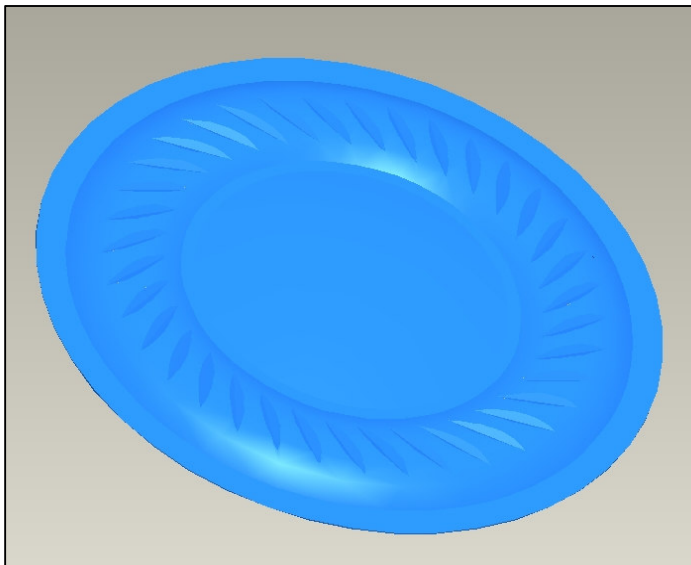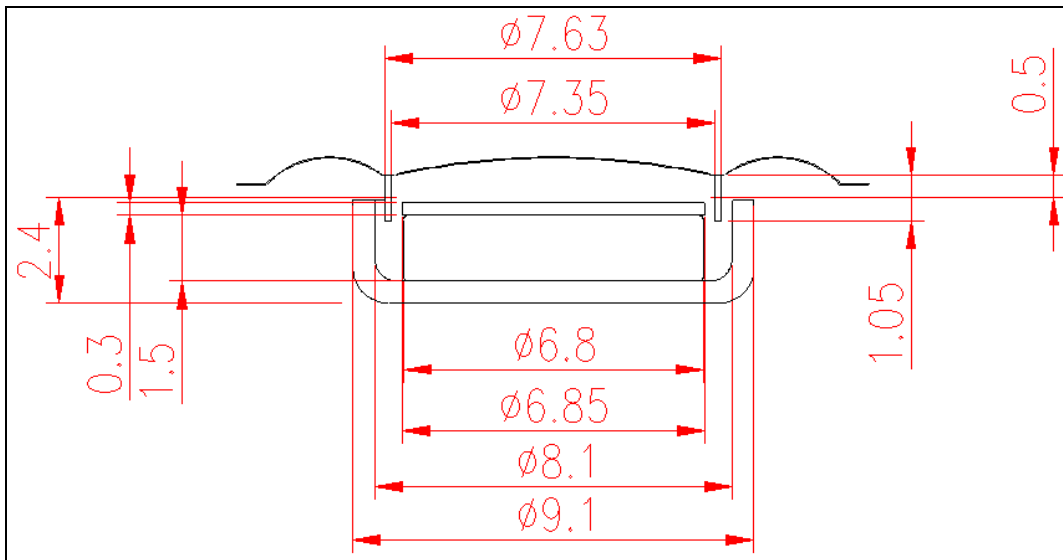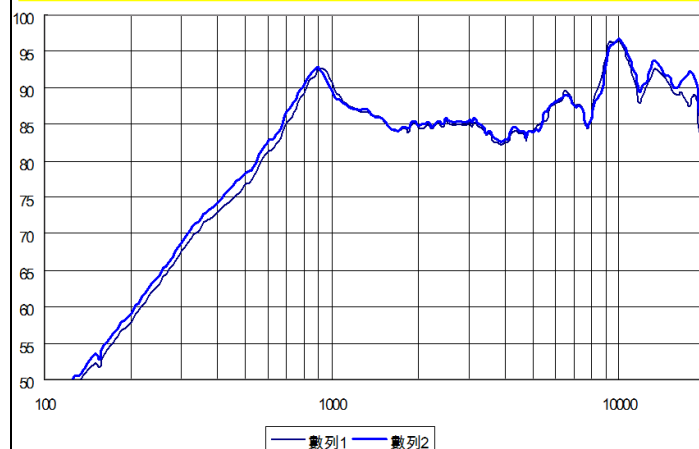# Micro Receiver Analysis

The following 15mm example specifications are given by the customer:

Diaphragm Material Properties:

Young's modulus : 620 kg/mm2
Poisson Ratio   : 0.24
Density   : 1.36 g/cm3
Thickness   : 25mm
Diaphragm mass : 0.0058   g

Customer Speaker measurement by B&K 2012
Test Condition : 0.1w (894mV) at 10cm

FINE simulations

The following is a short presentation of the results of the small 15mm micro speaker (receiver) analysis in FINECone, FINEMotor and FINEBox.

An acoustical simulation is very helpful to the design engineer. The acoustic FINECone simulation can help to decide the cone thickness, cone profile and material for obtaining the best frequency response and resonance. Further the Voice Coil and magnet system can be designed and optimized for sensitivity and linearity using FINEMotor. Finally FINEBox can be used to find the best rear and front volumes plus power rating and temperatures.

FINECone Simulation

The fastest and best ways is to first measure a similar speaker and use that response as a guide for the FINECone simulation. Then it is very easy and fast to change for example the cone thickness and see which thickness gives the best response.

The measured response is normally required to obtain correct values for impedance, damping, stiffness of glue joints and special features like pattern in the cone. Even the stiffness (Young's modulus) may be changed from table- or measured values to increase the accuracy. Methods how to do this is described in the FINECone Manual.

The FINECone simulation is changed to the standard 894mV input (100mW/8ohms) at 10cm distance. This brings up the SPL to about 85 dB as measured by the customer.
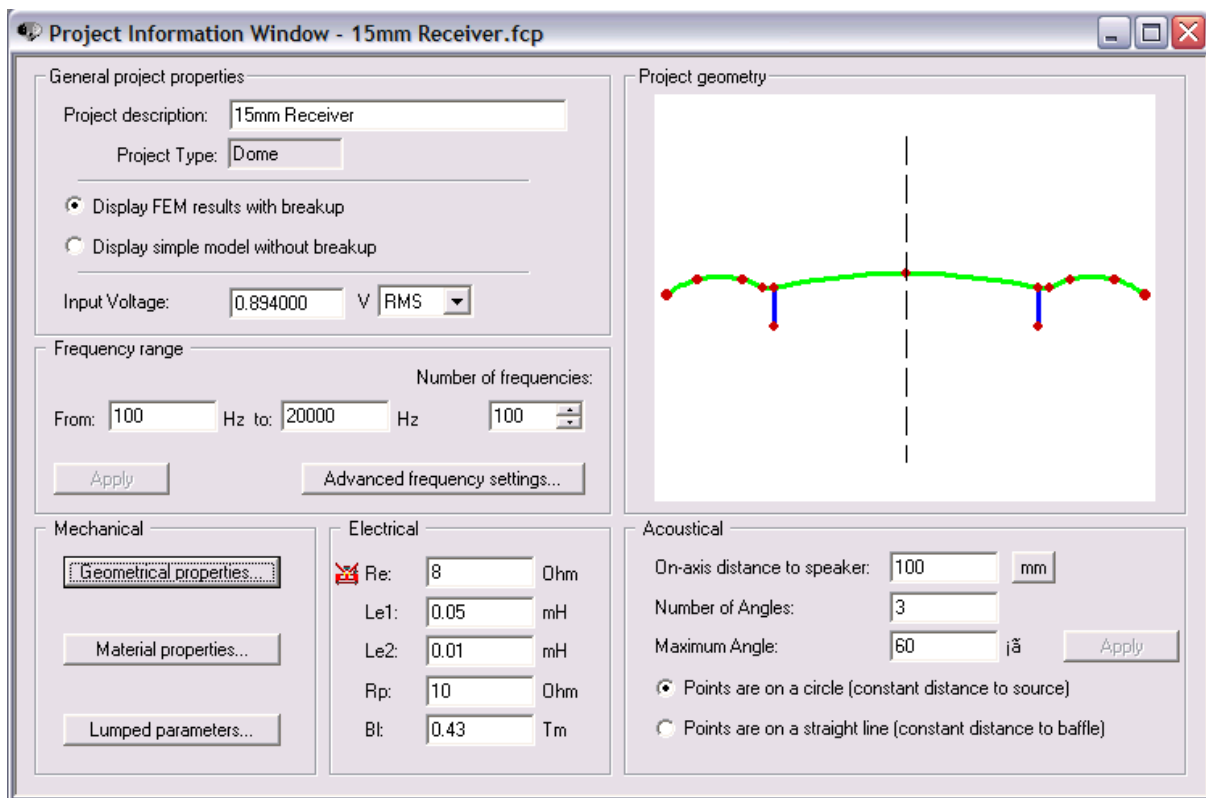
First the geometry is entered into FINECone using a DXF file, which can be created in any CAD program. The file is automatically checked for errors in the input editor.
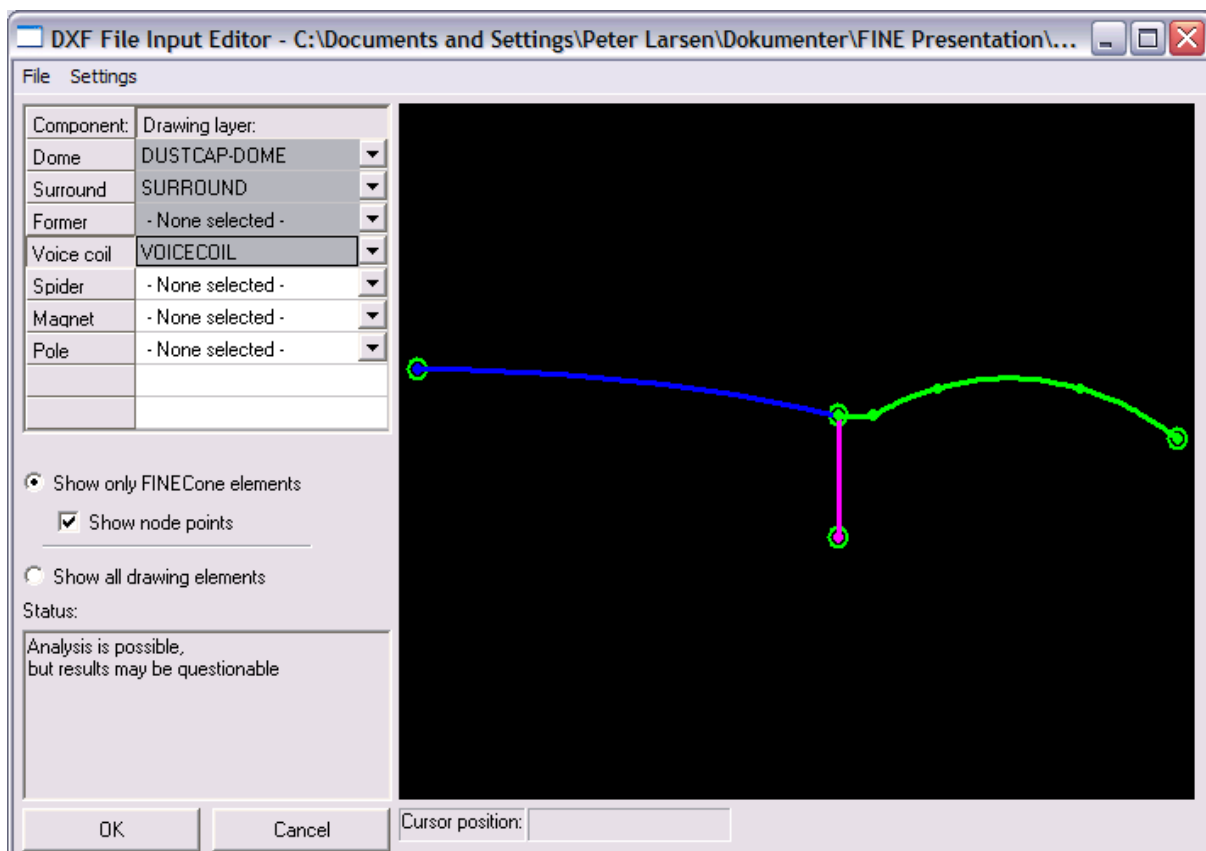
Then we define the material specs for the segments. Below is shown the centre dome spec., where we have entered the specs already known. Note that the damping is set to a low value in order to see break-up resonances in the response.
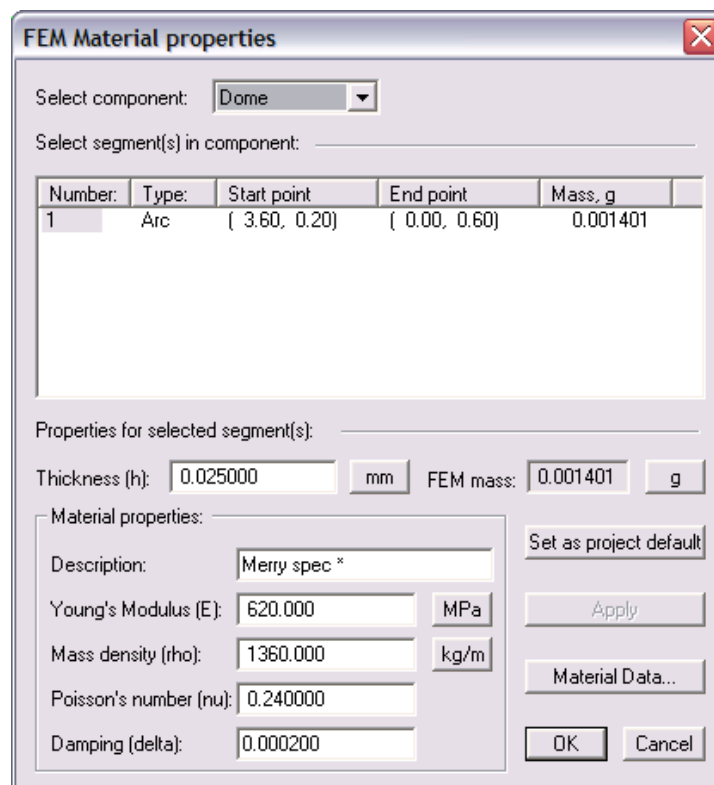
In case the material parameters are not known, we can open the built-in database and select a suitable material containing all data:

