A room-corrected Ambisonic listening rig made with free software

A fun usecase for Linux as a versatile and reliable tool for electro-acoustic hobbyists and professionals.

With a brief glimpse into Ambisonics in case you always wondered what it might be about.
(But the methods described here also work for stereo or any other surround system.)

And most of the discussed software runs on Mac OS X, too.

About me

Jörn Nettingsmeier, aged 33,

freelance audio engineer and IT admin,
classically trained musician,
qualified event technician,

been hanging out with the Linux audio crowd
since 1998.

About your next 20 mins:

My assumptions are:

- You are interested in **Linux** and/or in setting up an Ambisonic surround rig at home.
- You have between 4 and 24 speakers and sound I/O hardware available.
- Your speakers and room are **not perfect**.
- You are willing and able to afford software licensing costs of 0.00€ **and**
- You are interested in **doing stuff yourself**.

Why Ambisonics?

Free software is only fun with **free codecs**, **free algorithms** and **free exchange of information**.

All major Ambisonic patents have now expired, and there is a huge academic and hobbyist **community** of enthusiasts, plus a rich supply of freely available **code** and **documentation**.

And: ***it sounds good and scales well***.

Why Linux?

Thanks to the **JACK** sound server, Linux has very flexible **inter-application routing**.

You can **mix and match** different specialised applications.

This makes Linux/JACK an ideal platform for experimental *and* production use with non-standard requirements and workflows.

And: **it's free as in „speech“ *and* „beer“**.

Step 1a: arrange your speakers

For best spatial reproduction, choose a regular polygon or polyhedron.

(Yes, you can do 3D!)

Try to get the angles right. Distance errors can be corrected with delay.

Step 1b: measure angle and distance

For each speaker, measure its actual angle (front is 0°, turn is counter-clockwise) and distance from sweet spot.

laser range finder
laser angle gauge

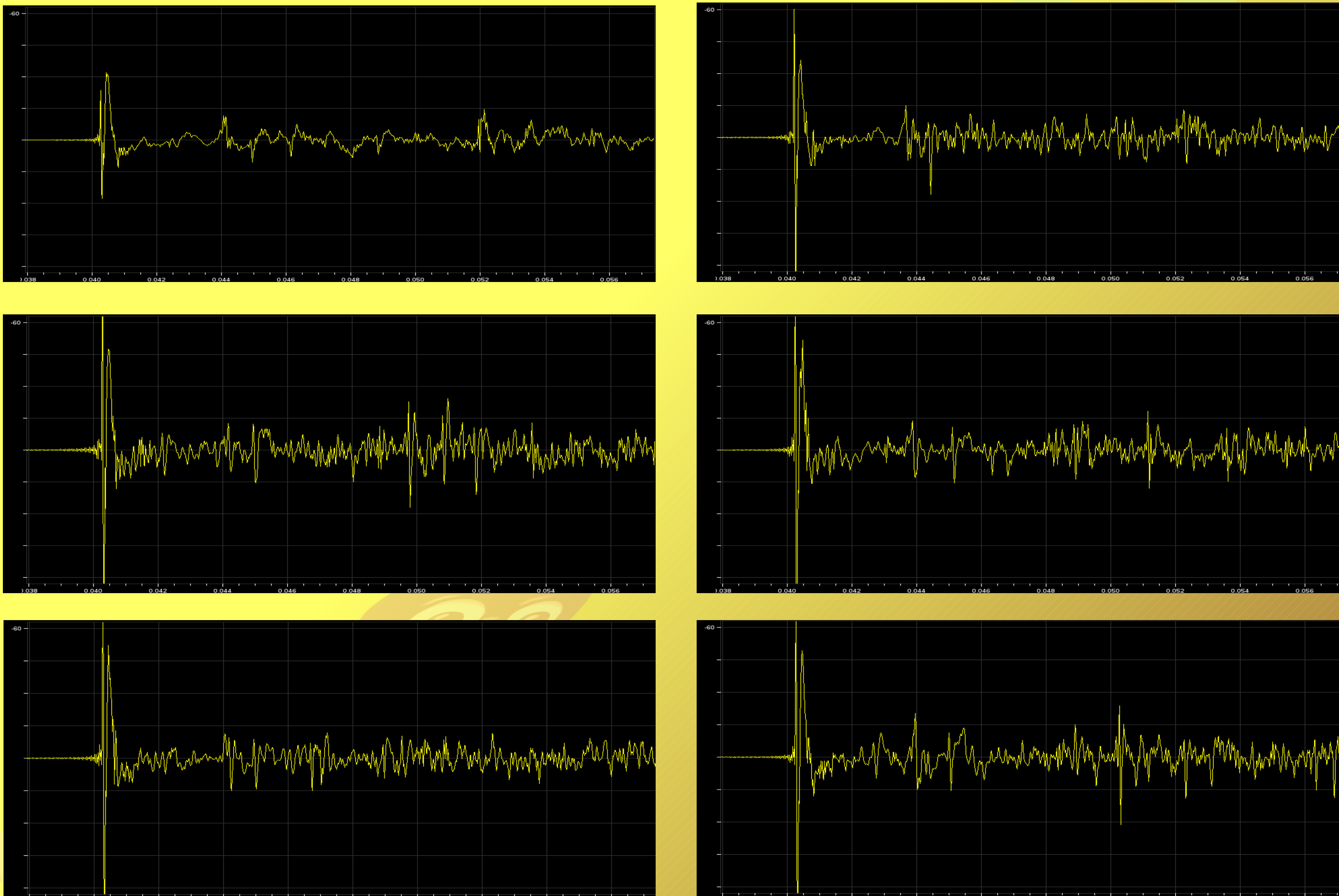
Step 2: Get speaker IRs

For each speaker, measure its impulse response at the listening position (which will include room effects).

For best S/N ratio, use the swept-sine technique (Farina 2000).

Aliki
a flat omni mike

Speaker IRs after deconvolution:



Step 3: „invert“ your IRs

To get a correction filter, answer this simple question:

„Which FIR kernel will yield a perfect pulse when convolved with the actual speaker/room IR?“

Ok, jokes aside, computer to the rescue (and of course getting a usable, stable filter is a lot harder in practice).

drc

Step 3: „invert“ your IRs

drc is a room correction package with excellent documentation:

http://drc-fir.sourceforge.net

Use version 2.7.0
(3.0.0 has some unresolved numerical instabilities and chokes on some IRs, like mine...)

Step 3: „invert“ your IRs

Begin with a mild correction setting (such as the ERB example configuration) for a large sweet spot.

Define your desired frequency response as a set of spline points in a text file.

If your speakers are port-loaded: don't push them below the port frequency!

```
0 -40.0
35 -40.0
40 0.00
50 0.00
100 0.00
150 0.00
19900 -3.95
20000 -4.00
20500 -4.00
22050 -40.0
```

Step 3: „invert“ your IRs

Oh, I forgot: For those new to the UNIX way of doing things, drc is a **command line tool**.

Step 3: „invert“ your IRs

```
$ for i in speaker_ir-*.pcm ; do drc --BCInFile $i -PSOutFile
  filter-$i erb-48.0.drc ; done

DRC 2.7.0: Digital Room Correction
Copyright (C) 2002-2008 Denis Sbragion

Input configuration file: erb-48.0.drc
Parsing configuration file...
<...>

$ for i in filter-speaker_ir-*; do sox -f -4 -r48000 -c1 -t raw  $i
  $i.wav; done
```

Invoke drc with the ERB configuration file (included), specify the input IR and the output file name for the filter kernels.

Step 3: „invert“ your IRs

```
$ for i in speaker_ir-*.pcm ; do drc --BCInFile $i -PSOutFile
  filter-$i erb-48.0.drc ; done

DRC 2.7.0: Digital Room Correction
Copyright (C) 2002-2008 Denis Sbragion

Input configuration file: erb-48.0.drc
Parsing configuration file...
<...>

$ for i in filter-speaker_ir-*; do sox -f -4 -r48000 -c1 -t raw  $i
  $i.wav; done
```

Process all speaker IRs at once using a shell loop.
(Nice, isn't it?)

Step 3: „invert“ your IRs

```
$ for i in speaker_ir-*.pcm ; do drc --BCInFile $i -PSOutFile
  filter-$i erb-48.0.drc ; done

DRC 2.7.0: Digital Room Correction
Copyright (C) 2002-2008 Denis Sbragion

Input configuration file: erb-48.0.drc
Parsing configuration file...
<...>
```

Convert the raw filters to .wav files with ***sox*** (again in a loop to save typing).

```
$ for i in filter-speaker_ir-*; do sox -f -4 -r48000 -c1 -t raw  $i
  $i.wav; done
```

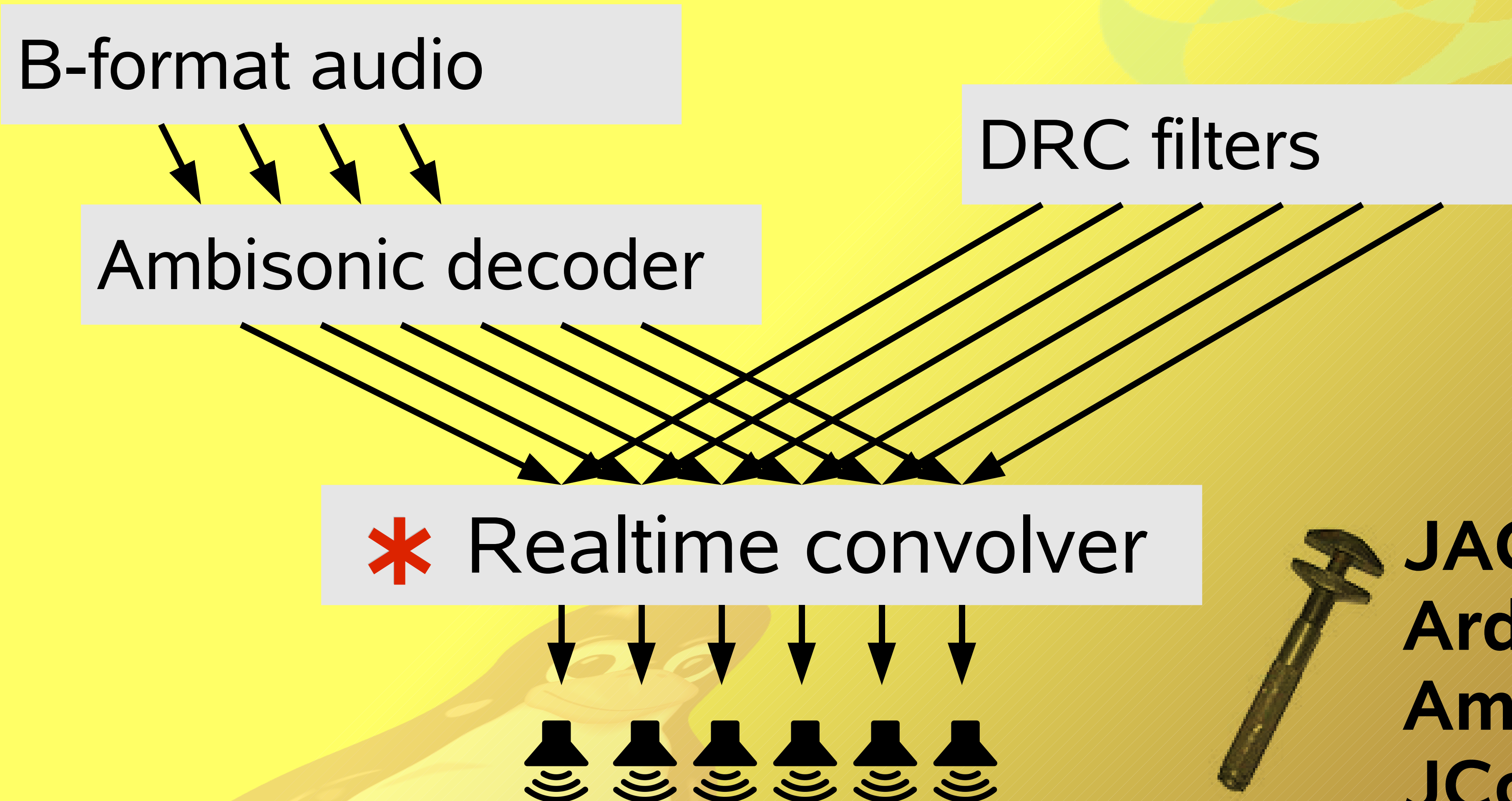
Step 3: „invert“ your IRs

```
$ for i in speaker_ir-*.pcm ; do drc --BCInFile $i -PSOutFile
  filter-$i erb-48.0.drc ; done

DRC 2.7.0: Digital Room Correction
Copyright (C) 2002-2008 Denis Sbragion

Input configuration file: erb-48.0.drc
Parsing configuration file...
<...>

$ for i in filter-speaker_ir-*; do sox -f -4 -r48000 -c1 -t raw  $i
  $i.wav; done
```

Scared? Well, you can always...

