



Loudspeaker DIY

2019-07-25

Alvis Chan



CONTENT

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2. Introduction
3. Essential loudspeaker components
4. Software required
5. Design steps
6. Box Design
7. Crossover Design and Tuning

Something about Alvis

- Uncountable acoustic projects done since 1997. Days and nights involved in loudspeaker tuning: >2000 days.
- Skills acquired:
 - Loudspeaker system design
 - Acoustic test hardware design
 - Acoustic software design
 - Enclosure ME design
 - Filter and DSP architecture and tuning
 - Concert system planning and tuning
 - Etc...



A collage of 12 images showing various custom-built and modified speakers. The speakers are made from different materials like wood, cardboard, and plastic, and feature various driver configurations. Some images show the speakers in use, while others show the internal components or the construction process.

Conventional HiFi System

Source:

CD Player



PC



Amplifier



Loudspeaker

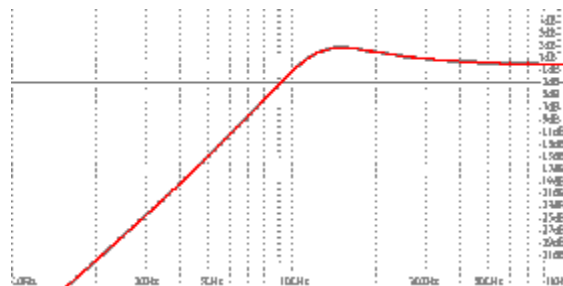


What constitute a loudspeaker?

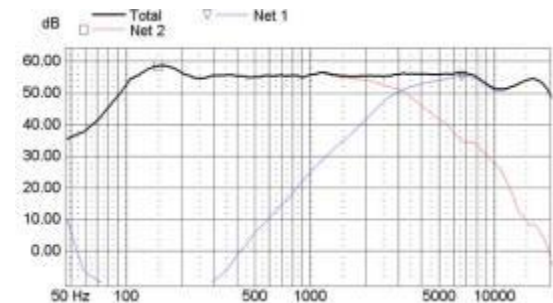
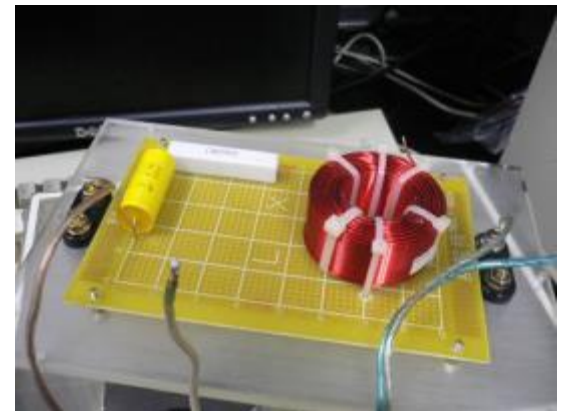
Drivers



Box



Filter / EQ



Essential components

- Woofer
- Tweeter
- Crossover
- Enclosure/Box



DIY惠威M1樱桃实木空箱

Test equipment

- Mic (U-mik)
- Impedance analyzer
 - Simply an amplifier, soundcard, and resistor network.
 - Or a PCBA design by Alvis
- Measurement Software:
 - Room EQ Wizard
- Box Simulation Software:
 - WinISD
- Crossover Simulation Software:
 - VituixCAD



Watch a DIY video

Design steps

1. Speaker size determination
2. Driver selection
3. Impedance measurements
4. Box design
5. Installation
6. SPL measurements
7. Crossover design
8. Build the crossover
9. SPL measurements
10. Listening test and fine tuning
11. Fine tune the crossover
12. Finish the DIY

Model No: TPY05W04O0089
Product Line: Tymphany Gold

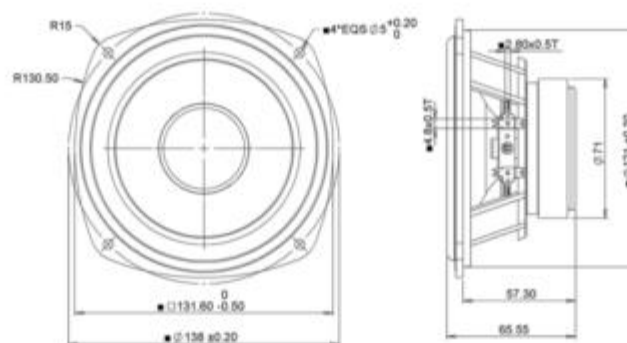
Rev 1
Last Update: 2017-04-26 05:32:09

Product Description

This 5.25 inch 4 ohm driver is a member of the Heritage family.



Mechanical Drawing

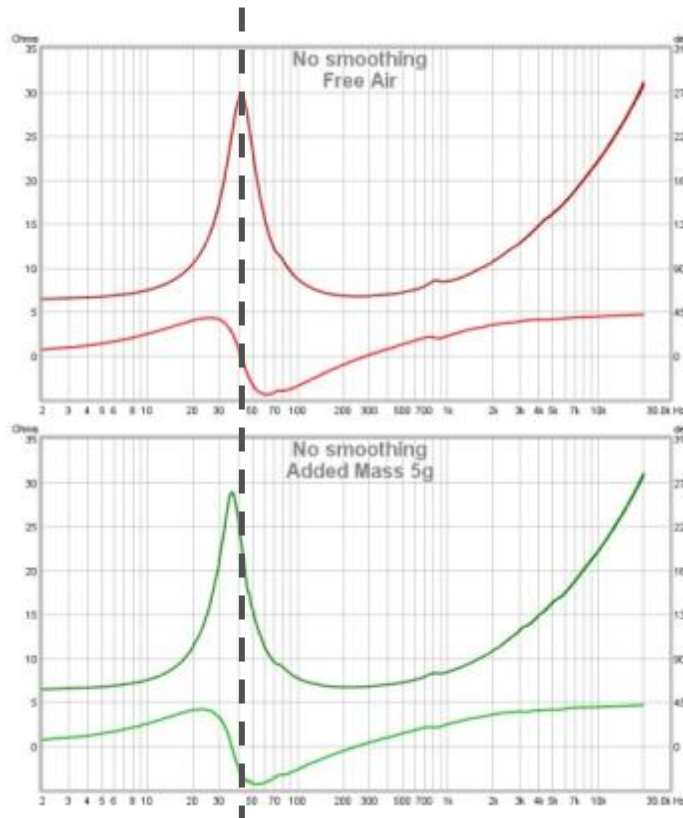


Specifications

DC Resistance	Rev	Ohms	3.74	5.0%	Energy Bandwidth Product	EBP	(1/Qes)*fs	120.08
Minimum Impedance	Zmin	Ohms	5.08	7.5%	Moving Mass	Mms	g	8.58
Voice Coil Inductance	Le	mH	0.18		Suspension Compliance	Cms	um/N	386.43
Resonant Frequency	Fs	Hz	87.42	15%	Effective Cone diameter	D	cm	10.7
Mechanical Q Factor	Qms		3.53		Effective Piston Area	Sd	cm^2	89.92
Electrical Q Factor	Qes		0.73		Effective Volume	Vas	L	4.39
Total Q Factor	Qts		0.6		Motor Force Factor	BL	lm	4.92
Ratio Fs/Qts	F	Fs/Qts	144.97		Motor Efficiency Factor	B	(T*M^2)/Ohms	6.48
Half Space Sensitivity @2.83V	db@2.83V/1M	dB	89.21	+/- 1.0db	Voice coil former Material	VCfm		ASV
Half Space Sensitivity @1W/1M	db@1W/1M	dB	87.23	+/- 1.0db	Voice coil inner diameter	VCd	mm	25.73
Gap Height	Gh	mm	6		Rated Noise Power	P	W	25
Maximum Linear Excursion	Xmax	mm	2.49		Test Spectrum Bandwidth	20Hz-4KHz		
Ferrofluid Type	FF				Transducer Size	Inch	5.25	
Transducer Mass	Kq	0.66						

Measuring impedance

- Use REW to get:
 - Impedance
 - TS parameters:



Thiele-Small Parameters

Free Air Measurement
 1: SPH170 horz

Secondary Measurement
 2: SPH170 horz+5g

Manually Entered Values
 Voice Coil DC Resistance (ohm): 6.20
 Effective Area (cm²): 137.0
 Air Temperature (Celsius): 20
 Air Pressure (mB): 1013.25
 Added Mass (g): 5.00
 Sealed Box Volume (Litres): 12.500
☐ Compensate for Leakage Losses
☒ Compensate for Air Load
 Calculate Parameters
 Write Parameters to File

Motional Impedance Parameters
 R_{ES} (ohm): 29.9
 C_{MES} (uF): 368.1
 L_{CEs} (mH): 39.67
 Λ_{ES} (mohm): 399.7

Blocked Impedance Parameters
 dR (ohm): 0.10
 L_{EB} (uH): 63.8
 L_E (mH): 1.090
 R_{SS} (ohm): 59.69
 K_E (S-H): 0.0904

Simplified Model Parameters
 R_E 6.30 ohm L_E 96.4 uH
 R_{ES} 23.27 ohm R₂ 16.30 ohm
 C_{MES} 368.1 uF L₂ 209.4 uH
 L_{CEs} 39.67 mH R₃ 4.36 ohm
 L₃ 462.6 uH

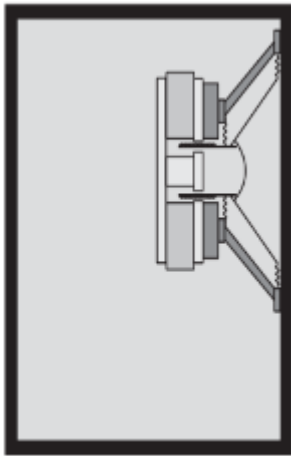
TS parameters for measurement: SPH170 horz

R _E 6.30 ohm	f _s 41.6 Hz	M _{MS} 14.39 g
Z _{min} 6.71 ohm	Q _{MS} 2.242	C _{MS} 1.015 mm/N
f _{min} 251 Hz	Q _{ES} 0.607	R _{MS} 1.680 kg/s
f ₂ 1,473 Hz	Q _{TS} 0.478	V _{AS} 27.01 litres
L _E (f ₂) 0.470 mH	F _{TS} 87.2 Hz	BI 6.253 Tm
Dd 13.21 cm	L _P 87.13 dB (1W/1m)	Eta 0.31 %
Sd 137.0 cm ²	Added mass 5.00 g	

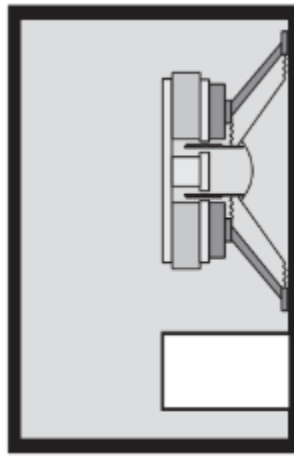
Secondary measurement: SPH170 horz+5g
 Air temperature 20.0 C, pressure 1,013.25 mB giving density 1.2041 kg/m³, c 343.2 m/s