3

Material Editor

List of materials in database:

Description:	Young's	Density	Poisson	Damping
Paper/phenolic	1.000e+009	350.000	0.330	0.060
Paper/pulp (typical)	5.000e+008	150.000	0.330	0.090
PEI	2.000e+009	2468.000	0.330	0.001
Plywood	8.600e+009	780.000	0.330	0.020
Polyamide film	3.000e+009	1400.000	0.330	0.020
Polyehylene	1.000e+009	940.000	0.330	0.090
Polyester film	1.400e+010	700.000	0.330	0.020
Polymethyl pentene	2.800e+009	8400.000	0.330	0.100

Properties of active material:

Description: PEI

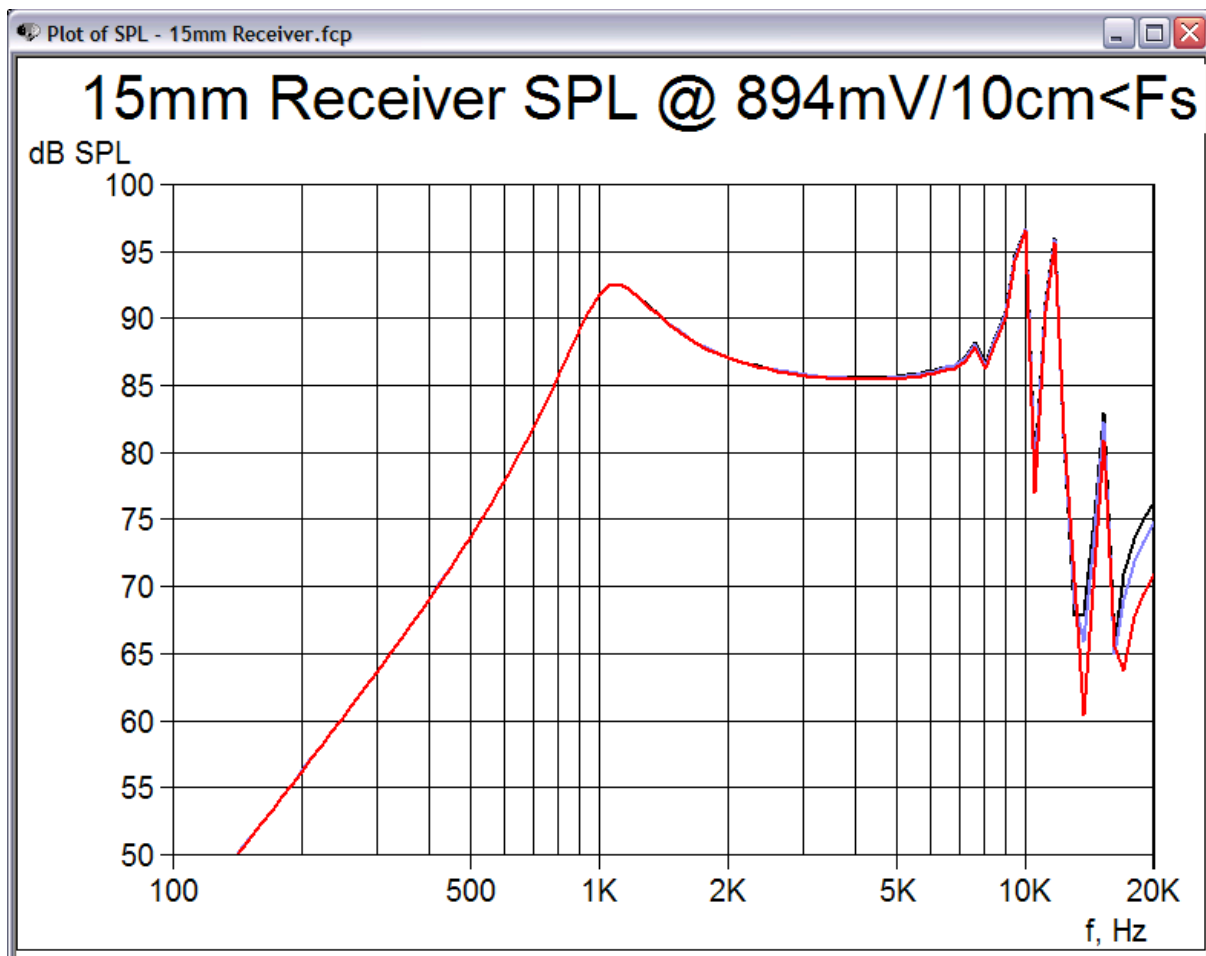Young's Modulus (E): 2000.000   MPa

Mass Density: 2468.000   kg/m2

Poisson's number: 0.330000

Damping (delta): 0.001000

Add   Delete   Update   OK   Cancel

The user can also add new or modify materials to the database.

Plot of SPL - 15mm Receiver.fcp

## 15mm Receiver SPL @ 894mV/10cm<Fs

dB SPL

f, Hz

Above is shown the simulated response from FINECone, which is close to the measured response from the customer. The top at ~1000 Hz is the main resonance Fs, which corresponds with the simulated impedance curve below.

