What can Ambisonics do for you?

A crash course for practising EA composers.

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Centre for Research in New Music

Overview

Spatial audio woes...

Ambisonics to the rescue!

How does it work?

Practical demo @ SPIRAL

Spatial audio woes...

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Great! People want to hear my music!

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Spatial audio woes...

Great! People want to hear my music!

… only there are fewer speakers available than my piece requires

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Spatial audio woes...

Great! People want to hear my music!

… only there are fewer speakers available than my piece requires

… or they are in the wrong places and can't be moved

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Spatial audio woes...

Great! People want to hear my music!

… only there are fewer speakers available than my piece requires
… or they are in the wrong places and can't be moved
… or there are more, but using them properly would require a remix session and studio time

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More spatial audio woes...

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- Why does my sound change when I move it around?

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- Why does my sound change when I move it around?
- Why does my sound stick to the speaker, then jump across, when I want uniform motion?

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More spatial audio woes...

- Why does my sound change when I move it around?
- Why does my sound stick to the speaker, then jump across, when I want uniform motion?
- How do I create convincing (or even correct) reverbs in surround?

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More spatial audio woes...

- Why does my sound change when I move it around?
- Why does my sound stick to the speaker, then jump across, when I want uniform motion?
- How do I create convincing (or even correct) reverbs in surround?
- How do I create stereo fold-downs for home use or grant applications, without doing a full remix?

Ambisonics to the rescue!

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- You can decode your mix to various speaker layouts without manual intervention.

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- Your music will be downwards compatible, and degrade gracefully all the way down to mono.

Ambisonics to the rescue!

- You can decode your mix to various speaker layouts without manual intervention.
- Your music will be downwards compatible, and degrade gracefully all the way down to mono.
- Your music will be upwards compatible, and make good use of all available speakers.

Ambisonics to the rescue!

- Sources will sound the same on or between speakers.

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Ambisonics to the rescue!

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Ambisonics to the rescue!

- Sources will sound the same on or between speakers.
- Panning will be perfectly smooth, and speaker locations inaudible.
- Using Ambisonic IRs and convolution, you can recreate natural ambience perfectly.
- Stereo and 5.0 fold-downs can be created automatically.

Is this a sales pitch, or what?

Well, yes and no.

Ambisonics is free!

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- Thanks to solid British engineering by Michael A. Gerzon et al., it's sound and future-proof.

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- Invented in the 1970s, all relevant patents have expired.
- Thanks to solid British engineering by Michael A. Gerzon et al., it's sound and future-proof.
- Thanks to solid British marketing, it was utterly forgotten for 20 years.

Ambisonics is free!

Thanks to the digital revolution, it's now easier and better than ever.

Ambisonics is free!

- There are free implementations for various environments/workflows:
  - Linux
  - Mac OS X
  - PD
  - Max/MSP
  - Supercollider
  - VST

So how does it work?

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Ambisonics is a “spatial sampling” technique.

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Ambisonics is a “spatial sampling” technique.

It tries to be physically correct where feasible, and exploits psychoacoustic effects otherwise.

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Ambisonics is a “spatial sampling” technique.

It tries to be physically correct where feasible, and exploits psychoacoustic effects otherwise.

The next slide has a a scary mathematical formula on it.

The Kirchhoff-Helmholtz Integral

The Kirchhoff-Helmholtz Integral

You are lucky. I'm very bad at differential field equations.

So here it is in plain English:

The Kirchhoff-Helmholtz Integral

“If you know the sound pressure and velocity in any point on the surface of a source-free volume, you have complete knowledge of the sound field inside.”

The Kirchhoff-Helmholtz Integral

= If you can record the boundary,

"If you <u>know</u> the sound pressure and velocity in any point on the surface of a source-free volume, you have complete knowledge of the sound field inside."

The Kirchhoff-Helmholtz Integral

= If you can record the boundary,

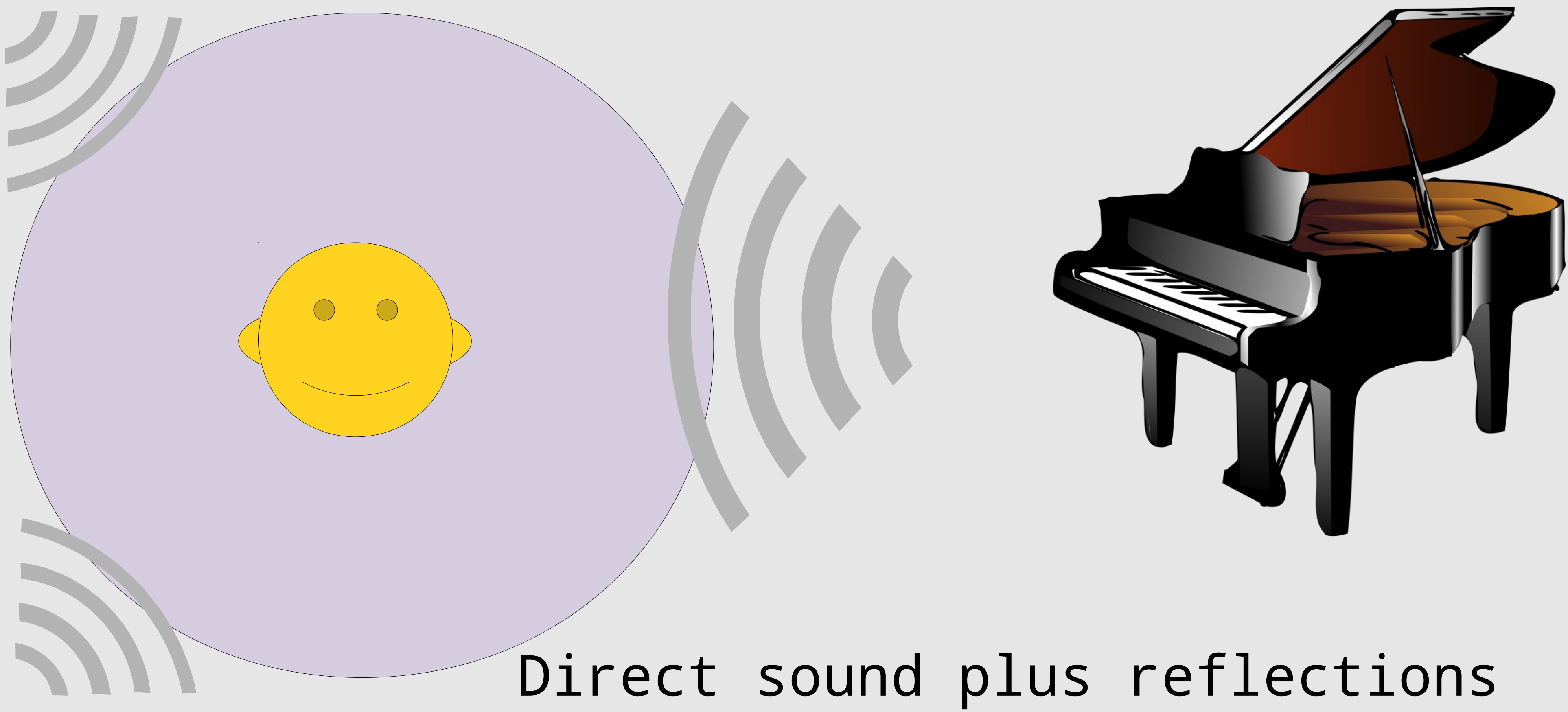
“If you know the sound pressure and velocity in any point on the surface of a source-free volume, you have complete knowledge of the sound field inside.”

you can reproduce the inside.

The Kirchhoff-Helmholtz Integral

Consider a spherical volume that encloses the listener:

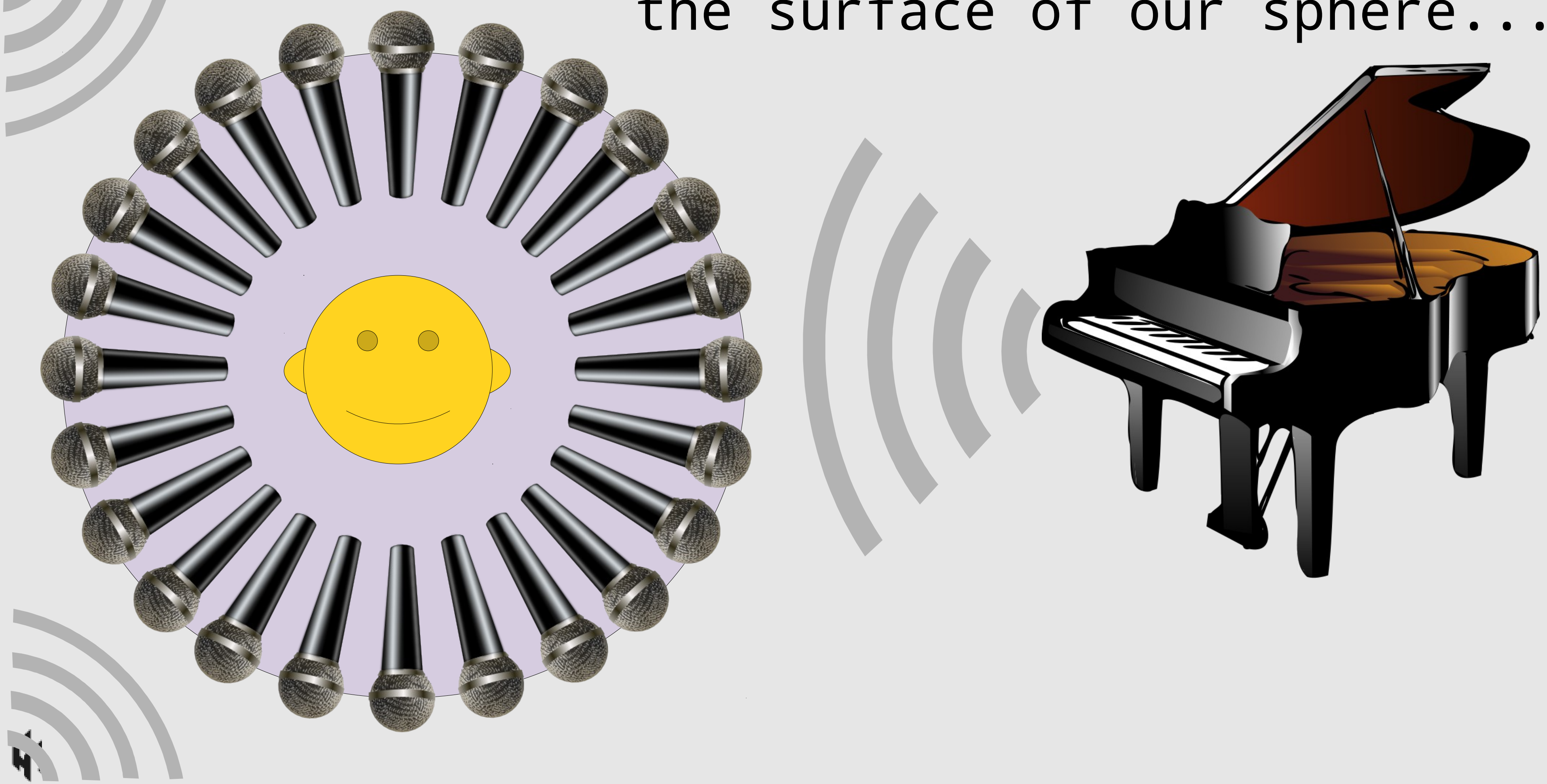
The Kirchhoff-Helmholtz Integral



Direct sound plus reflections from all around: the real thing!

The Kirchhoff-Helmholtz Integral

If we put an infinite number of mics all over the surface of our sphere...



