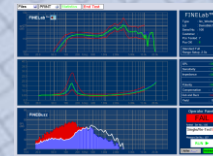
This workshop will explore FE/BE modeling of loudspeaker drivers. A case study of an existing loudspeaker driver will be modelled by each panellist to benchmark the capabilities of their modeling software package. A loudspeaker driver dimensions and material properties will be provided to panellists in advance of the convention so that they may develop a thorough model for presentation at the workshop. Results will be discussed along with measurement analysis of the real loudspeaker driver.

LOUDSOFT



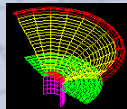
FINELab™QC

Loudspeaker/Transducer Production Test system



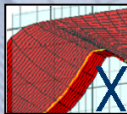
FINEMotor™

Magnet System & Voice Coil Design Program



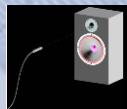
FINECone™

Acoustic Finite Element Dome/Cone Simulation



FINEBox™

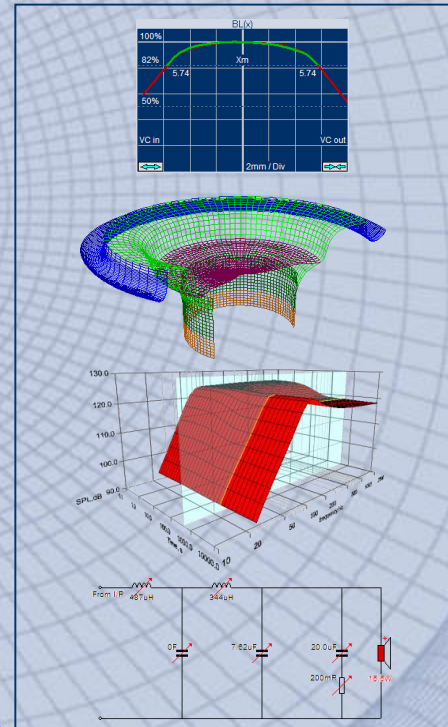
Non-Linear High Power Box Design Program



FINE X-over™

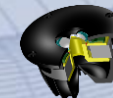
X-over Design Program

More than 500 software licenses worldwide



CONSULTING - Peter Larsen

Speaker design for customers using software and experience



LOUDSOFT

AES 126th Loudspeaker FEA/BEM Workshop

FINEMotor simulated TS parameters versus measured (Klippel)

Measurement in Vacuum

In air

In vacuum

Electrical Parameters

Re	7.13	Ohm
Le	0.046	mH
L2	0.181	mH
R2	1.84	Ohm
Cmes	182.02	μF
Lces	5.38	mH
Res	21.14	Ohm
fs	160.8	Hz

Mechanical Parameters (using laser)

Mms	1.277	g
Mind (3d)	1.244	g
Rms	0.332	kg/s
Cms	0.767	mm/N
Kms	1.30	N/mm
Bl	2.649	N/A
Lambda s	0.096	

Loss factors

Qtp	0.982
Qms	3.007
Qes	1.311
Qts	0.981

Vas 0.2443 l

Electrical Parameters

Re	7.04	Ohm
Le	0.048	mH
L2	0.198	mH
R2	1.96	Ohm
Cmes	162.01	μF
Lces	5.51	mH
Res	16.93	Ohm
fs	168.4	Hz

Mechanical Parameters (using laser)

Mms	1.095	g
Mind (3d)	1.002	g
Rms	0.399	kg/s
Cms	0.815	mm/N
Kms	1.23	N/mm
Bl	2.600	N/A
Lambda s	0.094	

Loss factors

Qtp	0.854
Qms	2.902
Qes	1.207
Qts	0.853

Vas 0.2596 l

TS Parameters

Sensitivity (2.83V/1.00m)	SPL	79.72	dB
VC Resistance DCR	Re	7.00	Ohms
Resonance	Fs	161.00	Hz
Mechanical	Qms	4.00	
Electrical	Qes	1.27	
Total	Qts	0.96	
Equivalent air vol.	Vas	0.25	l
Compliance	Cms	0.77	mm/N
Moving Mass(incl. air)	Mms	1.27	g
Force Factor	Bl	2.66	Tm
Eff. diaphragm area	Sd	15.33	sq.cm
Lin. Excursion +/-	Xmlin	0.87	mm

The predicted BL is really close to the Klipper Laser measurement

FINEMotor Prediction of TS Parameters

Flux Profile

Flux Contour w/ frame Bn500.txt

Bg=0.8147T
Bd=0.2570T
Bt=1.3174T

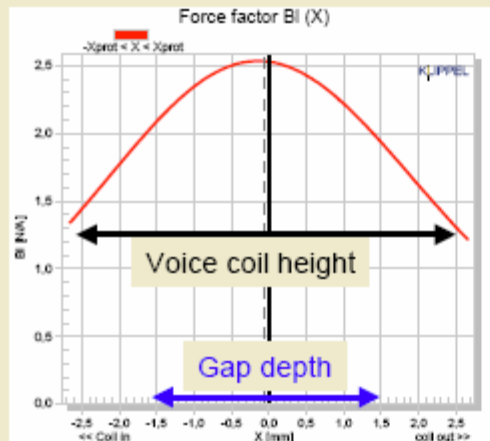
Offset 0.00mm

AES 126th Loudspeaker FEA/BEM Workshop

FINEMotor simulated BL(x) versus measured (Klippel)

Dominant Nonlinearities: BL(x)

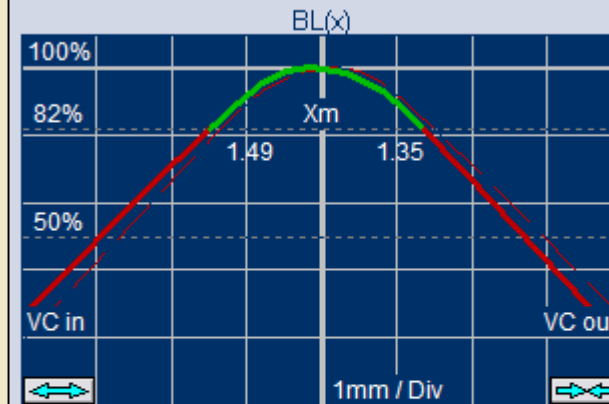
Measured by using the LSI module



50 %

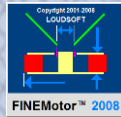
XBL=1.3 mm @ $BL_{min}=82\%$ (10 % intermodulation distortion in SPL, mainly 3rd-order)