Input Impedance Zin-Estimated
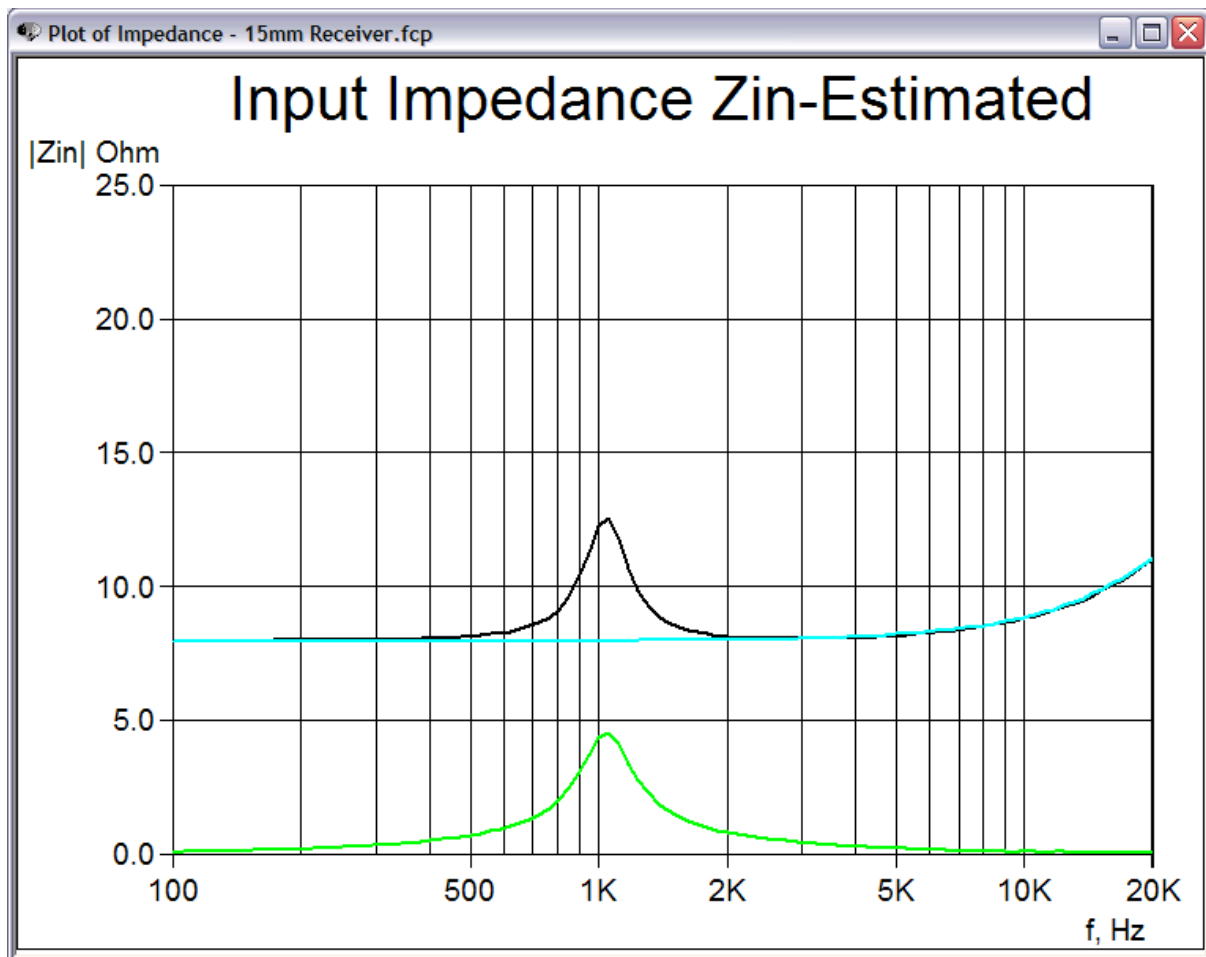
The peaks and dips in the frequency response from 8-20 kHz are caused by break-up in the diaphragm (cone). Below is shown how the centre dome is breaking up at 10522 Hz.
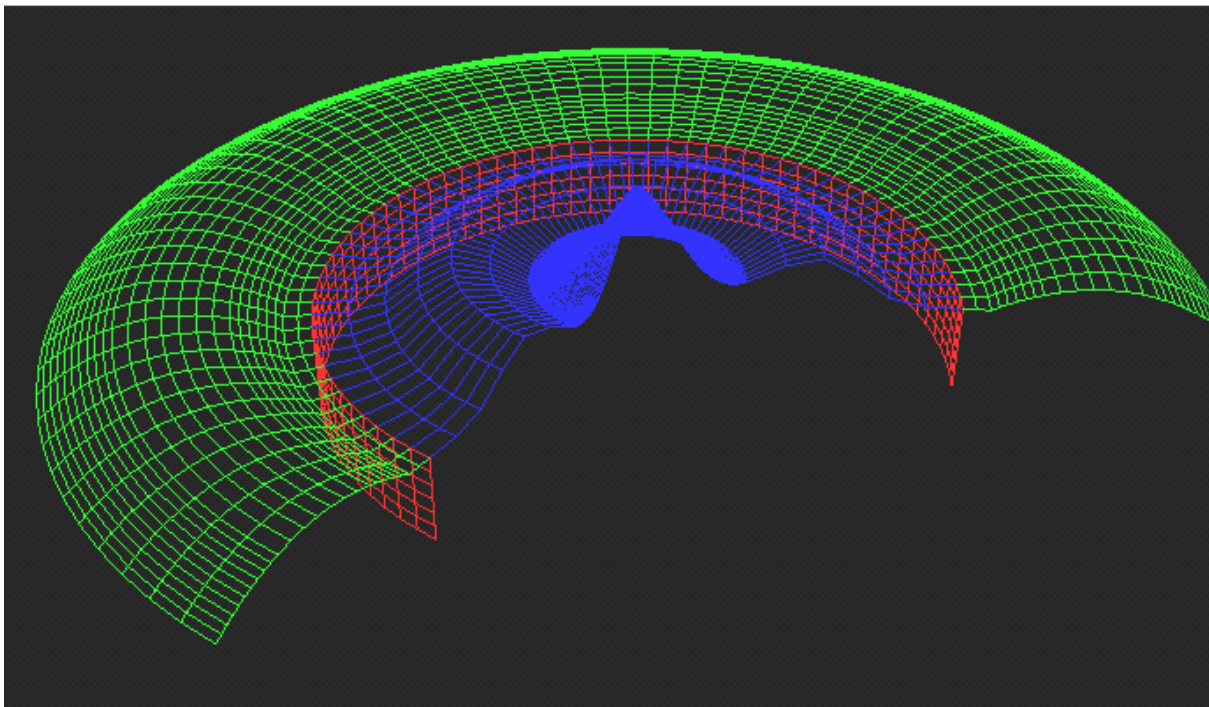
The next picture illustrates how to simulate a pattern in the diaphragm. But there is little effect on this 15mm because most of the break-up is in the center dome part.
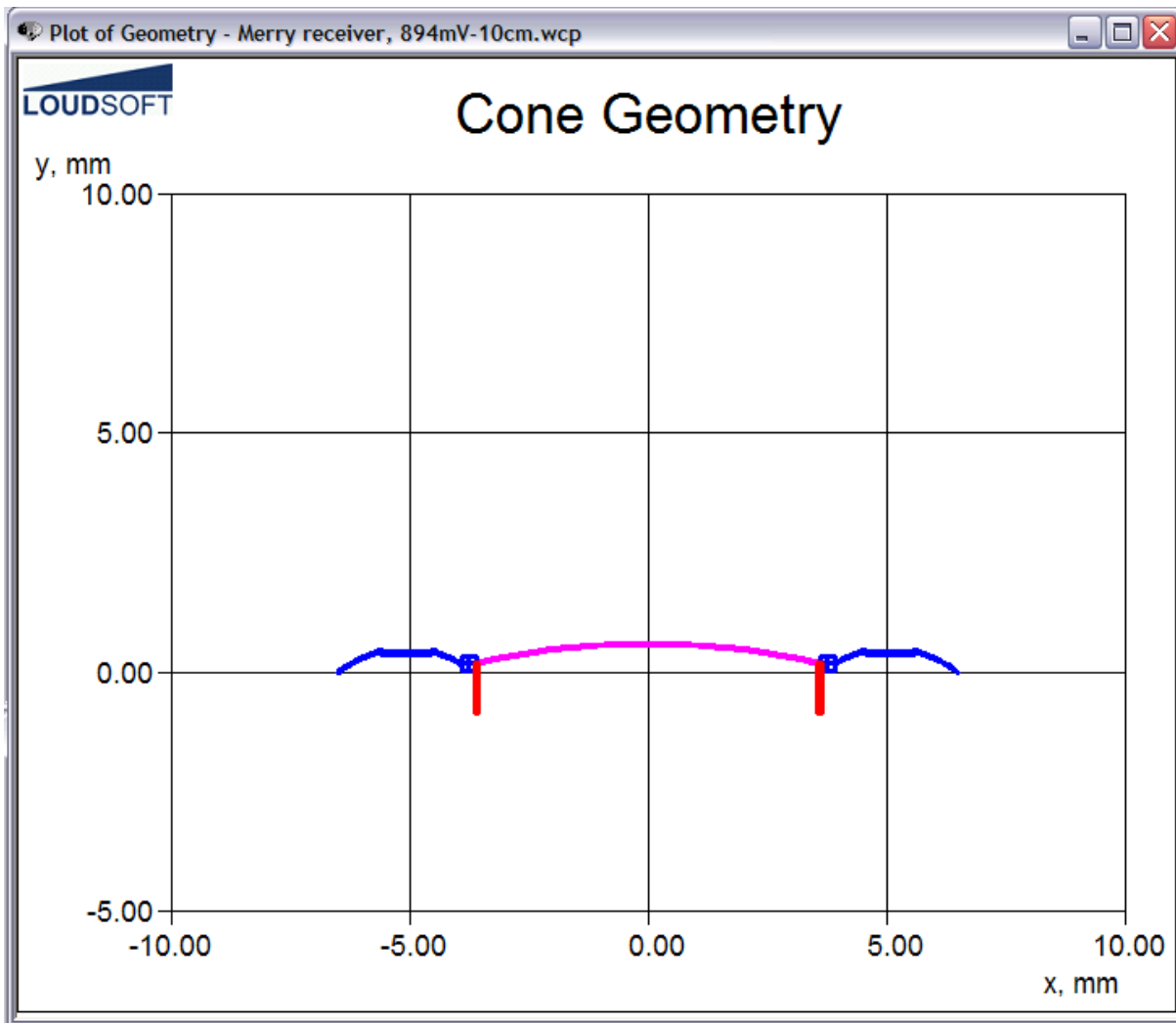
Now we have a model that is known and from here we can change the parameters to see what we need to change to get the best result. Instead of having to build a prototype receiver and experiment with that, we can make changes in seconds and see if we move in the right direction.