Box Type

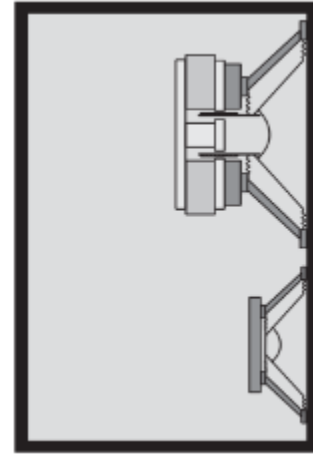
◆ Common Box Types



Sealed



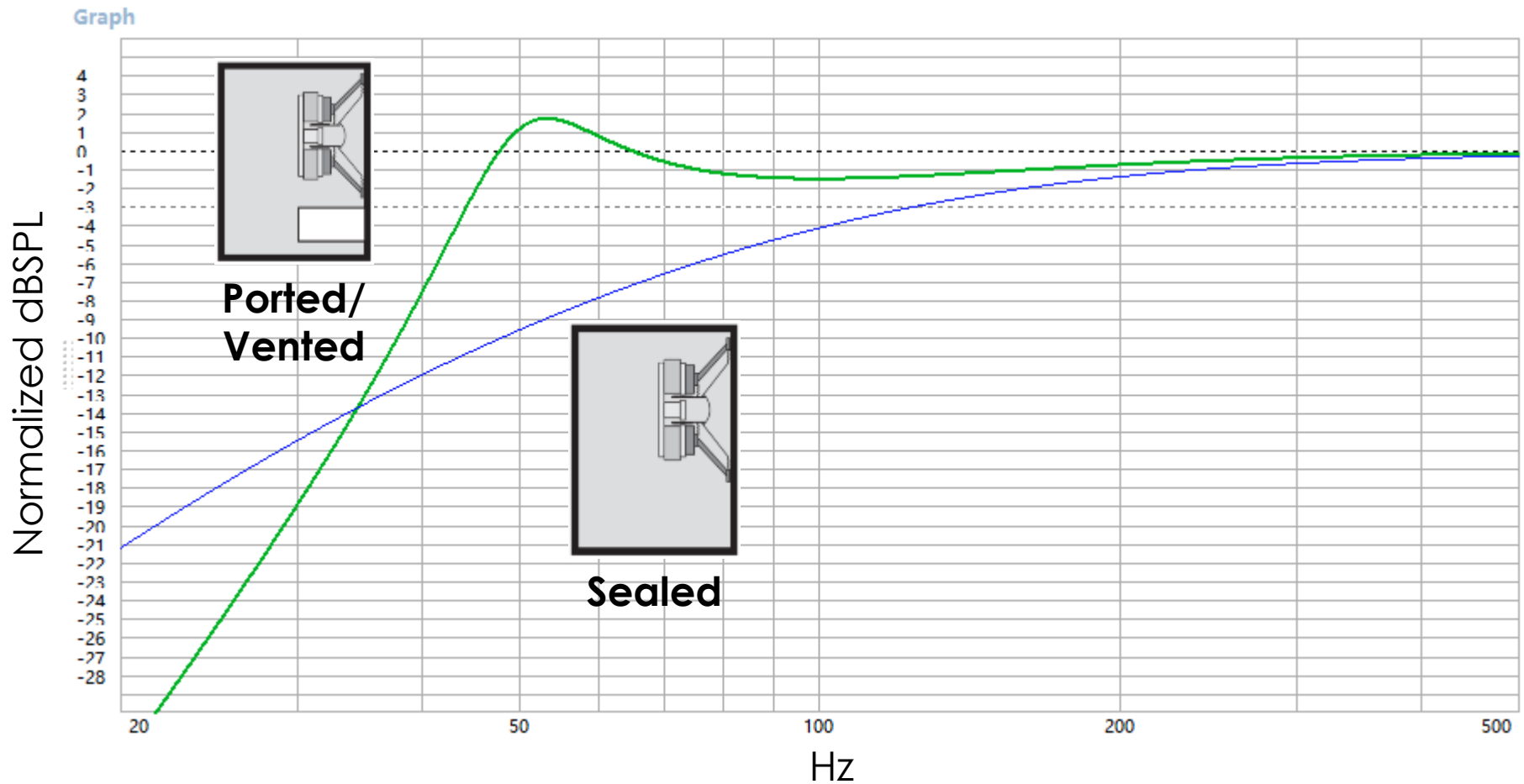
Ported/Vented



PR

Vented VS Closed Box

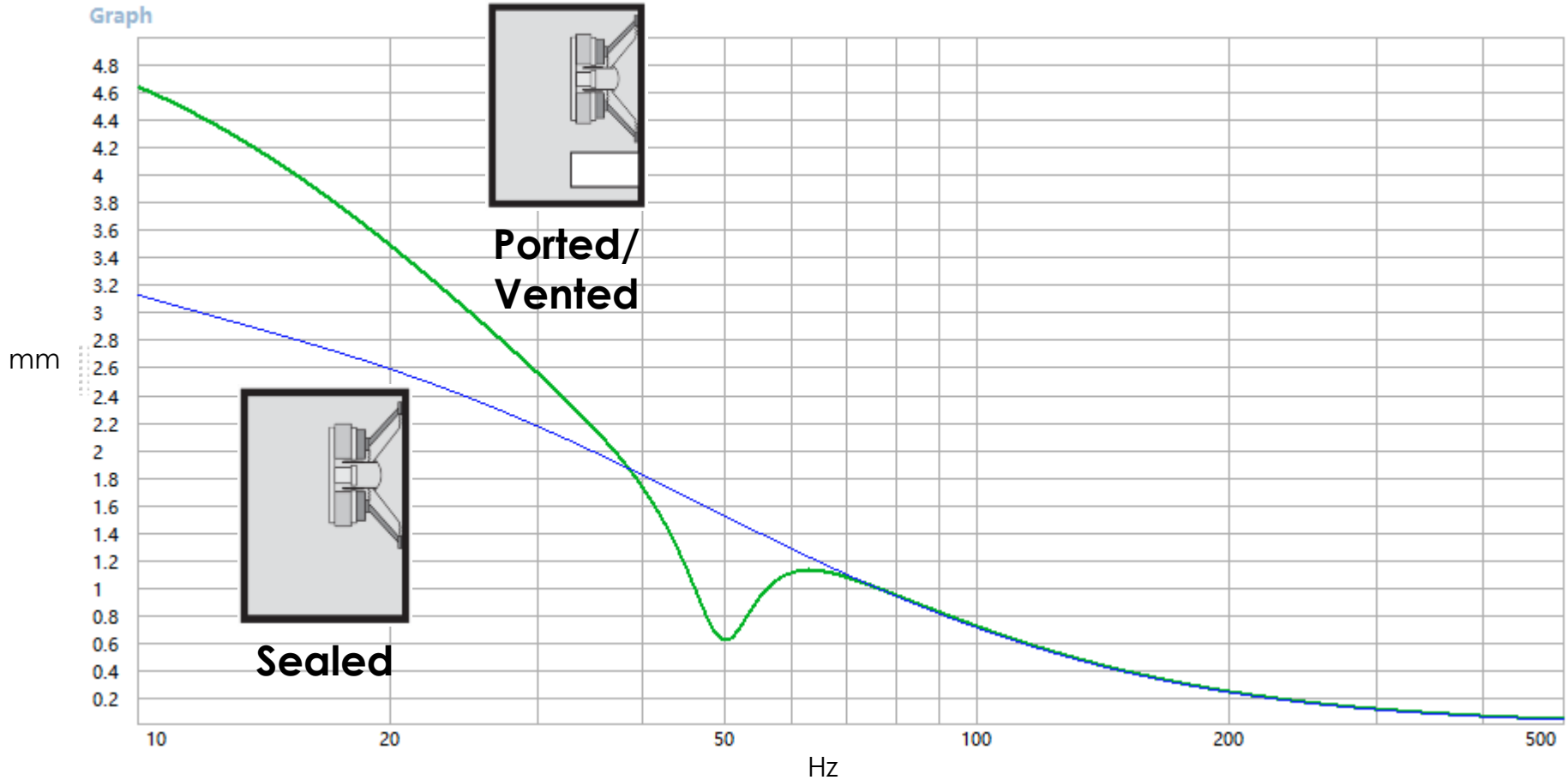
◆ Low frequency efficiency



Box internal volume = 9 Liter

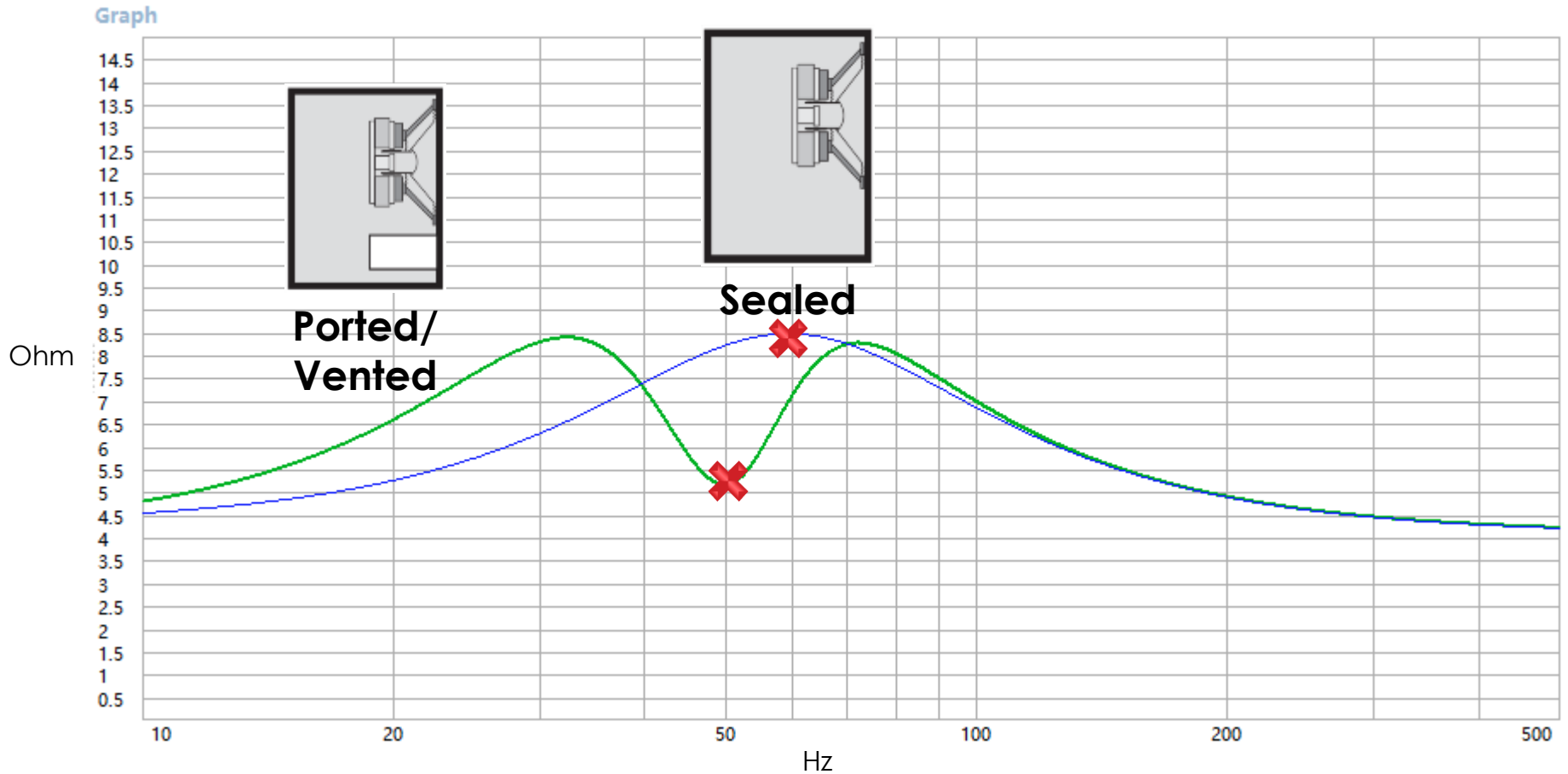
Vented VS Closed Box

◆ Speaker Excursion



Vented VS Closed Box

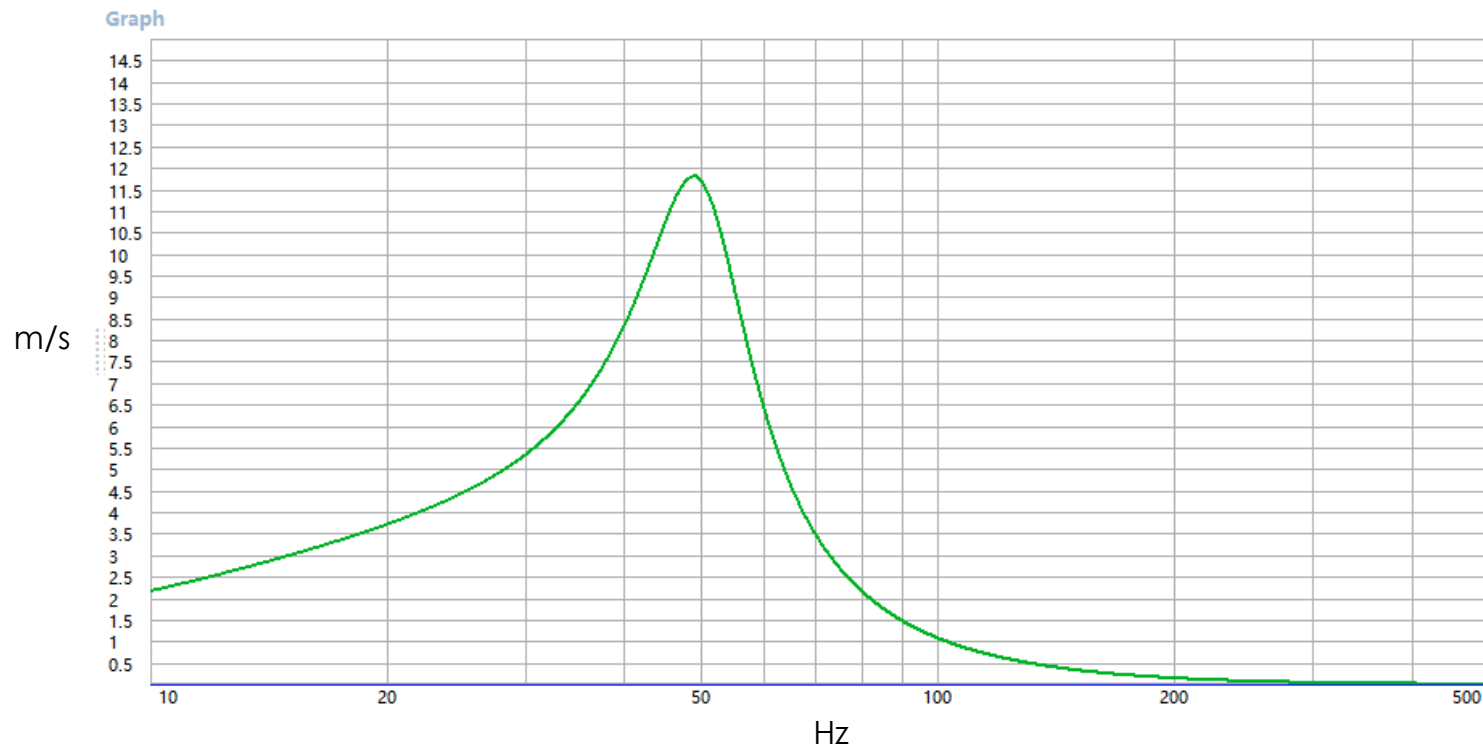
◆ Finding resonance by observing impedance



Vented Box

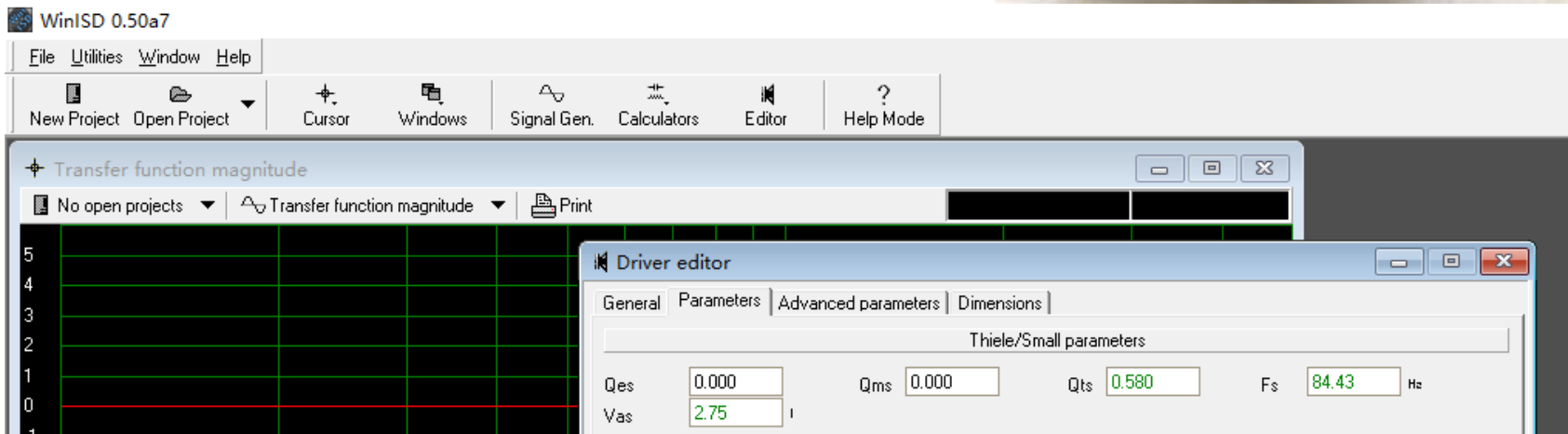
◆ Port Air Velocity

- Port Velocity Allowed $\leq 10\text{m/s}$ (Flared Port allows higher velocity)
- Port Noise Reduction (Turbulence/Compression)
 - Effective Port Area \uparrow , Port Length \uparrow , Flared Port.