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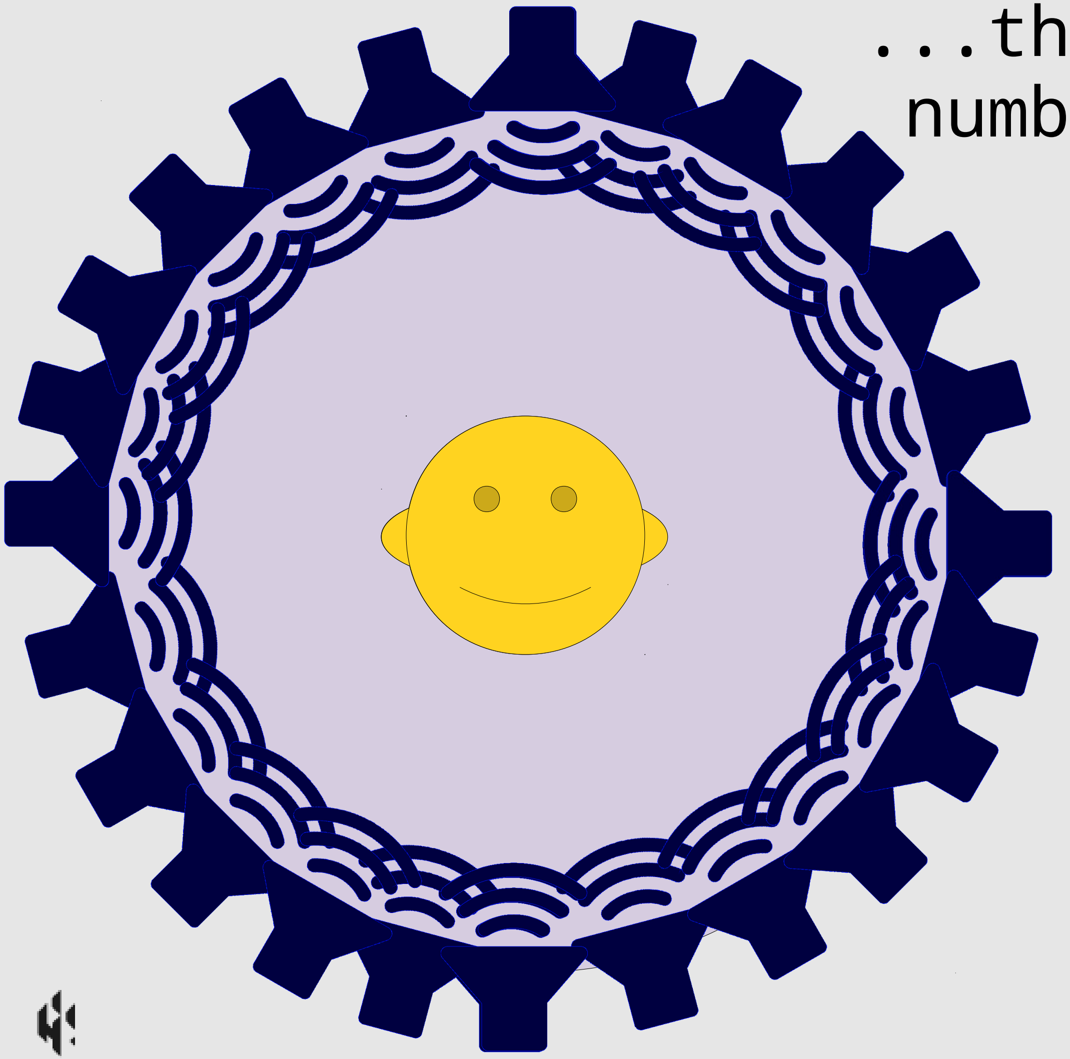
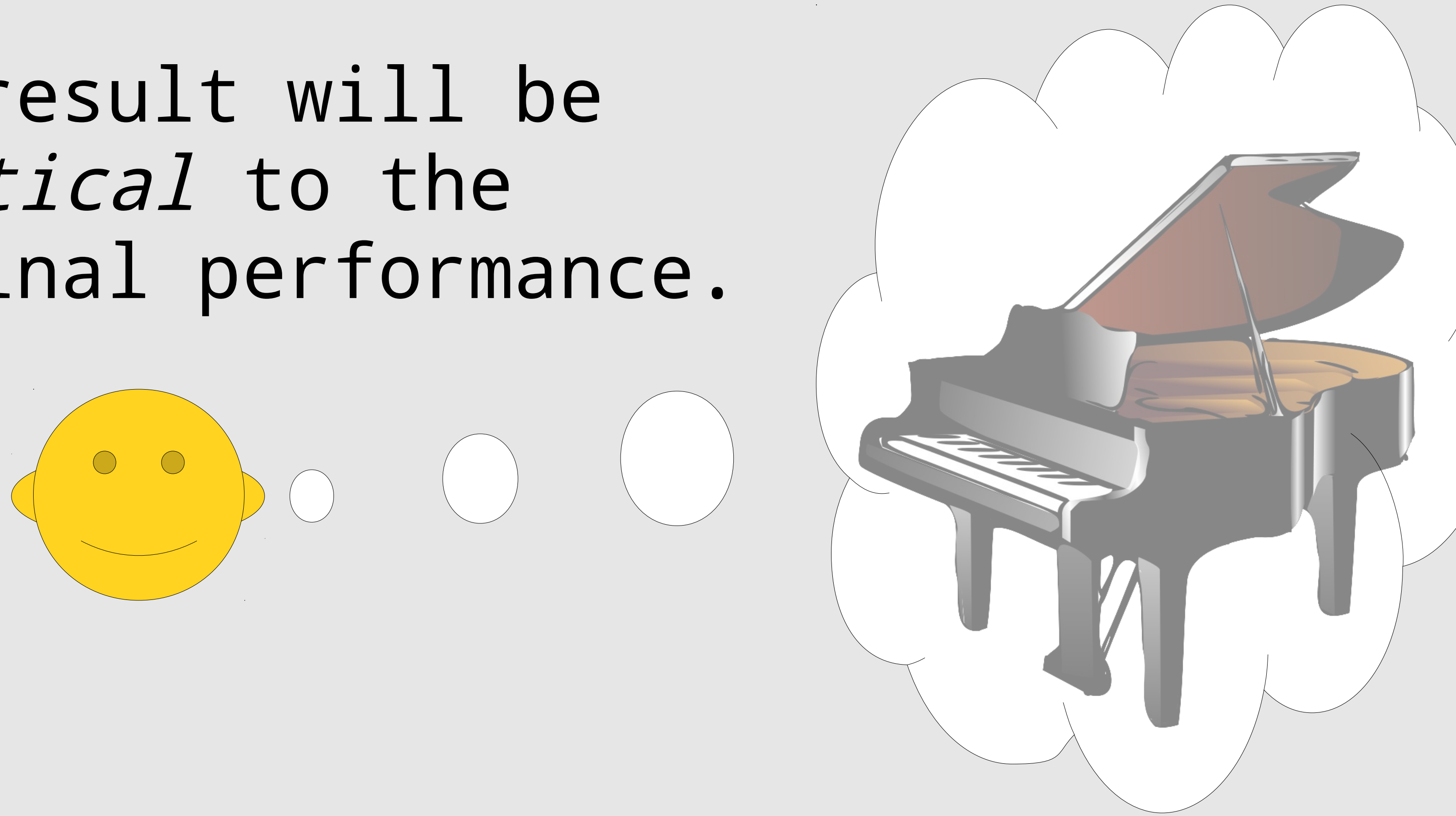
The Kirchhoff-Helmholtz Integral



...then use an infinite number of loudspeakers to play back the recorded signal...

The Kirchhoff-Helmholtz Integral

...the result will be *identical* to the original performance.

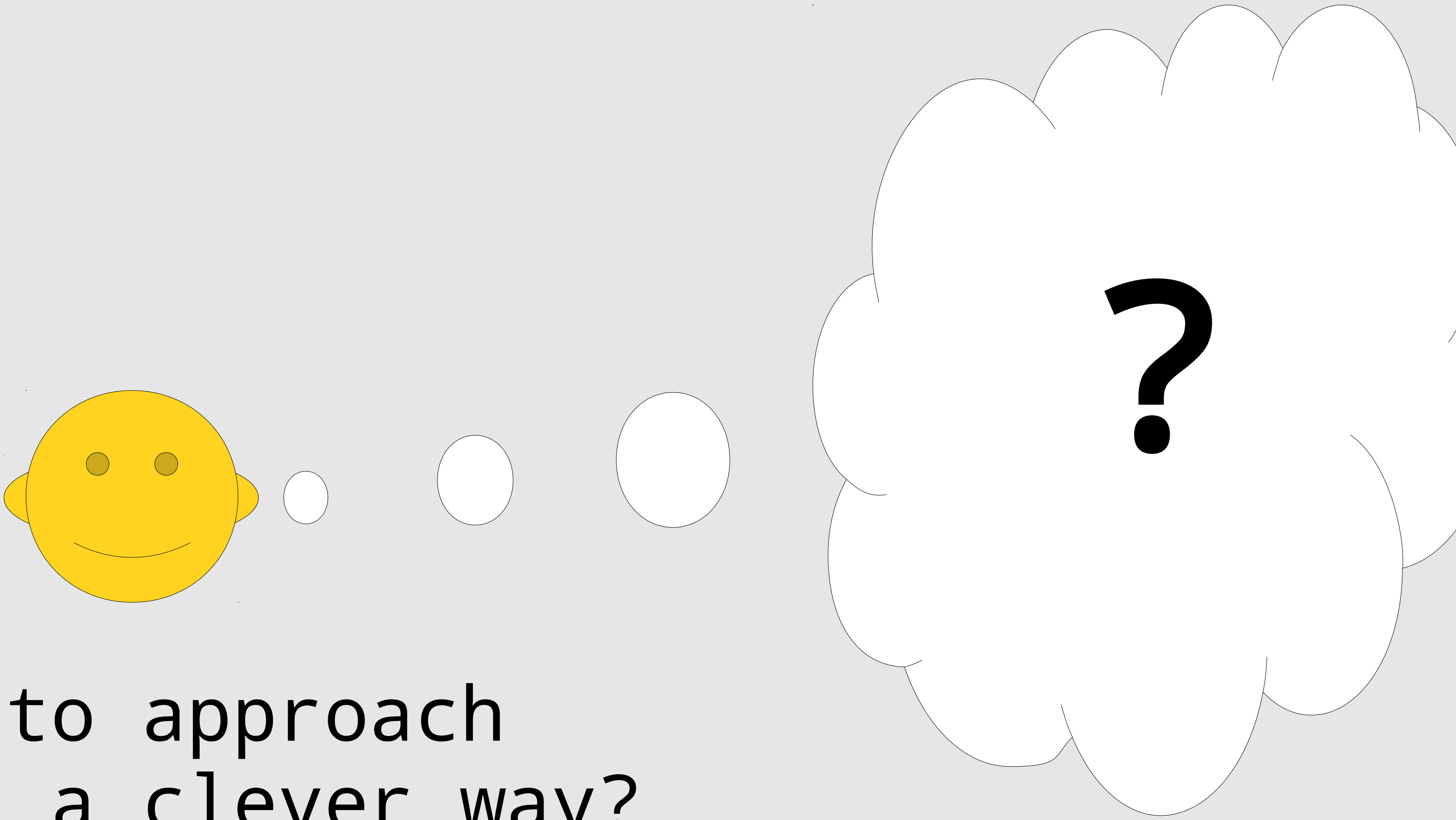


Sampling the sphere

Microphones can be thought of as spatial sampling instruments.

By using their directional characteristics, maybe we can use a finite number of mics and still get good results.

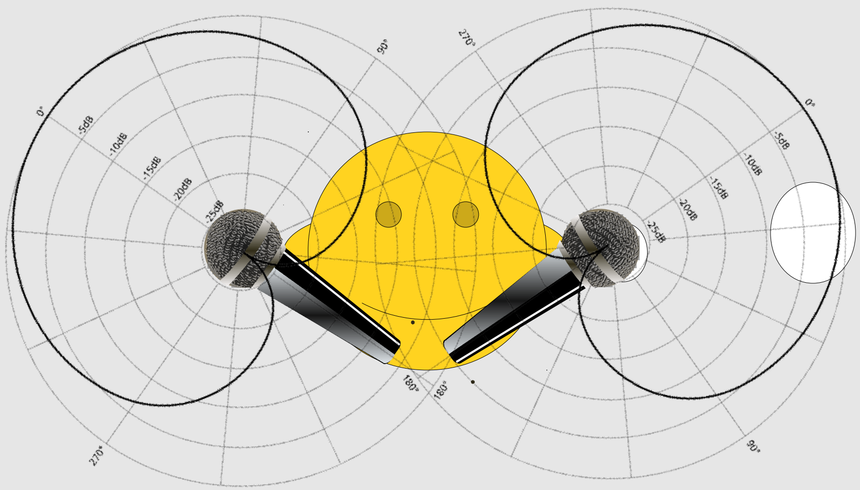
Sampling the sphere

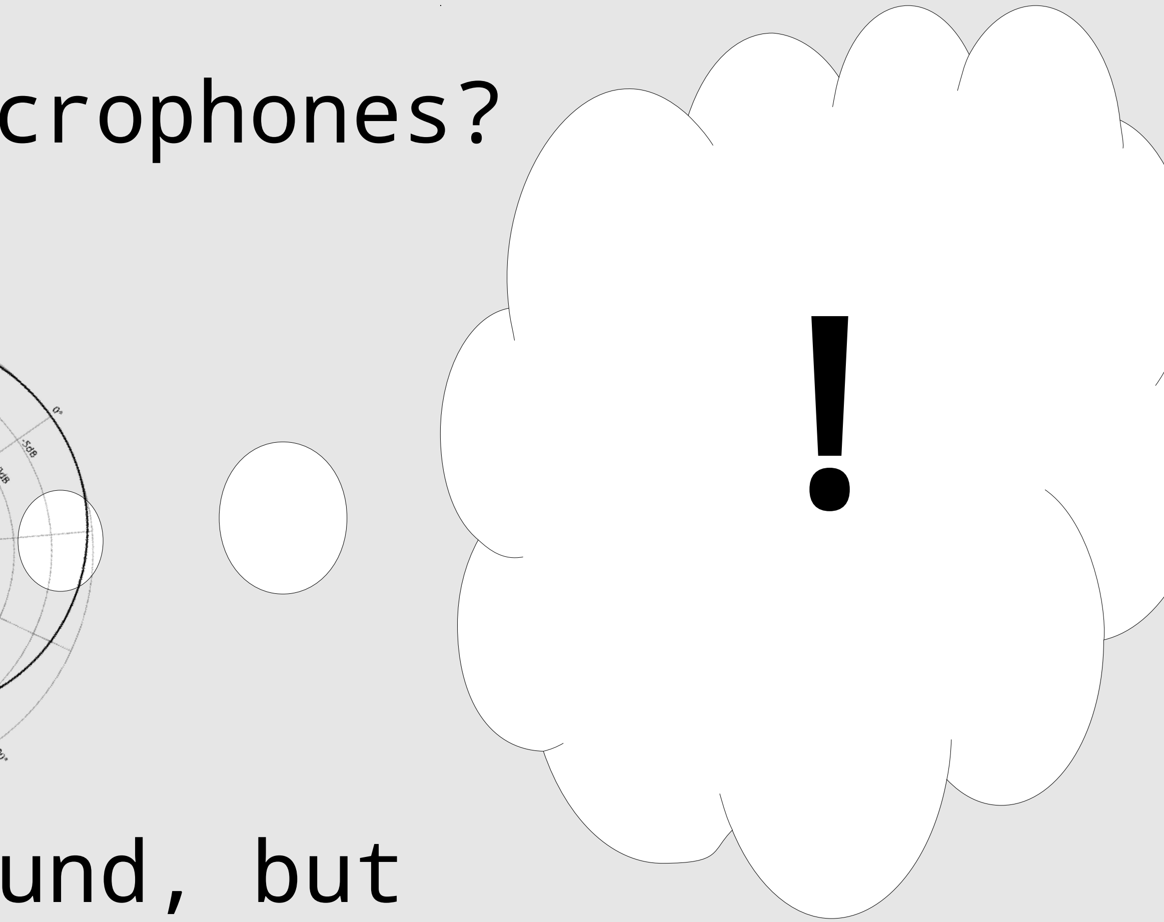


So how to approach this in a clever way?