Next paragraph is an analysis of an existing 15mm micro receiver motor. Following an improved motor version is developed using the FINE programs.
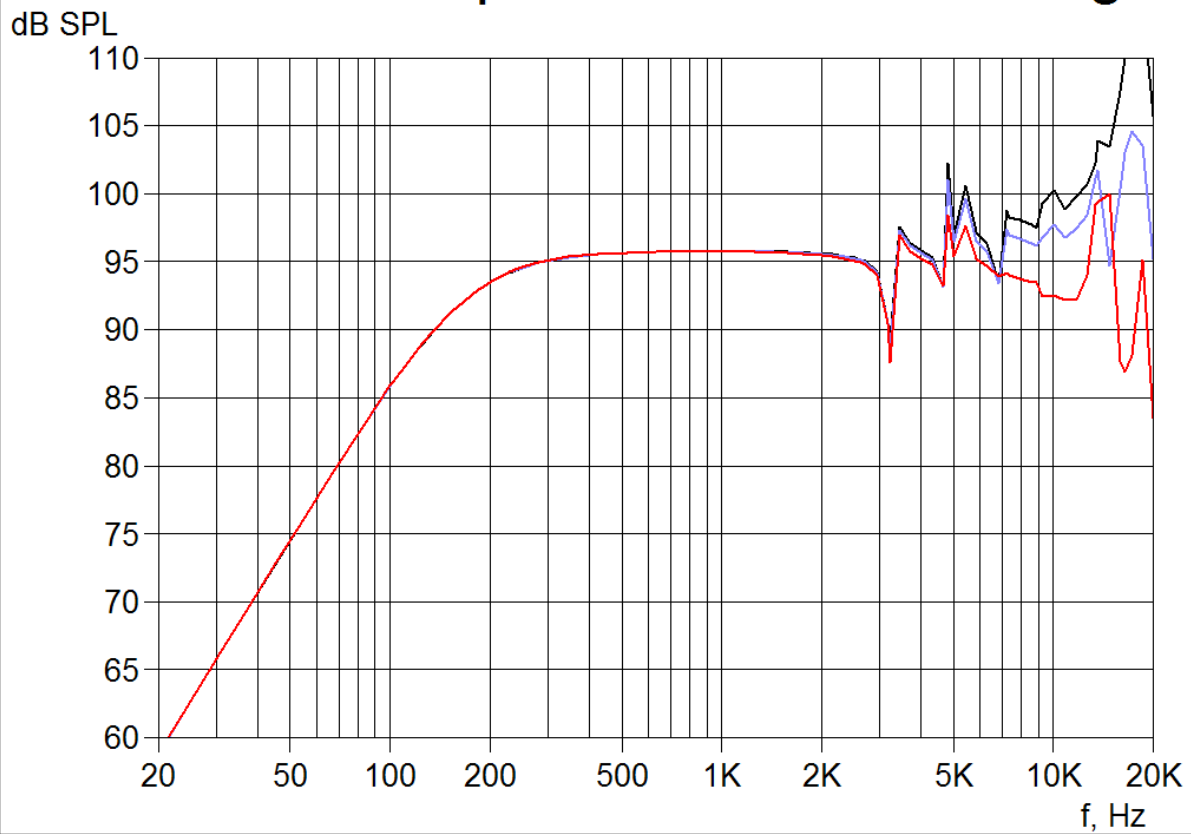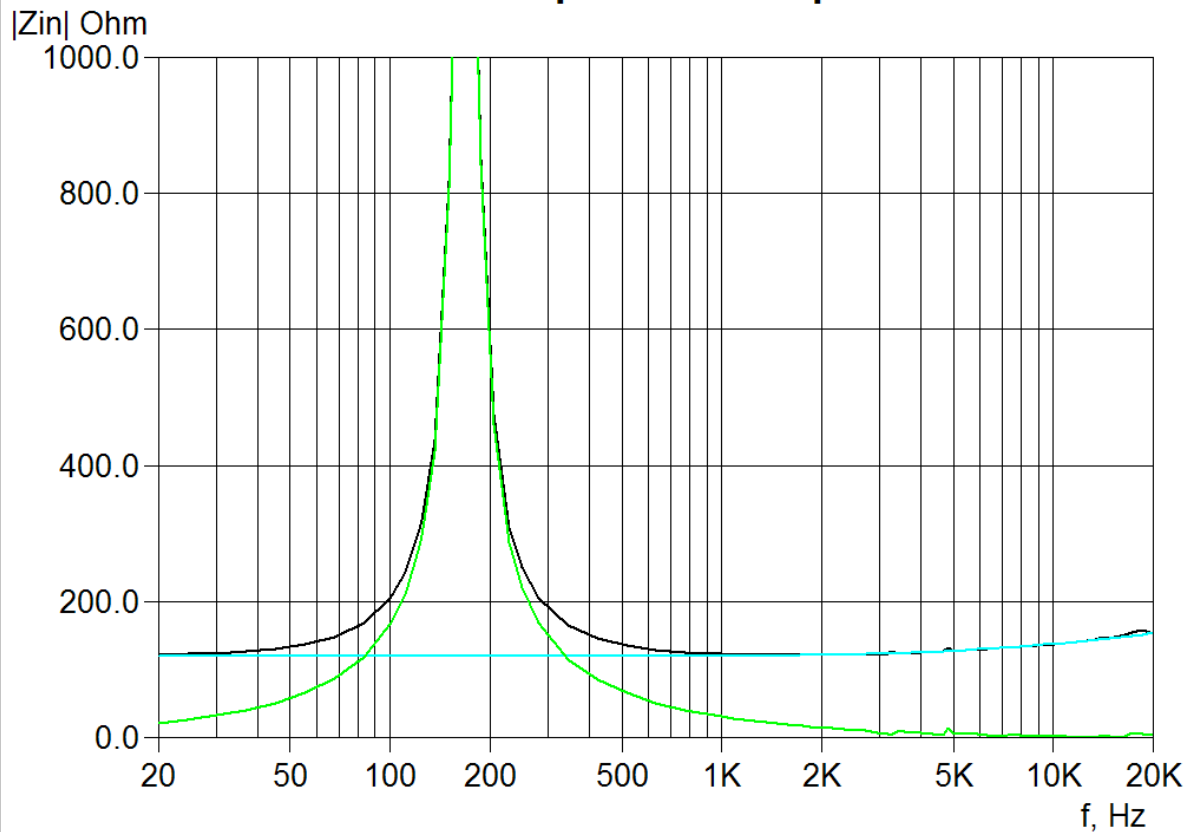
38mm Headphone Example
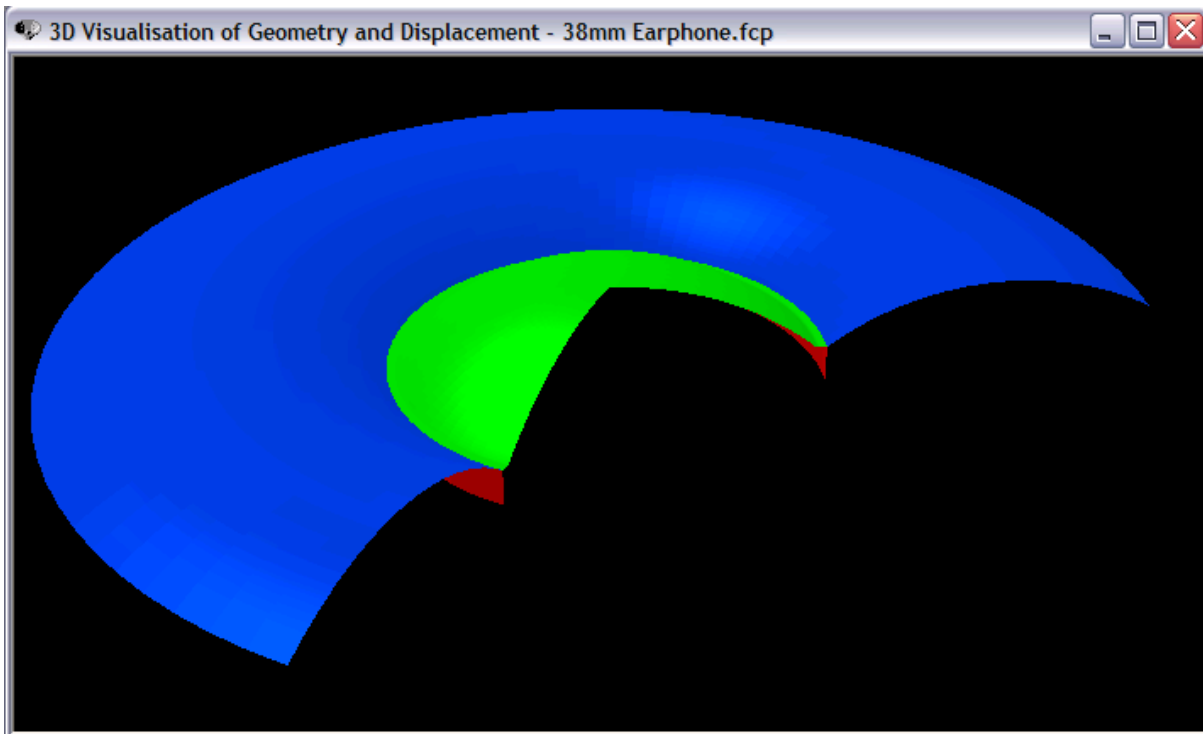
A 38mm headphone has been simulated in FINECone. The first break-up is just above 3 kHz, which is seen on the frequency response on the next page. The mode shape at this frequency is shown below. There is considerable break-up in the middle of the large surround.
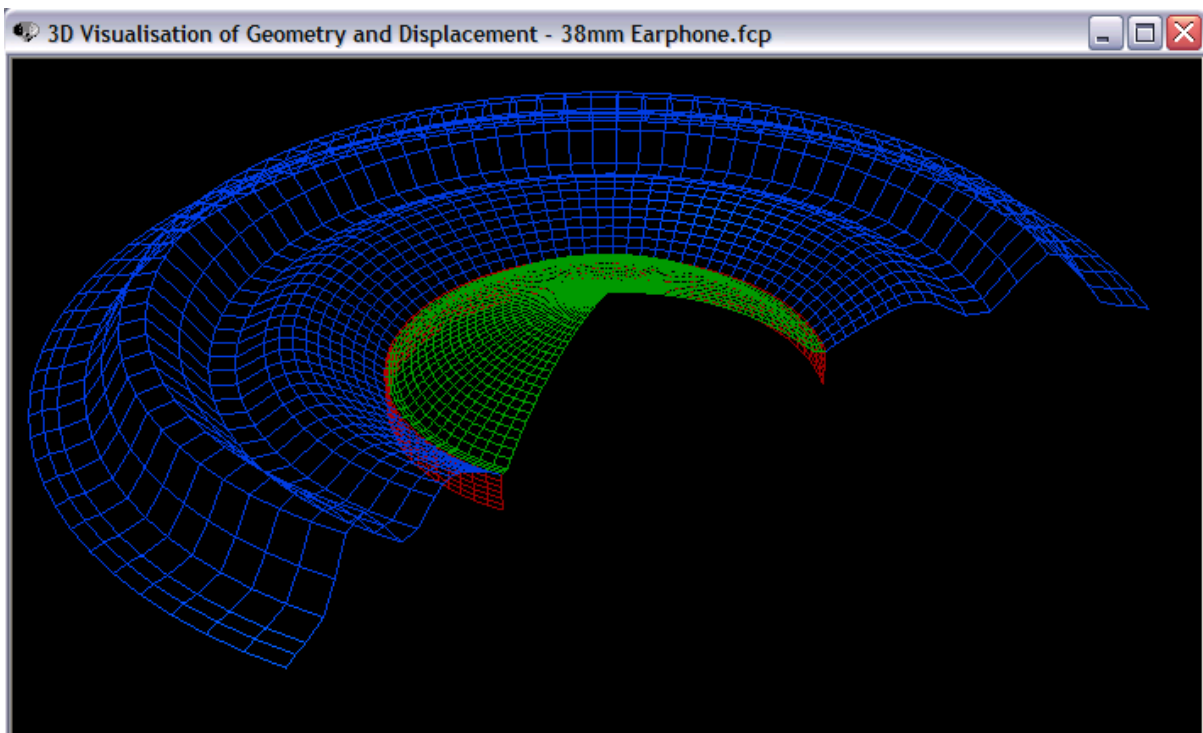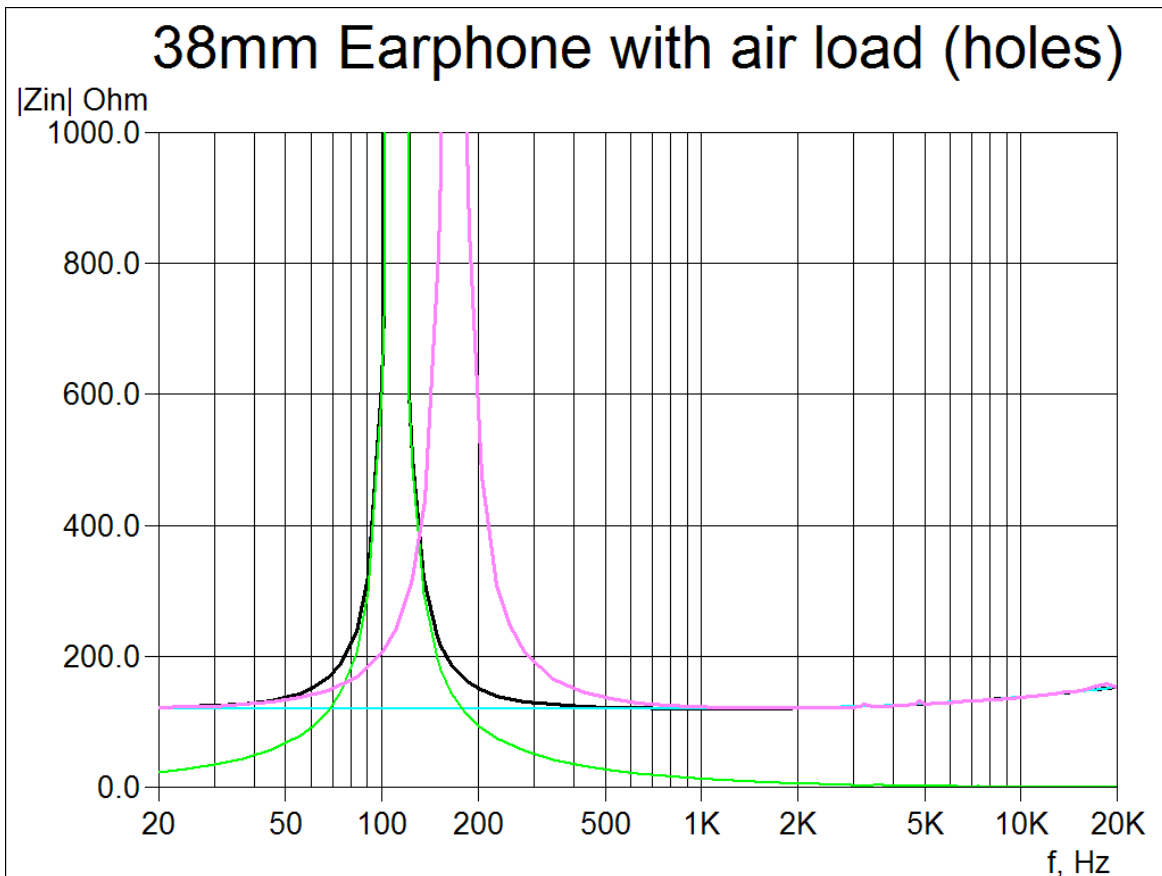
38mm Earphone SPL 0/30/60 deg