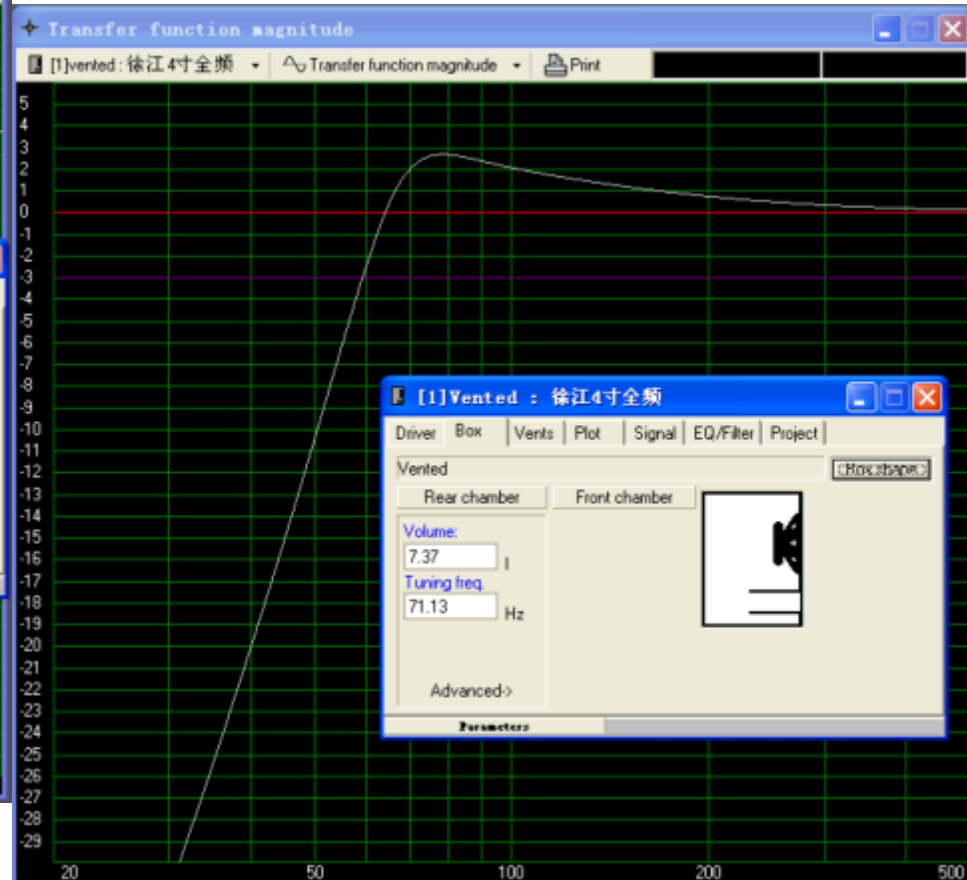
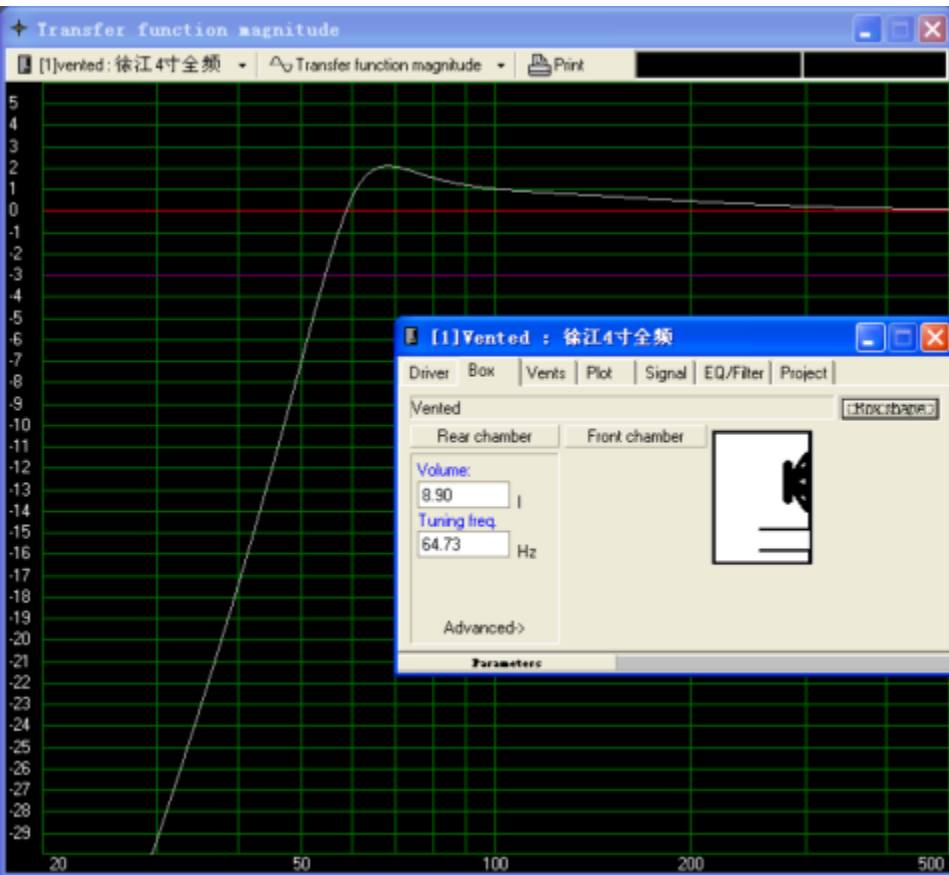


Design by given woofer

- Woofer parameters
- WinISD design demo



WinISD box simulation



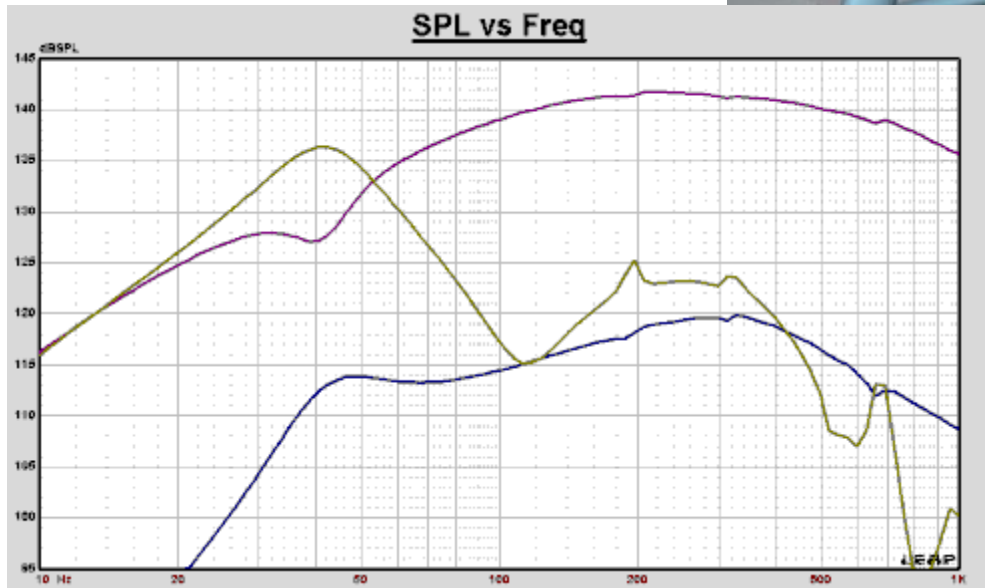
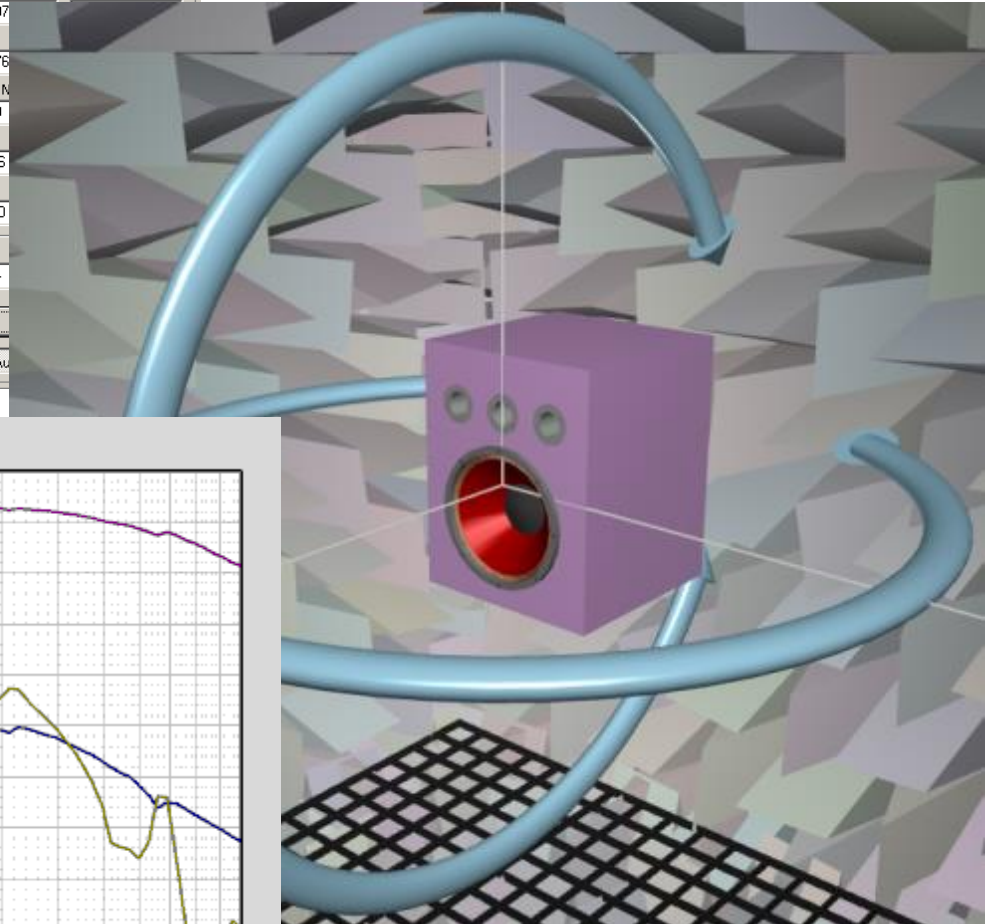
Enclosure Simulation

Transducer Parameters

Name	Levo Motor	Model	STD	Shape	Round	Fmd	KA	Flp	KA	Mms	Kg	Qms
	155WS1100					3.000		8.000		120.1000m		13.1492
Note	SPL Mech	Domain		Profile		Qmd	Qlp			Cms	M/N	Qes
						1.000	2.000			149.9997		