FINEMotor BL(x) Calculation

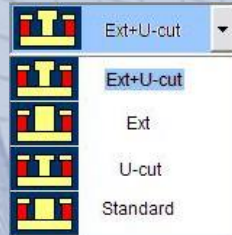


Predicted by FINEMotor:

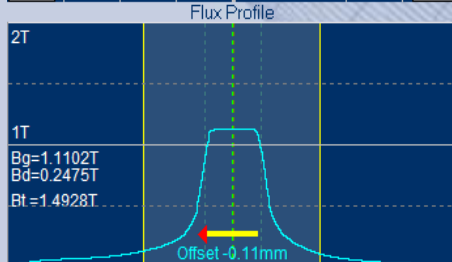
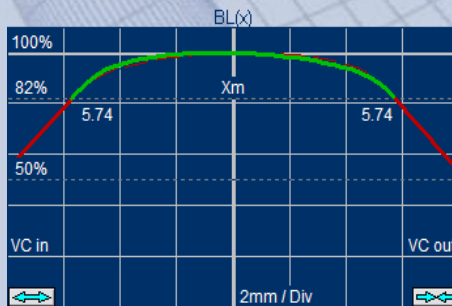
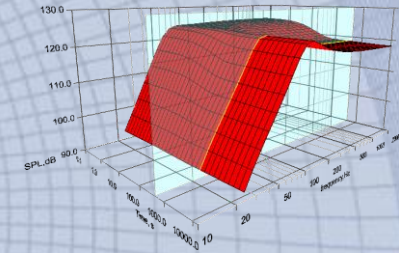
XBL @ 82% $BL_{min}=1.35$ mm.
The shape and symmetry of the $BL(x)$ curve is extremely close to that measured by Klippel



FINEMotor™

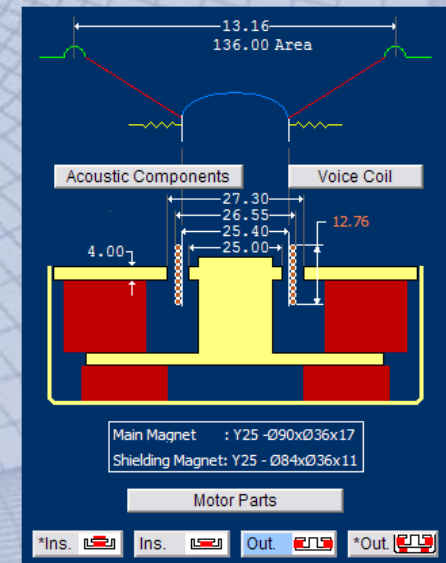


- *Instant TS parameters*
- *Non-linear BL(x) curves*
- *Flux profile with VC Offset*
- *Ferrofluid simulation*
- *Thermal compression model*



Mechanical Parameters			
Layers	n	2	
Wire Material		Copper	
Wire Type		Round	
Wind Width	WW	15.55	mm
Number of Windings	N	133.67	
Nom.(bare) Wire diam	BWD	0.200	mm
Total Winding OD	WOD	26.63	mm
Total Winding Mass	Mvc	3.157	g
Stretch		4.00	%

TS Parameters			
Sensitivity (2.83V/1.00m)	SPL	87.95	dB
VC Resistance DCR	Re	6.20	Ohms
Resonance	Fs	38.43	Hz
Mechanical	Qms	6.00	
Electrical	Qes	0.45	
Total	Qts	0.42	
Equivalent air vol.	Vas	39.35	l
Compliance	Cms	1.54	mm/N
Moving Mass(incl. air)	Mms	11.16	g
Force Factor	Bl	6.07	Tm
Eff. diaphragm area	Sd	134.99	sq.cm
Lin. Excursion +/-	Xmlin	5.28	mm

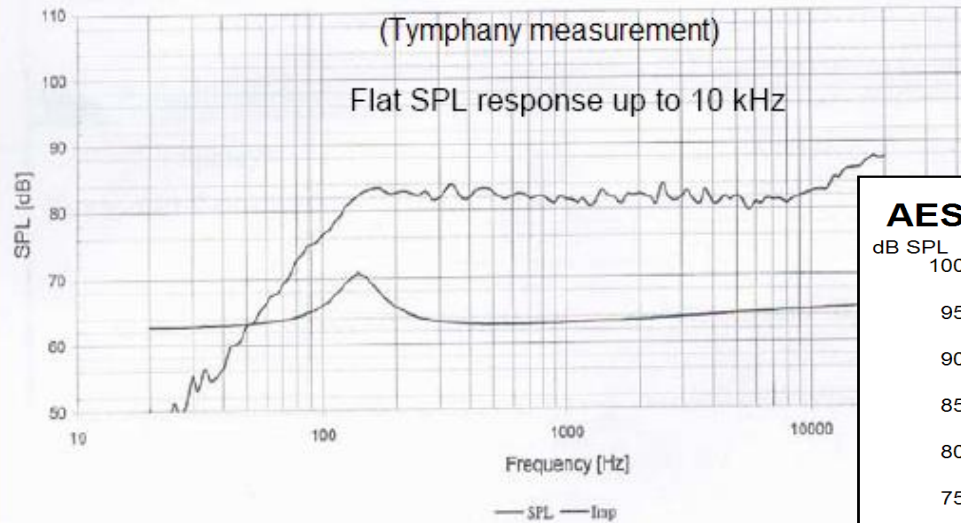
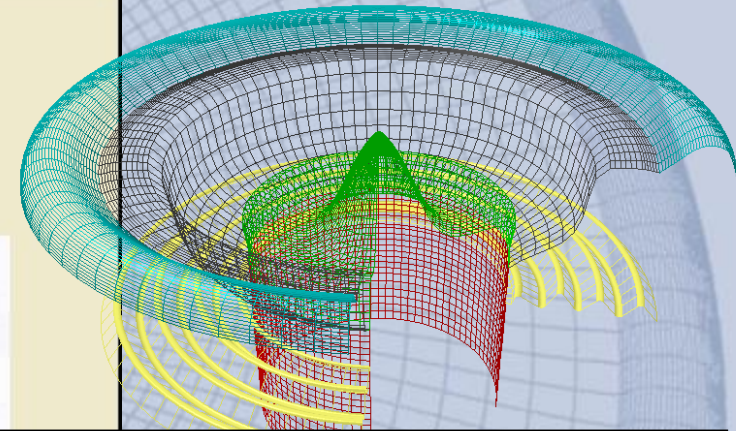


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FINECone FEA versus measured response