Sampling the sphere

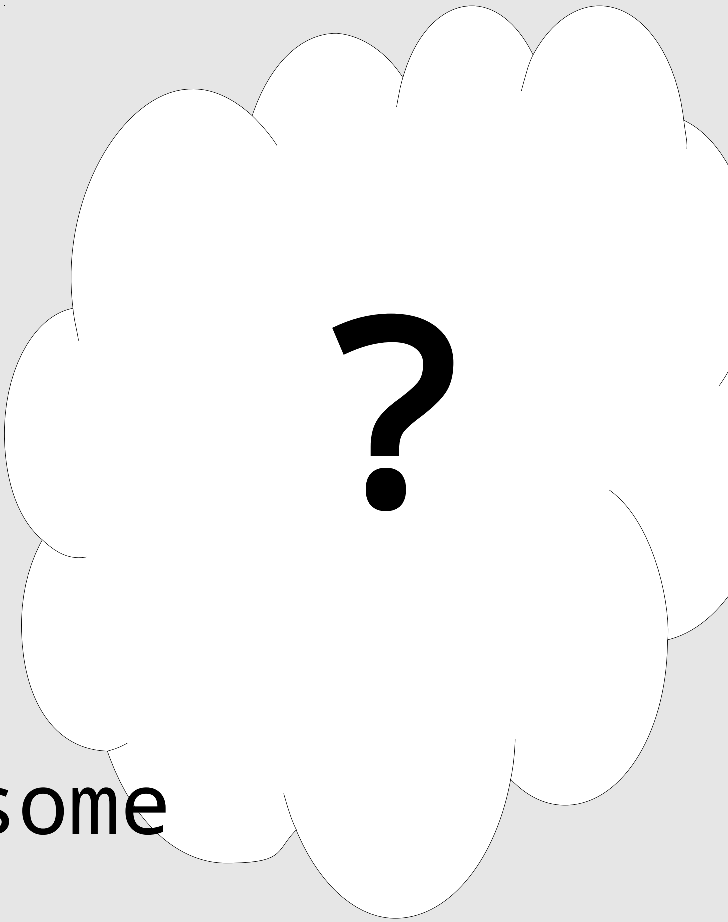
Two ears, two microphones?





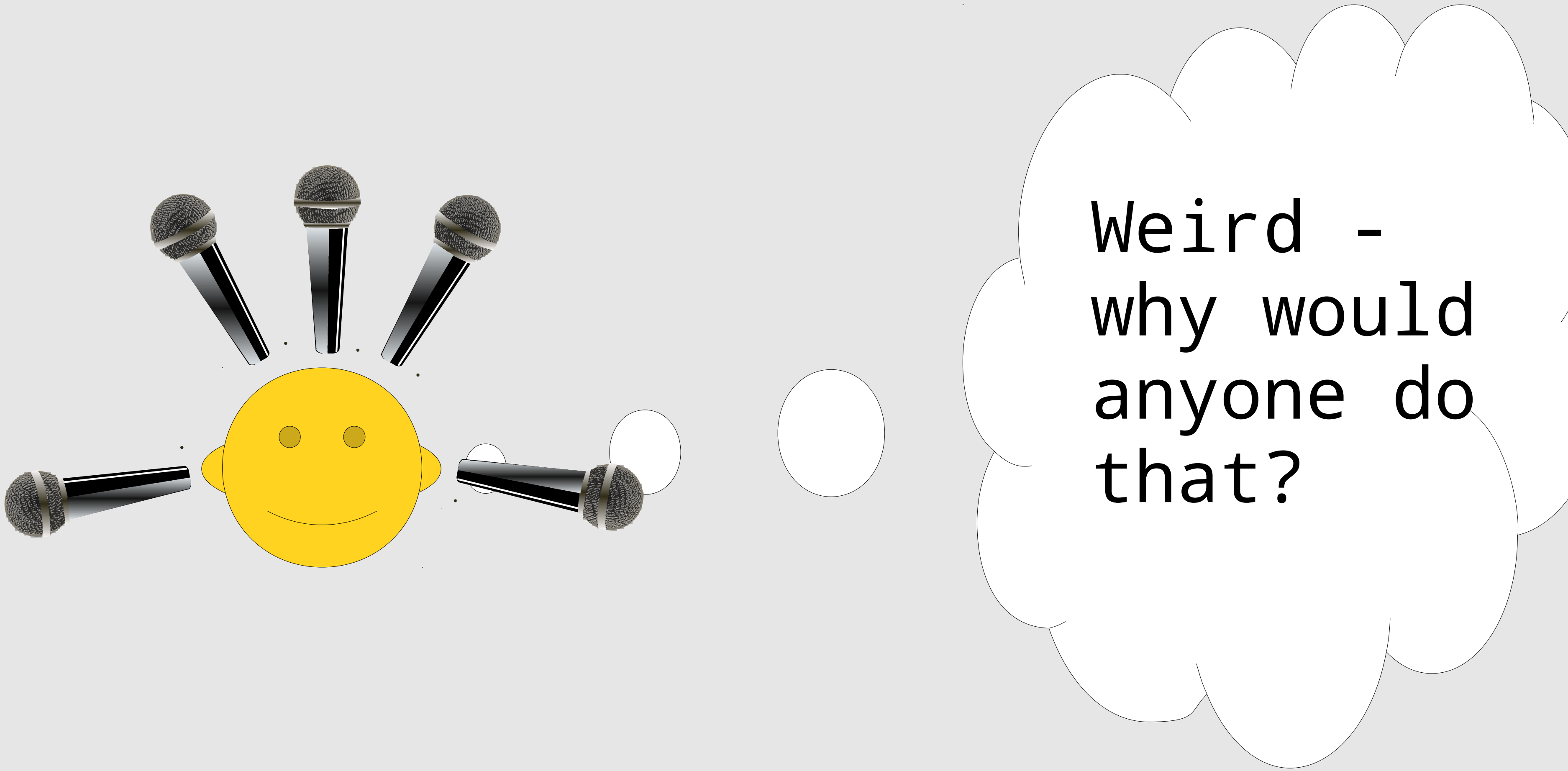
Not really surround, but surprisingly good. And cheap.

Sampling the sphere



Or five microphones, at some very odd angles?

Sampling the sphere



Sampling the sphere

The systematic approach:

Find a set of microphones that cover the sphere completely.

Sampling the sphere

The systematic approach:

Find a set of microphones that cover the sphere completely.

Avoid redundant information.

Sampling the sphere

An omni pattern will sample the sphere completely.

No directional information, unfortunately.

Sampling the sphere

Still, it's useful.
Within the Ambisonic
signal set (a.k.a.
B-format), it's
called the zeroth
order component, or

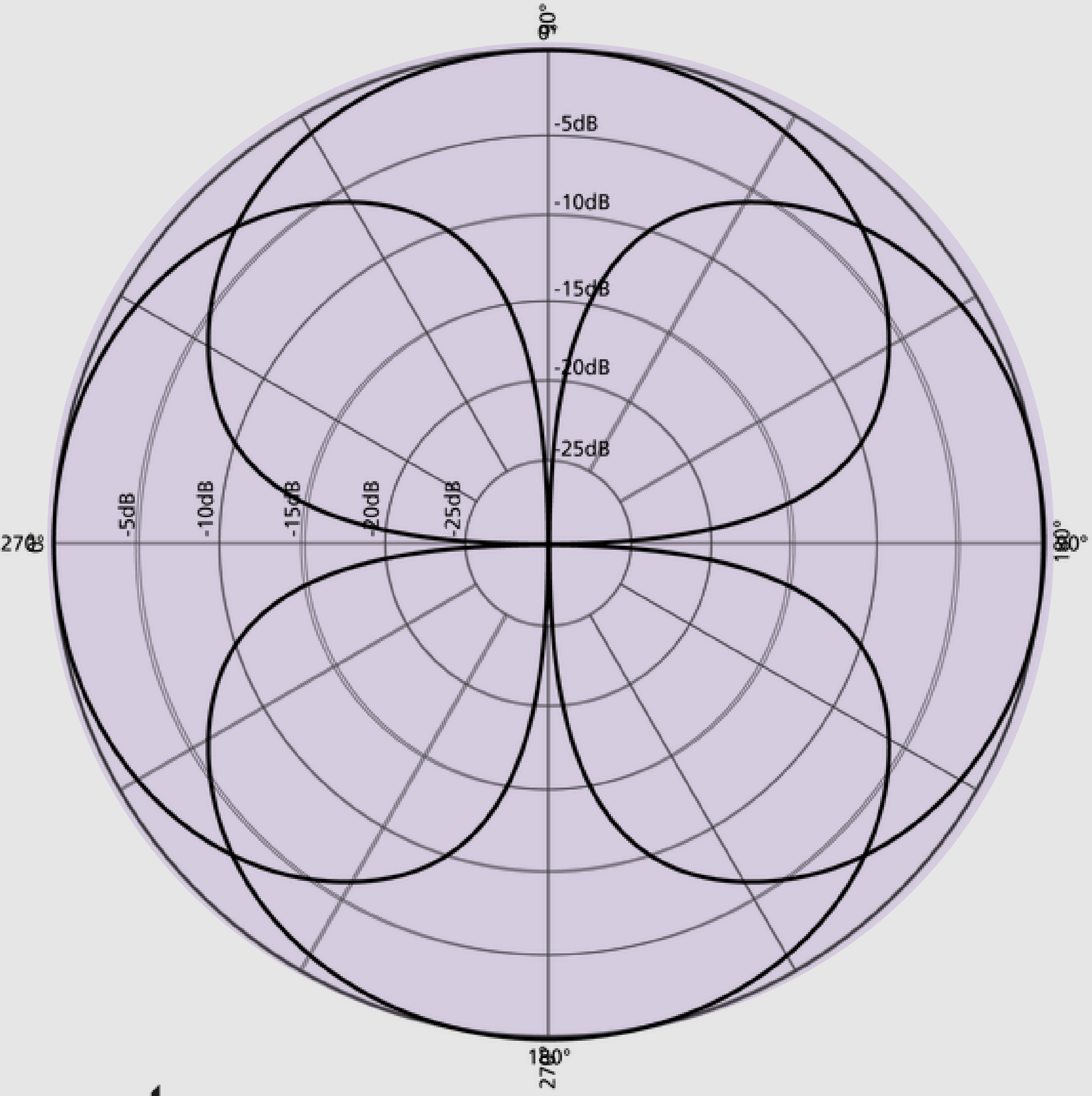
W.

Sampling the sphere

W

is the pressure component. It's what remains when you play Ambisonics back in mono.

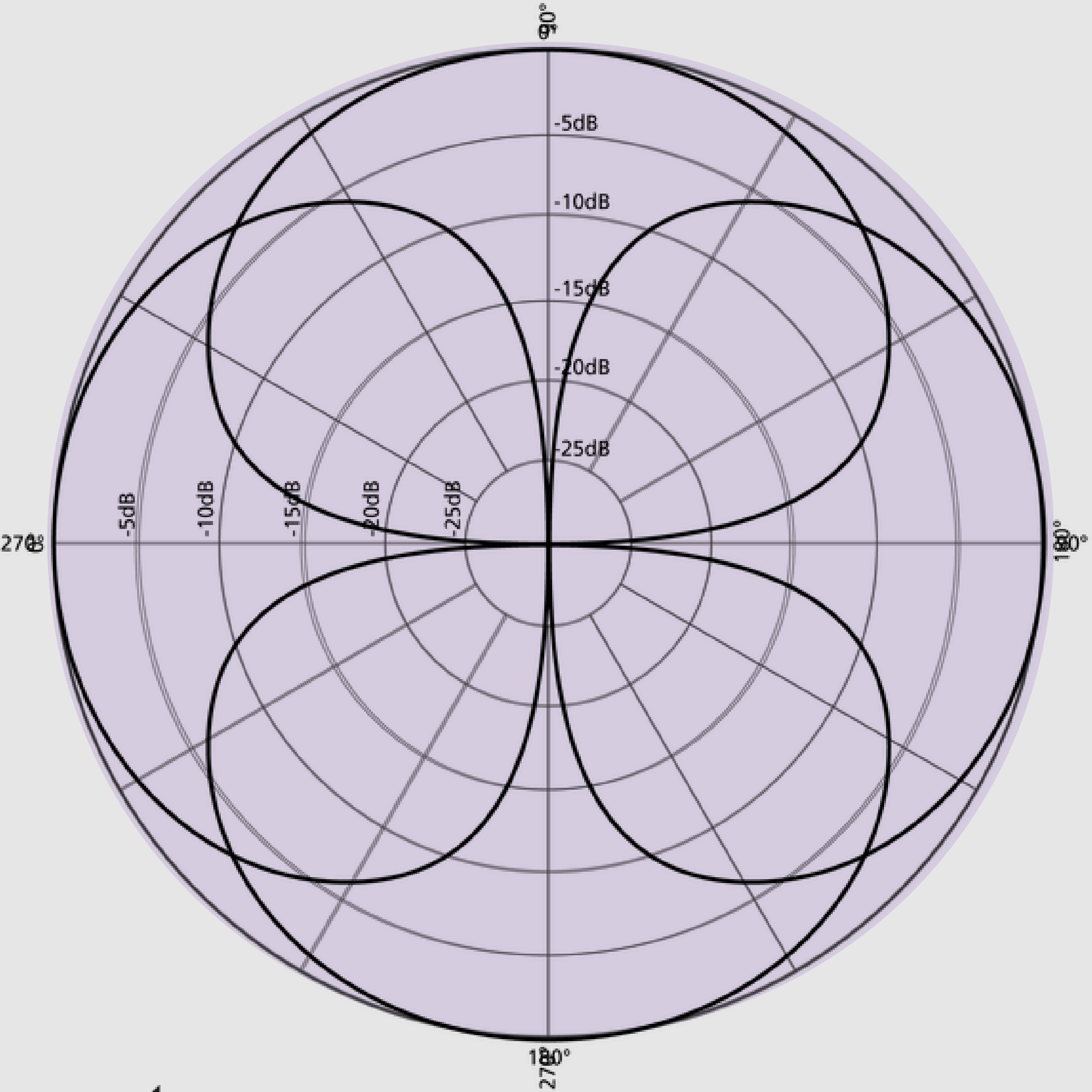
Sampling the sphere



Three figures-of-eight will also cover the sphere uniformly.