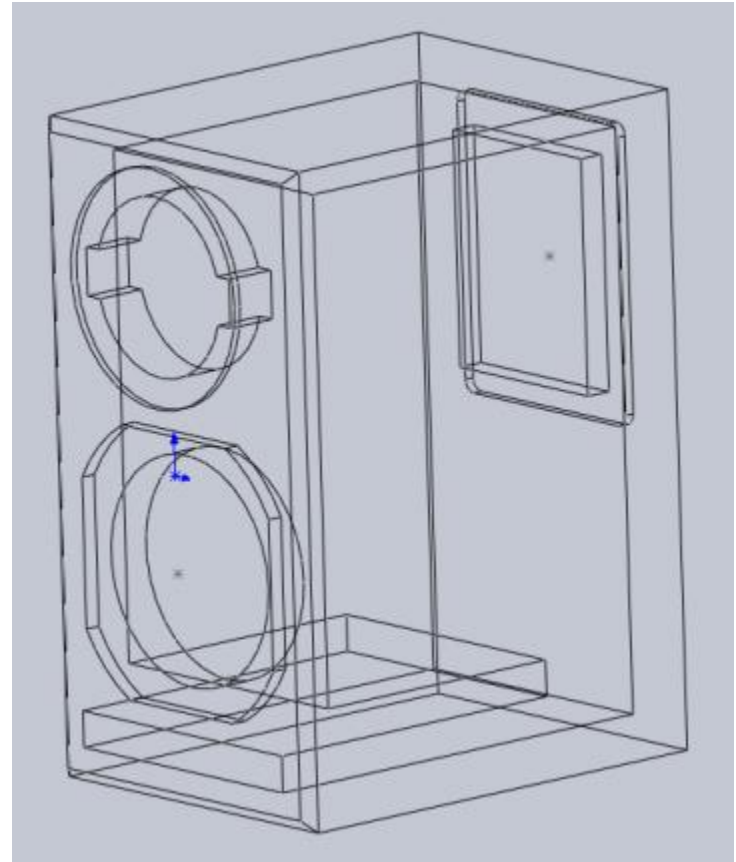
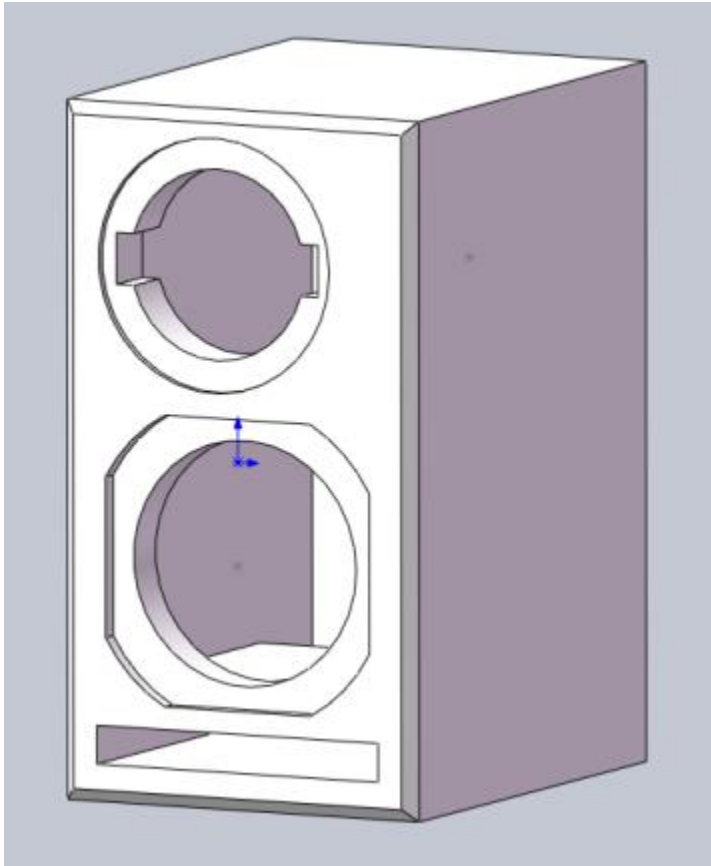
Znom	Xgap	M	Km	Kxm	H	Krs	N/M	Kcs	M/N	Vas
8.000	1.000		1.00000	1.00000		1.00000		1.00000		141.9576
Revc	Xcoil	M	Fm	Hz	Fxm	Hz	Xrs	M	Xcs	Rms
5.600	1.000		1.00000		1.00000		10.00000m	10.00000m		2.1519
Sd	Xmax	M	Drm	Dxm		Drs	Dcs			Fo
81.400m	0.000		0.00000	0.00000		1.00000	0.50000			37.4976
Mmd	Xtrg	M	Erm	Exm		Ers	Ecs			BL
106.754	1.000m		0.00000	0.00000		0.70000	0.00000			19.4230
Pmax	Walt	Etrg	Vrm	Vxm		Grs	Gcs			Vs
2200.007	1.00000		0.00000	0.00000		0.80000	0.80000			2.8284
Rtvc	C/W	BLo	Tm	Txm		Trs	Tcs			
113.636m	19.4230		0.000	0.000		0.000	0.000			

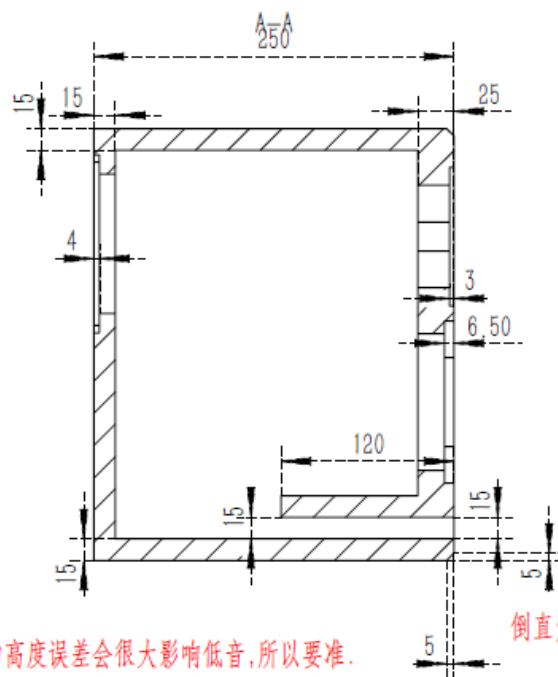
Copy as Text Copy as Binary Paste From Text Paste From Binary Check Params



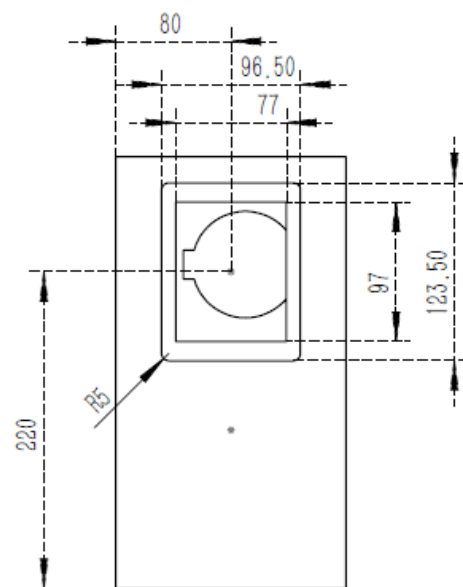
WinISD live demo

Box ME Design





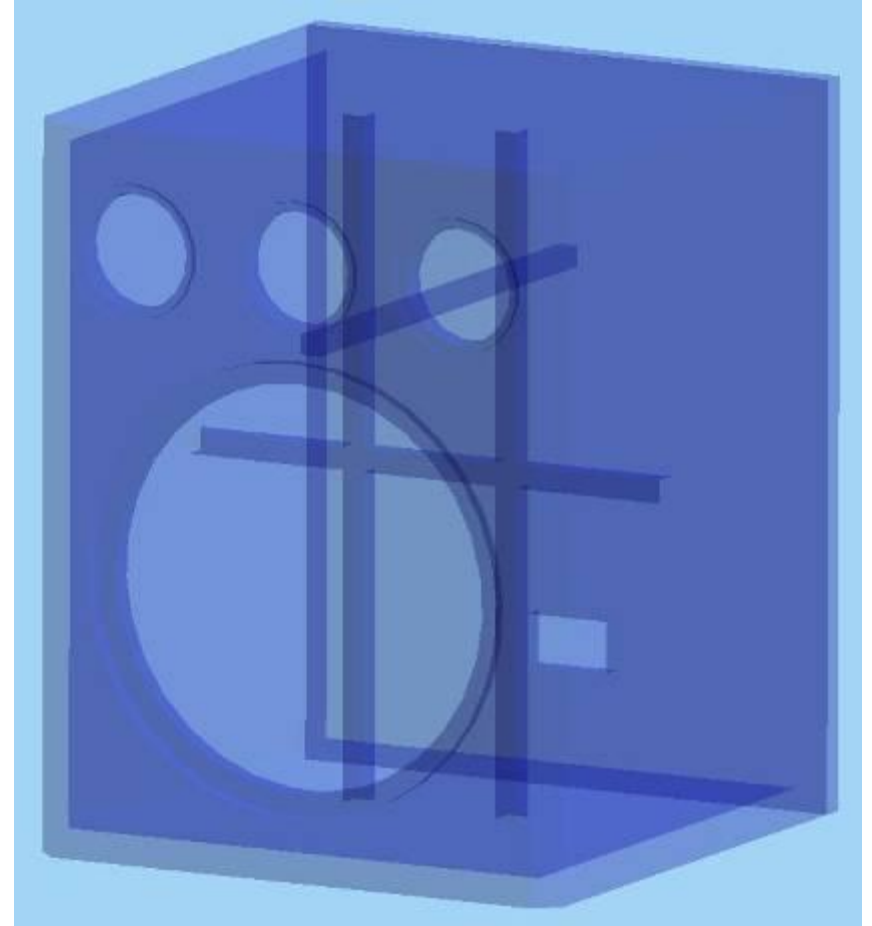
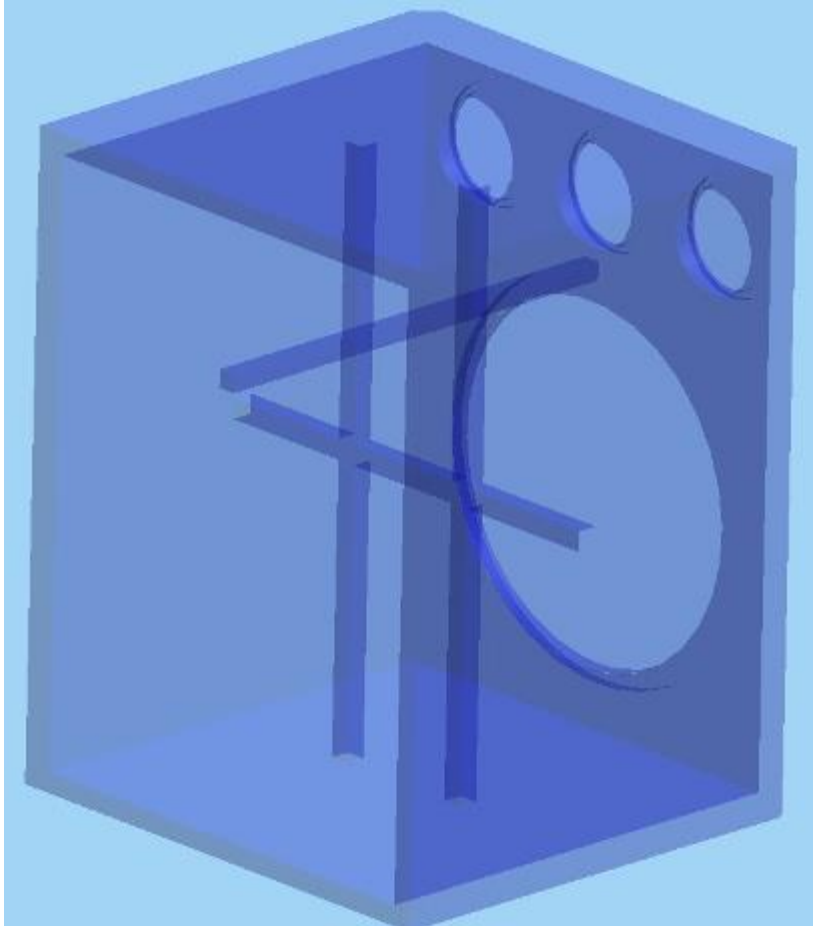
倒直角



When the box is finish



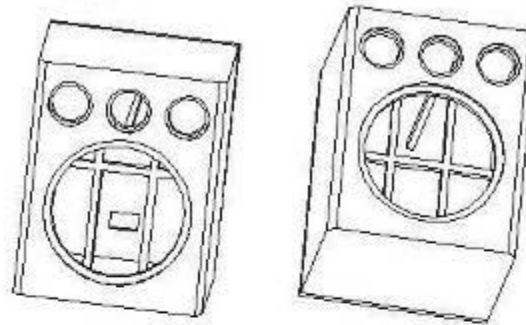
Box ME Design, 2nd example



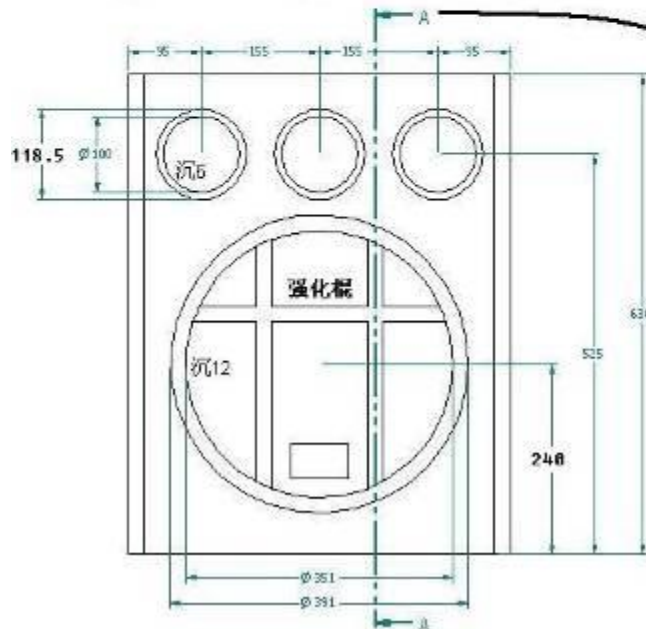
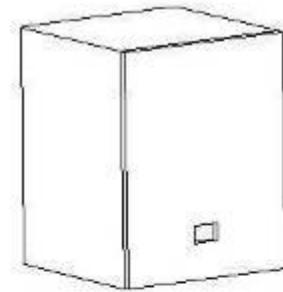
Box ME Design, 2nd example