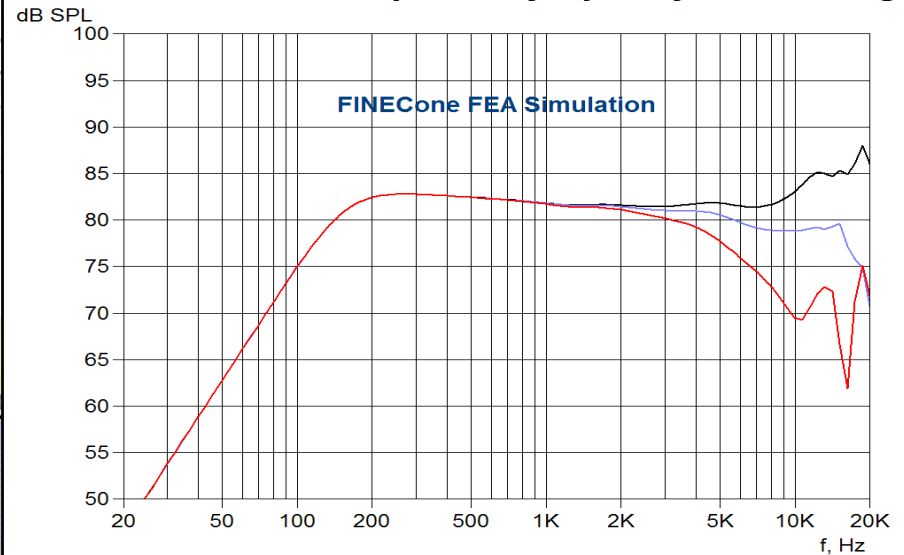
Sound Pressure Response

Baffle 1 m 1W



Klippel, Loudspeaker Analysis, Workshop AES 20

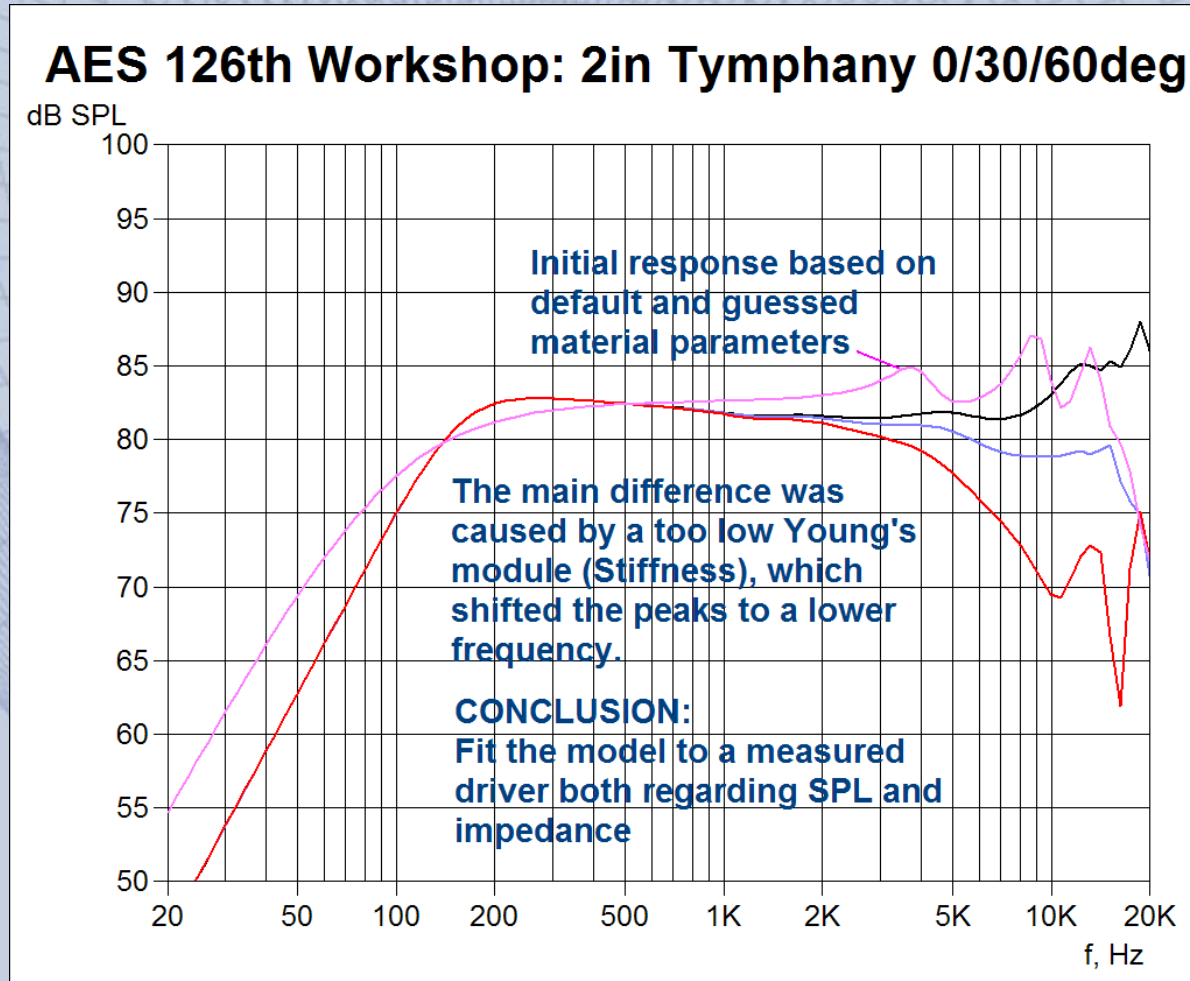
AES 126th Workshop: 2in Tymphany 0/30/60deg