Together with W, they provide directional information.

Sampling the sphere



In the B-format, they are denoted as

X,Y,Z.

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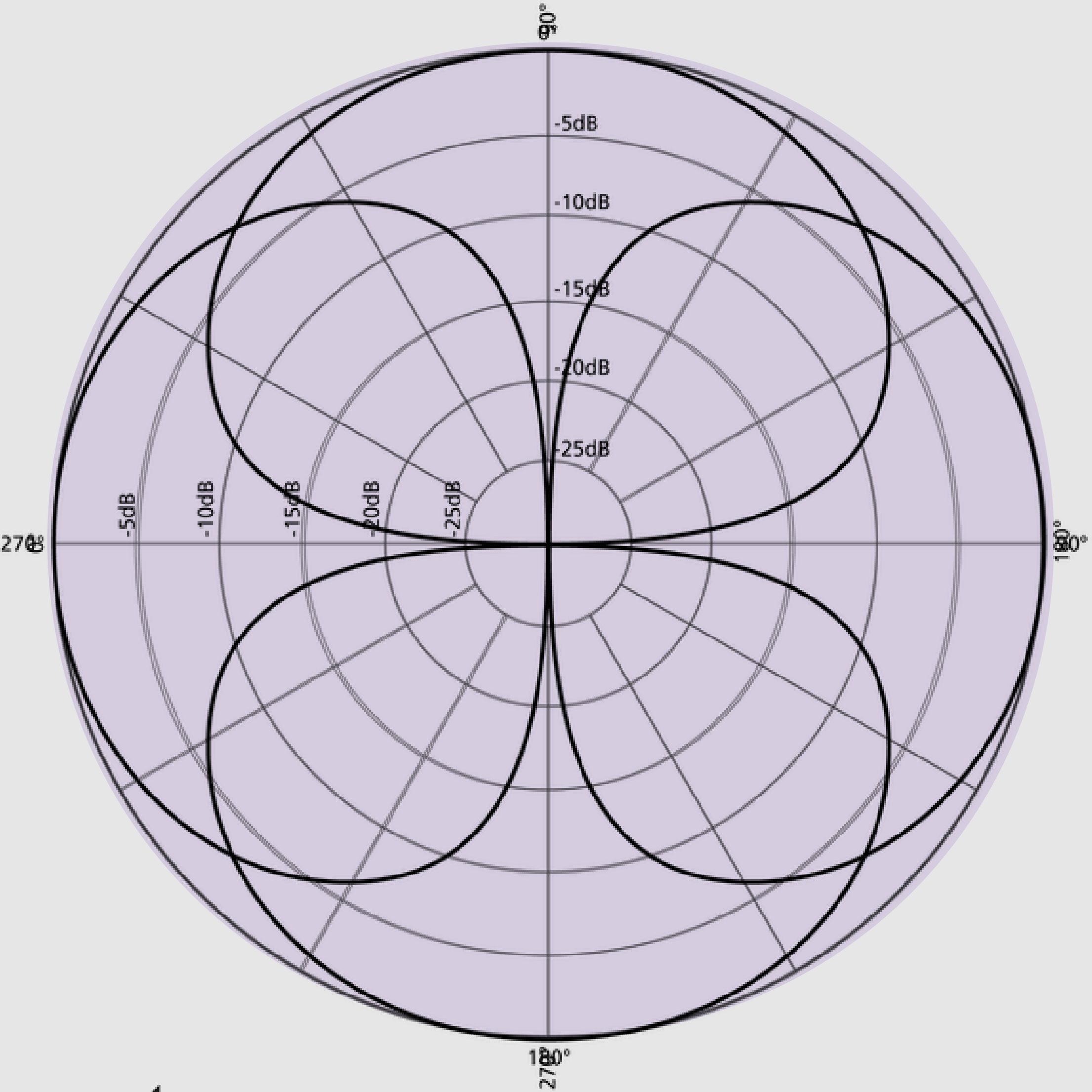
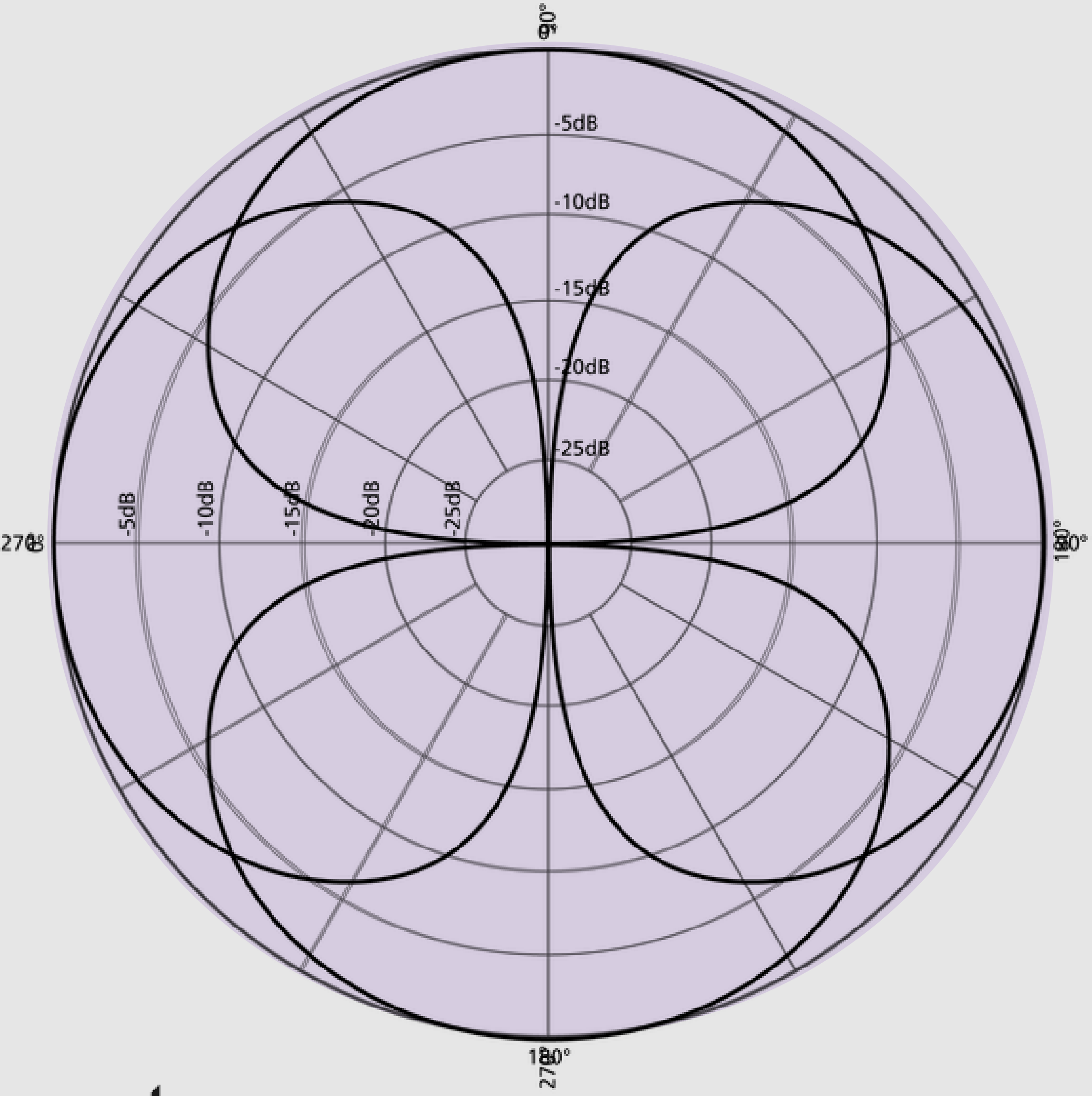
Sampling the sphere



X

is the
<u>front minus back</u>
component.

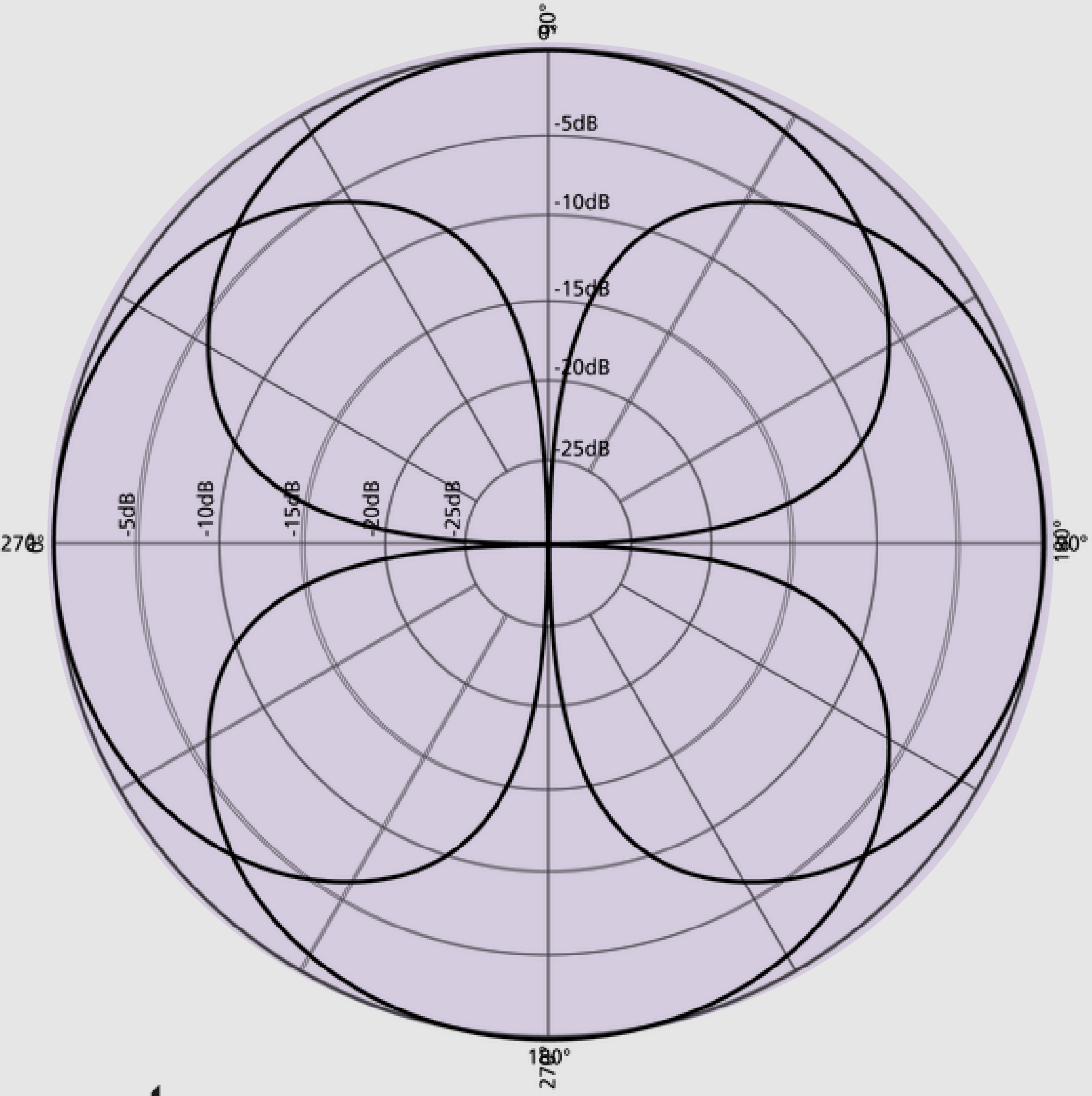
Sampling the sphere



Y

is the
<u>left minus right</u>
component.

Sampling the sphere

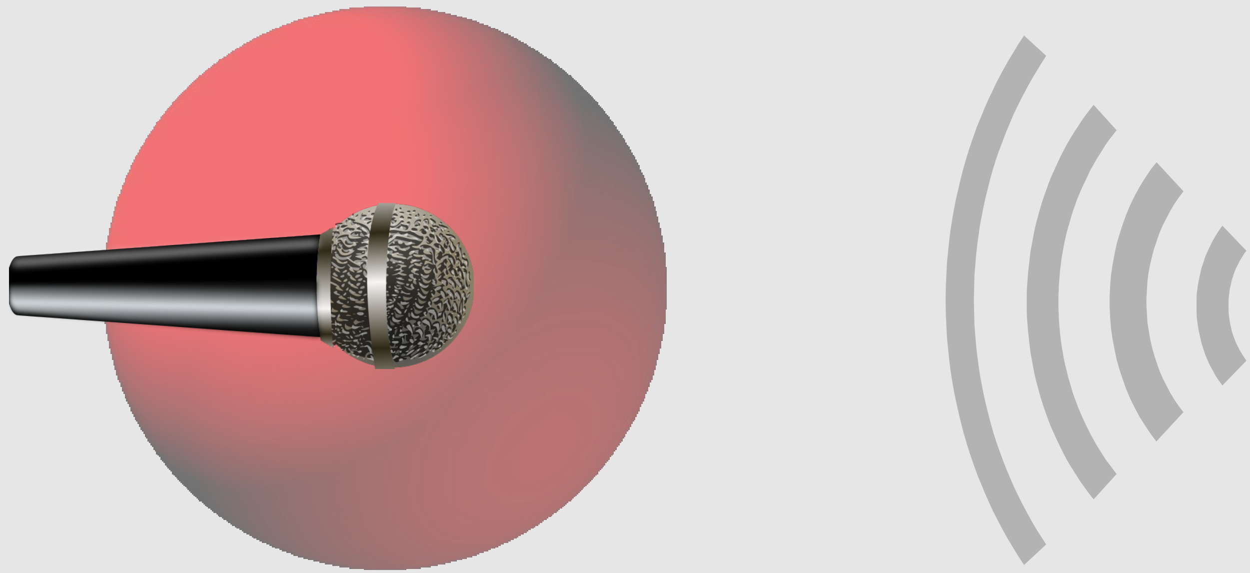


Z

is the
up minus down
component.