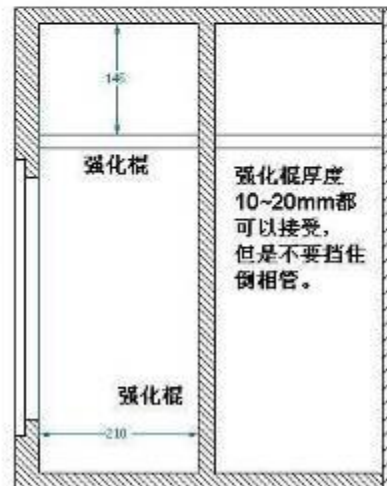
立体图供参考:



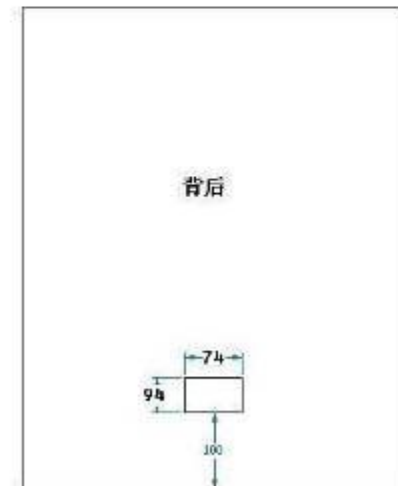
贴酸枝木皮, 烤漆。



沿A线切割内部剖图:



SECTION A-A

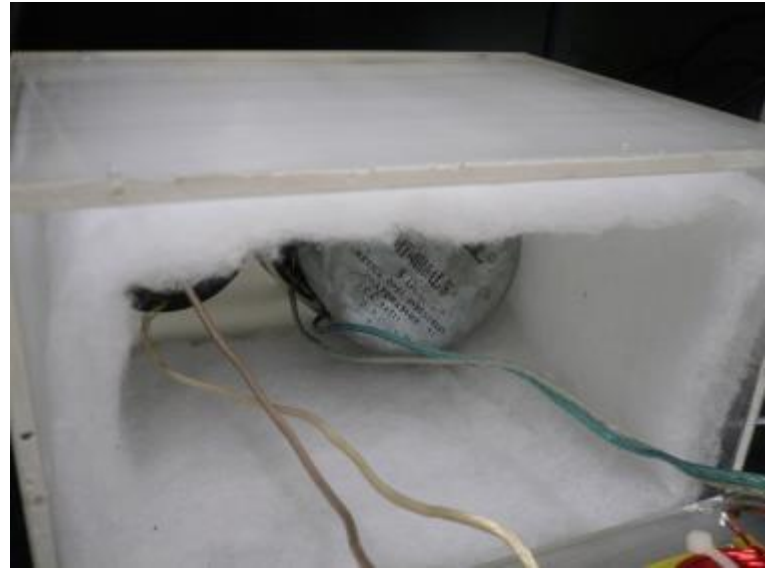


Construction



**Before you install the woofer...
...stuff the box**

Box filling/stuffing

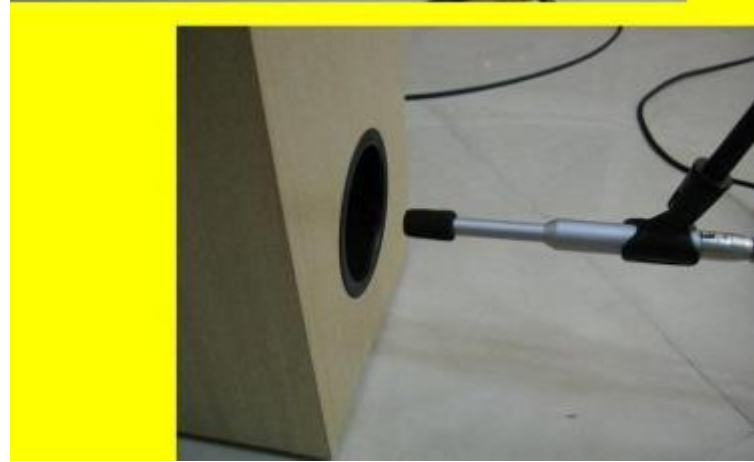


Measure near-field SPL for verification

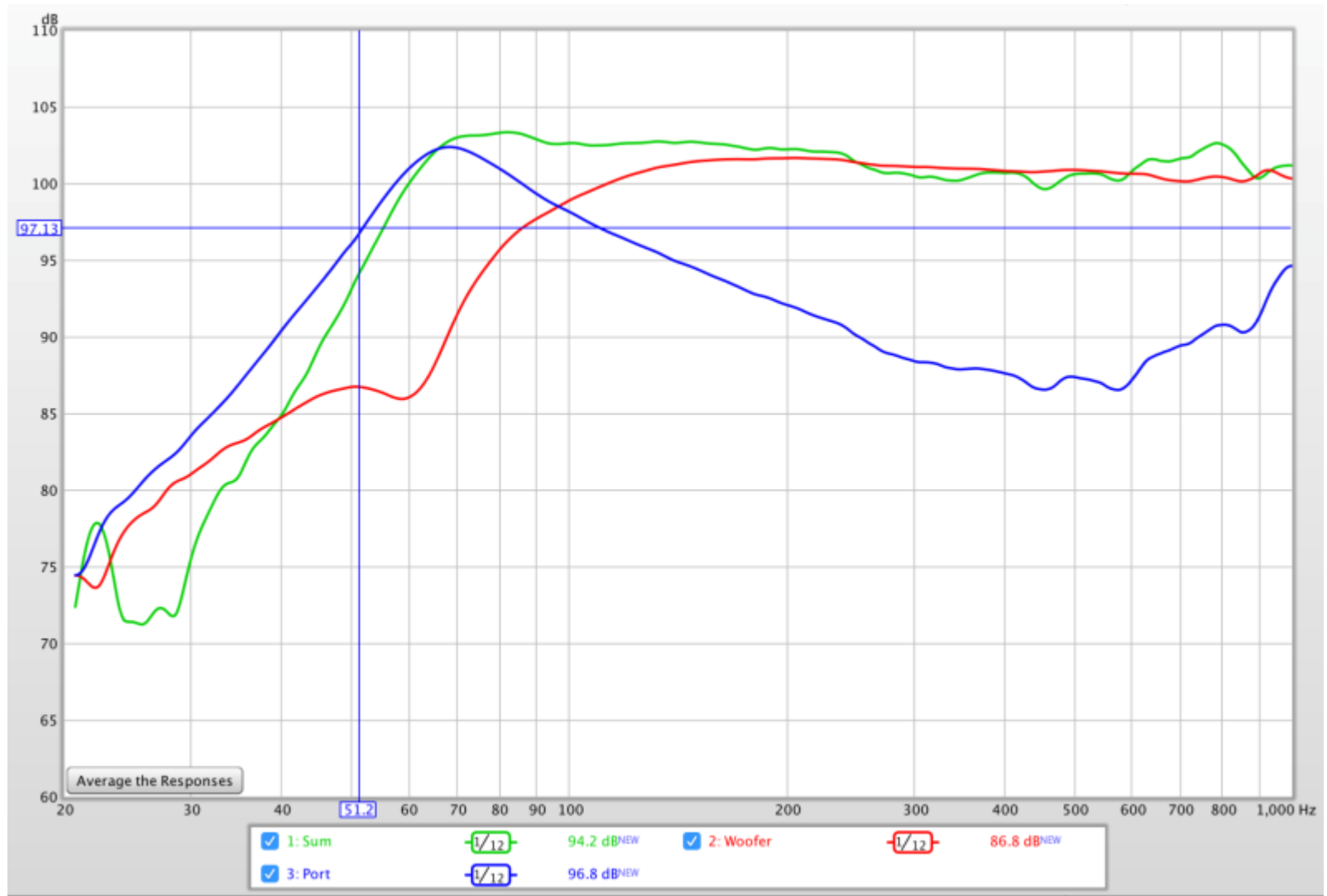
Woofer Nearfield SPL



Port Nearfield SPL



Woofers+box SPL measurement

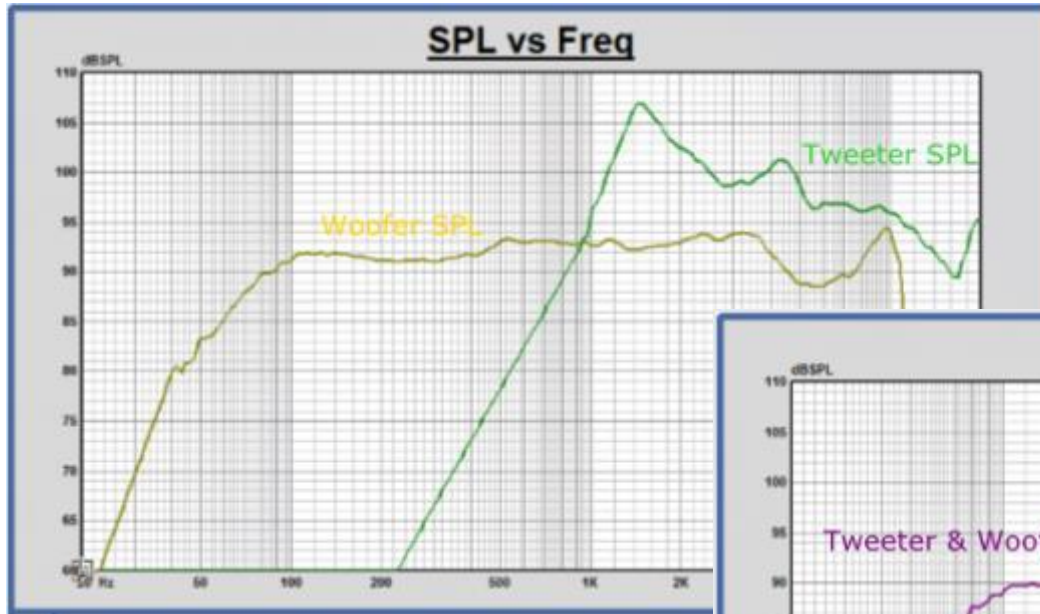


**Low frequency/box design is basically finish.
Now, we move to crossover design.**

Crossover design video

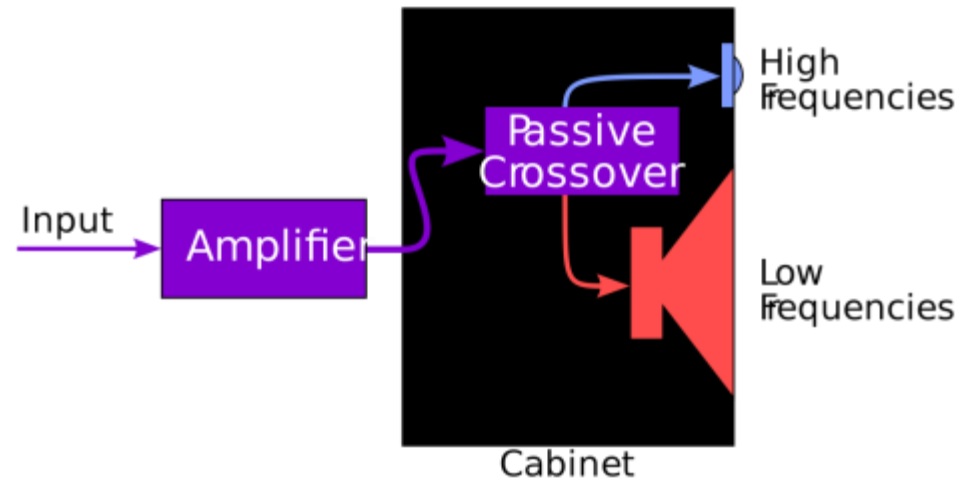
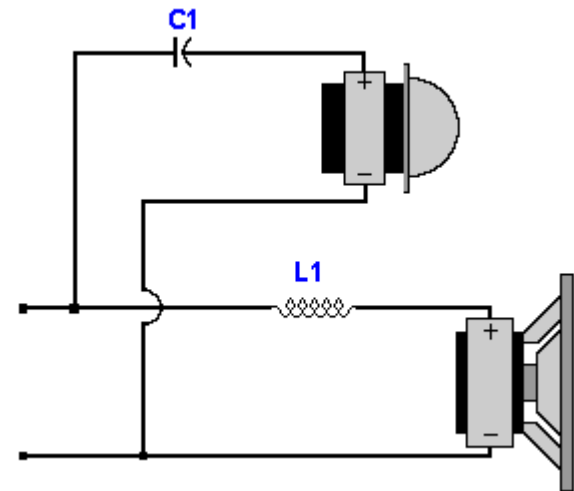
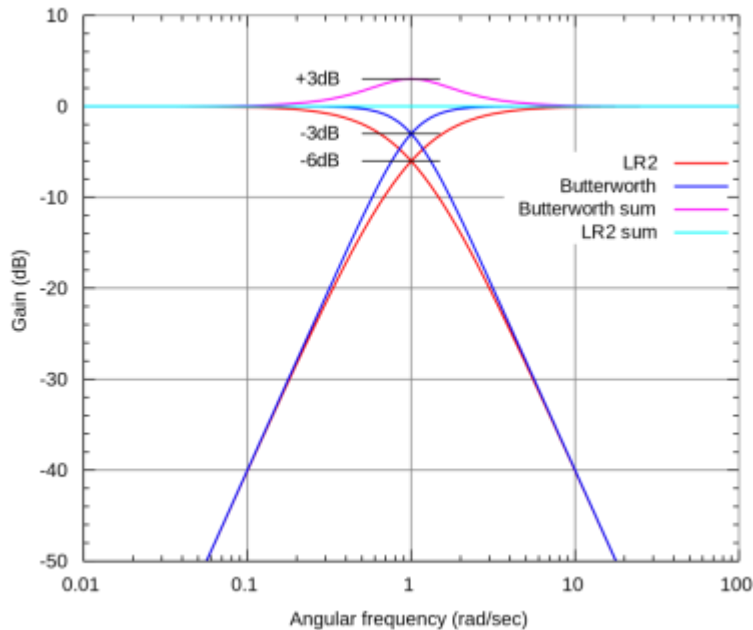
Why Crossover is Needed?