LOUDSOFT

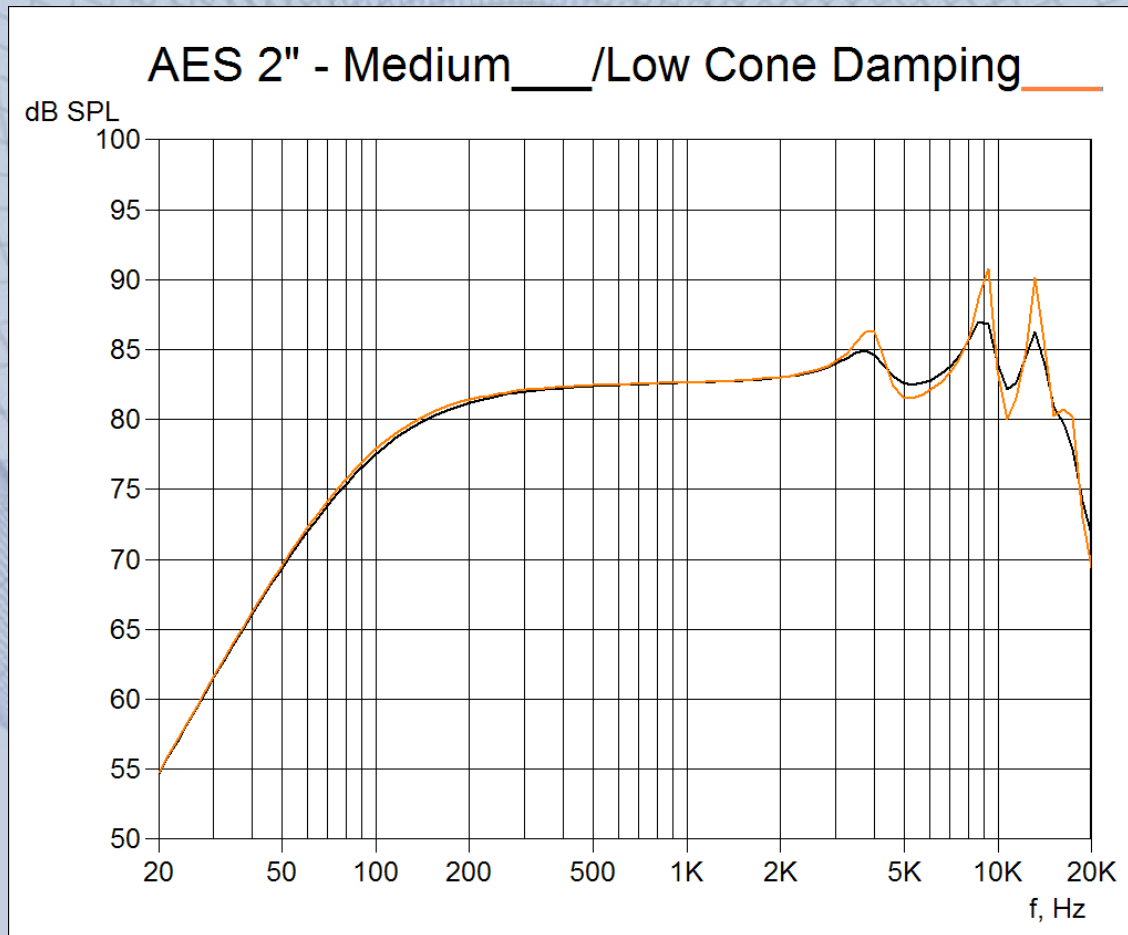
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Influence of Initial and Final FEA Material Parameters