“Native” B-format microphone:

an omni in
the middle



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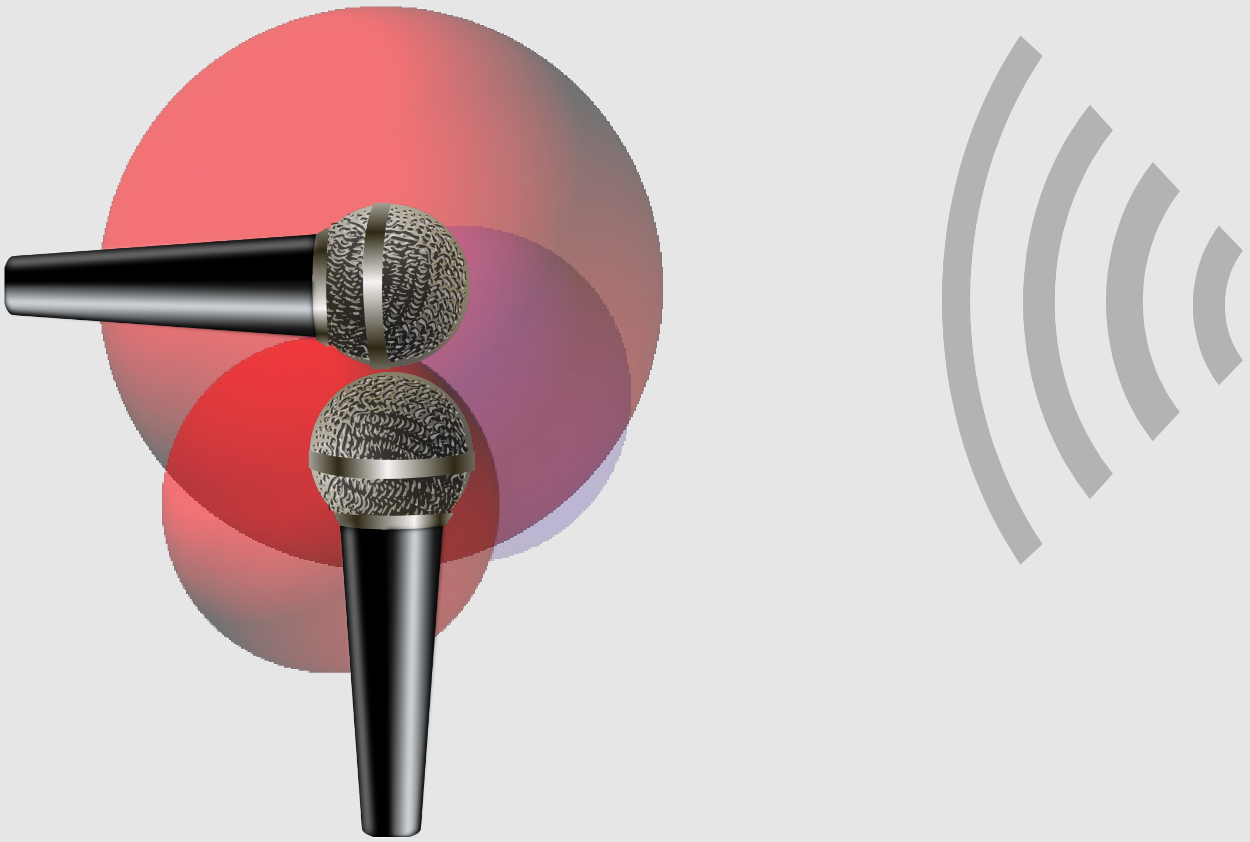
“Native” B-format microphone:



an omni in the middle

a fig8 for left-right

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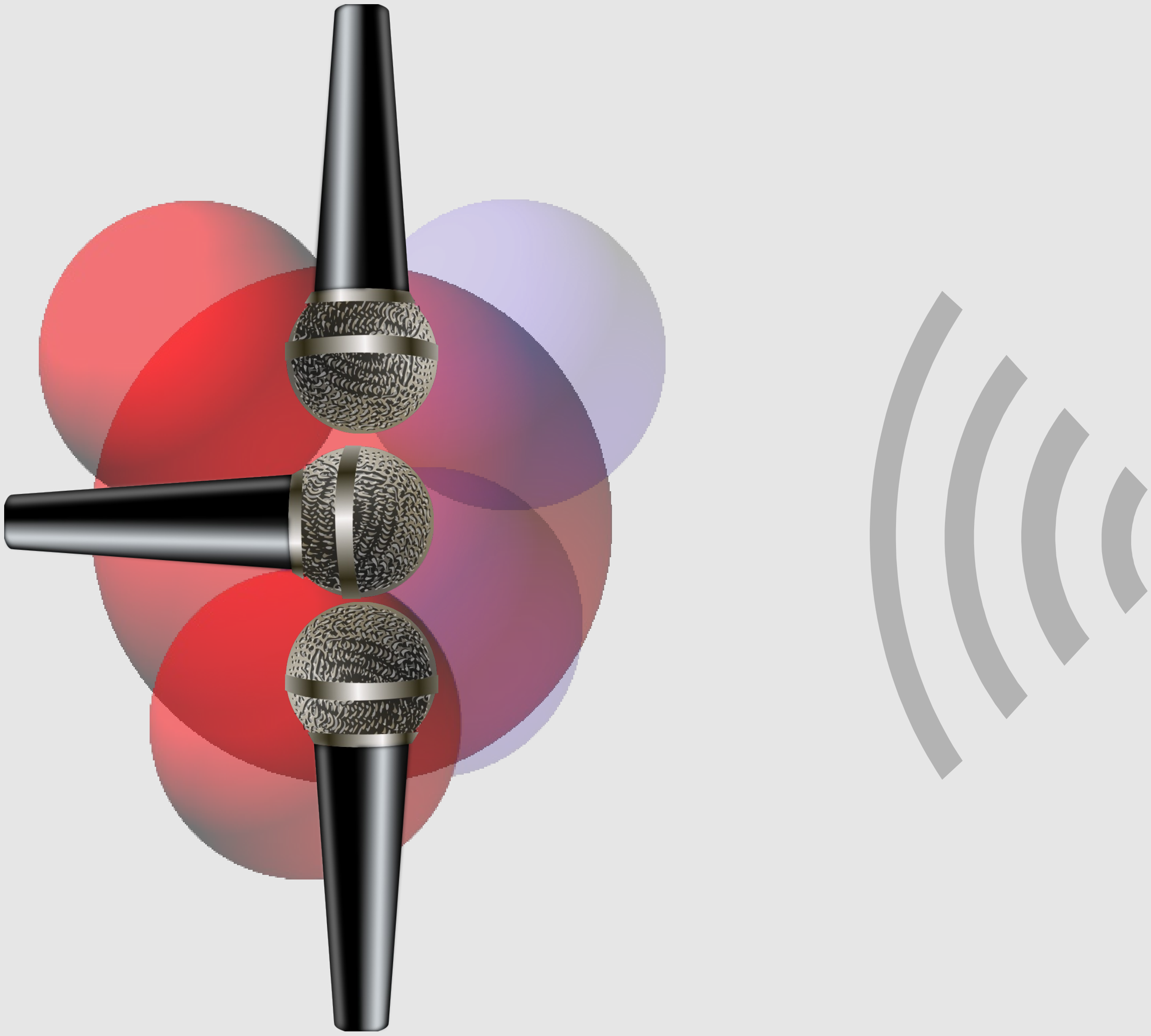
“Native” B-format microphone:

a fig8 for front-back

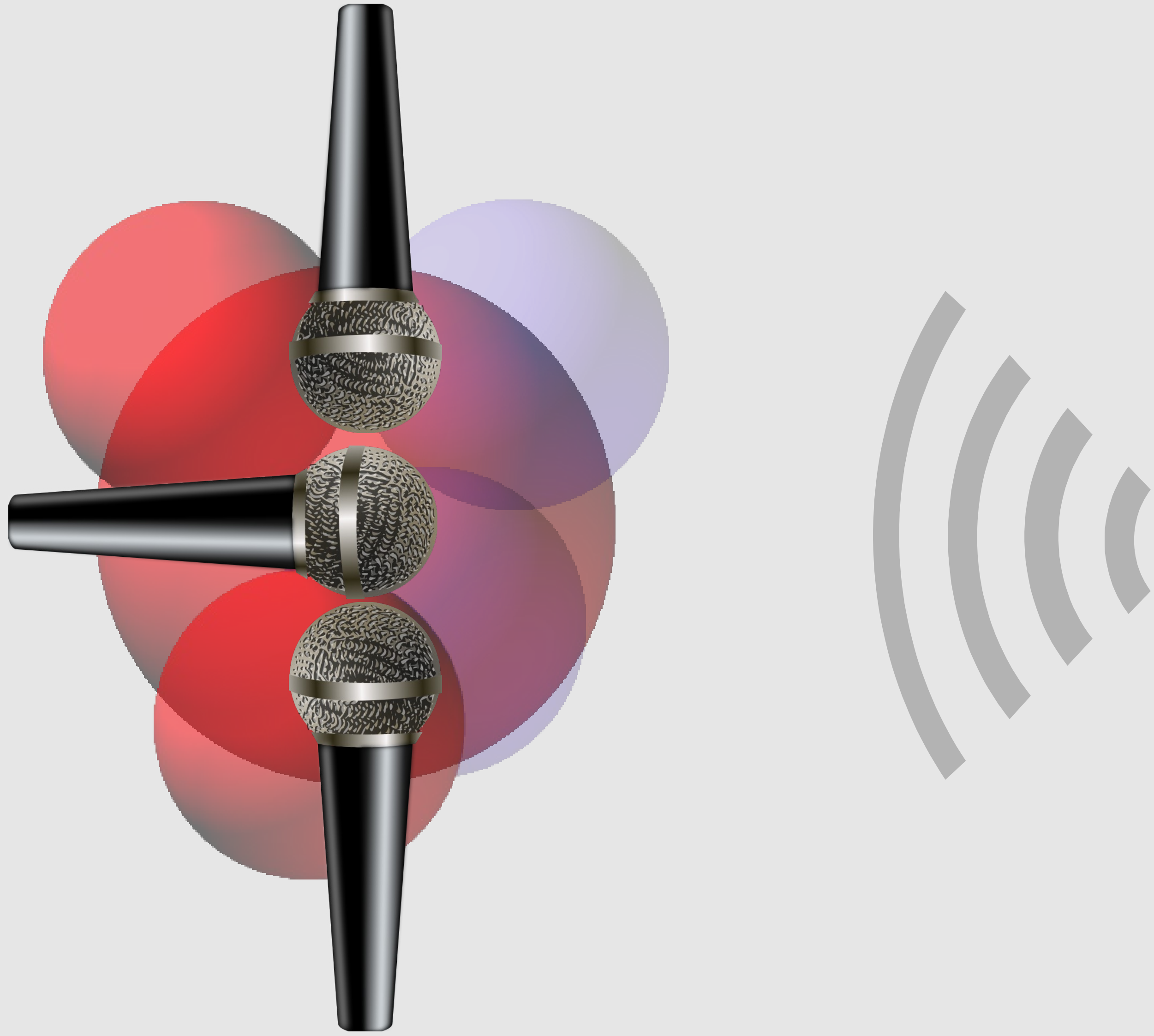
an omni in the middle

a fig8 for left-right



“Native” B-format microphone:

works well for horizontal sound



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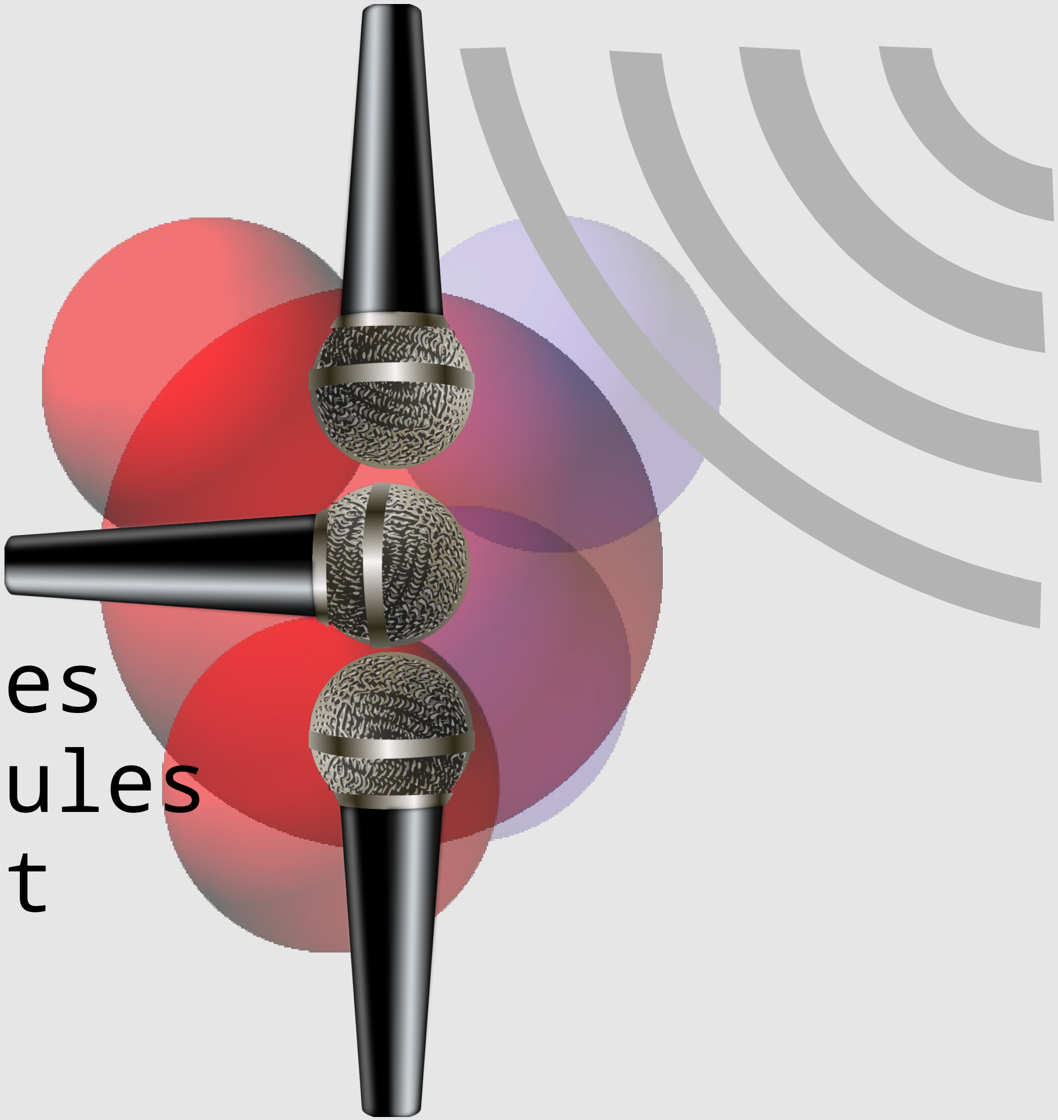
“Native” B-format microphone:

Problem:

Sound from outside the horizontal plane arrives at the capsules at different times.