38mm Earphone Impedance

Now a number of small holes with damping have been added to the rear side of the surround. The effect is added moving mass, which lowers the SPL and resonance Fs, but also reduces the break-up.

38mm Earphone with air load (holes)
Pink curve is without air load

38mm Earphone with air load (holes)
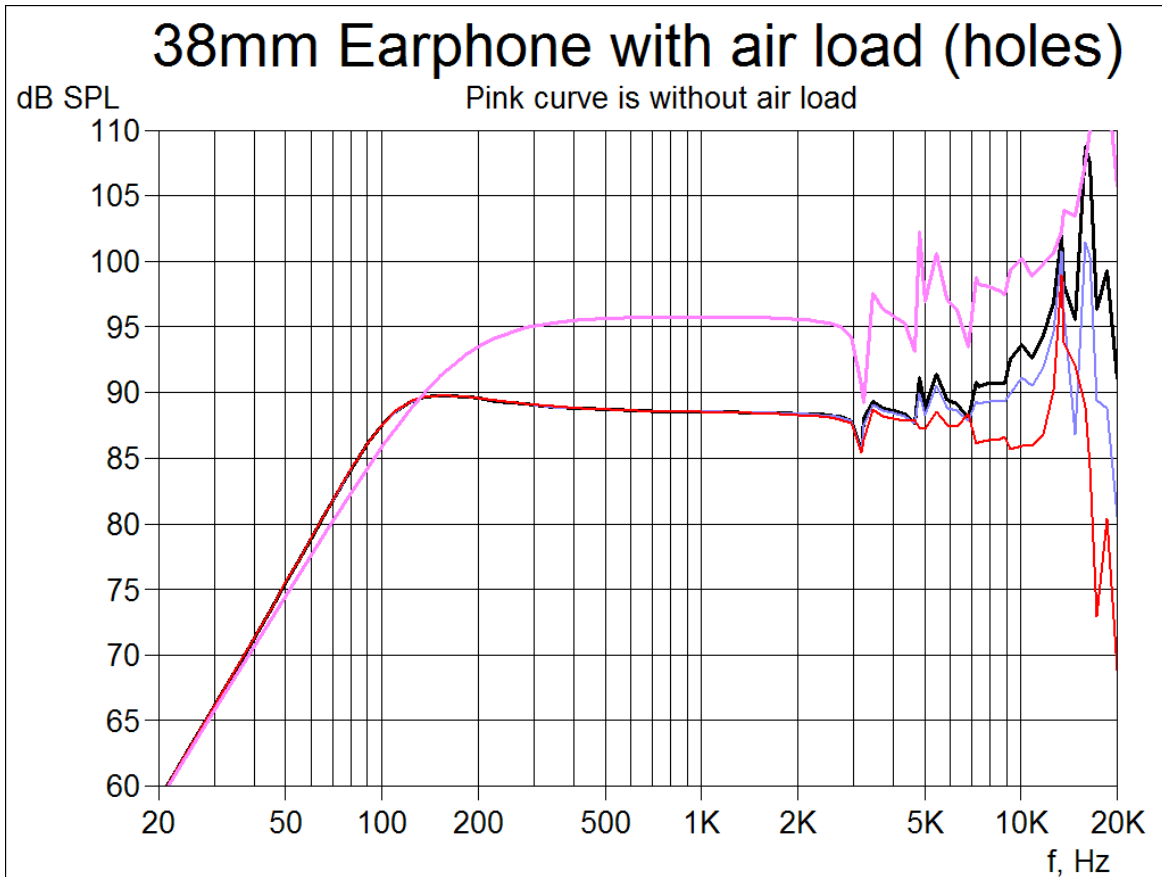
Finally we can simulate the addition of a pattern on the outer (surround) part of the diaphragm:

38mm Headphone Geometry with pattern

y, mm

(graph with axes: y from -10.00 to 20.00 mm, x from -20.00 to 20.00 mm)

x, mm

38mm Earphone with surround pattern

dB SPL

Pink curve is without pattern

(frequency response graph: dB SPL from 60 to 110, f from 20 Hz to 20K Hz)