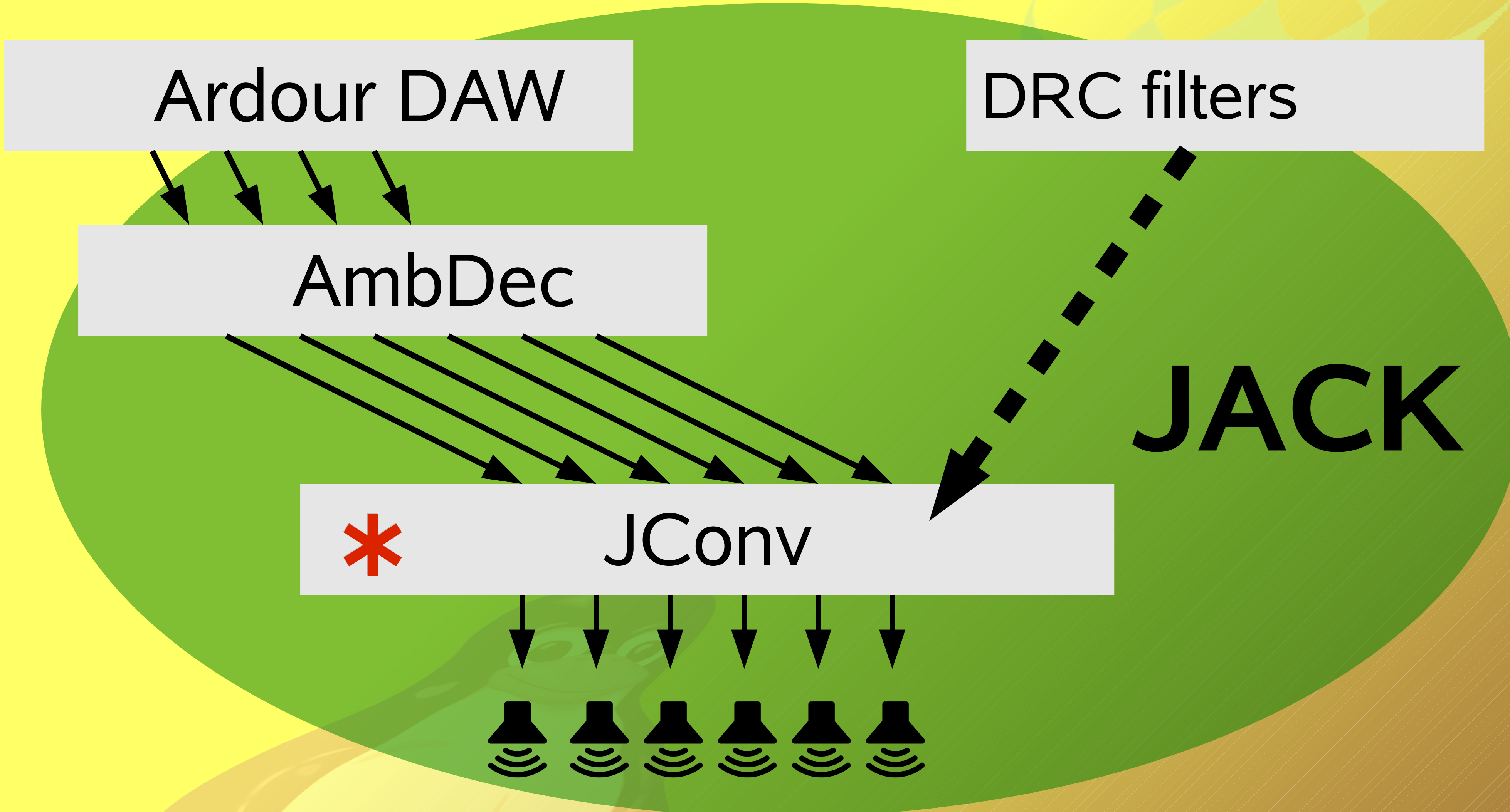

...rent a nerd!
Write to linux-audio-user@lists.linuxaudio.org!