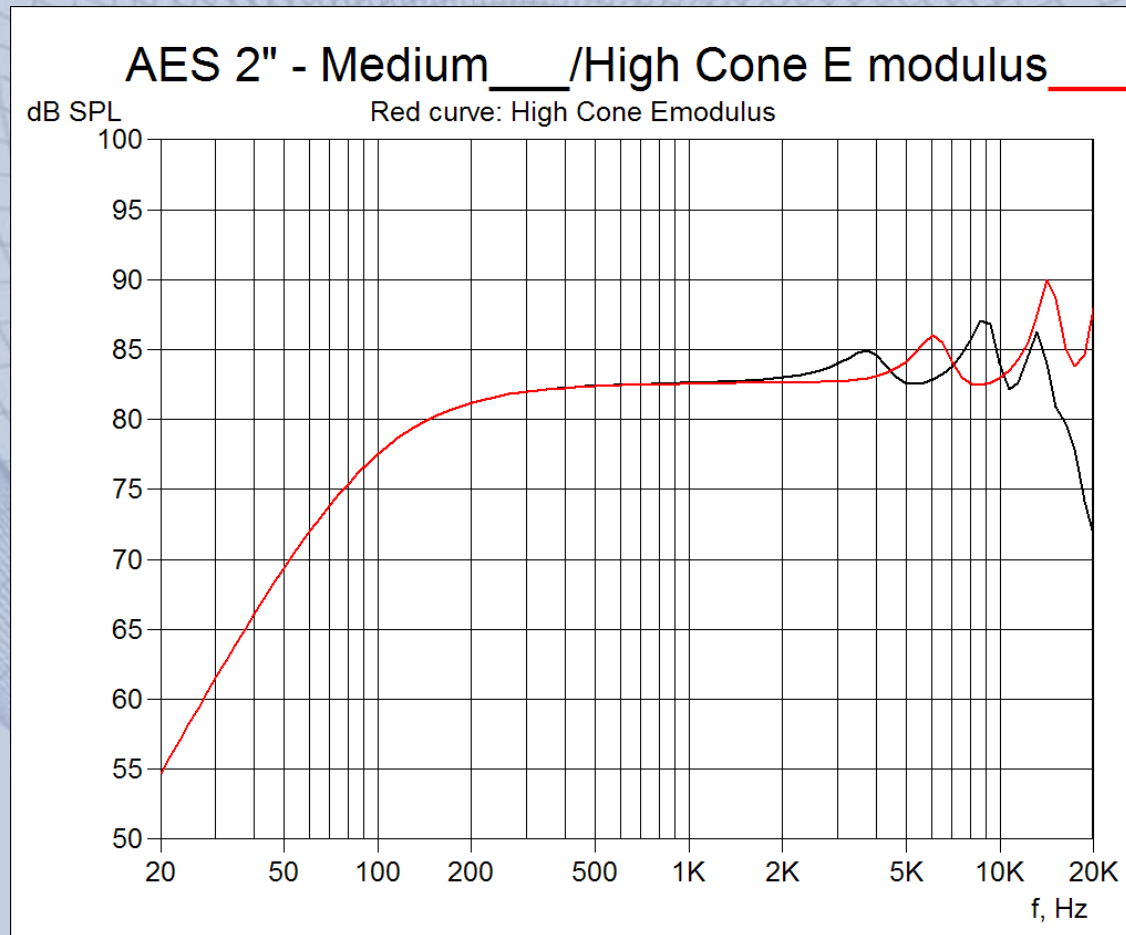
AES 126th Loudspeaker FEA/BEM Workshop

FEA Cone Damping



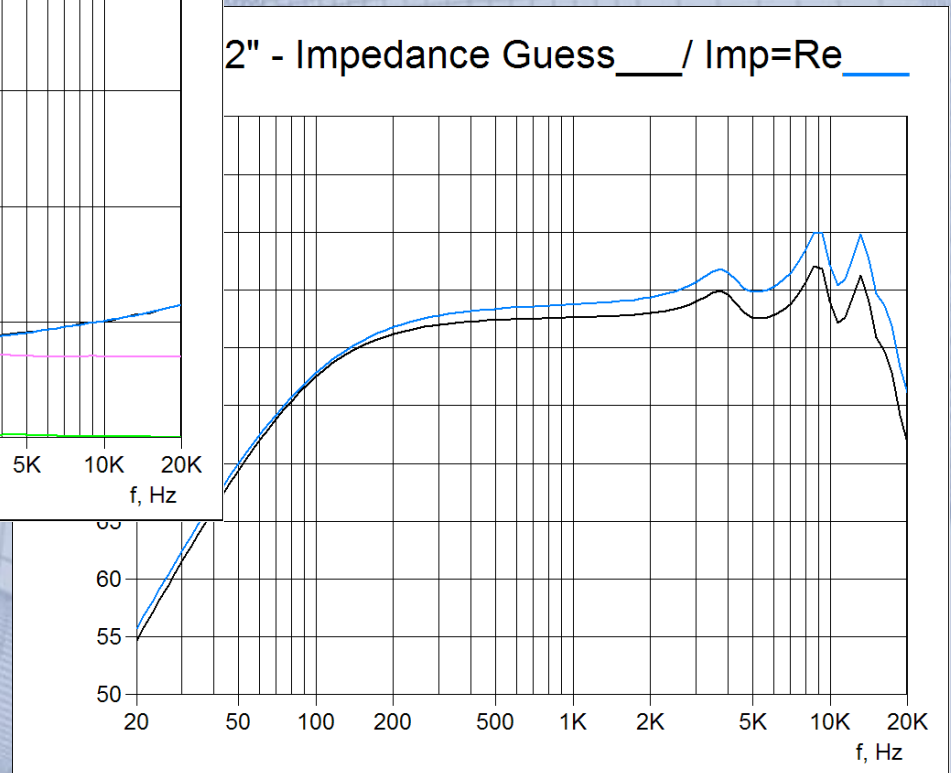
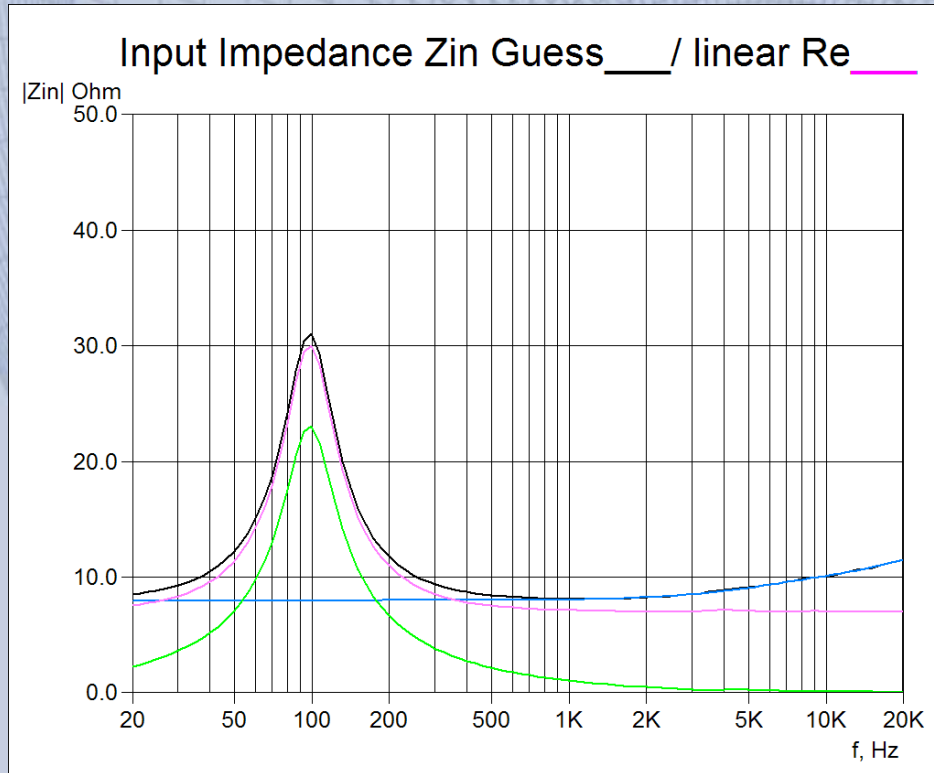
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FEA Cone Young's Modulus