Example: Two-way stereo speaker SPL and impedance measurements

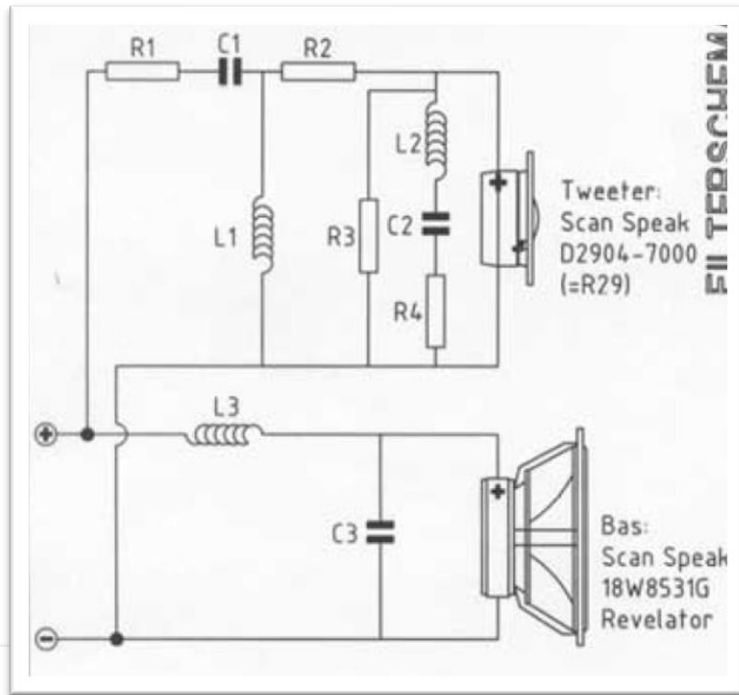


The Crossover

- Frequency dividing network
- Butterworth, max flat amplitude, $Q=0.7$
- LR, max flat phase, $Q=0.5$

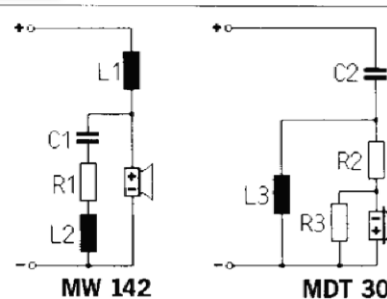
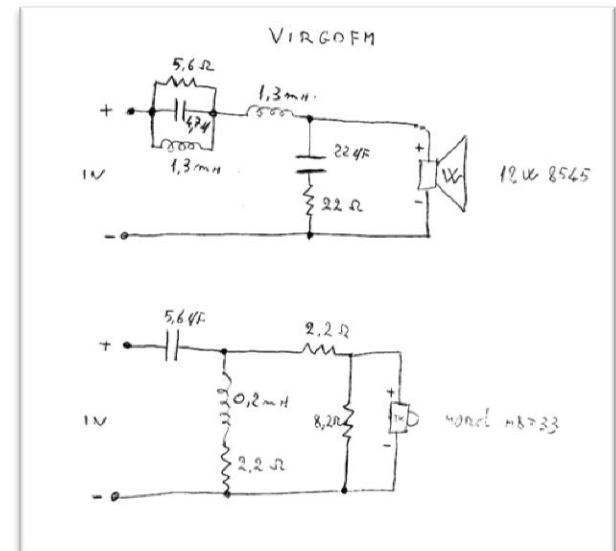
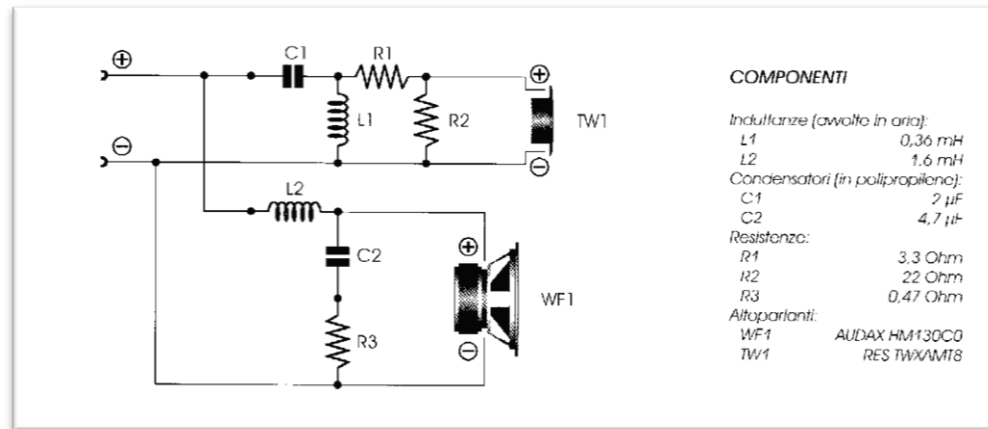


Some crossover circuit examples



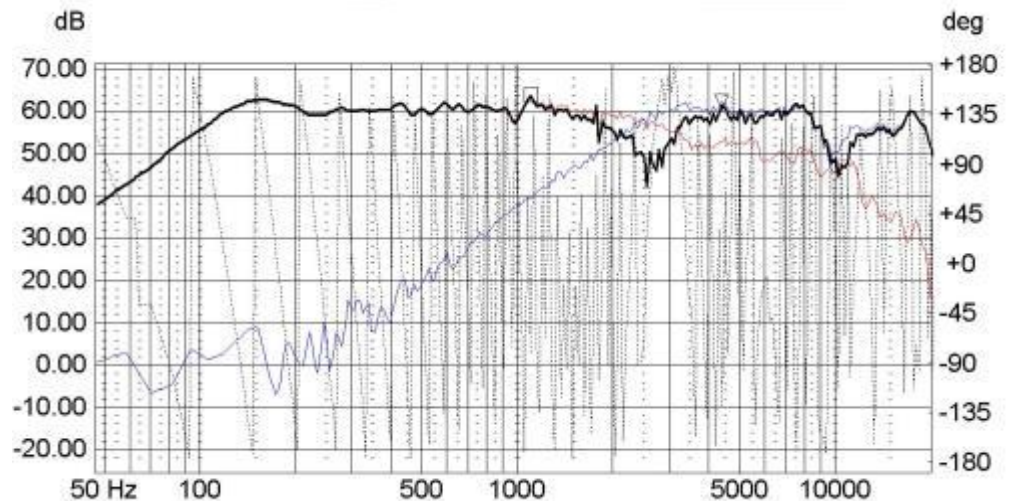
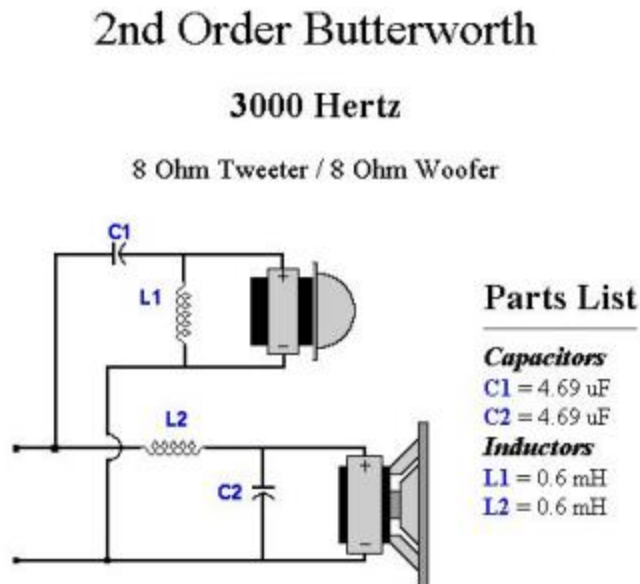
$L1 = 1.50 \text{ mH}$
 $L2 = 0.39 \text{ mH}$
 $L3 = 0.47 \text{ mH}$
 $C1 = 6.8 \text{ } \mu\text{F}$
 $C2 = 10 \text{ } \mu\text{F}$
 $R1 = 4.7 \text{ Ohm } 5 \text{ W}$
 $R2 = 3.9 \text{ Ohm } 10 \text{ W}$
 $R3 = 3.9 \text{ Ohm } 5 \text{ W}$

POLIESTERE = 0.25 mq



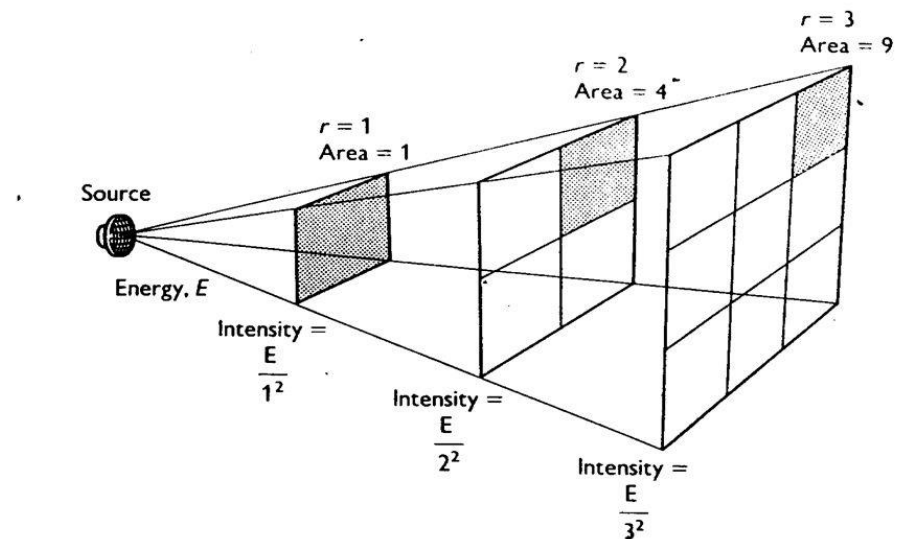
The Crossover

- Why the formula does not work?
 - Single resistor as the electrical model of loudspeaker
 - Acoustic response of loudspeaker is not flat
- What would happen with the formula from books and internet?

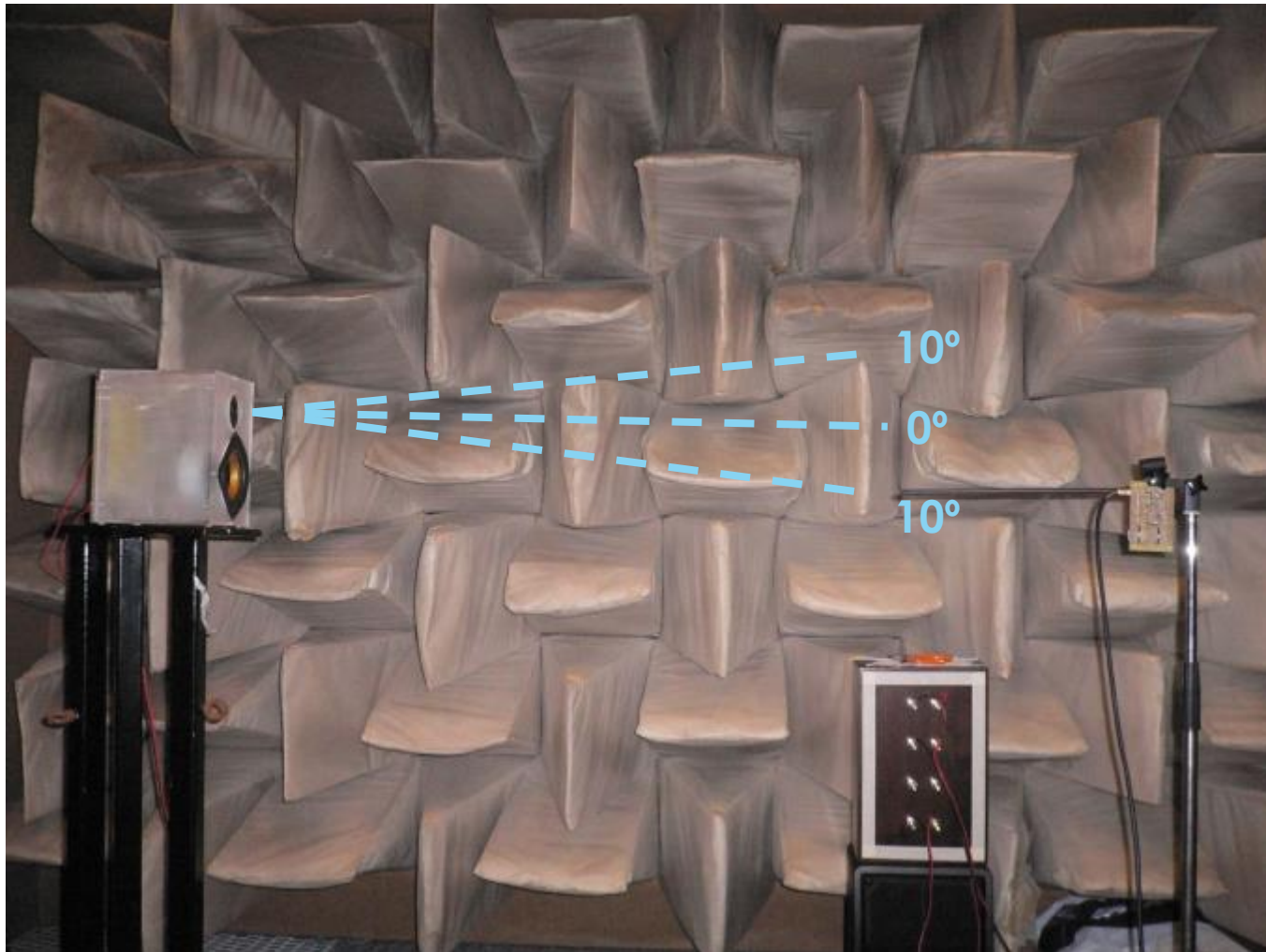


Measuring SPL for crossover tuning

- As studies have shown, listeners are not always listening on-axis with the speaker, they are on average 10° to 20° off-axis of the speaker. Therefore a spatial average of some responses in $10^\circ/15^\circ$ increments, $\pm 10^\circ$ vertically, and $\pm 30^\circ$ horizontally make up the “Listening Window” or the “Direct Sound”.
- Suggested listening window for averaging:
 - V10: H-30, H-15, 0, H15, H30
 - V0: H-30, H-15, 0, H15, H30
 - V-10: H-30, H-15, 0, H15, H30