Step 4: Signal flow & software setup

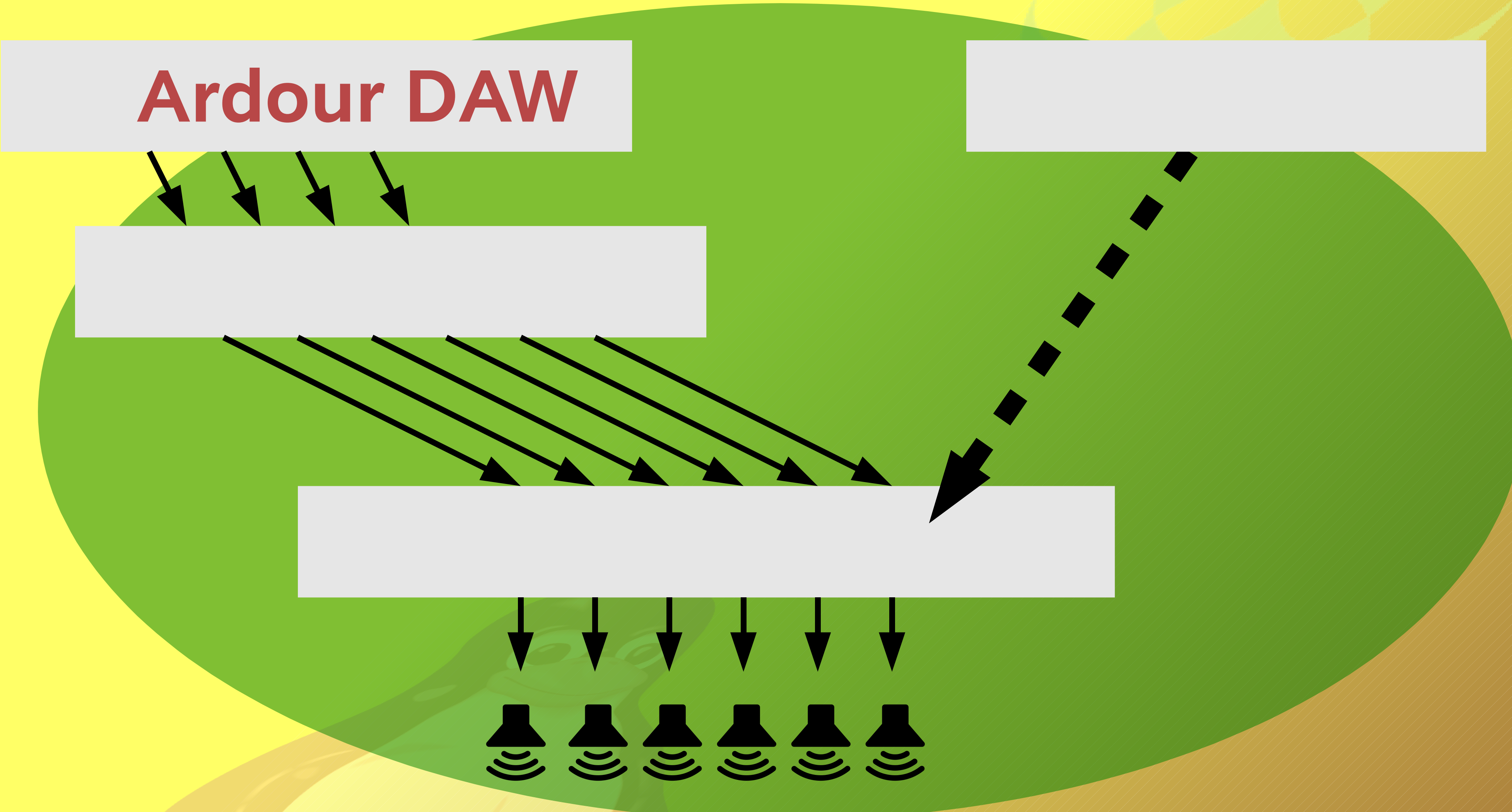


JACK
Ardour
AmbDec
JConv

Step 4: Signal flow & software setup

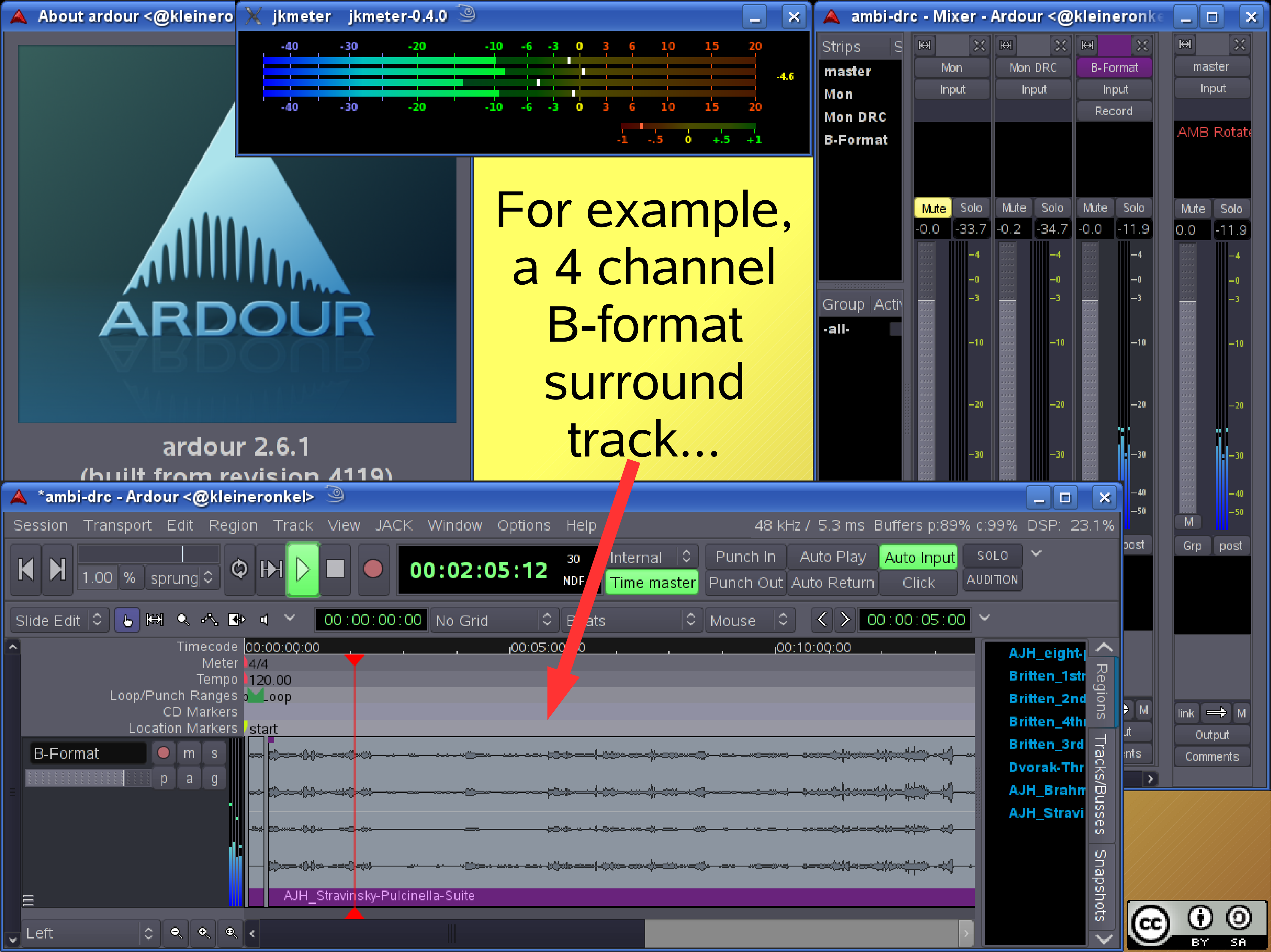


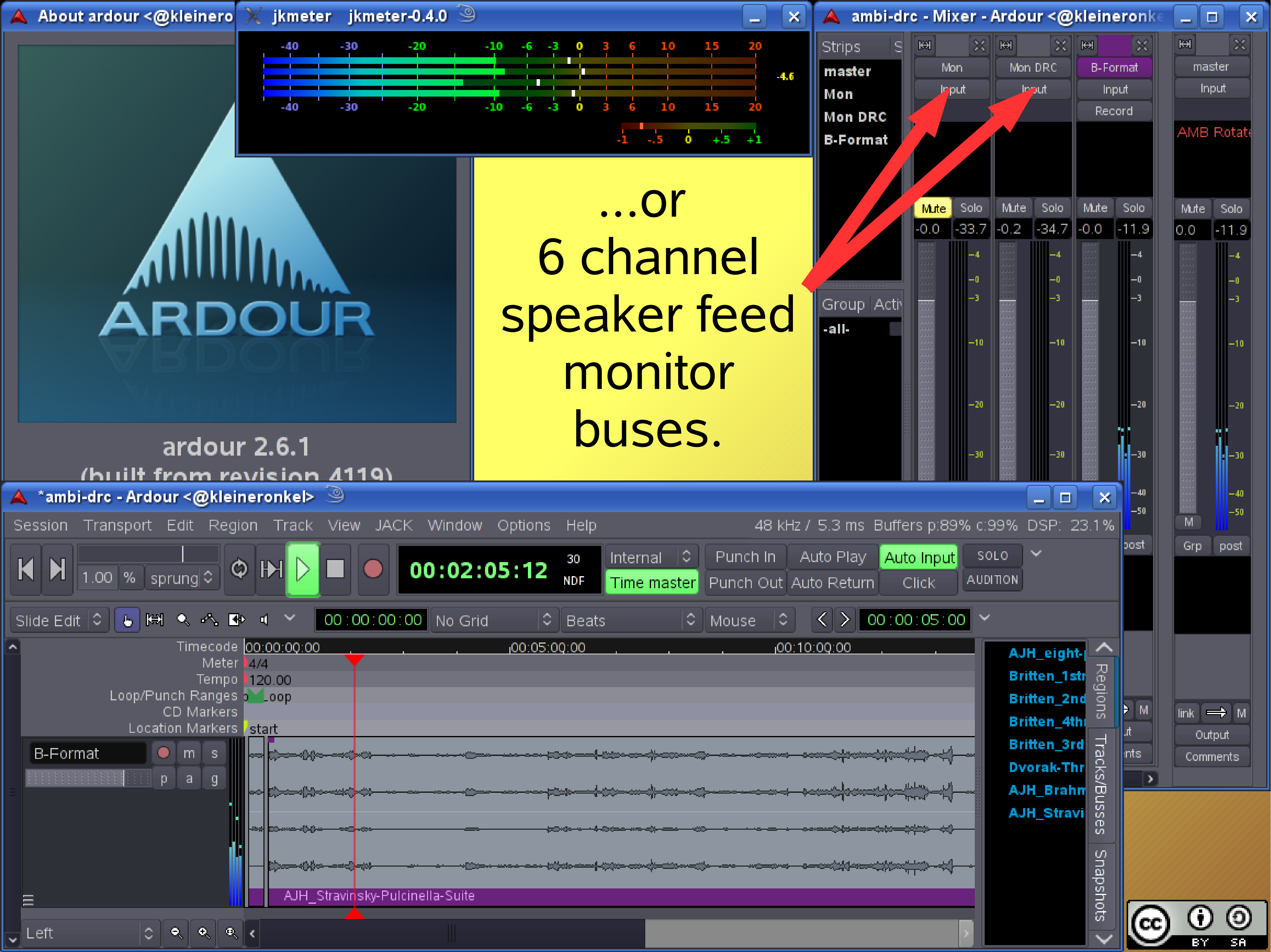
Step 4: Signal flow & software setup



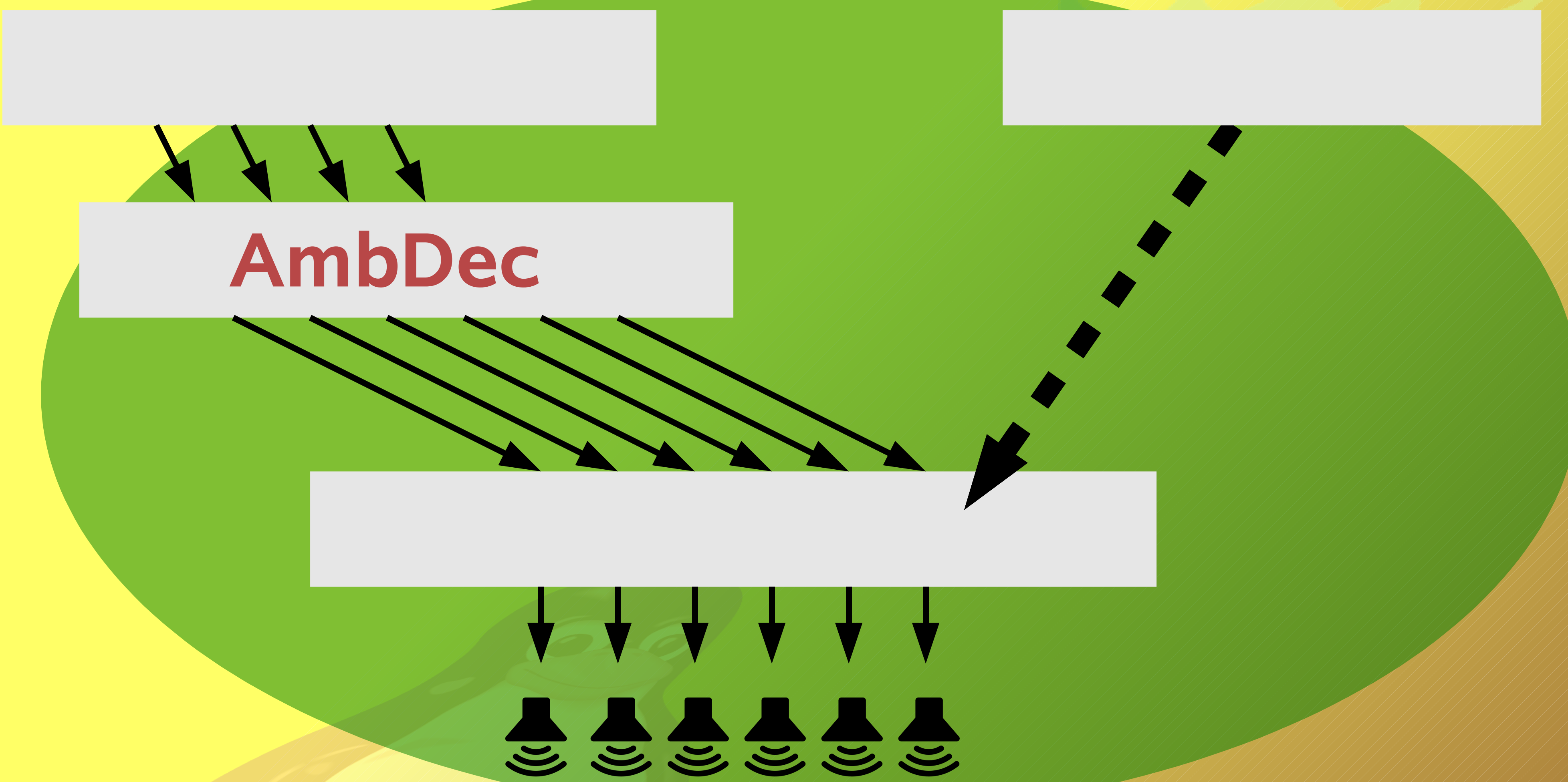

About ardour <@kleinero
jkmeter jkmeter-0.4.0
ambi-drc - Mixer - Ardour <@kleineronke
ARDOUR
ardour 2.6.1
(built from revision 4119)
Ardour is a complete DAW and also a very versatile mixer,
Strips
master
Mon
Mon DRC
B-Format
Group
-all-
Input
Record
AMB Rotate
Mute
Solo
*ambi-drc - Ardour <@kleineronkel>
Session Transport Edit Region Track View JACK Window Options Help
48 kHz / 5.3 ms Buffers p:89% c:99% DSP: 23.1%
00:02:05:12
Internal
Time master
Punch In
Punch Out
Auto Play
Auto Return
Auto Input
Click
SOLO
AUDITION
Slide Edit
No Grid
Beats
Mouse
Timecode
Meter
Tempo
Loop/Punch Ranges
CD Markers
Location Markers
start
Loop
B-Format
AJH_Stravinsky-Pulcinella-Suite
Regions
Tracks/Busses
Snapshots
Output
Comments

About ardour <@kleinero
jkmeter jkmeter-0.4.0
ambi-drc - Mixer - Ardour <@kleineronke
ARDOUR
ardour 2.6.1
(built from revision 4119)
with an arbitrary number of channels in tracks&buses!
Strips
master
Mon
Mon DRC
B-Format
Group
-all-
Mute
Solo
Input
Record
AMB Rotate
*ambi-drc - Ardour <@kleineronkel>
Session Transport Edit Region Track View JACK Window Options Help
48 kHz / 5.3 ms Buffers p:89% c:99% DSP: 23.1%
00:02:05:12
Internal
Time master
Punch In
Punch Out
Auto Play
Auto Return
Auto Input
Click
SOLO
AUDITION
Slide Edit
No Grid
Beats
Mouse
Timecode
Meter
Tempo
Loop/Punch Ranges
CD Markers
Location Markers
B-Format
AJH_Stravinsky-Pulcinella-Suite
Regions
Tracks/Busses
Snapshots

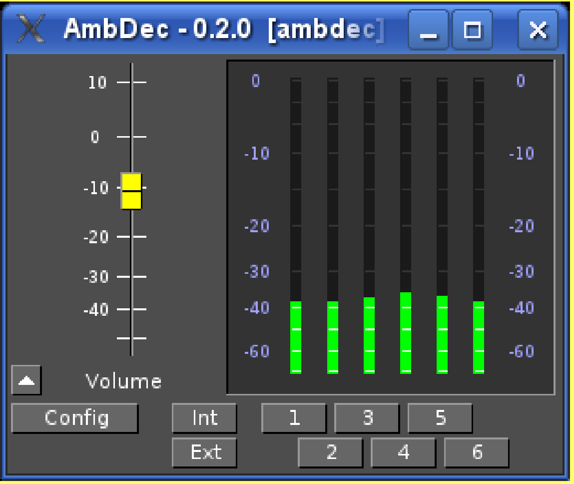

About ardour <@kleinero
jkmeter jkmeter-0.4.0
ambi-drc - Mixer - Ardour <@kleineronke
ardour 2.6.1
(built from revision 4119)
For example, a 4 channel B-format surround track...
Strips
master
Mon
Mon DRC
B-Format
Group
-all-
Mon
Mon DRC
B-Format
master
Input
Record
AMB Rotate
Mute
Solo
*ambi-drc - Ardour <@kleineronkel>
Session Transport Edit Region Track View JACK Window Options Help
48 kHz / 5.3 ms Buffers p:89% c:99% DSP: 23.1%
00:02:05:12
Internal
Time master
Punch In
Punch Out
Auto Play
Auto Return
Auto Input
Click
SOLO
AUDITION
Slide Edit
No Grid
Mouse
Timecode
Meter
Tempo
Loop/Punch Ranges
CD Markers
Location Markers
start
Loop
B-Format
AJH_Stravinsky-Pulcinella-Suite
Regions
Tracks/Busses
Snapshots
Left
Output
Comments
BY SA

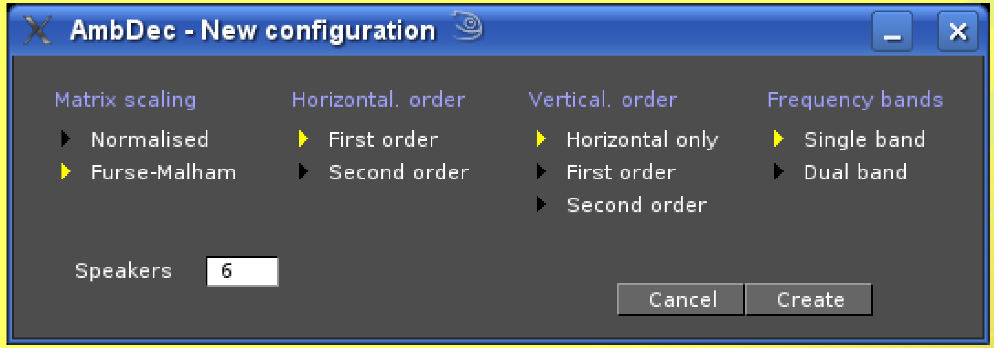

About ardour <@kleinero
jkmeter jkmeter-0.4.0
ambi-drc - Mixer - Ardour <@kleineronke
...or
6 channel
speaker feed
monitor
buses.
ardour 2.6.1
(built from revision 4119)
Strips
master
Mon
Mon DRC
B-Format
Input
Record
AMB Rotate
Mute
Solo
Group
-all-
*ambi-drc - Ardour <@kleineronkel>
Session Transport Edit Region Track View JACK Window Options Help
48 kHz / 5.3 ms Buffers p:89% c:99% DSP: 23.1%
00:02:05:12
Internal
Time master
Punch In
Punch Out
Auto Play
Auto Return
Auto Input
Click
SOLO
AUDITION
Slide Edit
No Grid
Beats
Mouse
Timecode
Meter
Tempo
Loop/Punch Ranges
CD Markers
Location Markers
B-Format
AJH_Stravinsky-Pulcinella-Suite
Regions
Tracks/Busses
Snapshots
Output
Comments