f, Hz
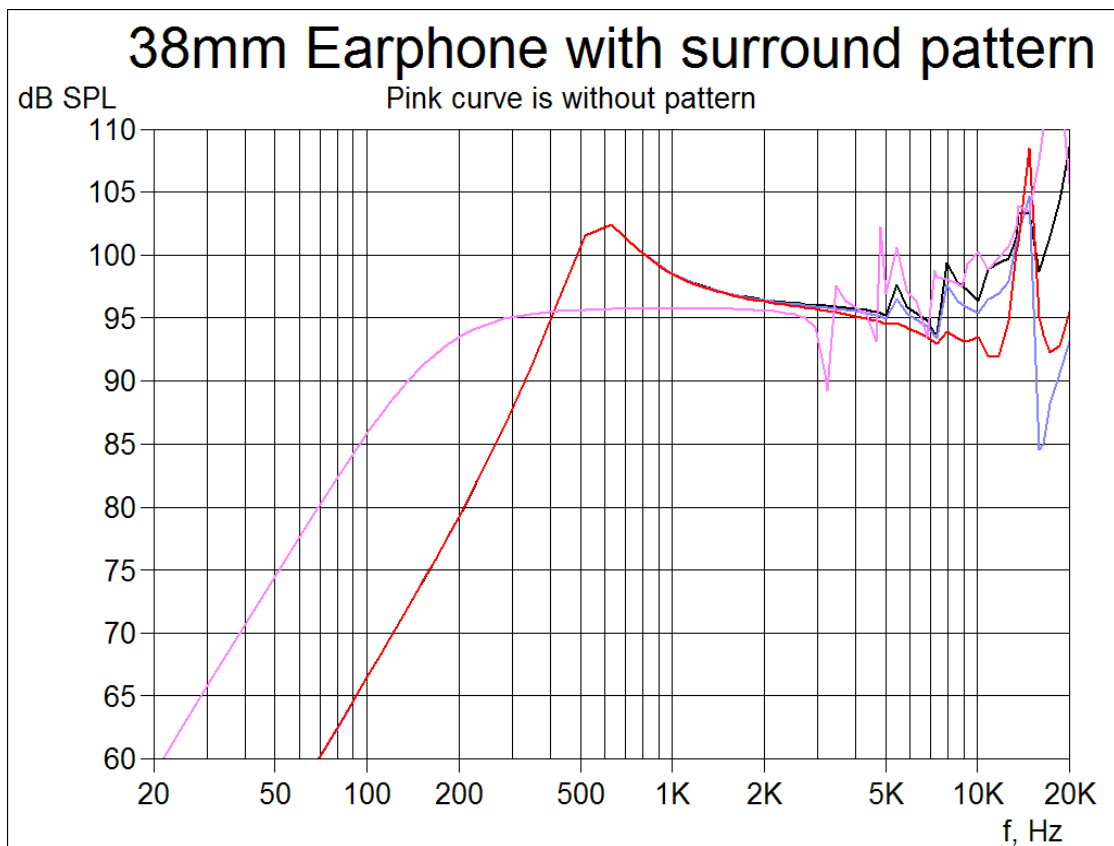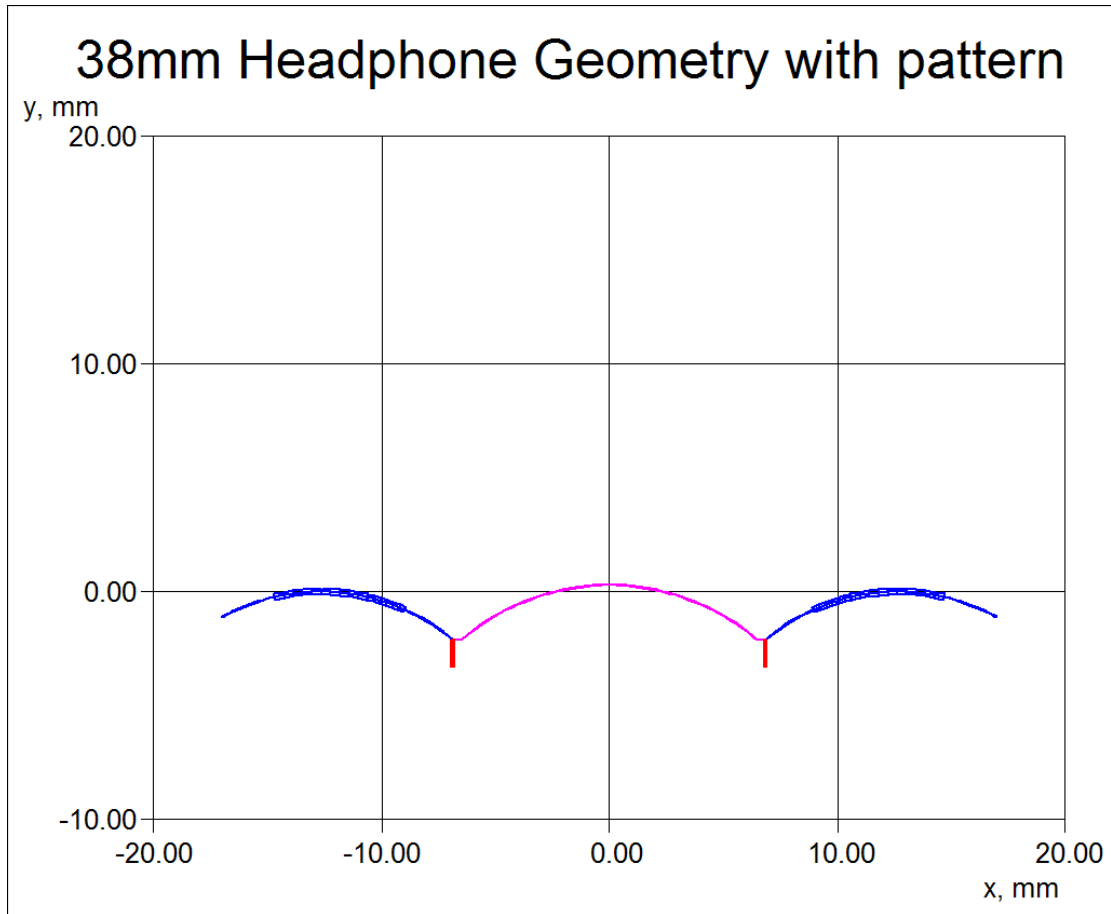
FINEMotor Simulation.

Further the 15mm Neodymium motor system has been modeled in FINEMotor. The magnet material is Neodymium N42. The DCR resistance is 7.0 ohms (Z nominal imp= 8 ohms). The winding width in FINEMotor was very close to the actual 1.05mm when a stretch of 5% was set. (The winding is normally stretched some % during winding)
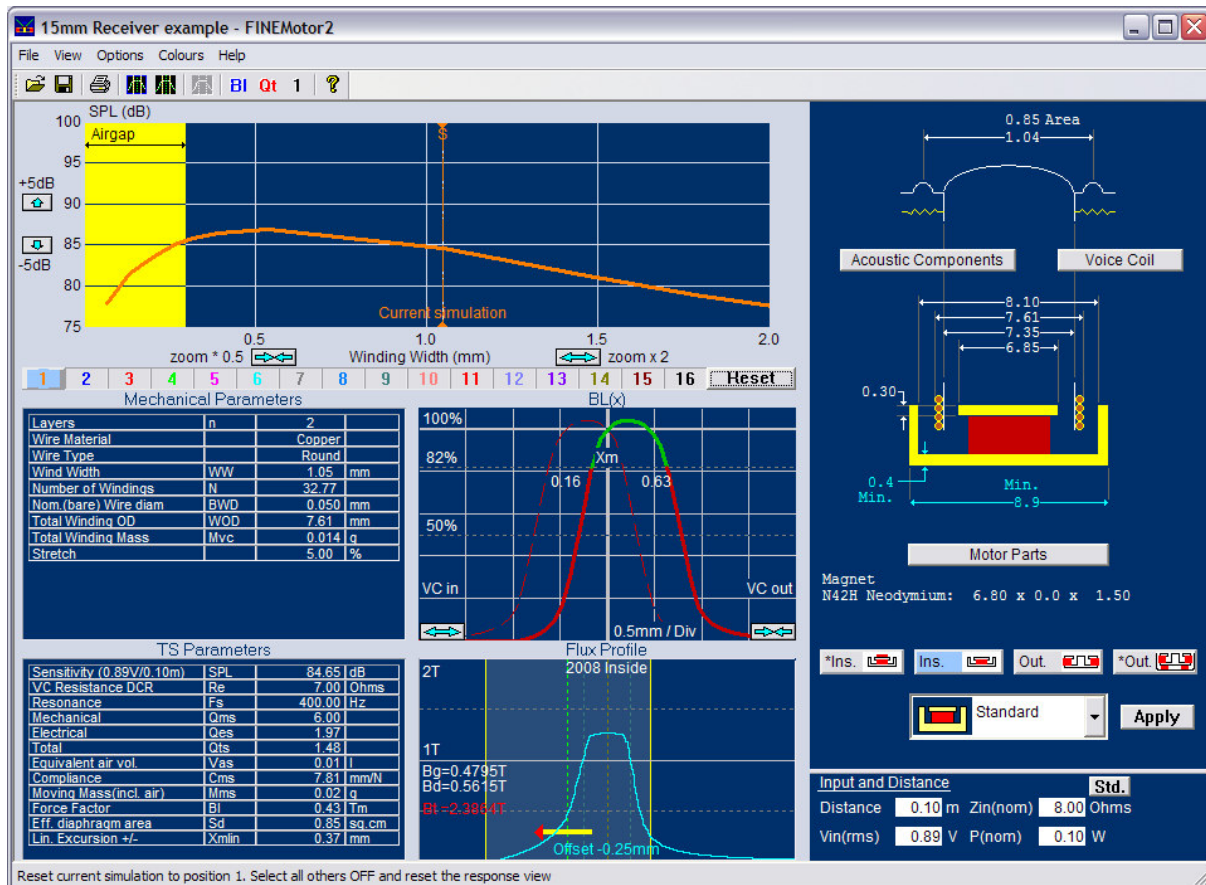
Note that the magnet system has a very thin top plate, which is saturated, indicated by Bt =2.39T. (Bt must be <2T)

And the Voice Coil is not placed symmetrically in the air gap, but offset 0.25mm up. The BL(x) curve shows how the force factor BL varies when moving up through the air gap. The ideal BL(x) curve is flat and symmetrical, but in this case it is NOT symmetrical. The usable range for getting low distortion is when BL is higher that 82% of the maximum value. FINEMotor shows that as the green range of BL(x). Here we get Xmax (up)= 0.63mm, but only Xmax (down)= 0.16mm, which is quite bad. In other words the usable Xmax is only 0.16mm, where we would have expected 0.37mm!