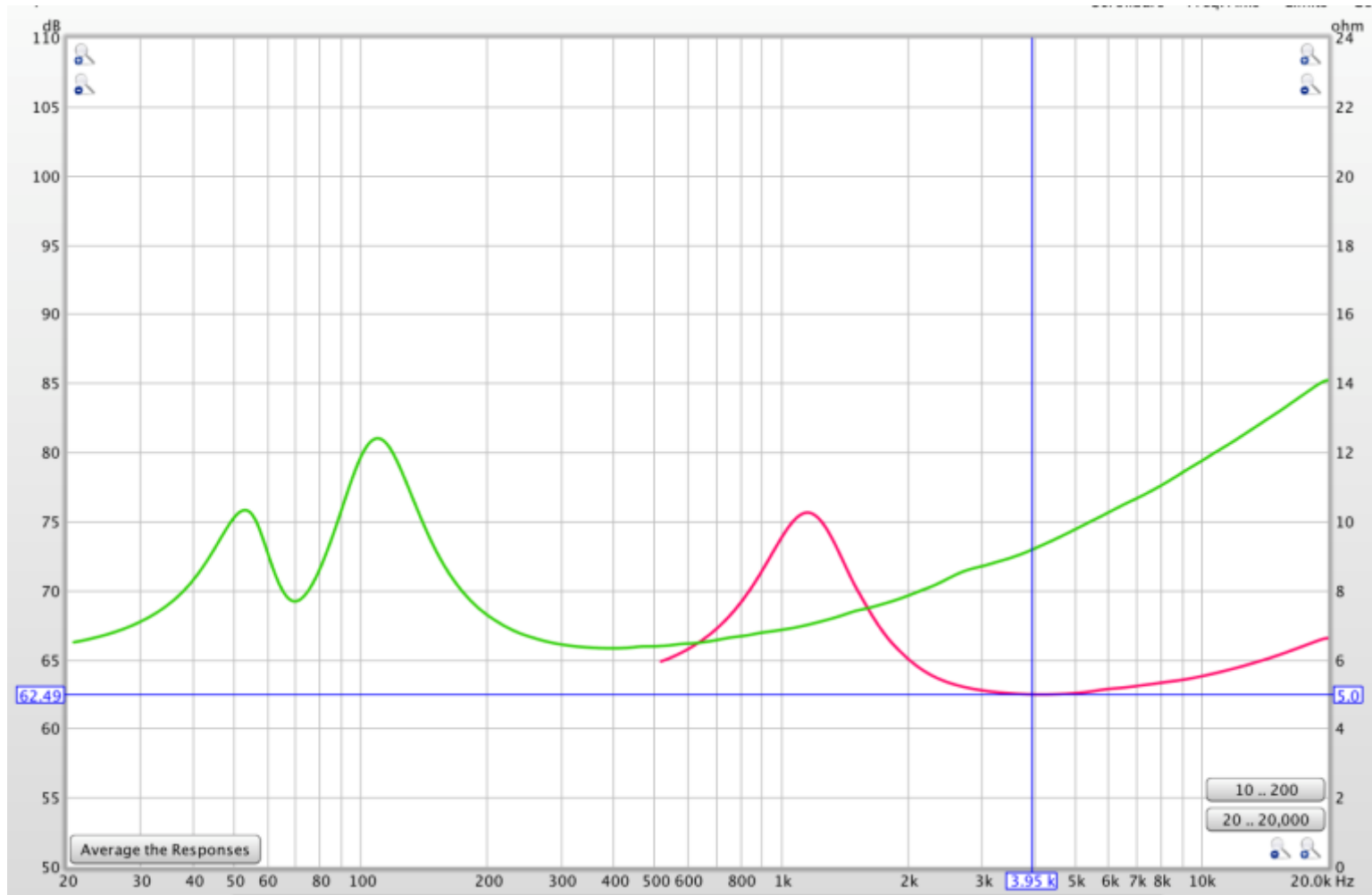
Measuring SPL



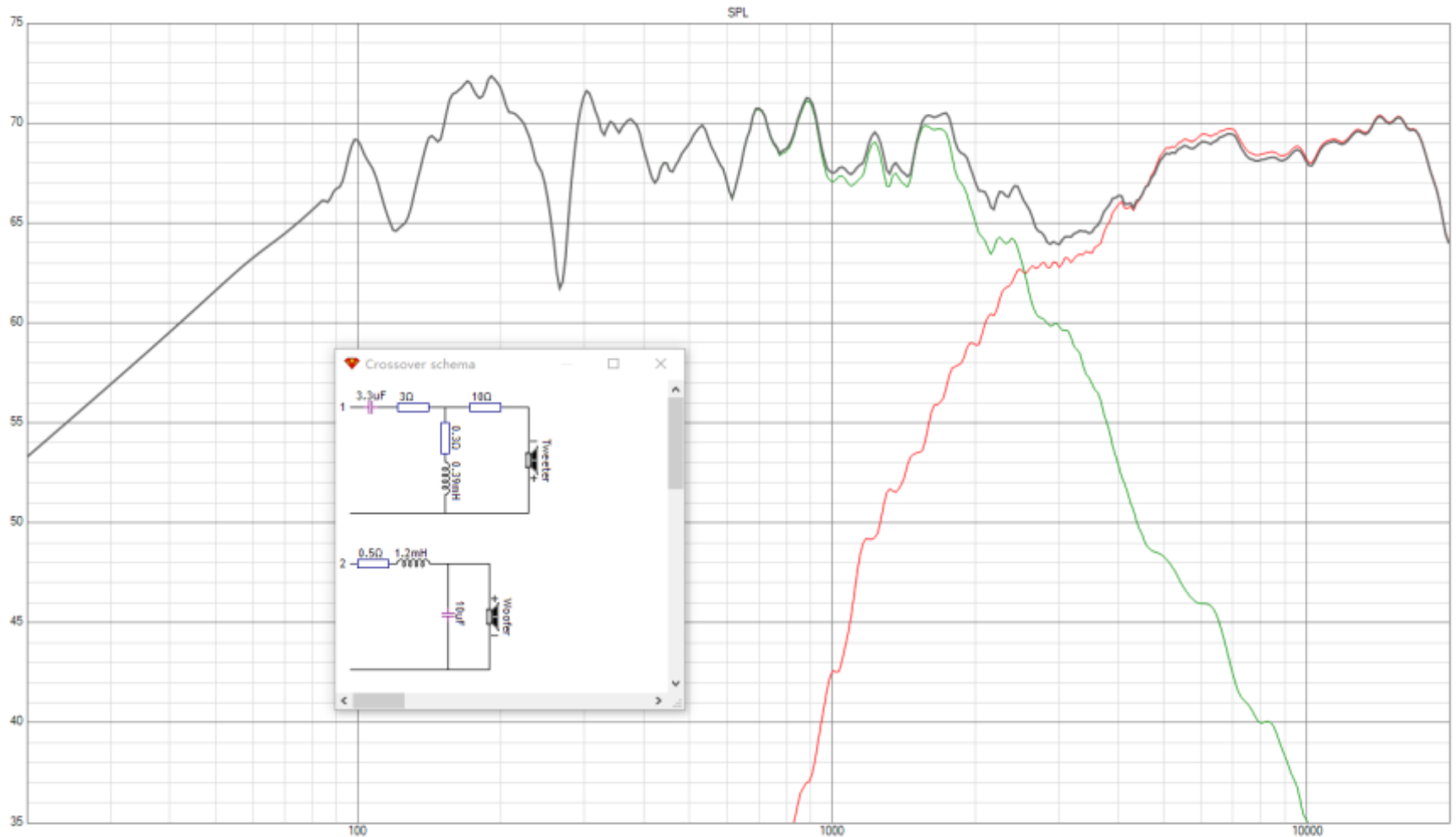
SPL measurements without crossover



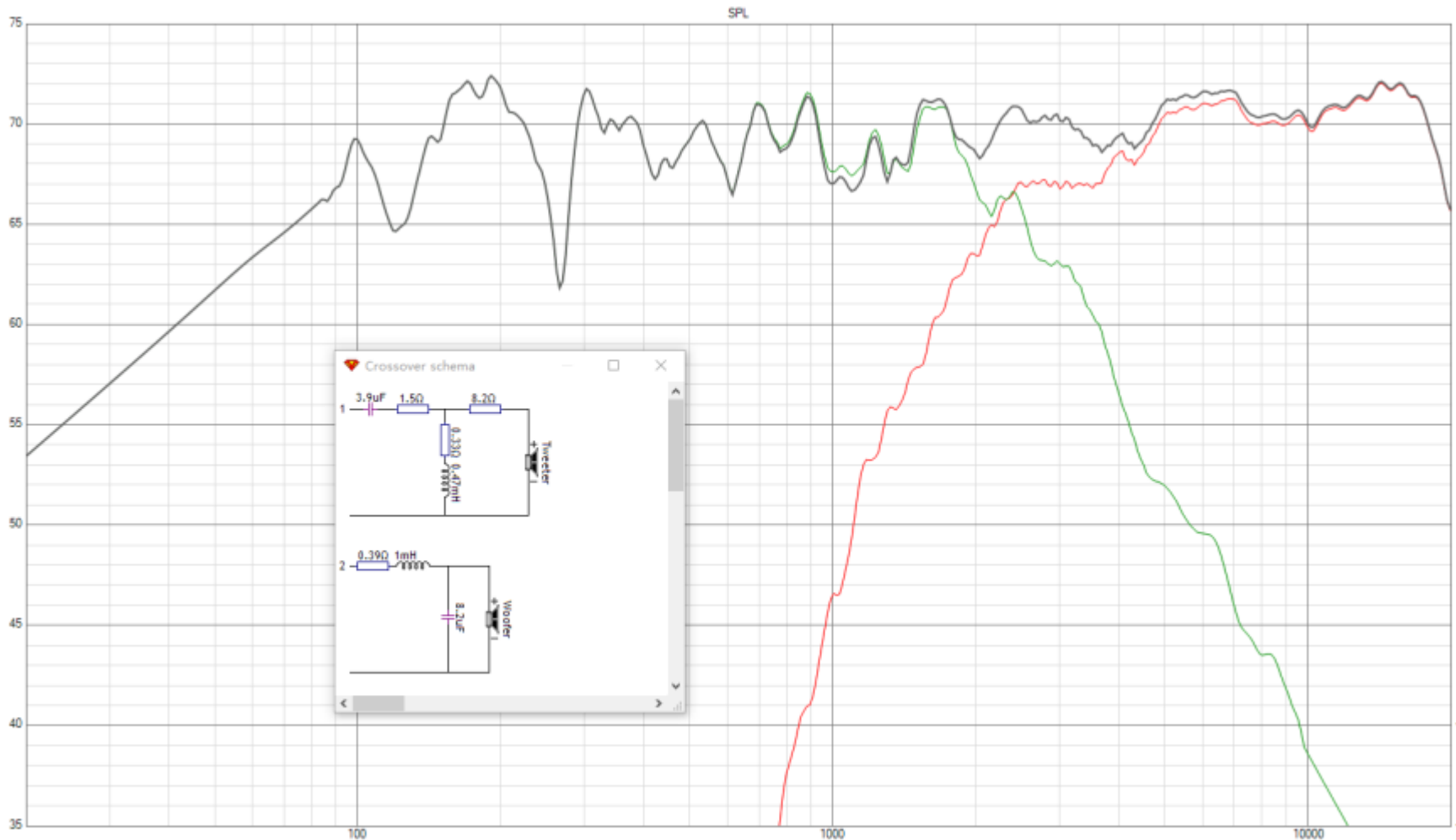
Impedance measurements without crossover