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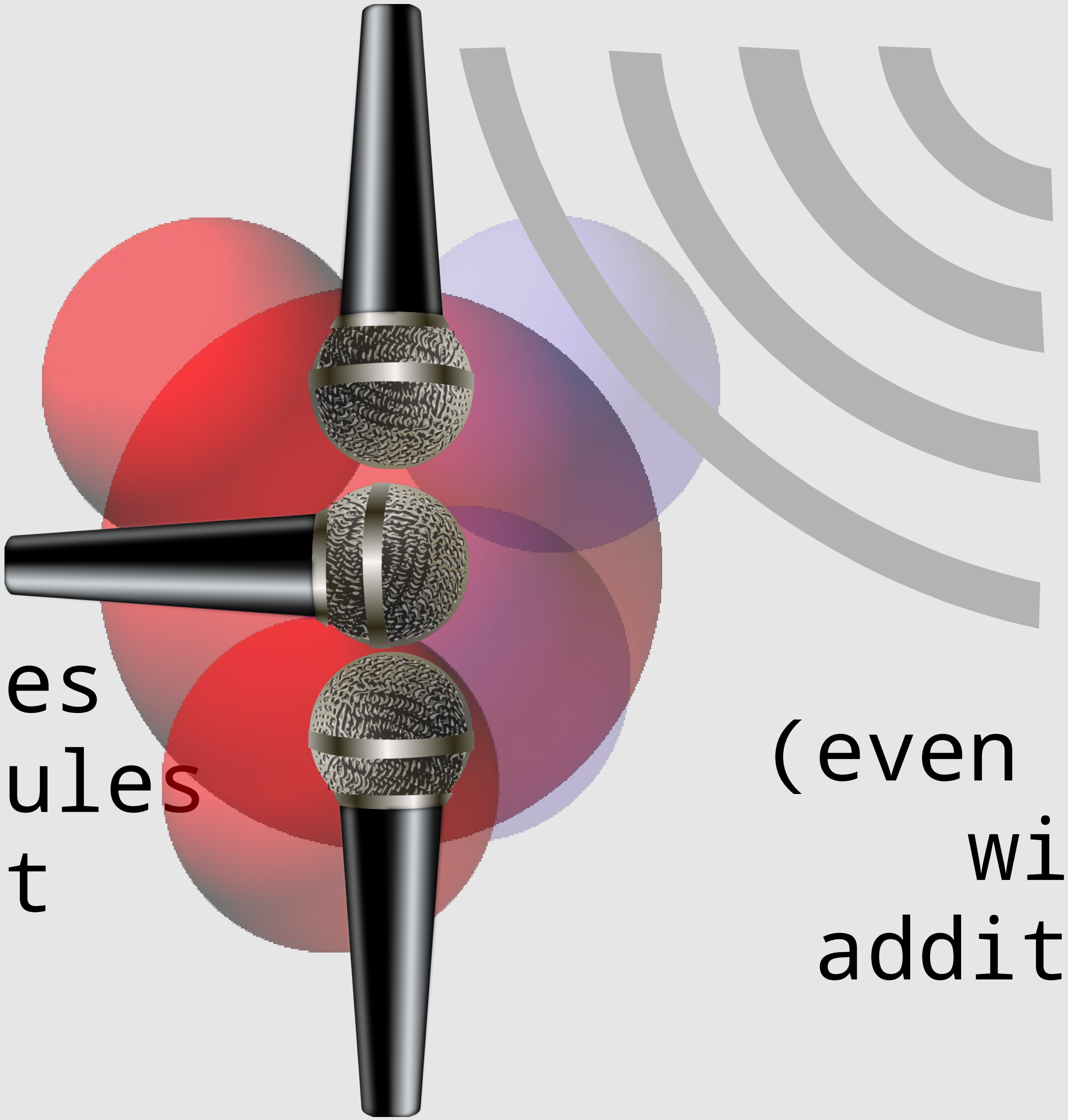
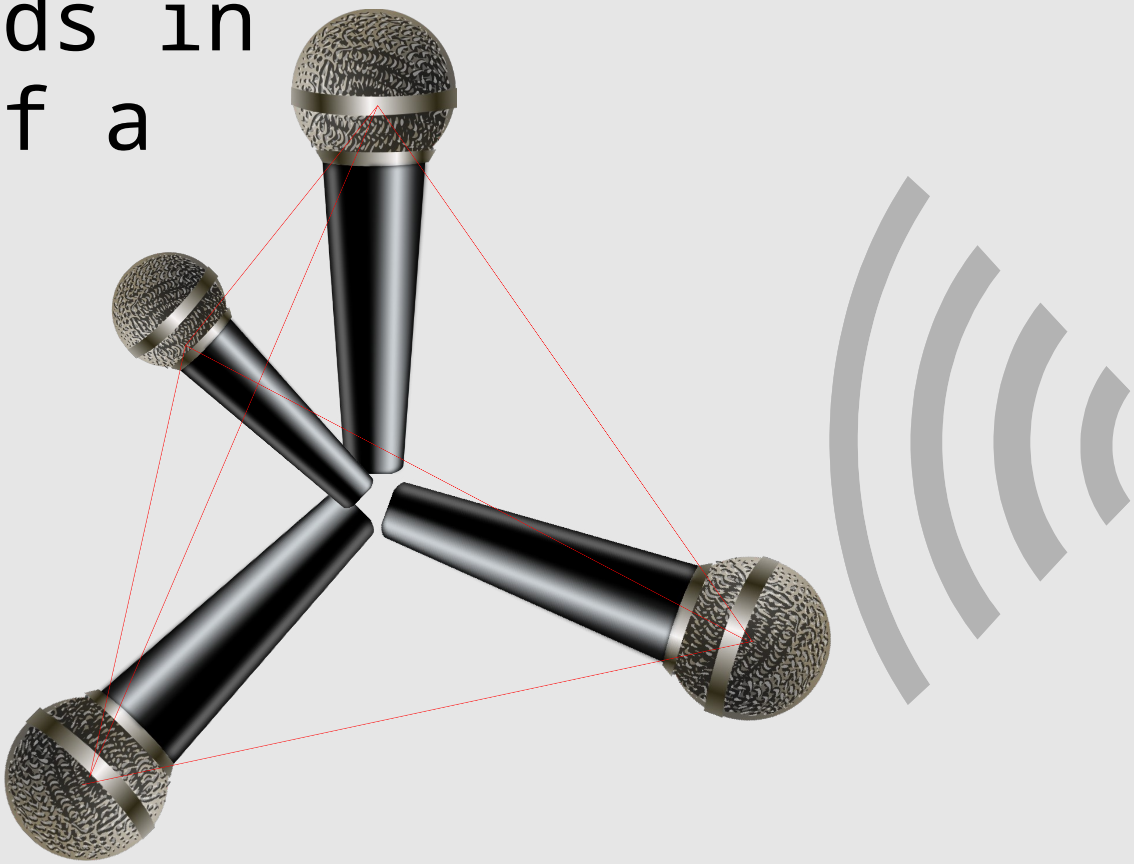


(even worse with an additional Z mic)

Sound field microphone:

three cardioids in the corners of a tetrahedron



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Sound field microphone:

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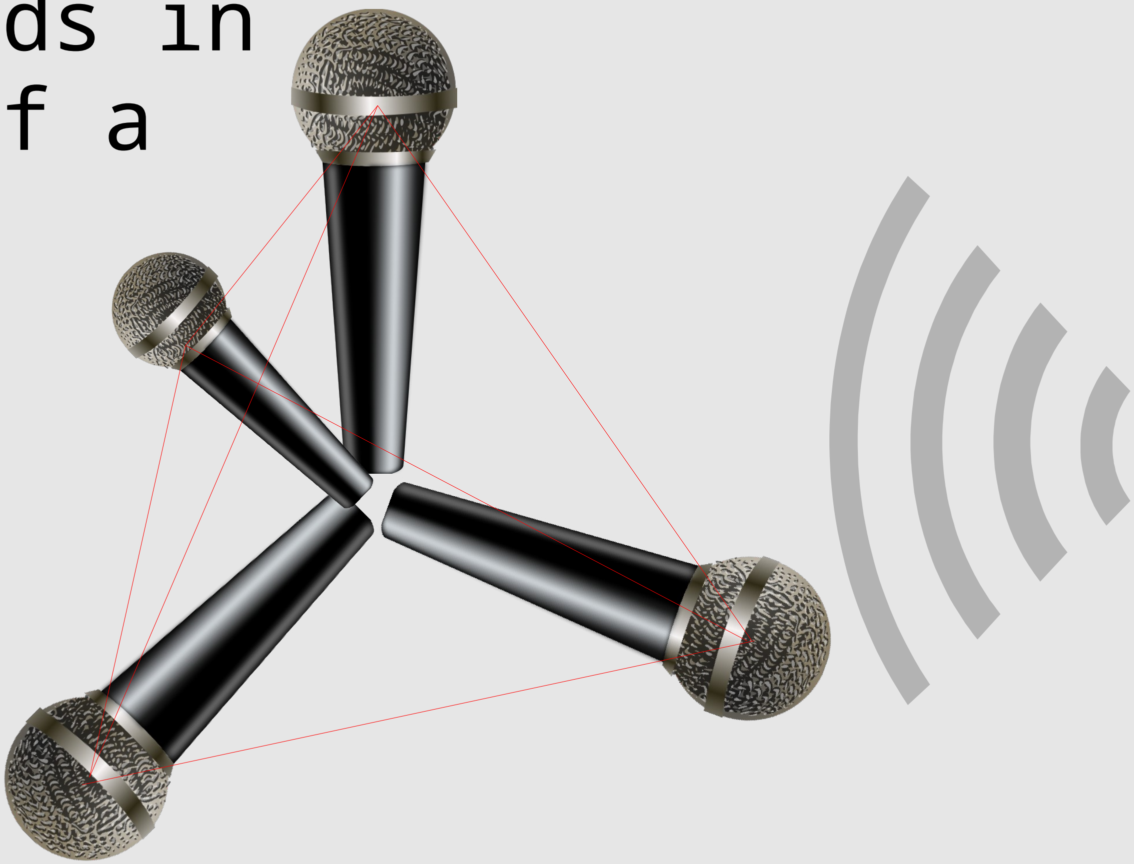
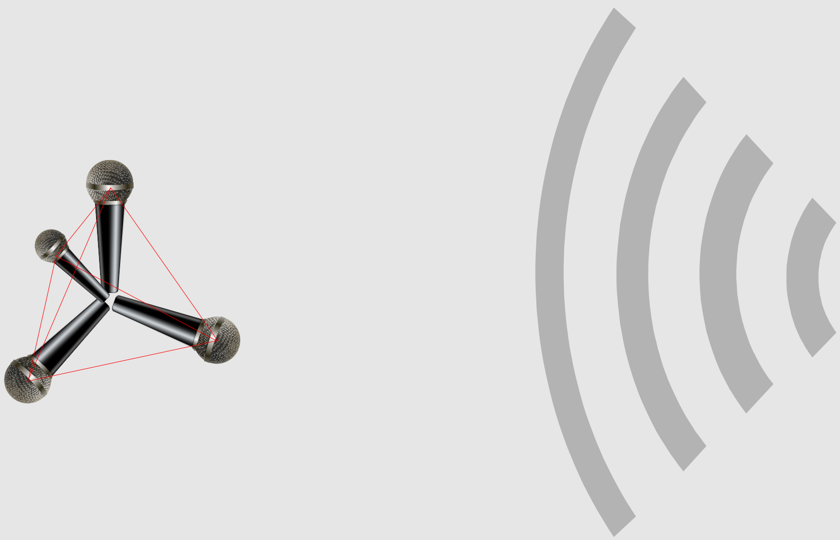


more uniform time errors in all directions

Sound field microphone:

works well when
you make the
array small



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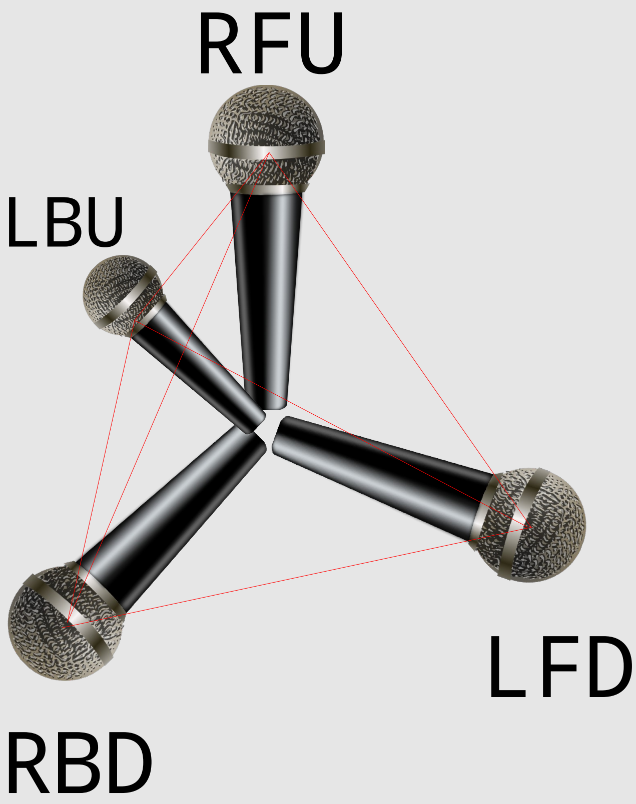
Sound field microphone:

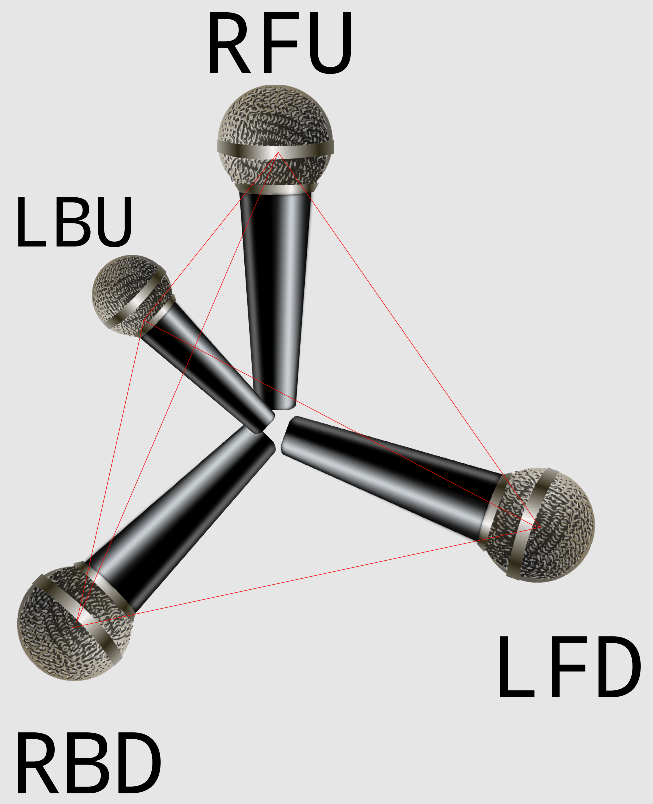
equivalent to
B-format:



Sound field microphone:

equivalent to
B-format:

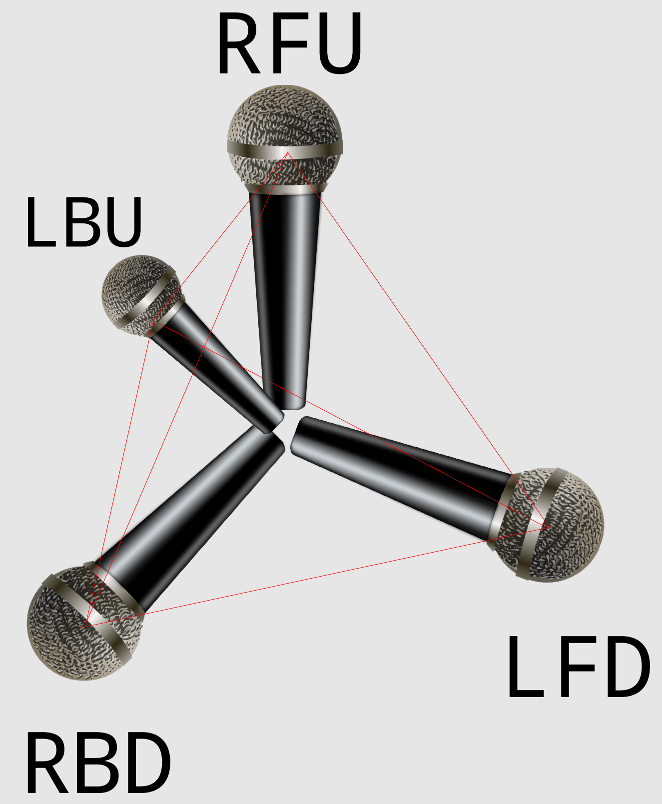
W = LFD + RFU + LBU + RBD



Sound field microphone:

equivalent to
B-format:

W =   LFD + RFU + LBU + RBD
X =   LFD + RFU – LBU – RBD



Sound field microphone:

equivalent to
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W =   LFD + RFU + LBU + RBD
X =   LFD + RFU – LBU – RBD
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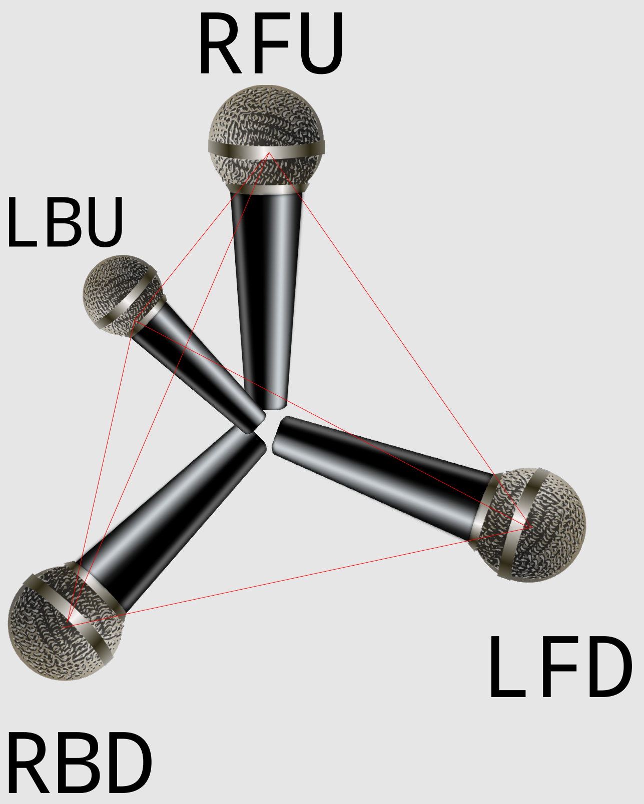
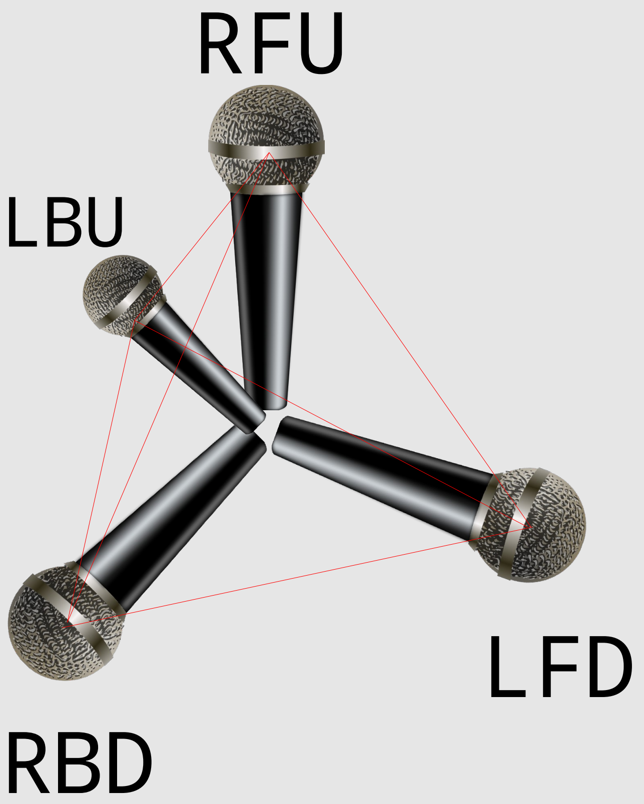


Sound field microphone:

equivalent to
B-format:

W = LFD + RFU + LBU + RBD
X = LFD + RFU – LBU – RBD
Y = LFD – RFU + LBU – RBD
Z = - LFD + RFU + LBU - RBD



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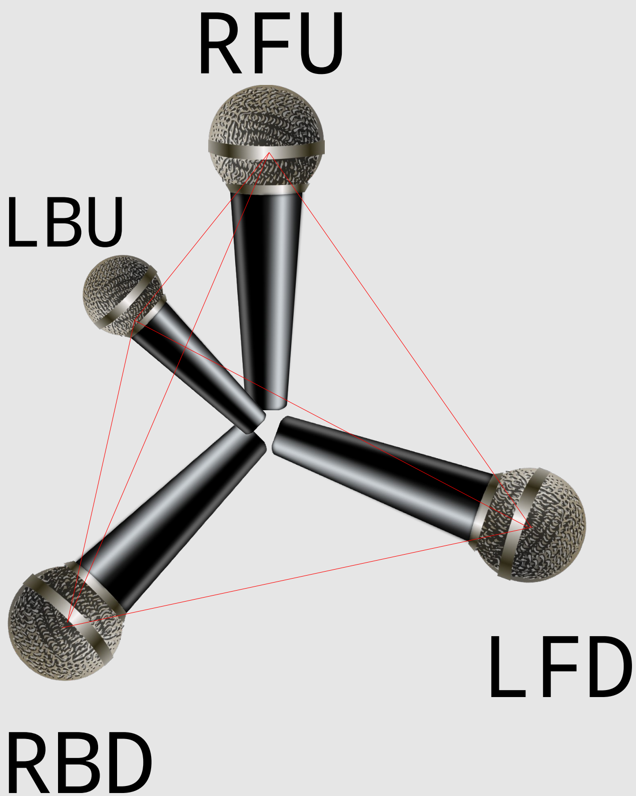

works because our approach is <u>systematic</u>!

Transmogrifying the B-format

Just as different microphone layouts can be converted to B-format, the B-format can be converted to different speaker layouts.

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Transmogrifying the B-format

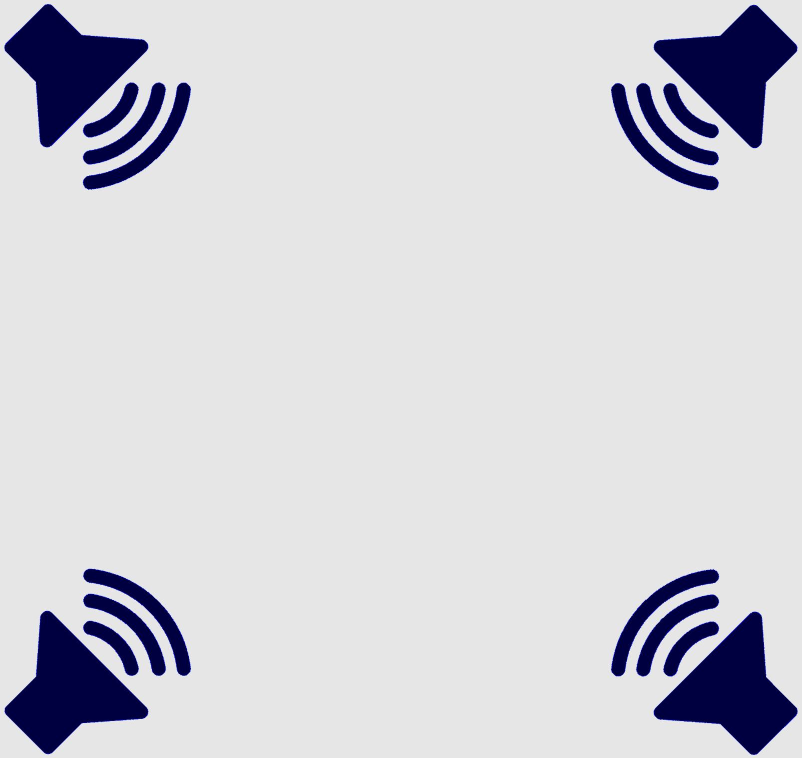
Just as different microphone layouts can be converted to B-format, the B-format can be converted to different speaker layouts.