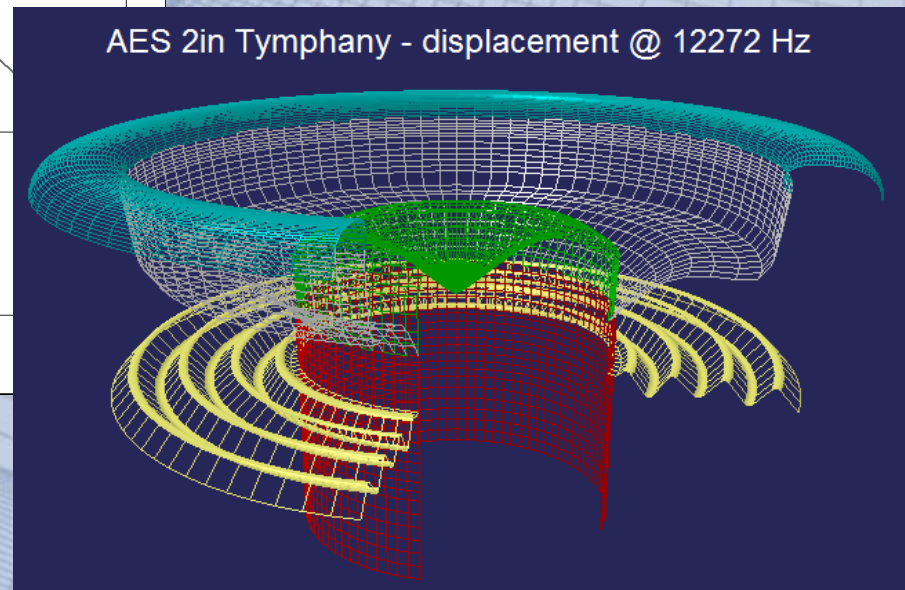
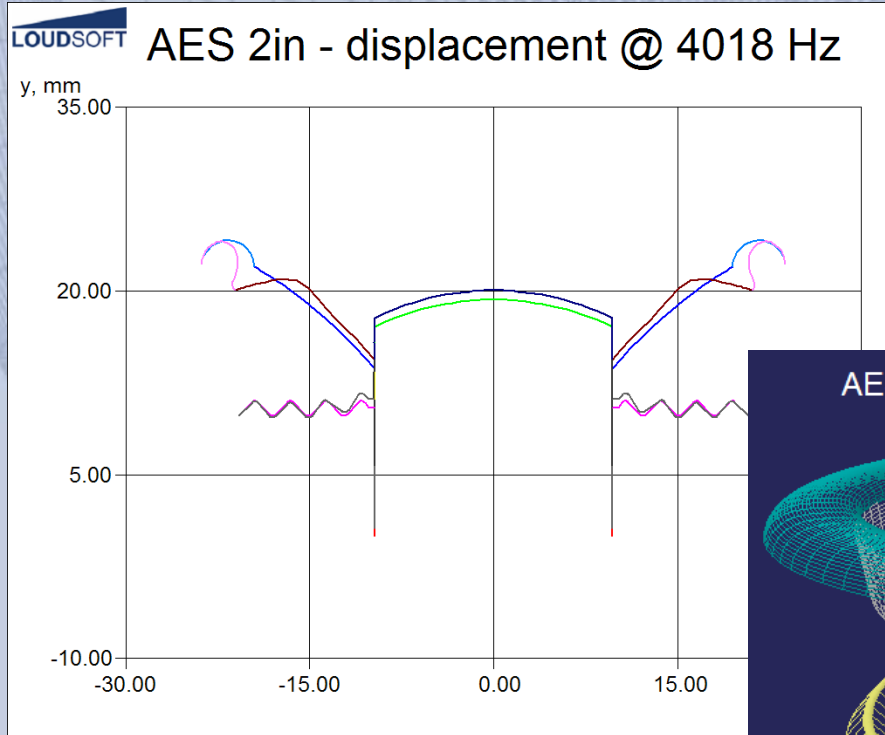
AES 126th Loudspeaker FEA/BEM Workshop

FEA Impedance Simulation



AES 126th Loudspeaker FEA/BEM Workshop

FEA cone Displacements

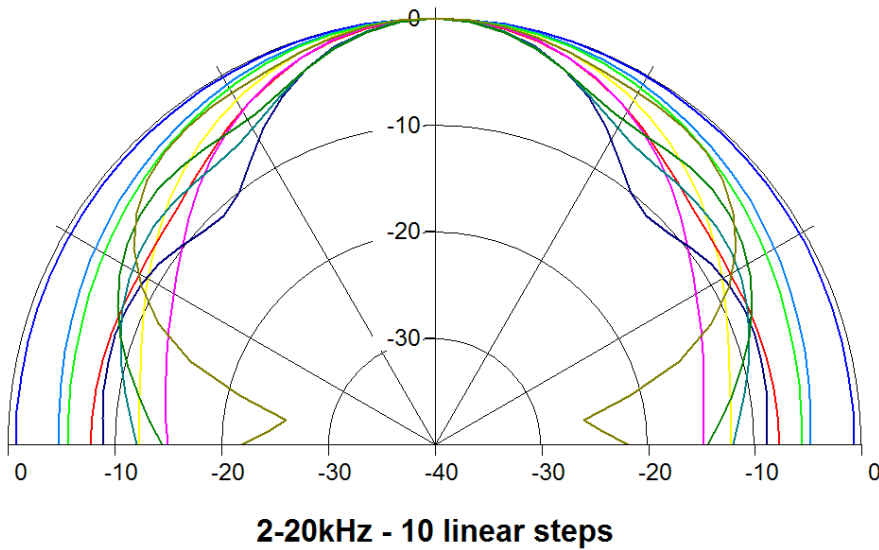


AES 126th Loudspeaker FEA/BEM Workshop

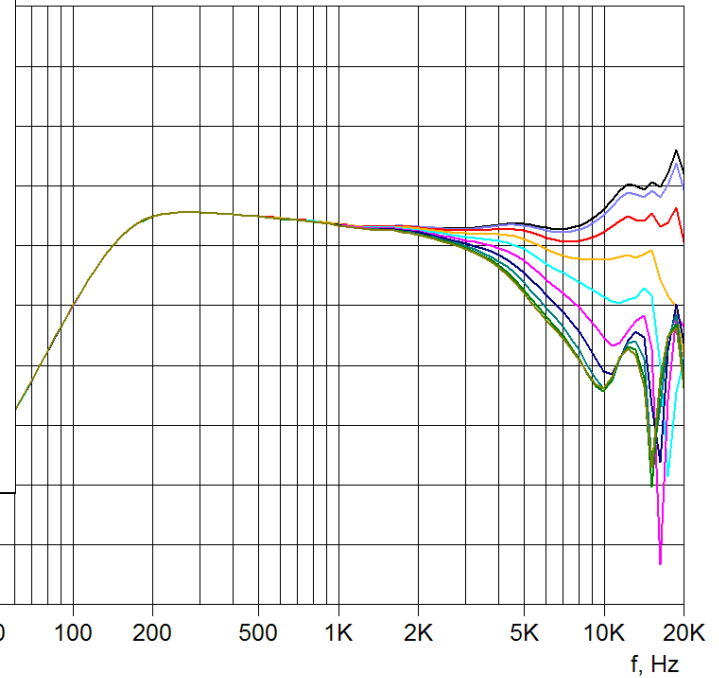
FEA Directivity and Dispersion

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Directivity of 2in Tymphany Fullrange



Workshop: 2in Tymphany 0-90deg



LOUDSOFT

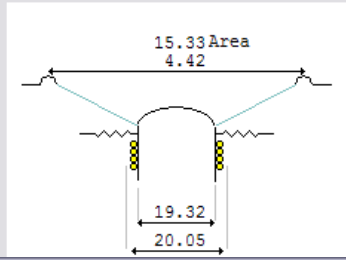
AES 126th Loudspeaker FEA/BEM Workshop

Lumped Parameters to/from FEA

Acoustic Components

Effective Area	Sd	15.33	sq. cm
Effective Diameter	D	4.42	cm
Fixed Mass	Mms-Mvc	0.90	g
Specify Qms	Qms	4.00	
Estimate Qms (from VC Former mat.)	☐	3.00	
Specify Fs	Fs	147.00	Hz
Use calculated Fs	☒	97.80	Hz
Cone+Surround Resonance	Fo	62.57	Hz
Surround Compliance (Approx.)	Cms(sur)	7.19	mm/N
Spider Load		2.83	g
Spider Resonance (loaded, dyn.)	Fsp	50.00	Hz
Spider Deflection (loaded, static)		0.10	mm
Spider Compliance		3.58	mm/N
Spider Flexibility (German Std)		17.90	Fdz