Crossover simulation, 1st Design

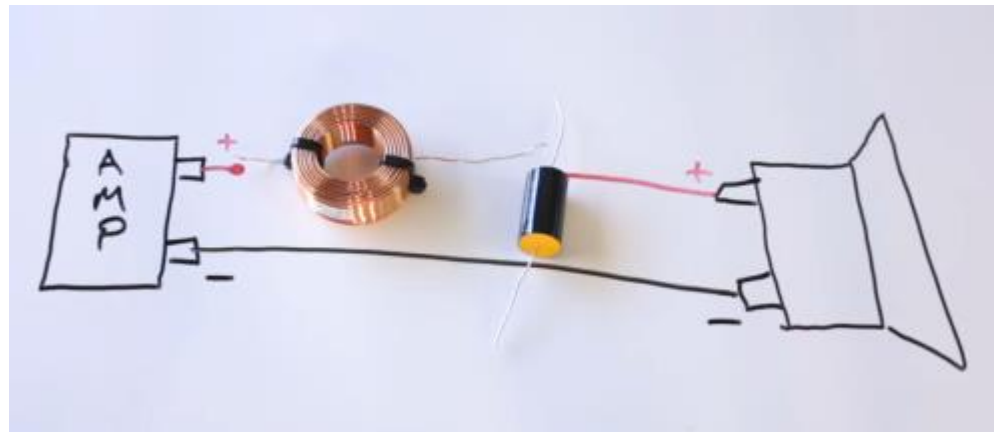


Crossover simulation, 2nd Design

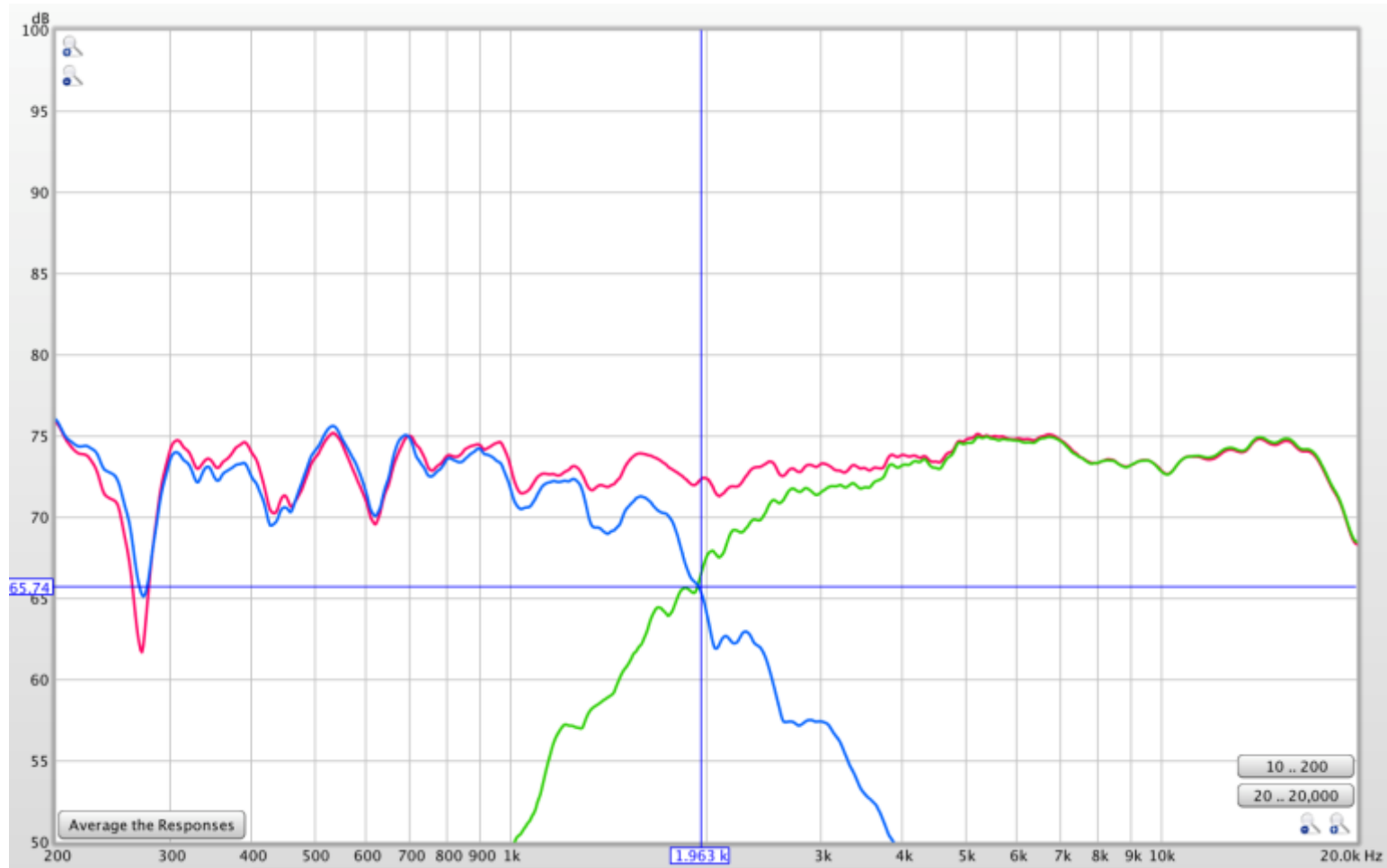


Crossover construction

- Construct the crossover and then install it.



Measure final SPL



Listening Test

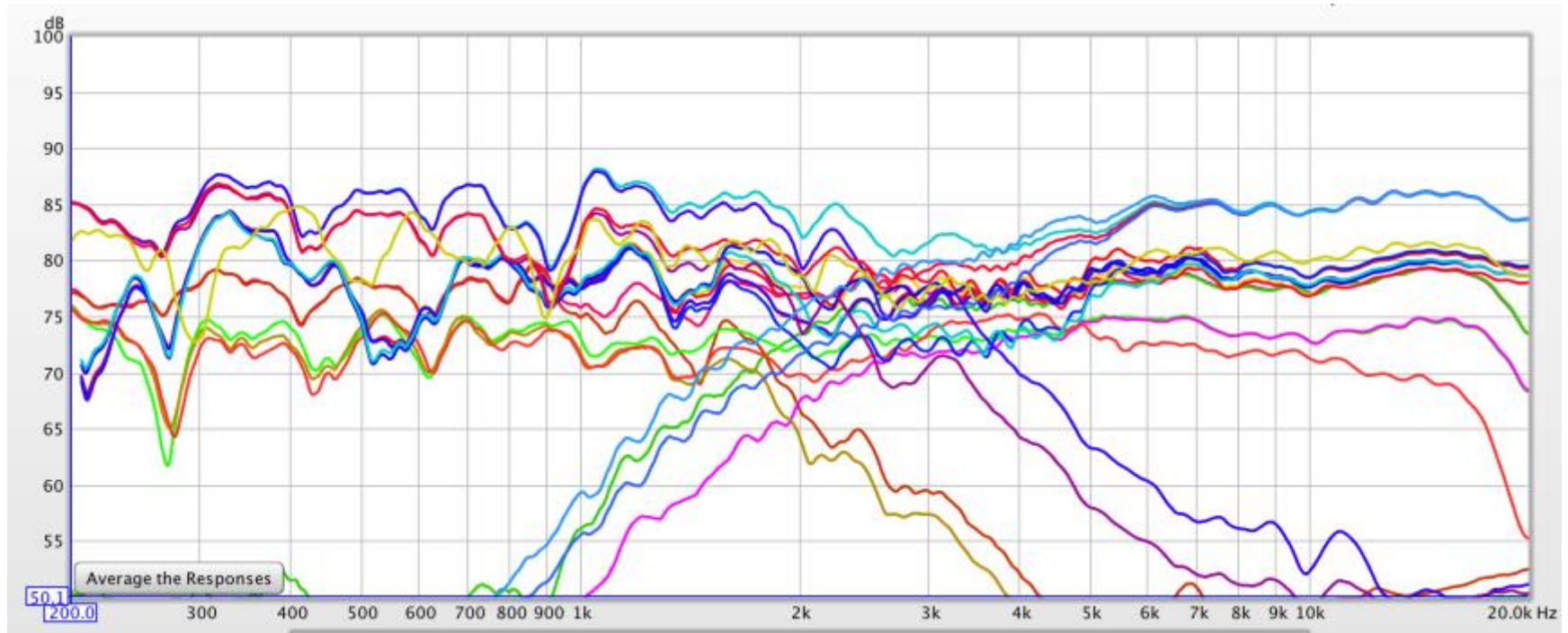


General Sound Quality



Fine tune the crossover by listening test and measurements...hundreds hours of work skipped.

After so many tuning and measurements...



It's actually much more than this...

Completed example

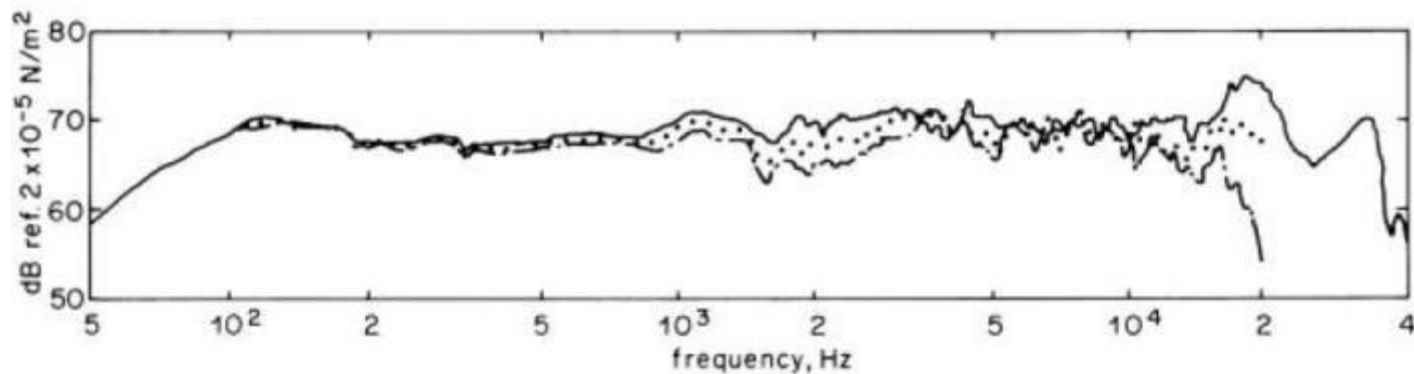
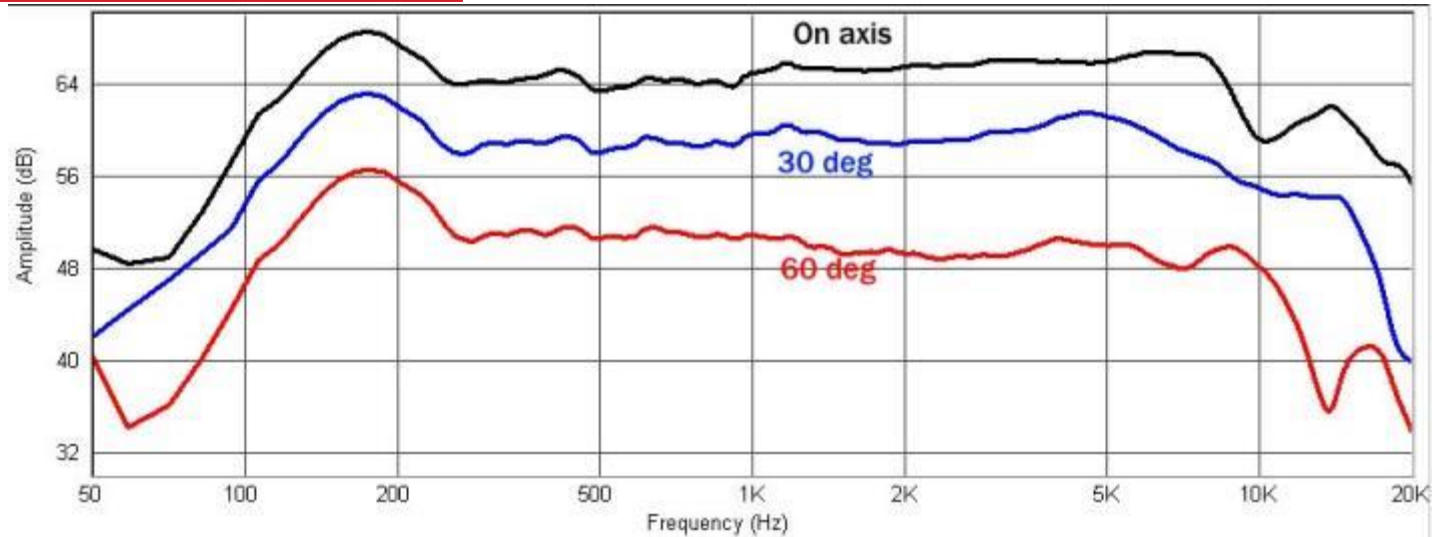


Fig. 4 - Response/frequency characteristics at 1.5 m for various angles in the horizontal plane. 1V input.

———— 0° 30° - - - - - 45°



Crossover design live demo

Suggested components

- Peerless 5.25寸中低音喇叭
 - <https://item.taobao.com/item.htm?spm=a1z10.5-c-s.w4002-14974603413.22.41a514fdKaGJC9&id=553186797103>
- Peerless 1英寸高音喇叭
 - <https://item.taobao.com/item.htm?spm=a1z10.5-c-s.w4002-14974603413.28.27ee146c6SCNqv&id=13490255397>
- USB mic for SPL measurement
 - <https://www.minidsp.com/products/acoustic-measurement/umik-1>
- WinISD for Box Design
 - <http://www.linearteam.org/>
- REW for measurements
 - <https://www.roomeqwizard.com/>
- Crossover simulation
 - <https://kimmosaunisto.net/Software/Software.html>
- Impedance analyzer
 - See REW user manual

References

1. Loudspeaker Design Brief Instruction_V0_2017-03-10, Rihanna Xu
2. Undergraduate FYP report 2006, Alvis Chan.
3. https://en.wikipedia.org/wiki/Audio_crossover
4. "Introduction to loudspeaker system", Alvis Chan

QR code