First we move the Voice coil by dragging with the left mouse button. This makes the BL(x) curve quite symmetrical. Now Xmax=0.35 both up and down. Next we need to increase the thickness of the top plate to avoid saturation. In the simulation below the top plate has been increased from 0.3 to 0.4mm. The sensitivity has increased about 1dB and Bt is still a little too high (2.17T).
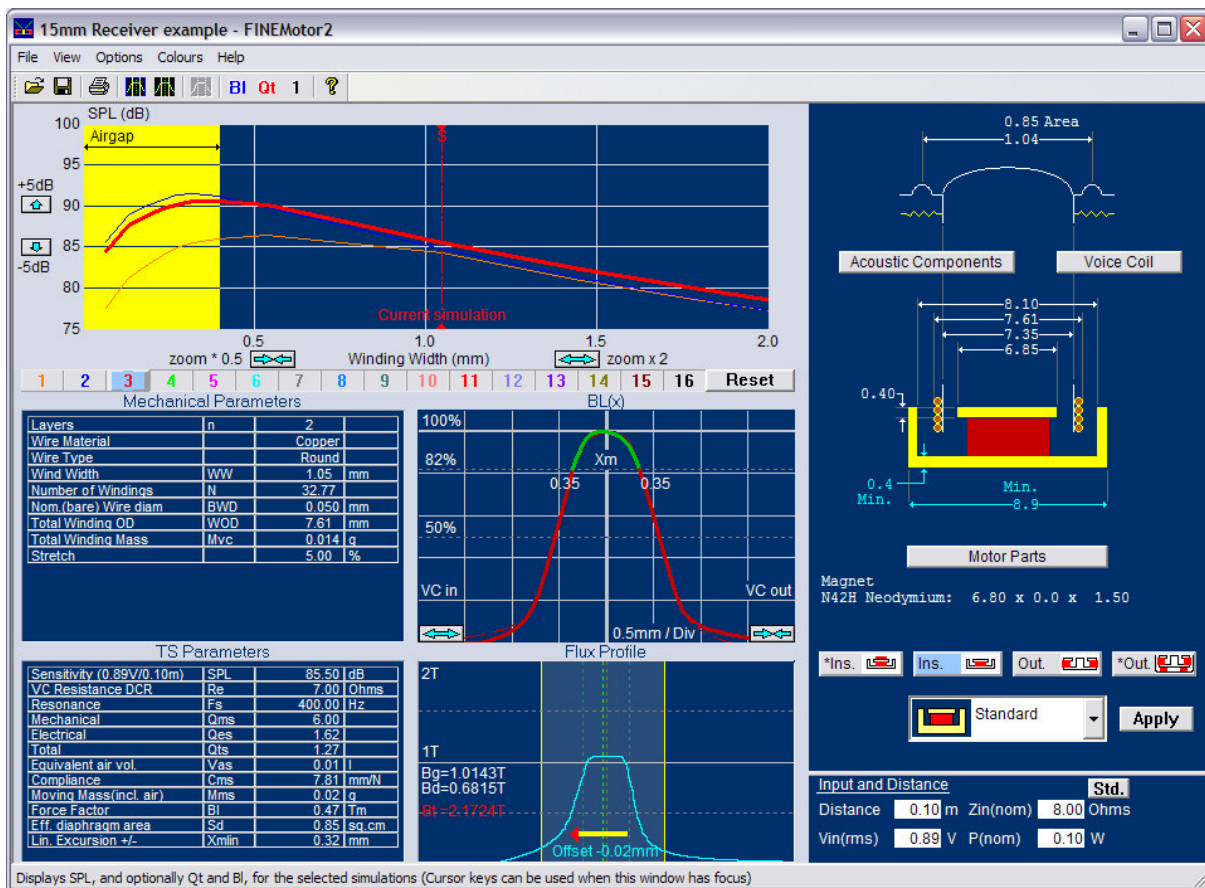
In such cases it may be a good idea to do a separate magnetic simulation in another FEM program. On the next page is shown a FEMM simulation with the 0.4mm top plate. The top plate is just saturated, and the back plate must be thicker to avoid saturation here.

Now the flux profile (along the red line) is imported into FINEMotor, see below. Many import formats are supported and LOUDSOFT recommends the FEMM program (Freeware).
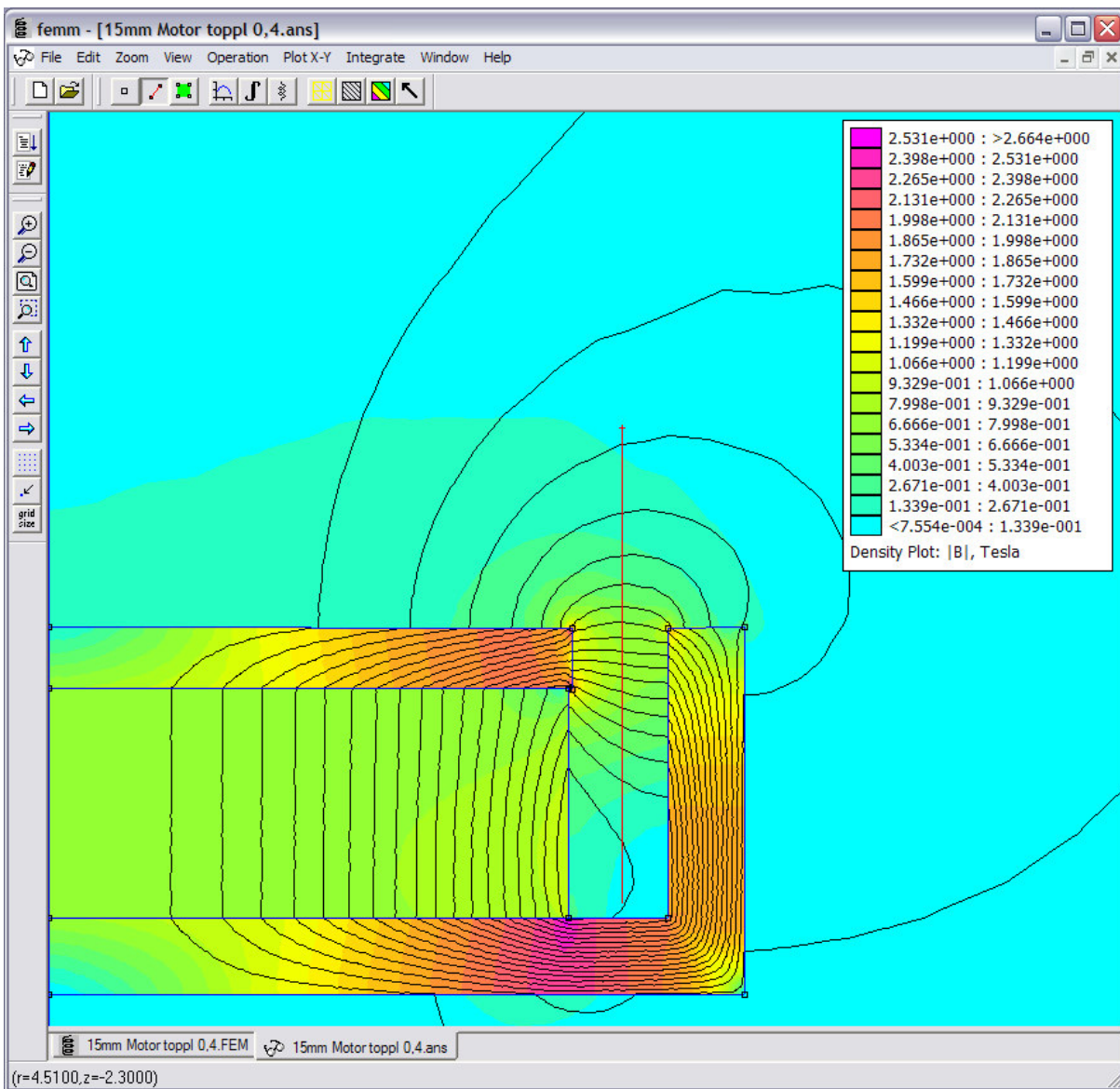
The imported flux profile is shown in the lower right corner below. The profile has more flux outside the gap than normally, because of the dimensions and the saturated top plate. Therefore the Xmax is actually 0.40mm, slightly larger than the 0.35mm predicted before.

There is another way to obtain more SPL from the micro speaker: By placing a second neodymium magnet (magnetized opposite) on top of the top plate, some of the leakage flux is forced back into the air gap.
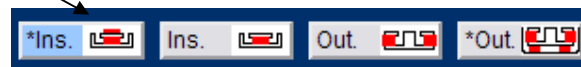
However this solution requires some available space below the center of the diaphragm, which is not possible in this case.

SPL (dB)

Airgap

+5dB ⬆ 90

-5dB 85

100
95
90
85
80
75

Current simulation

zoom * 0.5 ⇨⇦   Winding Width (mm)   ⬌ zoom x 2
0.5   1.0   1.5   2.0

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Reset |

Mechanical Parameters

Layers	n		2	
Wire Material			Copper	
Wire Type			Round	
Wind Width	WW		1.05	mm
Number of Windings	N		32.77	
Nom.(bare) Wire diam	BWD		0.050	mm
Total Winding OD	WOD		7.61	mm
Total Winding Mass	Mvc		0.014	g
Stretch			5.00	%

BL(x)

100%
82%
50%

Xm
0.40   0.40

VC in   VC out

⬌   0.5mm / Div   ⇨⇦

TS Parameters

Sensitivity (0.89V/0.10m)	SPL		85.91	dB
VC Resistance DCR	Re		7.00	Ohms
Resonance	Fs		400.00	Hz
Mechanical	Qms		6.00	
Electrical	Qes		1.47	
Total	Qts		1.18	
Equivalent air vol.	Vas		0.01	l
Compliance	Cms		7.81	mm/N
Moving Mass(incl. air)	Mms		0.02	g
Force Factor	Bl		0.49	Tm
Eff. diaphragm area	Sd		0.85	sq.cm
Lin. Excursion +/-	Xmlin		0.32	mm

Flux Profile

2T
1T

15 Motor FEMM toppl 0.4.txt

Bg=0.7568T
Bd=0.6545T
Bt=2.0861T

Offset -0.02mm

Finally we may improve the 15mm micro receiver by using Ferrofluid in the air gap. There are 3 significant advantages by doing so:

1. The power handling is increased considerably due to the cooling with the Ferrofluid in the air gap.
2. The Ferrofluid can be selected to add much damping at resonance (Fs), which prevents distortion and increases power handling.
3. The air gap can be made smaller, which will increase SPL and improve cooling.

The next picture shows the exact volume of Ferrofluid to be dispensed in the air gap, the saturation strength, and viscosity.

More info about Ferrofluid can be found at www.ferrotec.com

Mechanical Parameters

Layers	n	2	
Wire Material		Copper	
Wire Type		Round	
Wind Width	WW	1.05	mm
Number of Windings	N	32.77	
Nom.(bare) Wire diam	BWD	0.050	mm
Total Winding OD	WOD	7.61	mm
Total Winding Mass	Mvc	0.014	g
Stretch		5.00	%
Ferrofluid Volume	FF vol	4.19	uL
Ferrofluid Saturation	FF sat	200 - 150	Gauss
Ferrofluid Viscocity		200.00	Cps

TS Parameters

Sensitivity (0.89V/0.10m)	SPL	86.56	dB
VC Resistance DCR	Re	7.00	Ohms
Resonance	Fs	400.00	Hz
Mechanical	Qms	1.16	
Electrical	Qes	1.27	
Total	Qts	0.60	
Equivalent air vol.	Vas	0.01	l
Compliance	Cms	7.81	mm/N
Moving Mass(incl. air)	Mms	0.02	g
Force Factor	Bl	0.53	Tm
Eff. diaphragm area	Sd	0.85	sq.cm
Lin. Excursion +/-	Xmlin	0.32	mm

The Ferrofluid is specified (in red). First is the exact volume as given by FerroTec, and then the necessary magnetic saturation strength and finally the chosen viscosity.