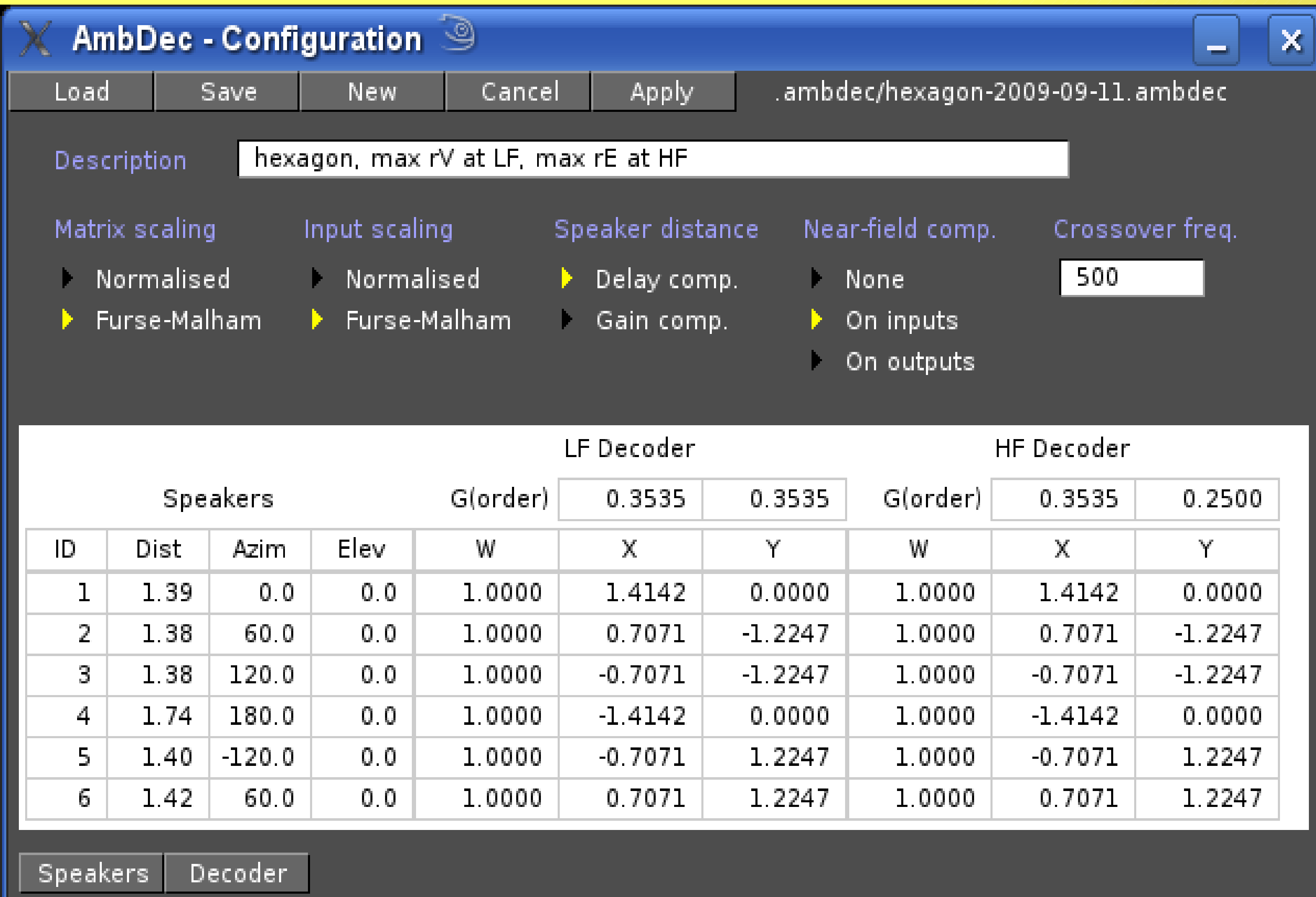
Step 4: Signal flow & software setup



AmbDec







				LF Decoder			HF Decoder		
Speakers				G(order)	0.3535	0.3535	G(order)	0.3535	0.2500
ID	Dist	Azim	Elev	W	X	Y	W	X	Y
1	1.39	0.0	0.0	1.0000	1.4142	0.0000	1.0000	1.4142	0.0000
2	1.38	60.0	0.0	1.0000	0.7071	-1.2247	1.0000	0.7071	-1.2247
3	1.38	120.0	0.0	1.0000	-0.7071	-1.2247	1.0000	-0.7071	-1.2247
4	1.74	180.0	0.0	1.0000	-1.4142	0.0000	1.0000	-1.4142	0.0000
5	1.40	-120.0	0.0	1.0000	-0.7071	1.2247	1.0000	-0.7071	1.2247
6	1.42	60.0	0.0	1.0000	0.7071	1.2247	1.0000	0.7071	1.2247

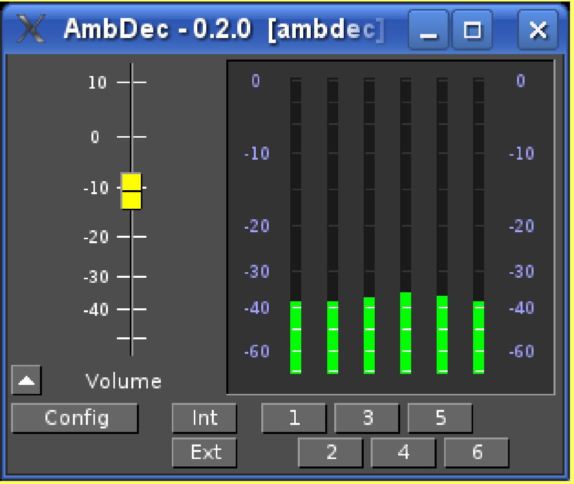
an Ambisonic decoder for 2D and 3D

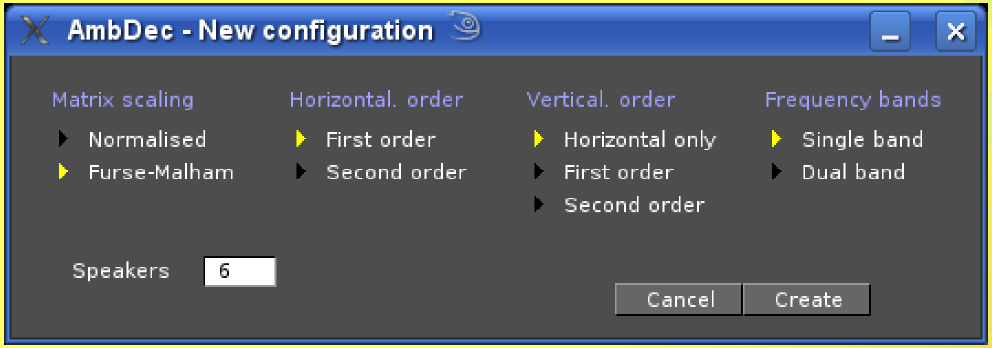
up to 24 speakers

psycho-acoustically correct dual-band operation

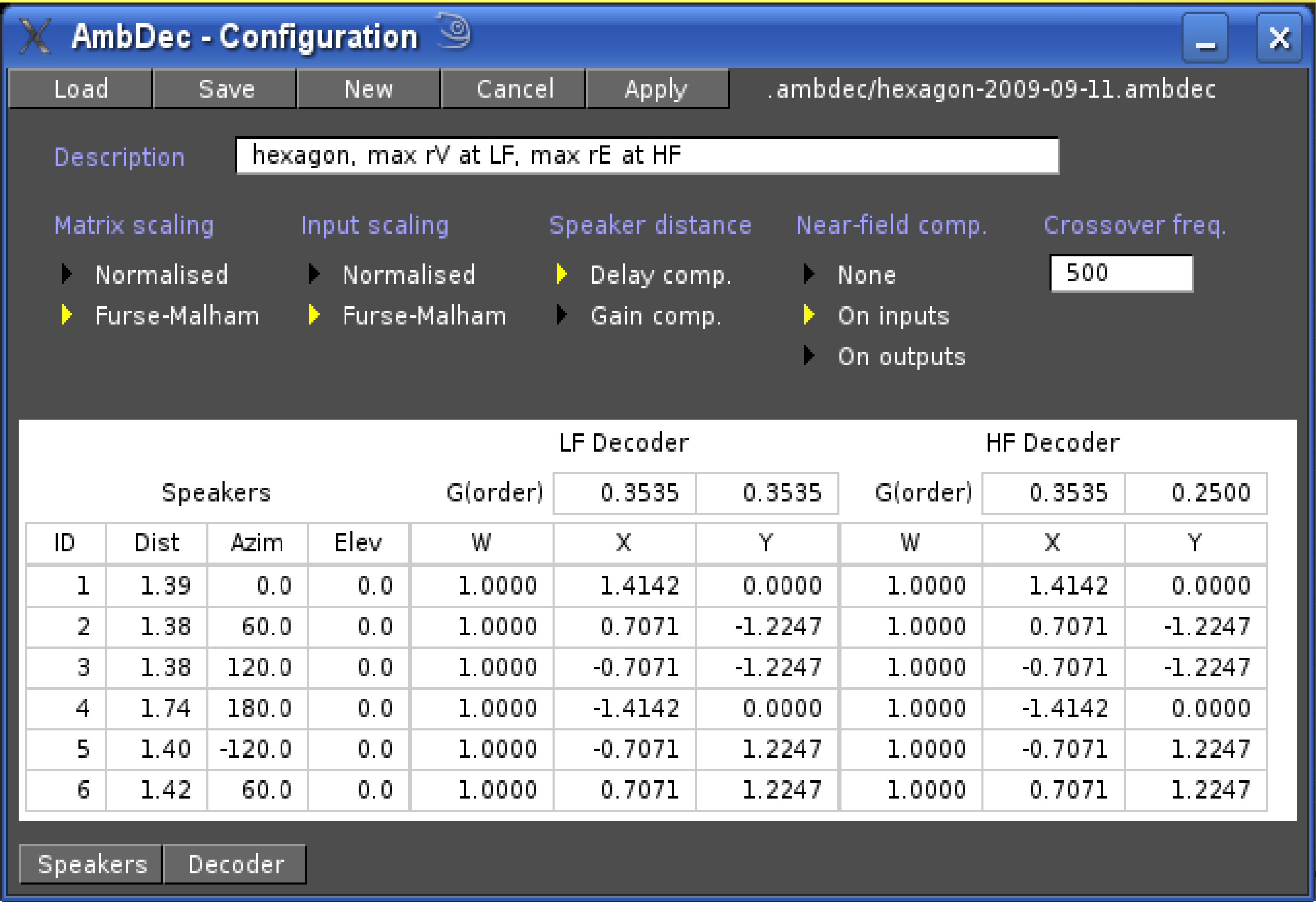
near-field compen-sation

AmbDec



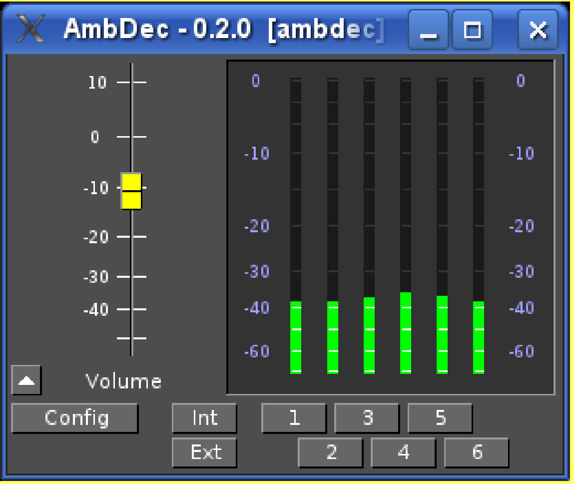


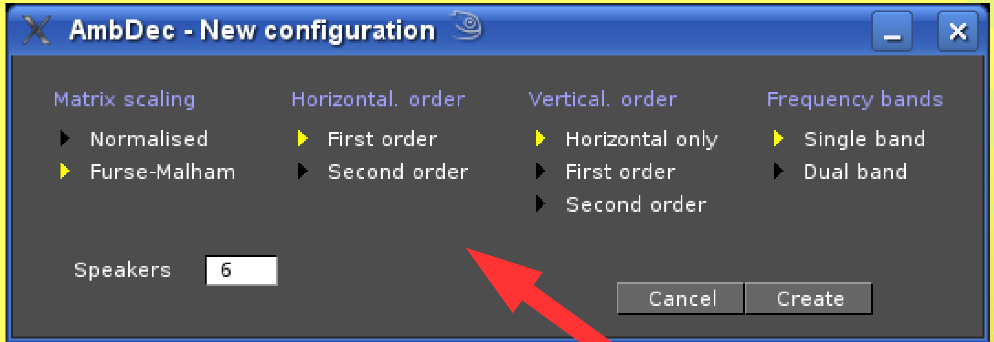
Create a configuration for your speaker rig:



Speakers				LF Decoder			HF Decoder		
			G(order)		0.3535	0.3535	G(order)	0.3535	0.2500
ID	Dist	Azim	Elev	W	X	Y	W	X	Y
1	1.39	0.0	0.0	1.0000	1.4142	0.0000	1.0000	1.4142	0.0000
2	1.38	60.0	0.0	1.0000	0.7071	-1.2247	1.0000	0.7071	-1.2247
3	1.38	120.0	0.0	1.0000	-0.7071	-1.2247	1.0000	-0.7071	-1.2247
4	1.74	180.0	0.0	1.0000	-1.4142	0.0000	1.0000	-1.4142	0.0000
5	1.40	-120.0	0.0	1.0000	-0.7071	1.2247	1.0000	-0.7071	1.2247
6	1.42	60.0	0.0	1.0000	0.7071	1.2247	1.0000	0.7071	1.2247

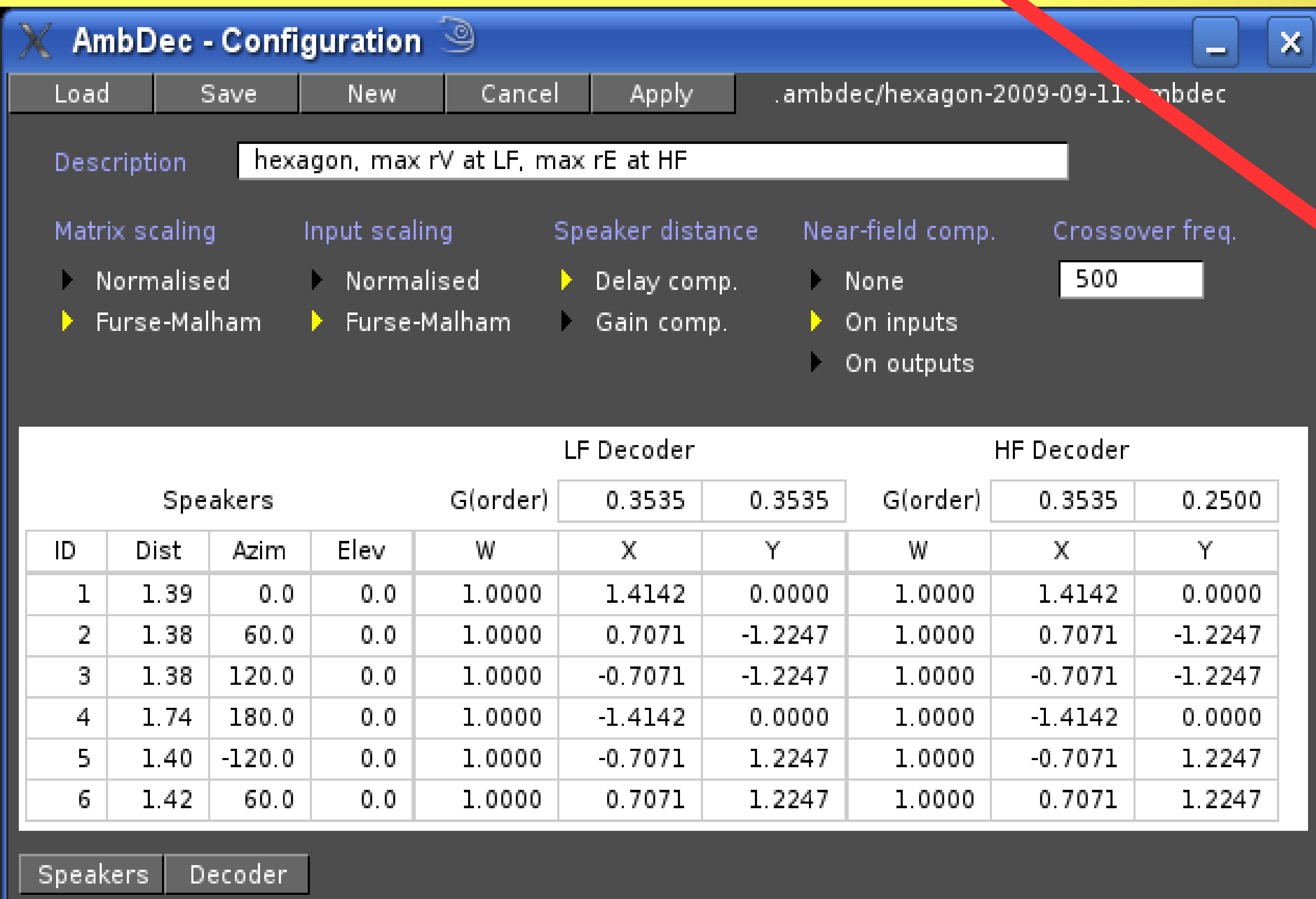
AmbDec





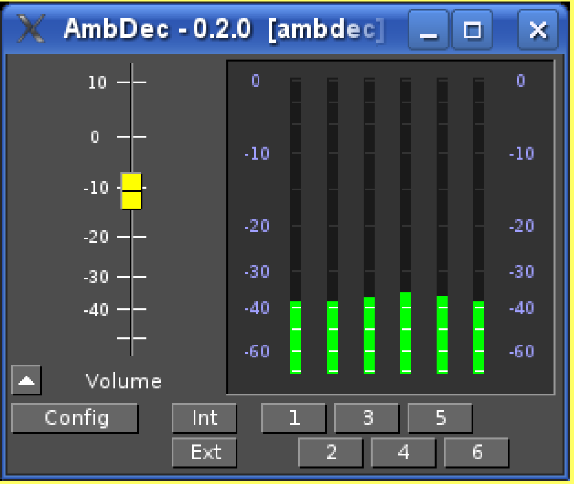
Create a configuration for your speaker rig:

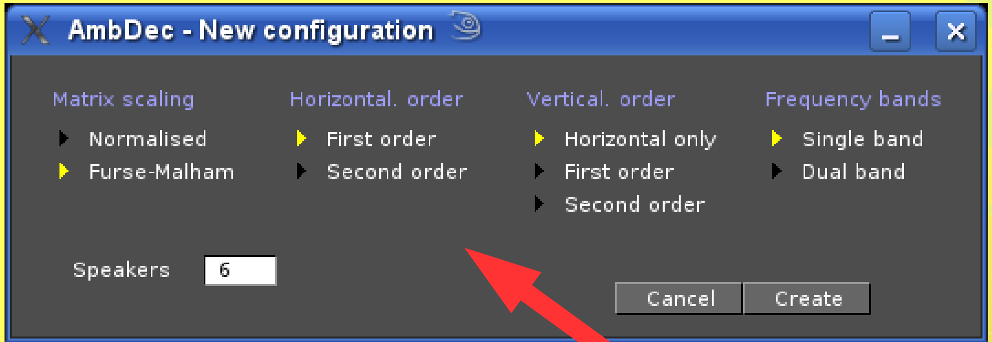
Basic settings (order, number of speakers)



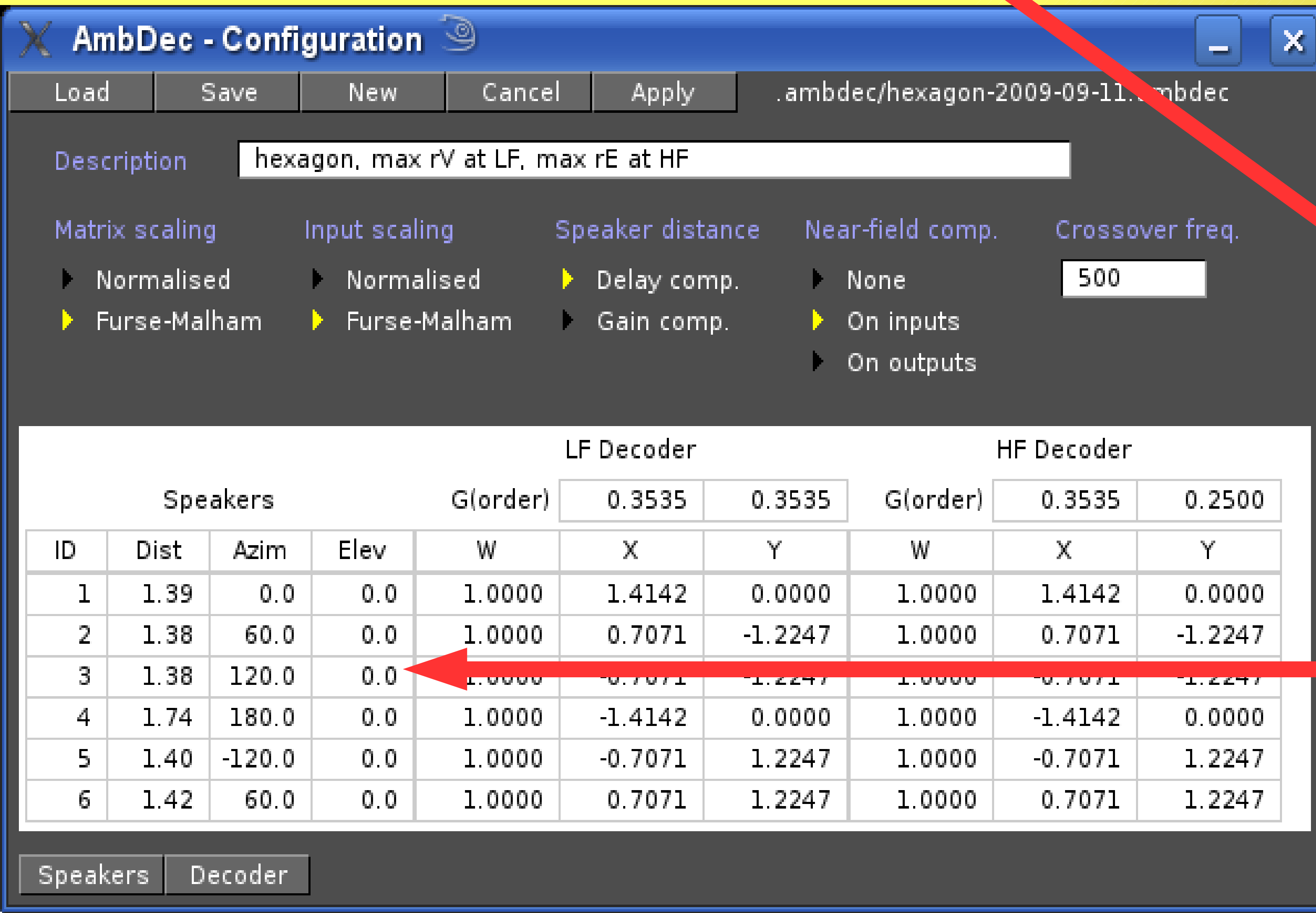
				LF Decoder			HF Decoder		
Speakers				G(order)	0.3535	0.3535	G(order)	0.3535	0.2500
ID	Dist	Azim	Elev	W	X	Y	W	X	Y
1	1.39	0.0	0.0	1.0000	1.4142	0.0000	1.0000	1.4142	0.0000
2	1.38	60.0	0.0	1.0000	0.7071	-1.2247	1.0000	0.7071	-1.2247
3	1.38	120.0	0.0	1.0000	-0.7071	-1.2247	1.0000	-0.7071	-1.2247
4	1.74	180.0	0.0	1.0000	-1.4142	0.0000	1.0000	-1.4142	0.0000
5	1.40	-120.0	0.0	1.0000	-0.7071	1.2247	1.0000	-0.7071	1.2247
6	1.42	60.0	0.0	1.0000	0.7071	1.2247	1.0000	0.7071	1.2247

AmbDec





Create a configuration for your speaker rig:

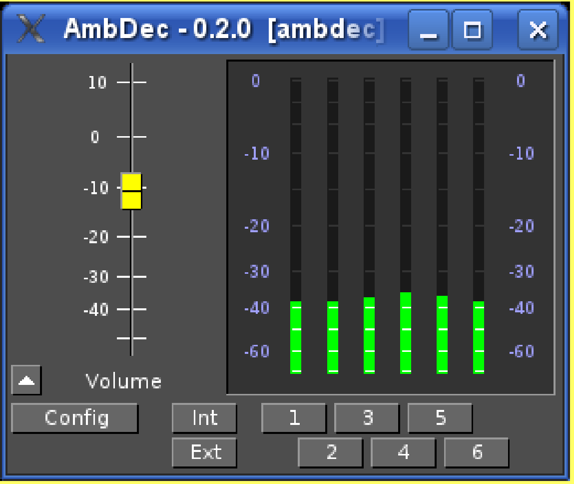


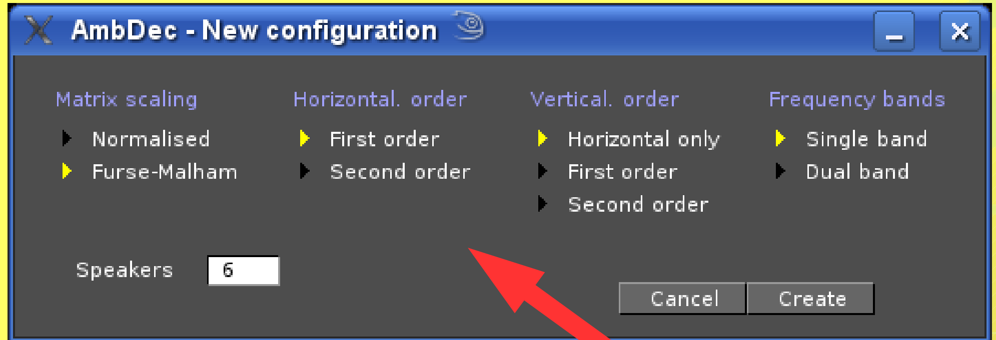
				LF Decoder			HF Decoder		
Speakers				G(order) 0.3535	0.3535		G(order) 0.3535	0.2500	
ID	Dist	Azim	Elev	W	X	Y	W	X	Y
1	1.39	0.0	0.0	1.0000	1.4142	0.0000	1.0000	1.4142	0.0000
2	1.38	60.0	0.0	1.0000	0.7071	-1.2247	1.0000	0.7071	-1.2247
3	1.38	120.0	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	1.74	180.0	0.0	1.0000	-1.4142	0.0000	1.0000	-1.4142	0.0000
5	1.40	-120.0	0.0	1.0000	-0.7071	1.2247	1.0000	-0.7071	1.2247
6	1.42	60.0	0.0	1.0000	0.7071	1.2247	1.0000	0.7071	1.2247

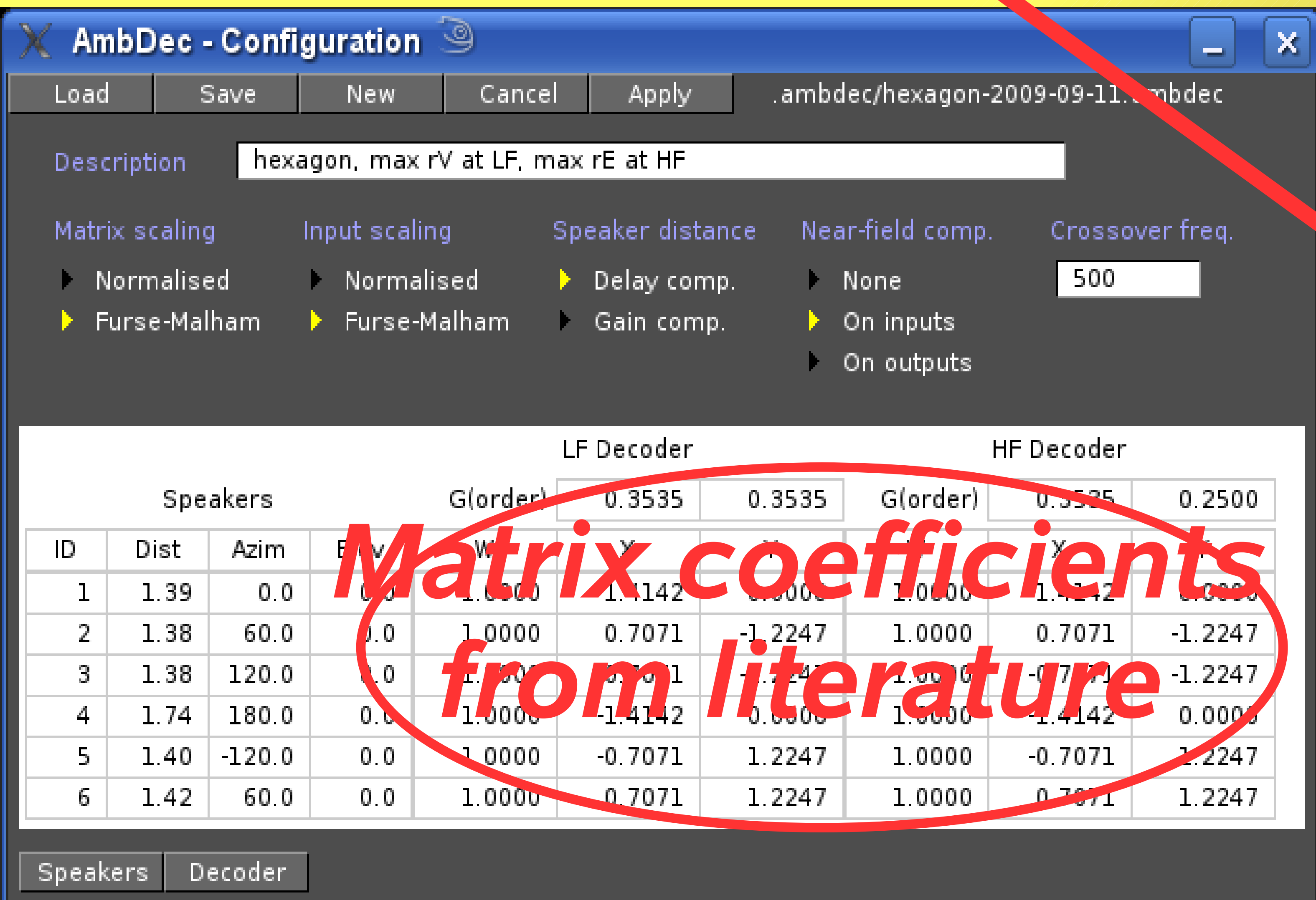
Basic settings (order, number of speakers)

Decoding Matrix (fill in your speaker positions).

AmbDec





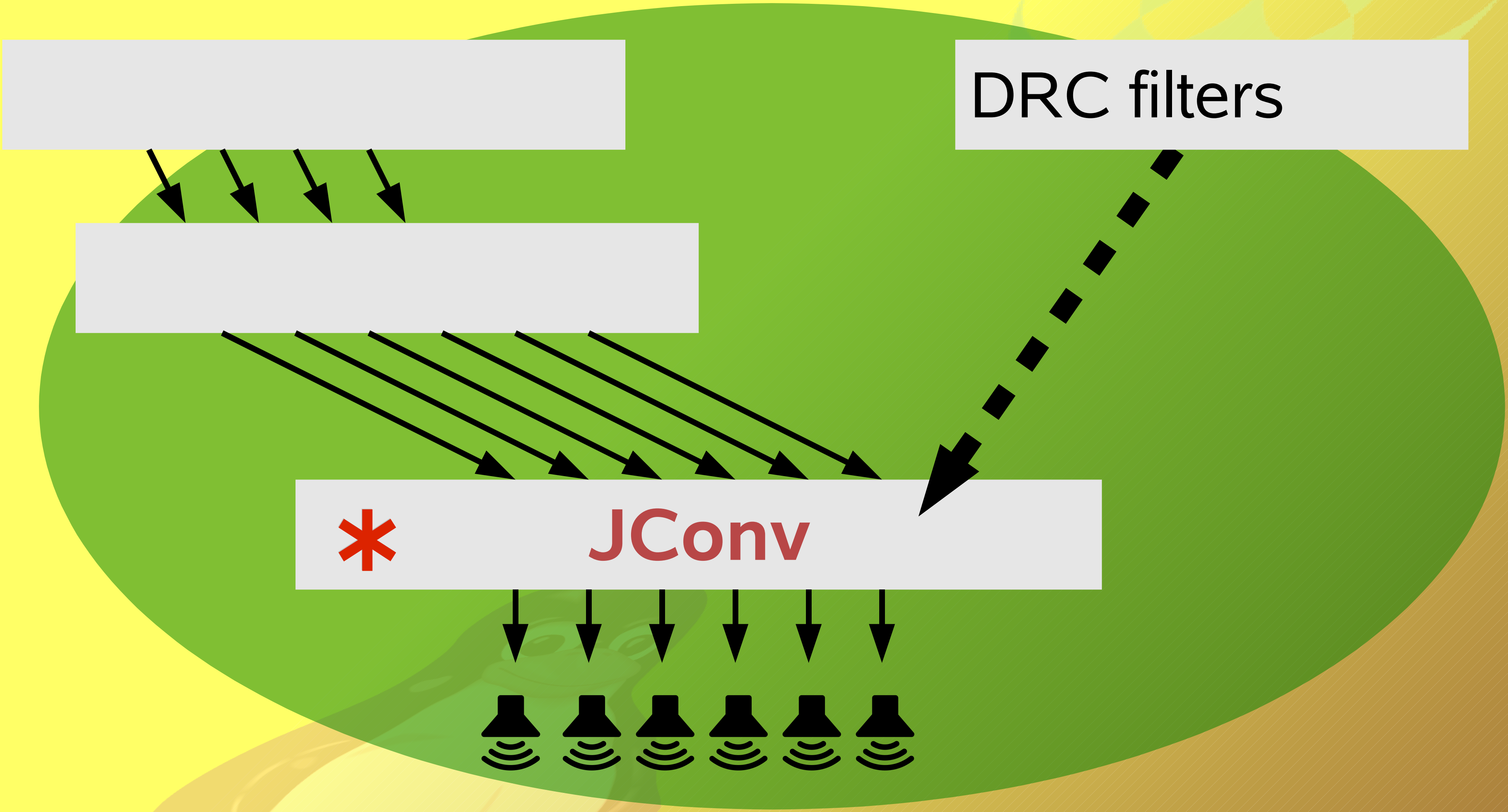


Create a configuration for your speaker rig:

Basic settings (order, number of speakers)

Decoding Matrix (fill in your speaker positions).

Step 4: Signal flow & software setup



JConv is a real-time convolution engine (and another command-line tool). :-D

It runs in the background and takes a simple configuration file:

```
/cd /home/nettings/drc-filters

#                 in   out   partition    maxsize
# -----------------------------------------------
/convolver/new     6    6         1024      256000

#
#                in out  gain  delay  offset  length  chan      file
# -------------------------------------------------------------------
/impulse/read    1    1  1       0        0       0     1  filter-speaker_ir-1.pcm.wav
/impulse/read    2    2  1       0        0       0     1  filter-speaker_ir-2.pcm.wav
/impulse/read    3    3  1       0        0       0     1  filter-speaker_ir-3.pcm.wav
/impulse/read    4    4  1       0        0       0     1  filter-speaker_ir-4.pcm.wav
/impulse/read    5    5  1       0        0       0     1  filter-speaker_ir-5.pcm.wav
/impulse/read    6    6  1       0        0       0     1  filter-speaker_ir-6.pcm.wav
```