Discard any edits to these parameters



Lumped parameters

Former	Voice coil	Spider	Whizzer
General	Diaphragm	Surround	Dust cap

☒ Cs: 1.485861 mm/N ☒ Air mass: 0.026520 g

☒ Rs: 0.620760 Nm/s ☒ Sd: 13.000000 cm²

☒ Fs: 122.657116 Hz

☒ Qms: 3.060000

☒ Mms: 1.133000 g

☒ Imported from FINEMotor (TM)

OK Annu

Lumped parameters

General	Diaphragm	Surround	Dust cap
Former	Voice coil	Spider	Whizzer

Spider parameters

Mass, g: 0.255850 From Finite element...

Mass factor: 0.500000 *

Compliance, mm/N: 3.577546 From Finite element...

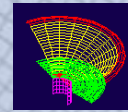
Resistance, Nm/s: 0.210640 From Finite element...

Items marked with * are optional for this component

OK Annuller Anvend Hjælp

Lumped Elements
extracted from
FINECone FEA
model

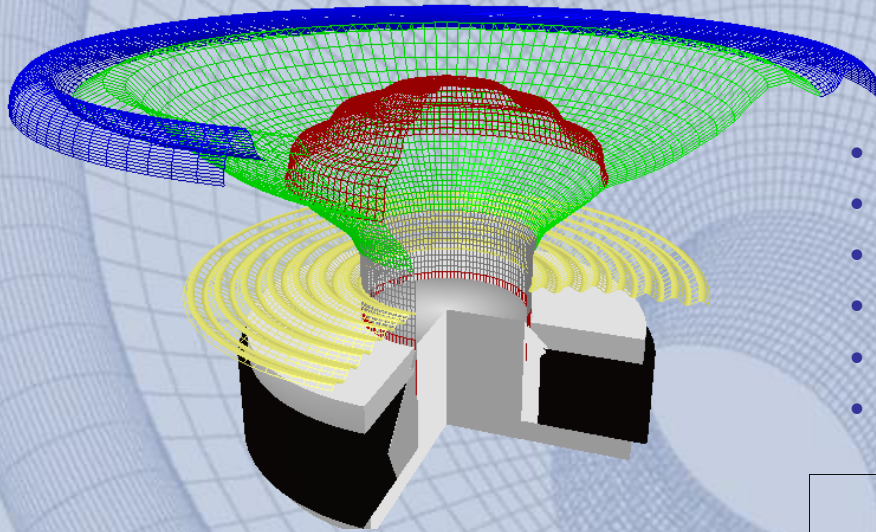
Spider Resonance defined
in FINEMotor



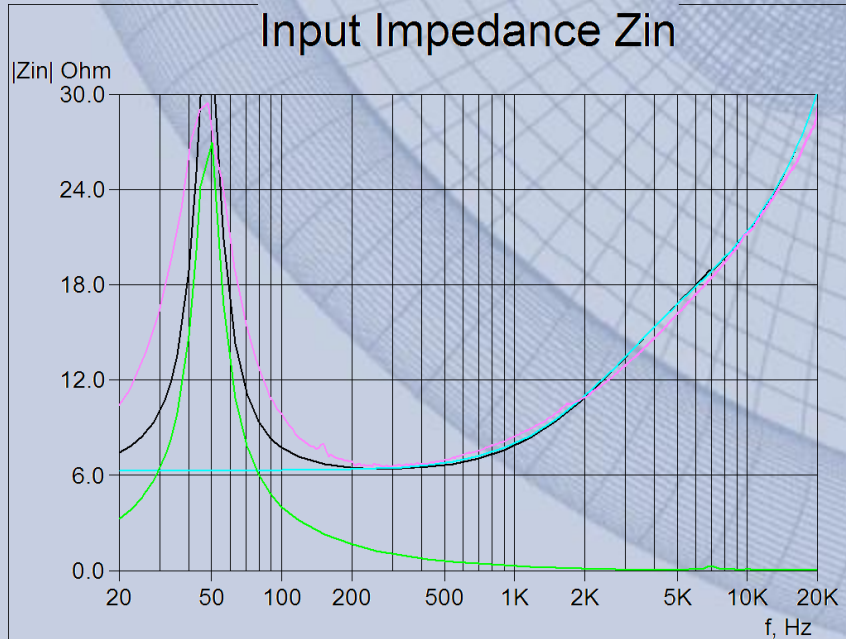
FINECone™

Acoustic Finite Element Modelling:

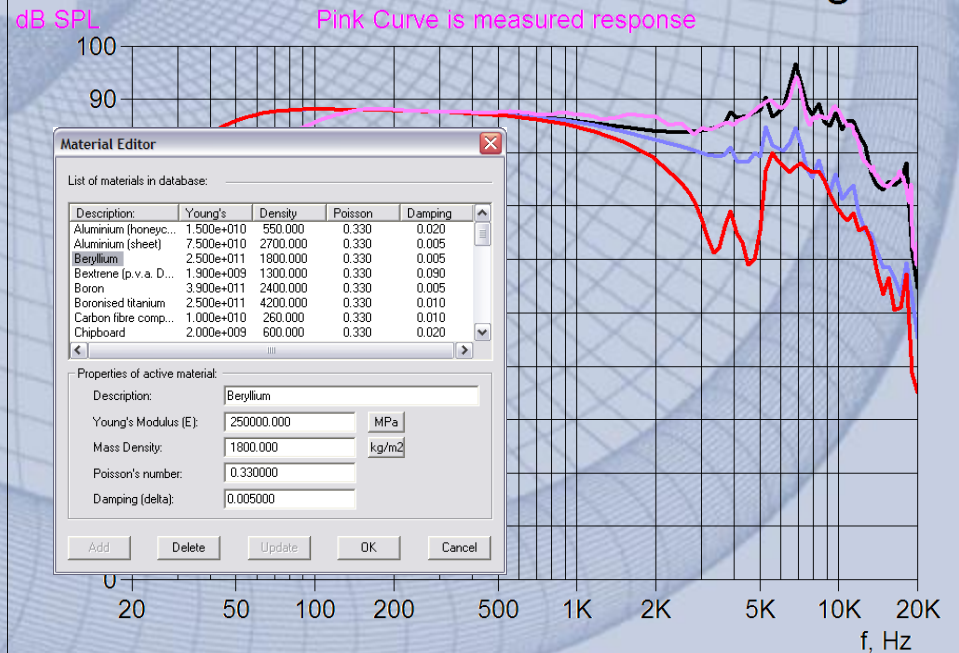
- **Very Fast Calculation < 12 sec (100 points)**
- **Axi-Symmetric modes most important**
- **Simple 2D input geometry (DXF)**
- **Built-in Material Database (+ Kurt Müller)**
- **Extracted Lumped TS parameters**
- **Low Cost FEA Software**