The sensitivity was increased due to the narrow gap which is possible with Ferrofluid, and the mechanical damping was increased due to the damping from the Ferrofluid.
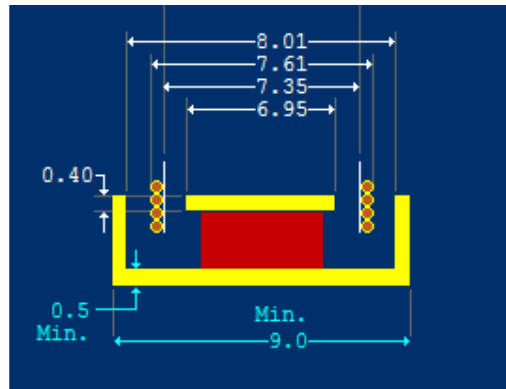
Micro Loudspeaker / Receiver Box Design

Micro loudspeakers and receivers can be designed in FINEMotor2008 and imported into FINEBox, where the acoustic loading / box volume and tuning can be simulated.
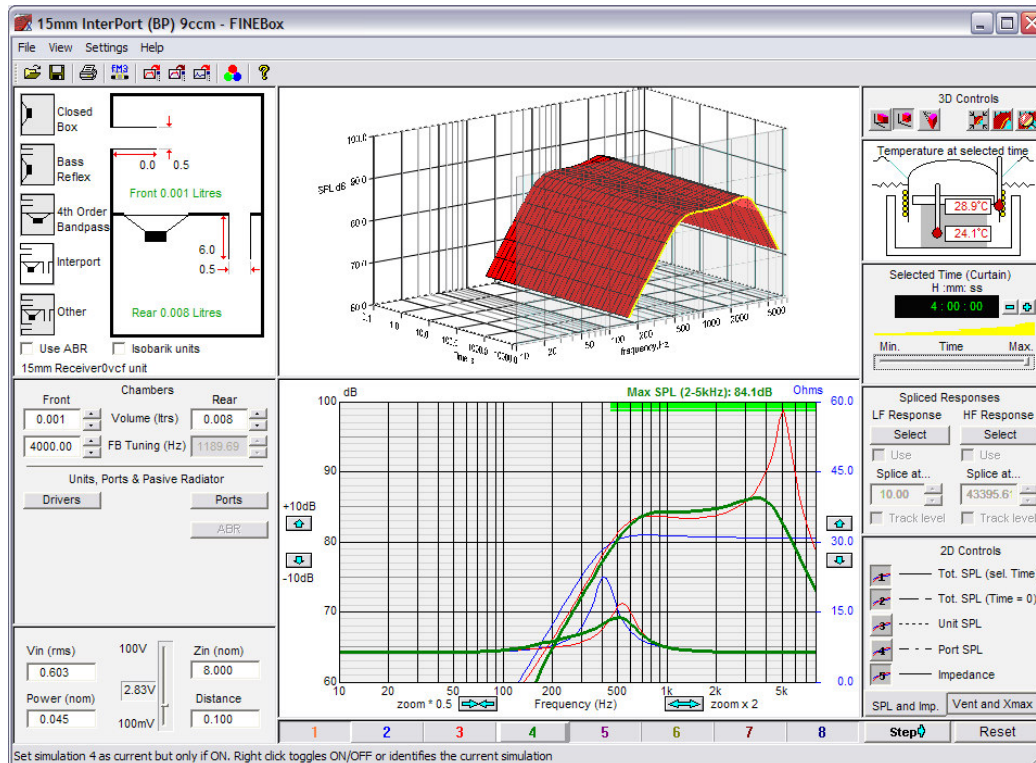

Figure 4: 15mm micro speaker in closed___/Band pass___/ damped InterPort____

Now we will start a 15mm box design by importing a FINEMotor file (with T/S parameters and thermal data) directly into FINEBox by pressing the "Read Unit" button.

(Fig. 5) defines the additional information, first is the distance from winding to diaphragm, which here is 0, since the VC is glued directly to the diaphragm. The second number is the thermal conductivity, which here is the lower number 0.45 Wm/K for isolating materials. The linear excursion Xmax=0.276mm is also imported.

Figure 5: Thermal Info Input

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Fig. 6 shows the complete driver data, imported from FINEMotor. The thermal time constants of the VC and motor are automatically simulated.

Figure 6: Complete 15mm micro speaker data imported from FINEMotor

First the 15mm micro speaker/receiver unit is put it a closed box volume of 0.1 L (100ccm) by selecting the upper left button "Closed Box" and adjusting the (Front-) volume to 0.100 L by rolling the mouse wheel. This is shown as the blue curve in Fig.4 (Button #2).
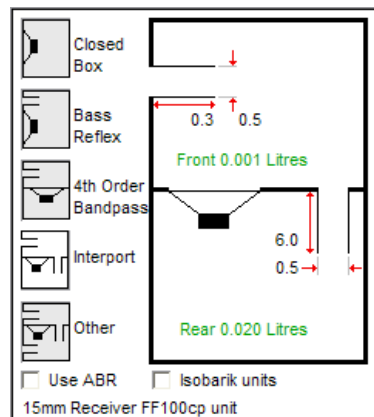

Figure 7: FINEBox Acoustic Loadings

The blue curve (#2) has an impedance peak close to 400 Hz, which is the resonance Fs. The input voltage was adjusted to give an Xmax excursion of 0.28mm, (= Xmlin: max excursion with Voice Coil still in the gap). This gives a max SPL of 81dB at 0.1m defined by the frequency range indicated by the green line. See also later Fig.10.

In contrast the red curve #3 is a Bandpass design, with a small hole (port) in front of the speaker. This port is tuned to 5000 Hz, after which the response drops at higher frequencies. Again the input voltage was adjusted to give a max excursion of 0.28mm, giving a max SPL of ~83.7 dB at 0.1m. However there is a very large peak at 5000 Hz.

Choosing the InterPort option (Figs.4 & 7) and adjusting the InterPort Q to 0.9, (Fig. 8) brings down the peak and gives a quite flat Bandpass response. The high damping (lower Q) is made by covering the (Inter-) port with a cloth or felt, which will pass air but add damping. Actually the front port can be damped in the same way. Max SPL (2-5 kHz) is dB.

The VC and magnet temperature is in the upper right picture. The VC is at 28.9C which is no problem. See the next two sections regarding high power simulations.
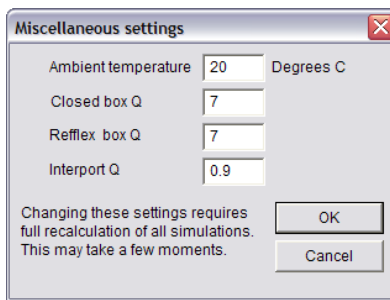
Figure 8: Setting of Port Q and damping

The ports can be changed by modifying the port diameters (Fig. 9), and the length will automatically be simulated according to the chosen tuning frequency. A flange (trumpet) can reduce port noise/whistling.
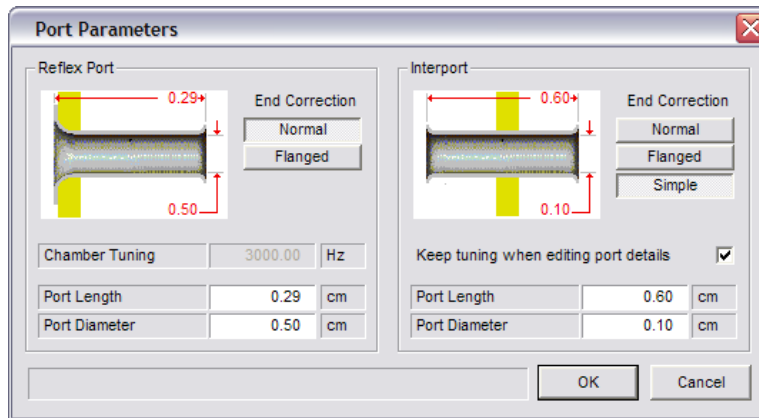

Figure 9: Change of Port diameters and simulated lengths
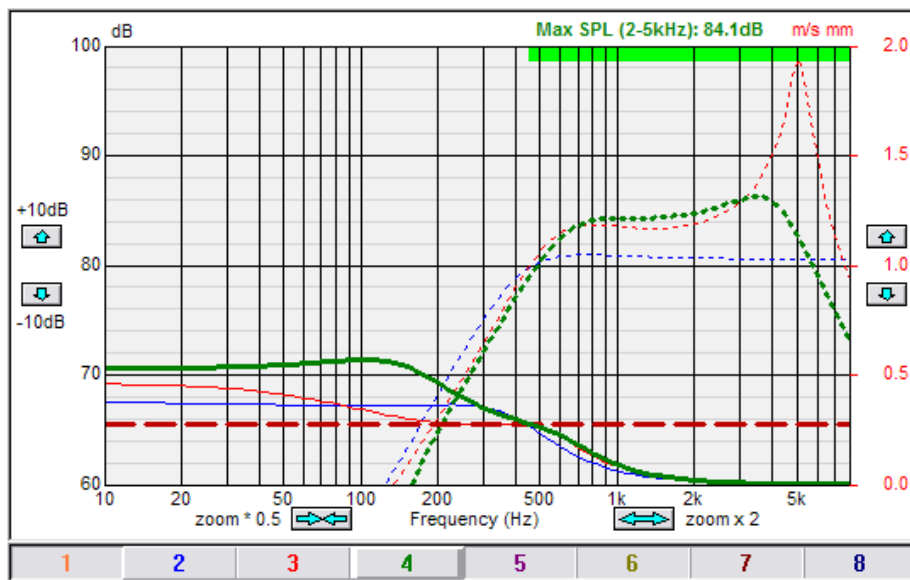

Figure 10: Excursion of 15mm closed/Band pass/InterPort from Fig. 4

Fig. 10 shows the VC excursion of the 3 designs, where the input was set to produce 0.28mm (Xmlin) at the resonance frequency (Fs) in the box. Because the excursion is increased at low frequencies, the design with the higher box resonance (green #4) can produce a higher SPL in the pass band. In order to prevent problems, it is advisable to insert a High Pass filter to limit the low frequencies below Fs.