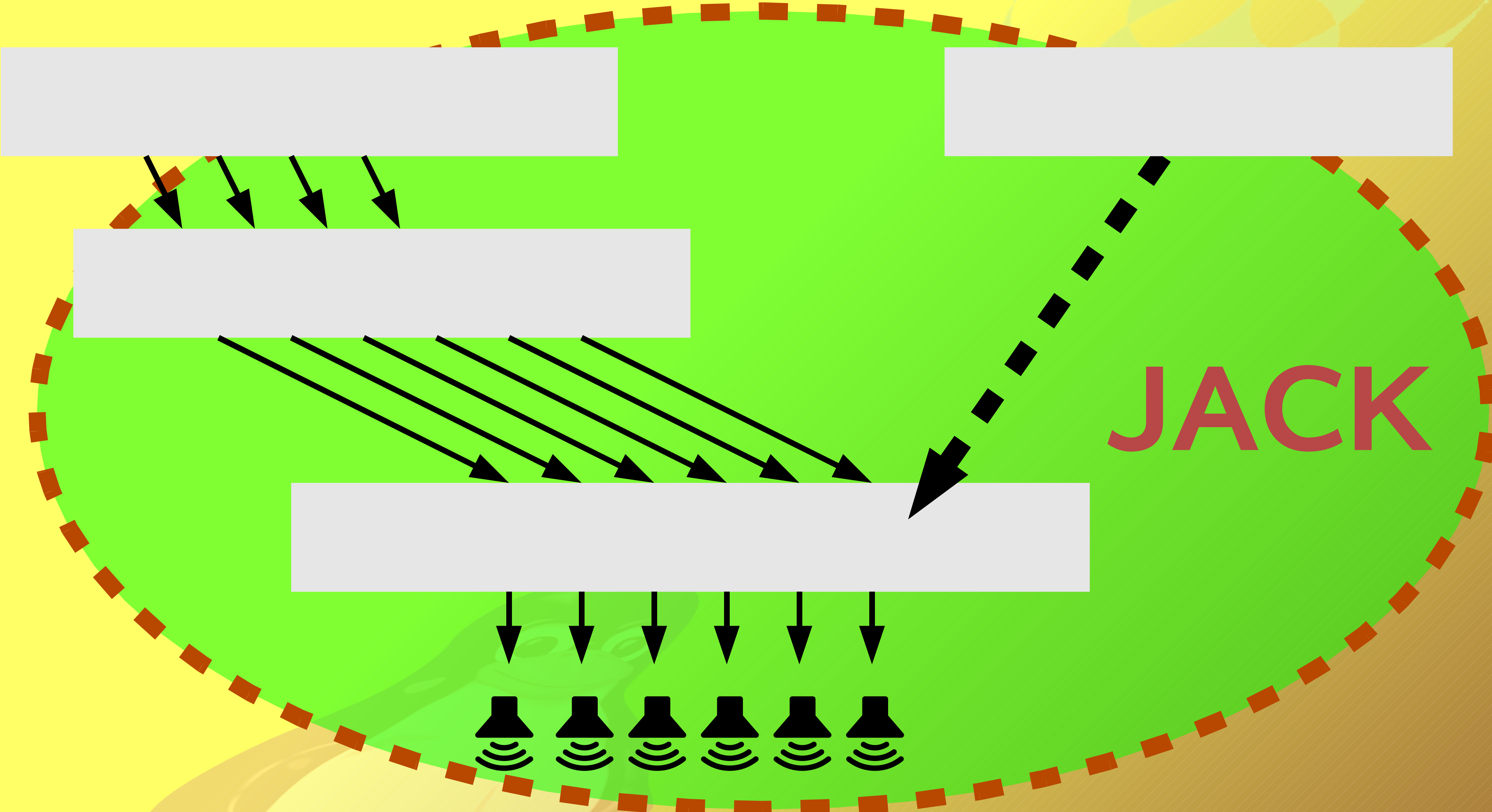
JConv is a real-time convolution engine (and another command-line tool). :-D

It runs in the background and takes a simple configuration file:

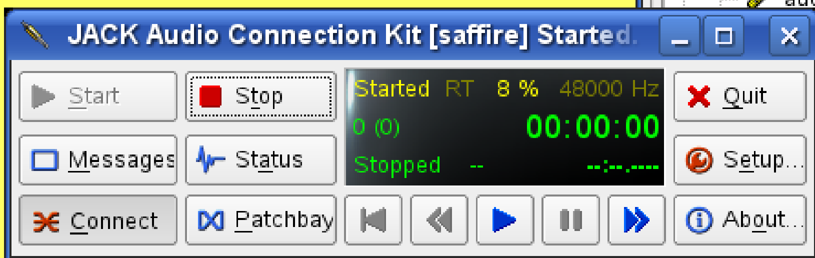
```
/cd /home/nettings/drc-filters

#                 in   out    partition     maxsize
# -----------------------------------------------
/convolver/new     6     6         1024       256000


#
#                in  out   gain   delay   offset   length   chan       file
# ---------------------------------------------------------------------
/impulse/read     1    1   1       0         0        0      1   filter-speaker_ir-1.pcm.wav
/impulse/read     2    2   1       0         0        0      1   filter-speaker_ir-2.pcm.wav
/impulse/read     3    3   1       0         0        0      1   filter-speaker_ir-3.pcm.wav
/impulse/read     4    4   1       0         0        0      1   filter-speaker_ir-4.pcm.wav
/impulse/read     5    5   1       0         0        0      1   filter-speaker_ir-5.pcm.wav
/impulse/read     6    6   1       0         0        0      1   filter-speaker_ir-6.pcm.wav
```

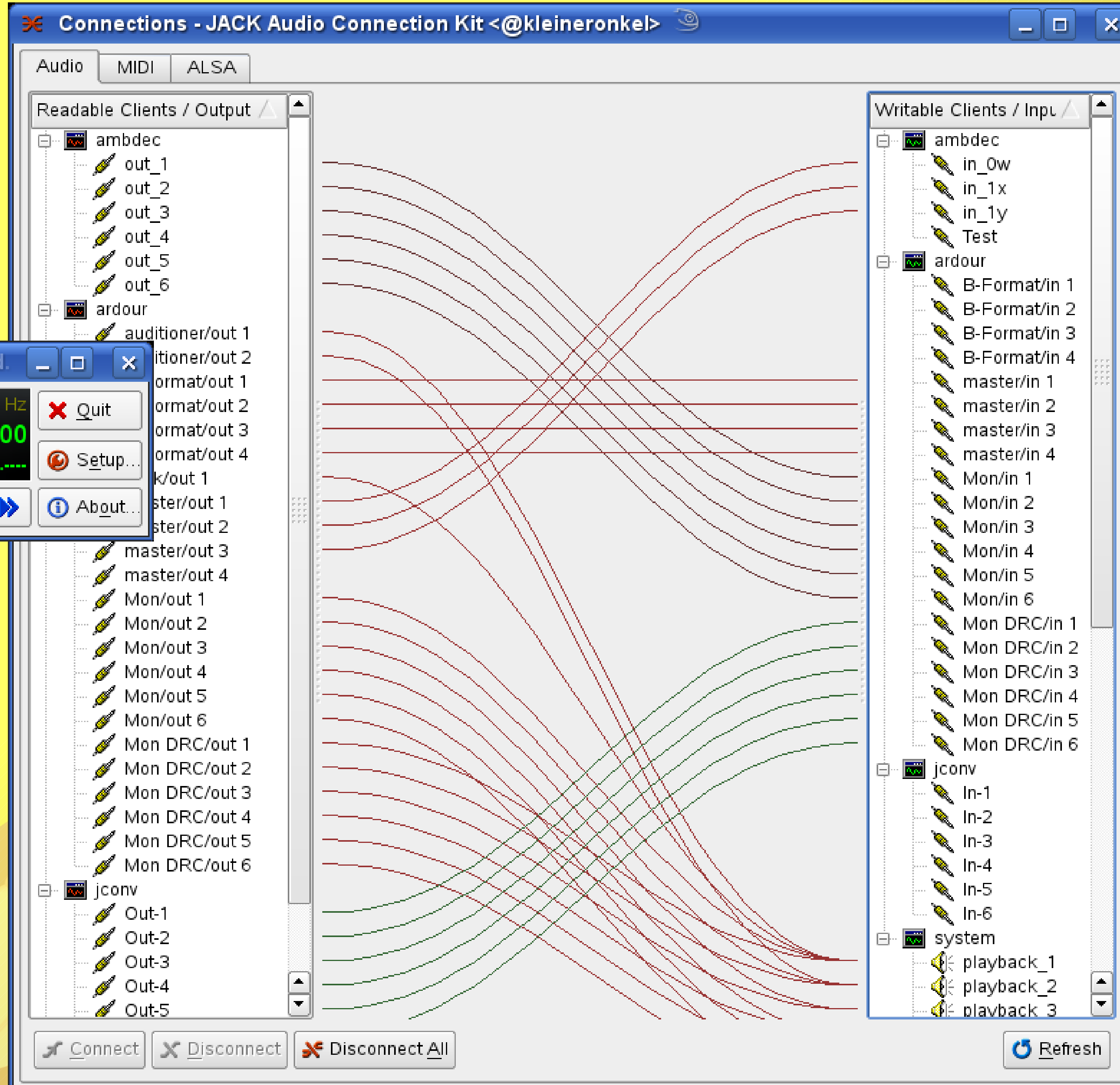
The filter kernels we created earlier:

Step 4: Signal flow & software setup



Putting it all together with JACK and qjackctl:





Imagine this with 24 speakers!

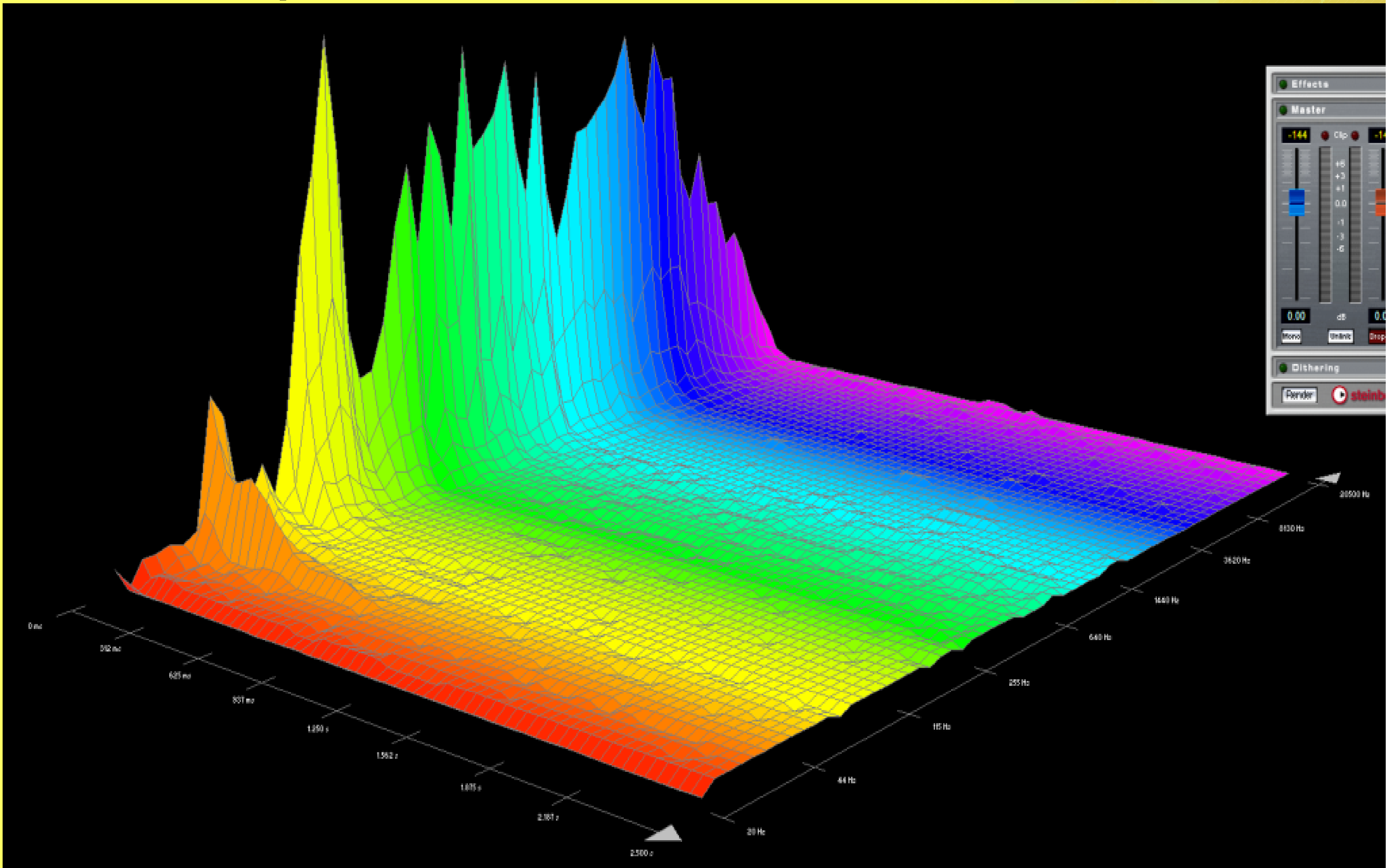
Thankfully, virtual cables are cheap :-D

So what does it sound like?