Input Impedance Z_{in}



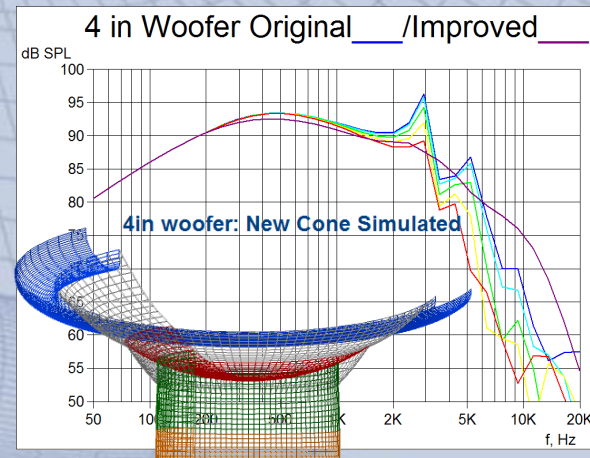
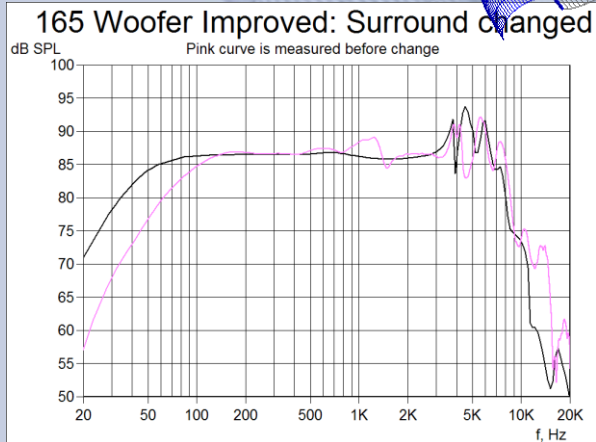
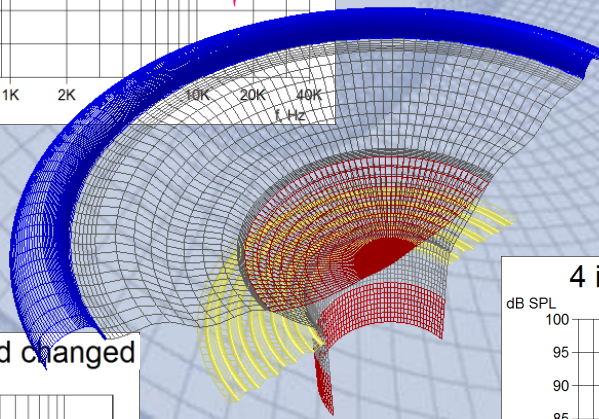
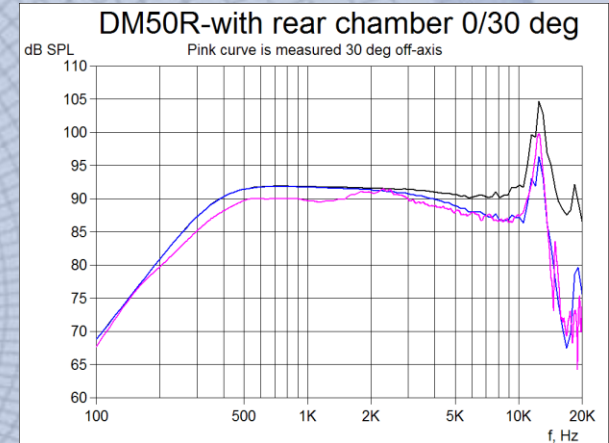
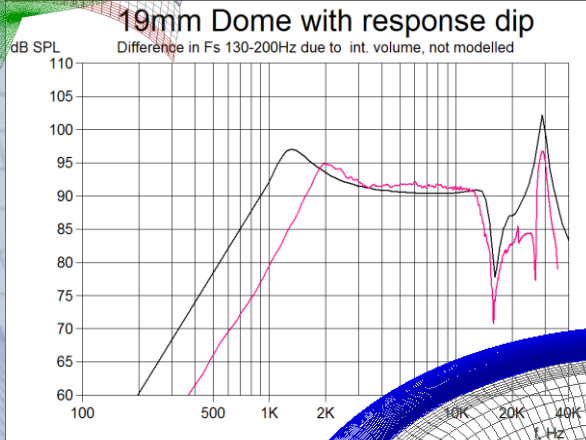
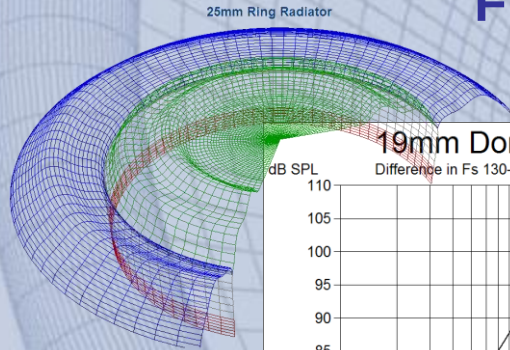
FEA of 6" Woofer 0/30/60 deg



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FINECone Practical FEA Examples:



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- 1. Precise information about E-Modulus, and damping of the cone, surround and dust cap was not available for the initial study.*
- 2. The previous slides illustrate the very large response variations that are possible when the material parameters are unknown.*
- 3. Consequently the 2nd FINECone/FEA Iteration was performed with adjusted mechanical data using the measured Tymphany response as reference*

General FEA Conclusion of the Workshop:

The most productive FEA Simulation is done by using SPL response and Impedance measurements as a reference to find the material parameters

LOUDSOFT Conclusions

- *Complete FINECone FEA is setup in few hours*
- *High resolution response solved in seconds*
- *Simple 2D drawings as input*
- *Standard Windows PC (XP/Vista)*
- *FINECone: Problem Solving + Guide Development*
 - *Save Development Time*
 - *Save Tooling & Costs*