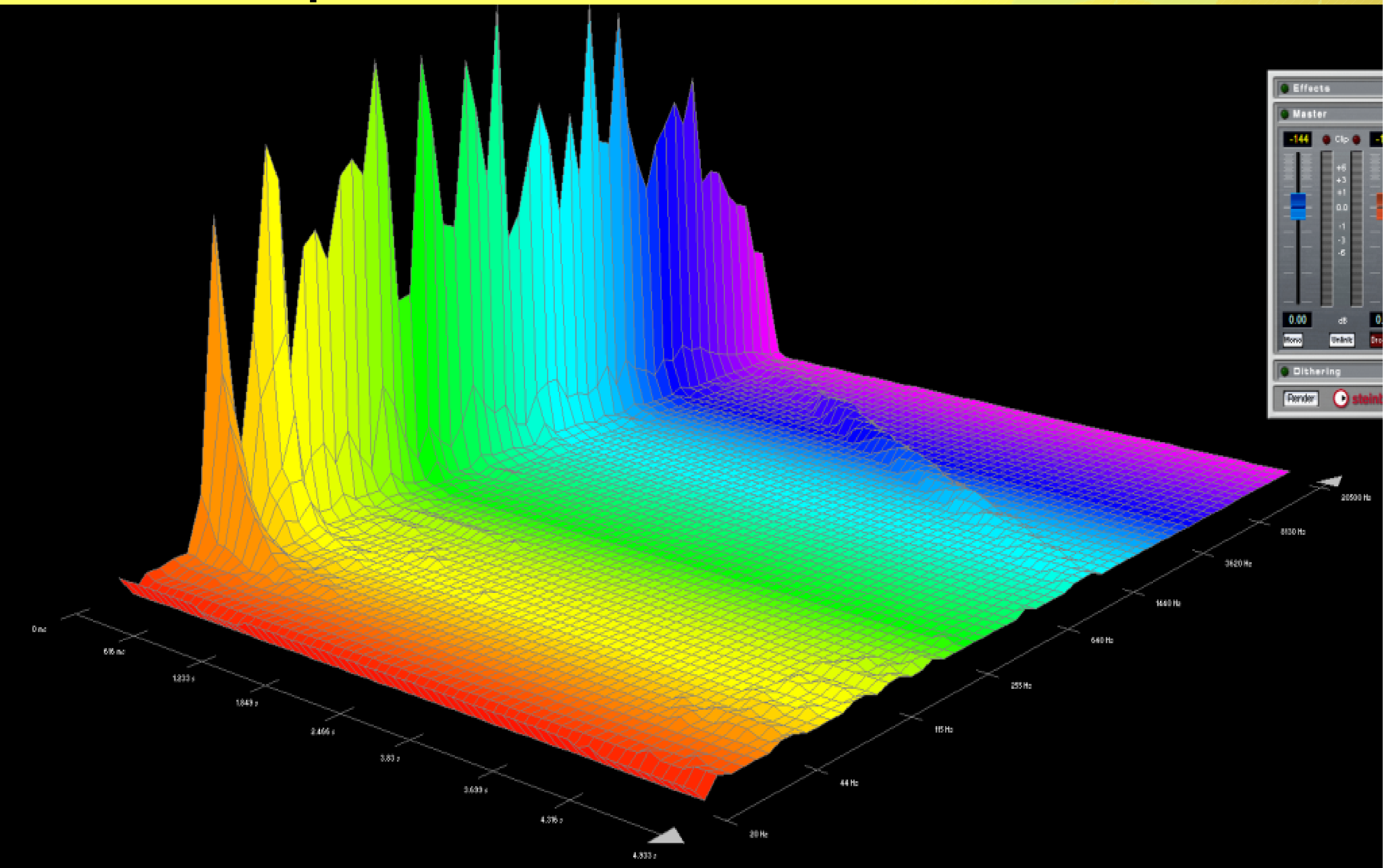
To evaluate the effects of the application of DRC, here are a few „before & after“ comparisons...:

JAPA,
WaveLab (er, well...)

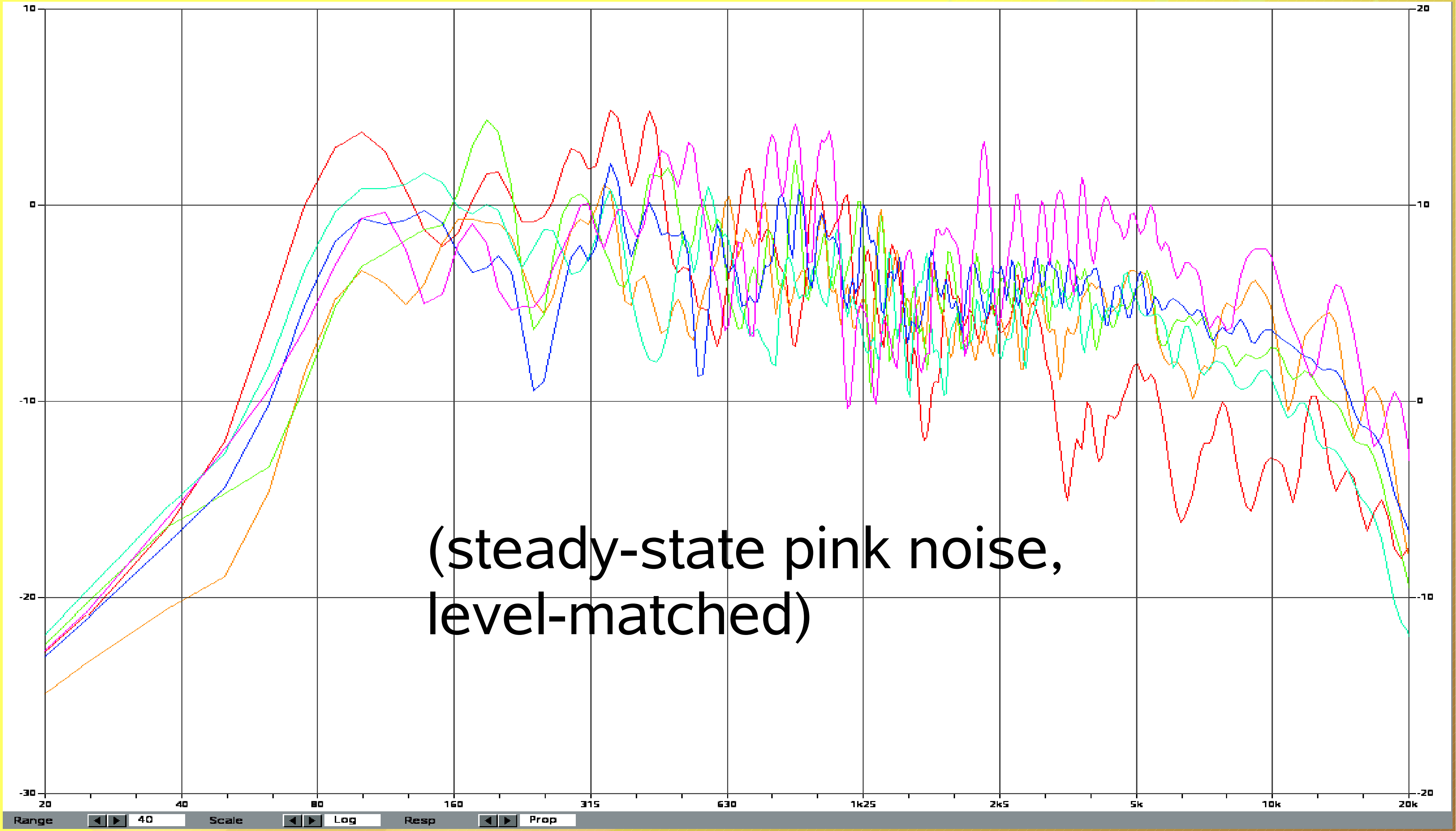
Speaker No. 6 before DRC:



Speaker No. 6 after DRC:

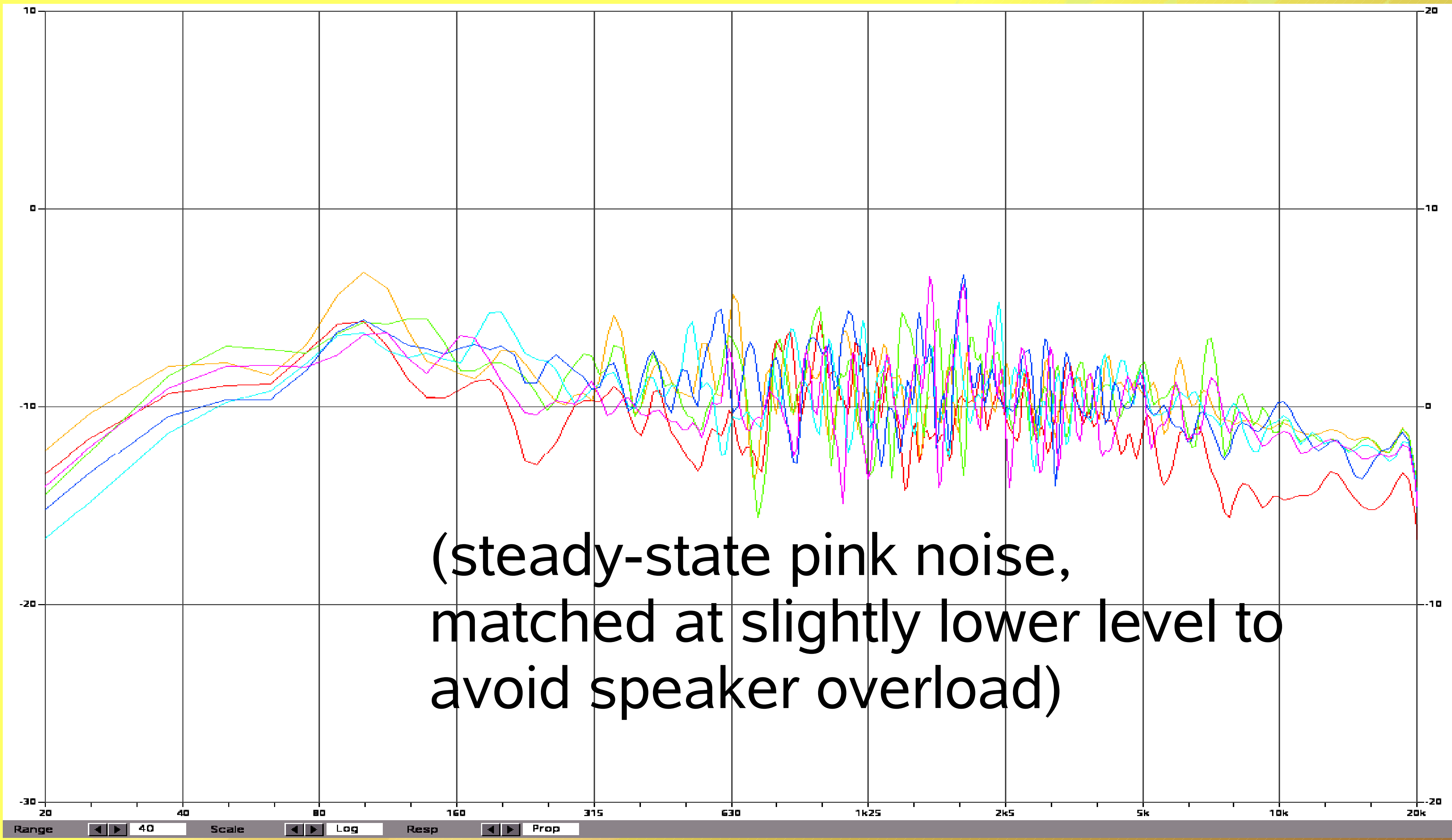


Frequency response before DRC:



(steady-state pink noise, level-matched)

Frequency response after DRC:



(steady-state pink noise, matched at slightly lower level to avoid speaker overload)

Evaluation of the DRC:

Listening tests show **more pleasant timbre**, especially with stringed instruments, more **„sparkle“ in the treble band**, a **„tighter“ bass** and improved precision of **localisation**.

(The speakers used for this test are low-end active studio monitors with a cost of ca. 200€ per channel.)

Thanks to:

the VdT and especially Sebastian Gabler for the invitation,

Fons Adriaensen (author of Aliki, AmbDec and JConv),

Denis Sbragion (author of drc),

the JACK development team,

the Ardour development team,

Eric Benjamin, Richard Lee and other patrons of the sursound mailing list,

and of course

http://www.have-a-great-time-in-south-australia.com for the shark images.

Thanks for your attention!

Your Questions?

References:

Aliki, AmbDec, JConv, JAPA:
http://kokkinizita.net

drc: http://drc-fir.sourceforge.net

JACK: http://jackaudio.org

Ardour: http://ardour.org

qjackctl: http://qjackctl.sourceforge.net

sox: http://sox.sourceforge.net

Farina 2000: *Angelo Farina, Simultaneous measurement of impulse response and distortion with a swept-sine technique, AES Preprint, http://pcfarina.eng.unipr.it/Public/Papers/134-AES00.PDF, 2000*

The corresponding paper to this presentation can be downloaded from http://spunk.dnsalias.org/public_stuff/linux_audio/tmt08/