(following examples slightly simplified)

Transmogrifying the B-format

B-format to square layout:

$$LF = W + X + Y$$
$$RF = W + X - Y$$
$$LB = W - X + Y$$
$$RB = W - X - Y$$



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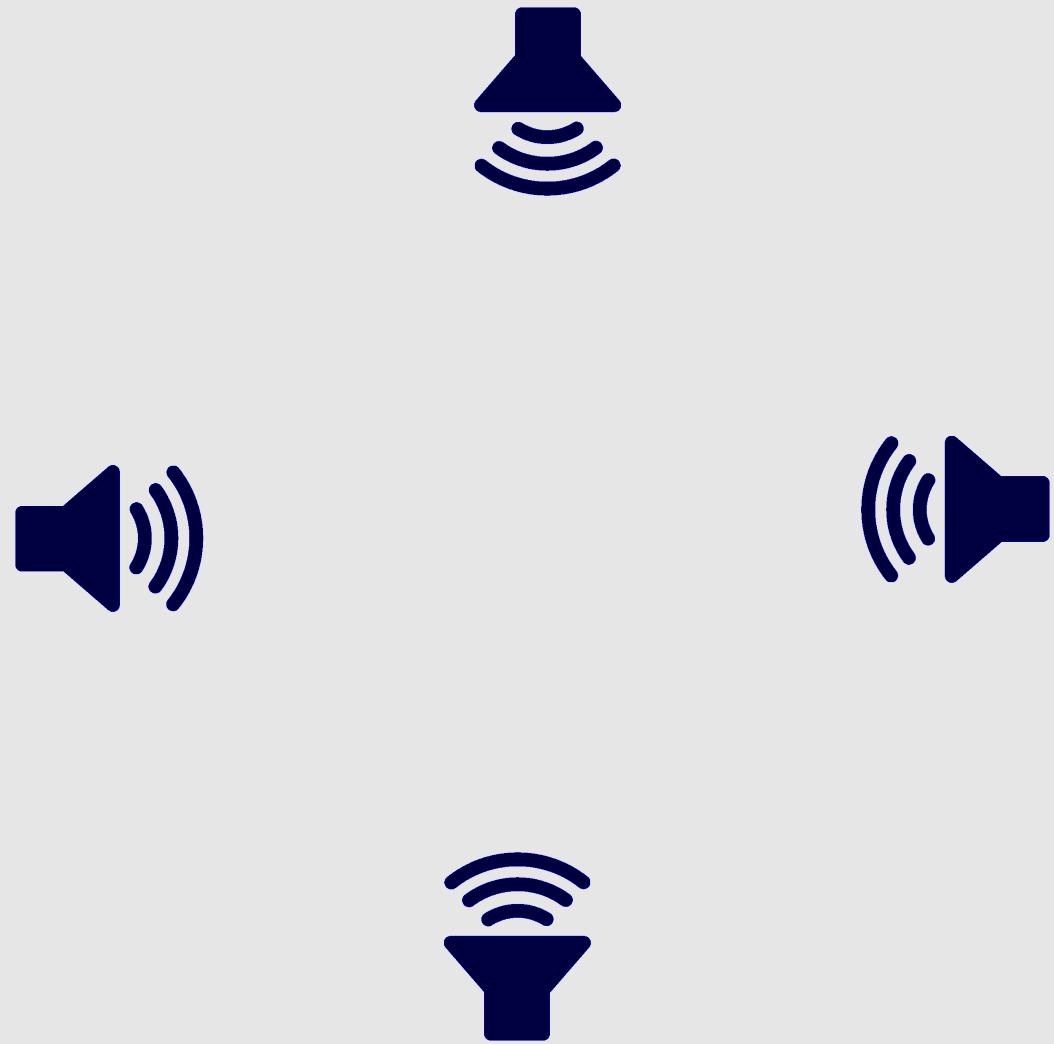
Transmogrifying the B-format

B-format to
diamond layout:

$$F = W + X$$
$$L = W + Y$$
$$R = W - Y$$
$$B = W - X$$



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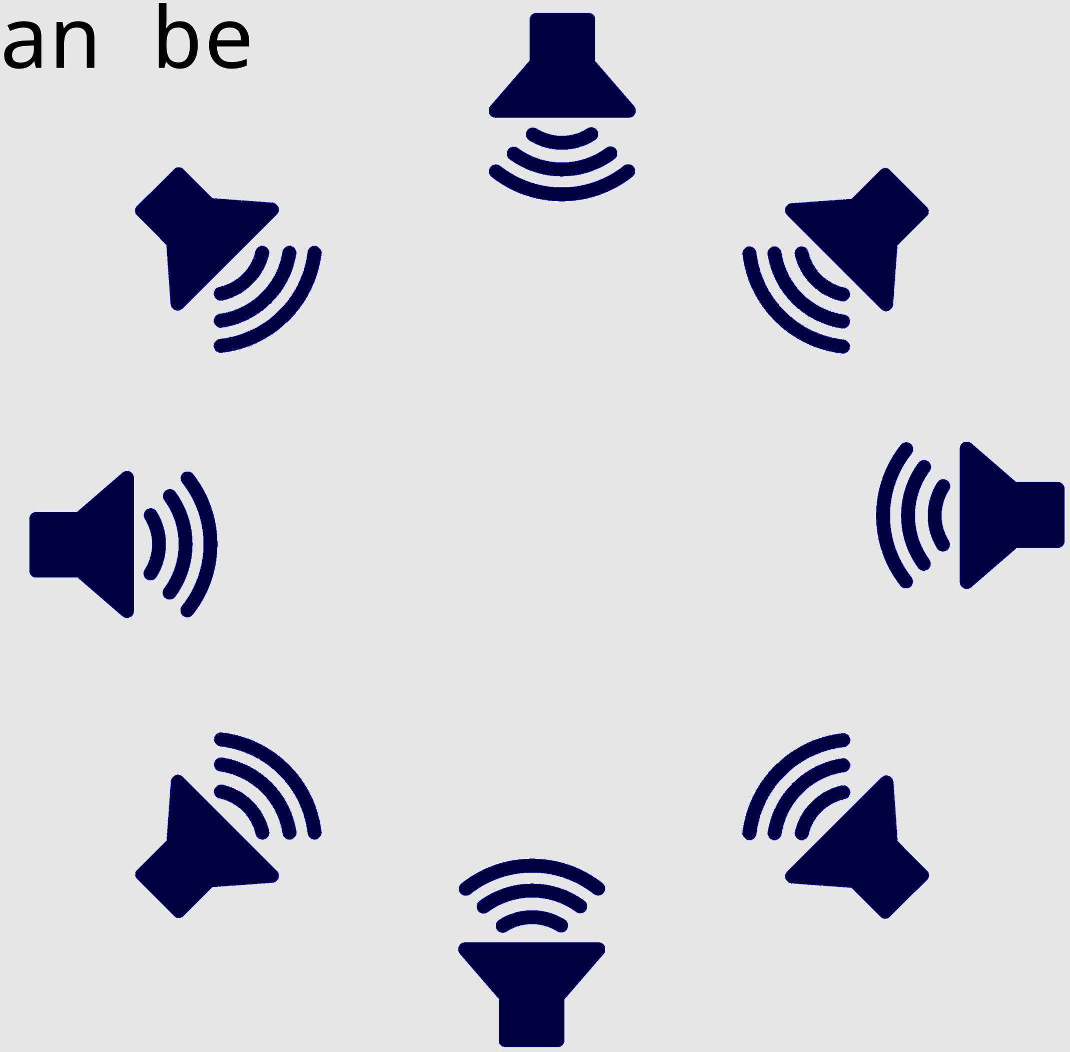
Transmogrifying the B-format

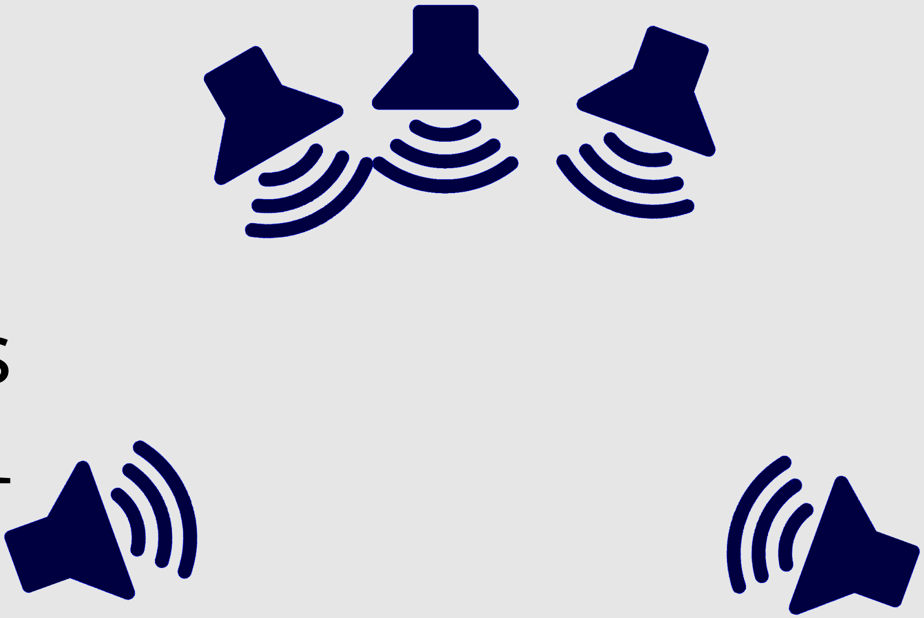
Other layouts can be derived using trigonometric functions and gain coefficients.



Transmogrifying the B-format

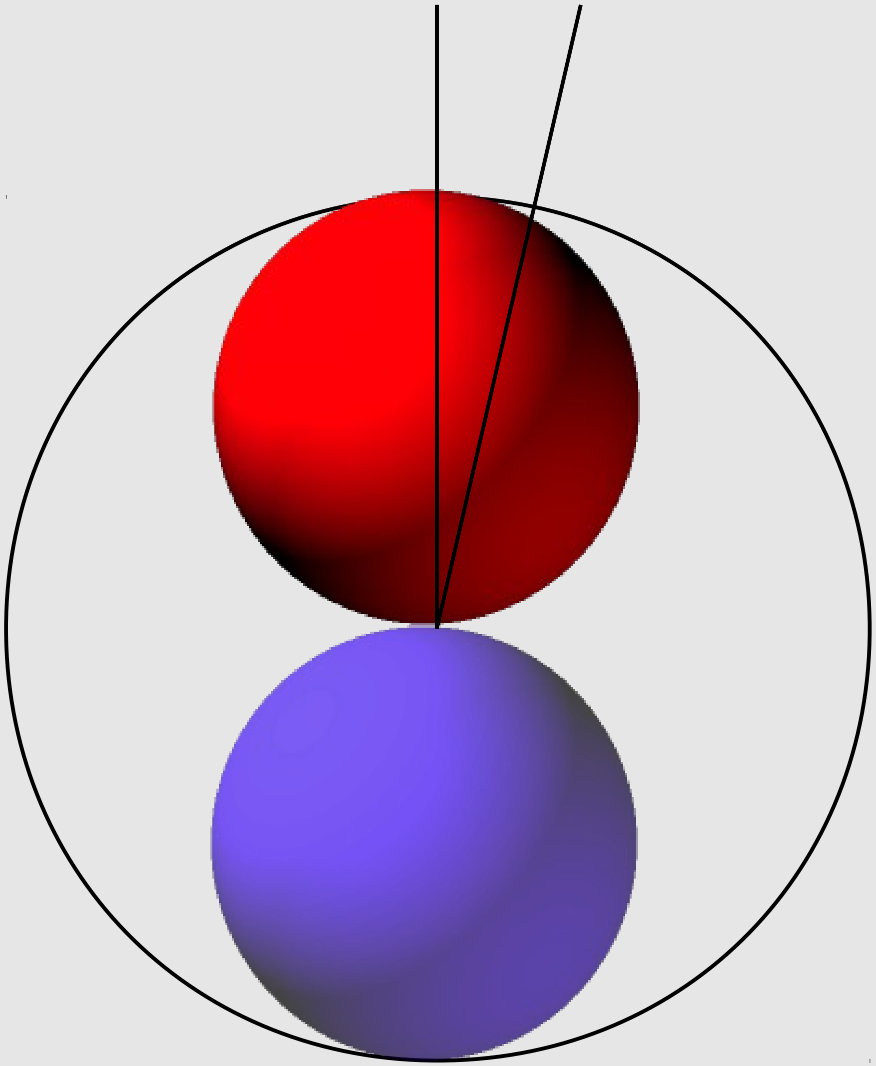
5.0 or stereo fold-downs work similarly.

Irregular layouts lose some spatial resolution and will introduce slight localisation errors.



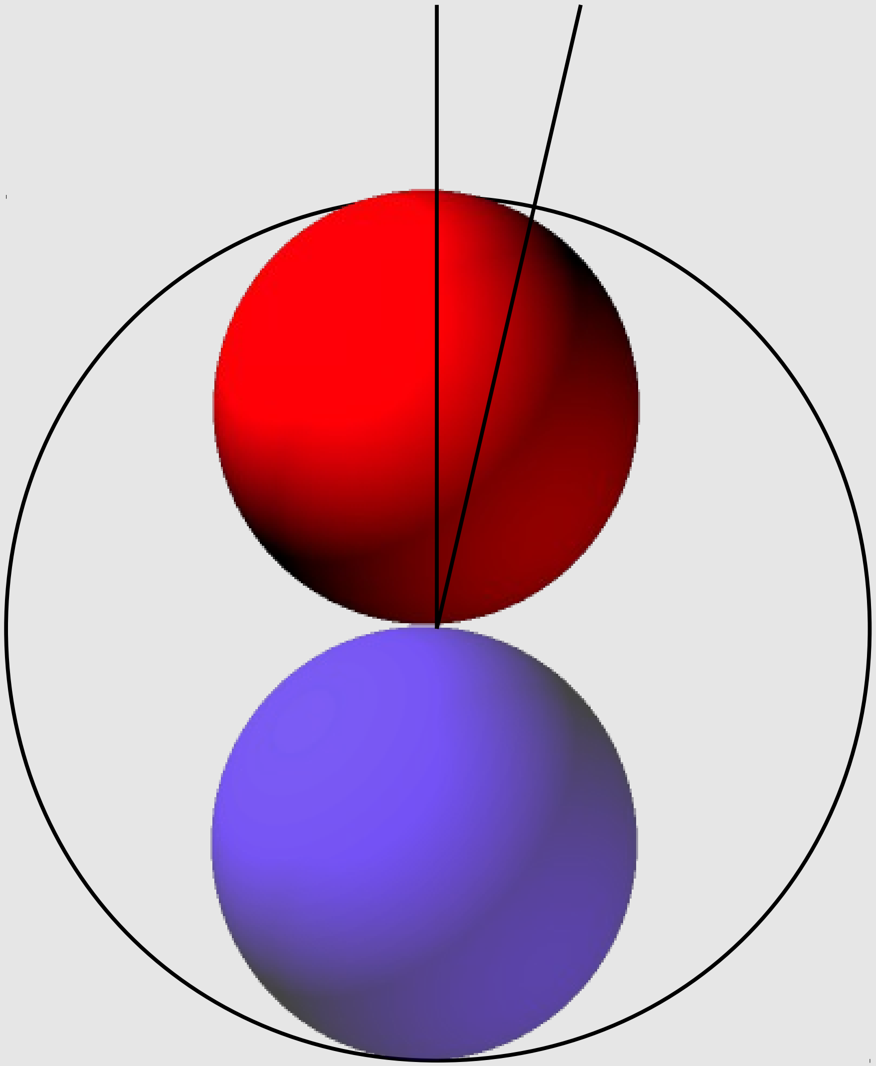
What's wrong with first-order Ambisonics?

What's wrong with first-order Ambisonics?



Low angular resolution: off-axis sources have a shallow roll-off.

What's wrong with first-order Ambisonics?



In practise, this means a small <u>sweet spot</u> (= listening area)

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So we need
narrower polar patterns
which also sample the sphere
uniformly and linearly independent

...

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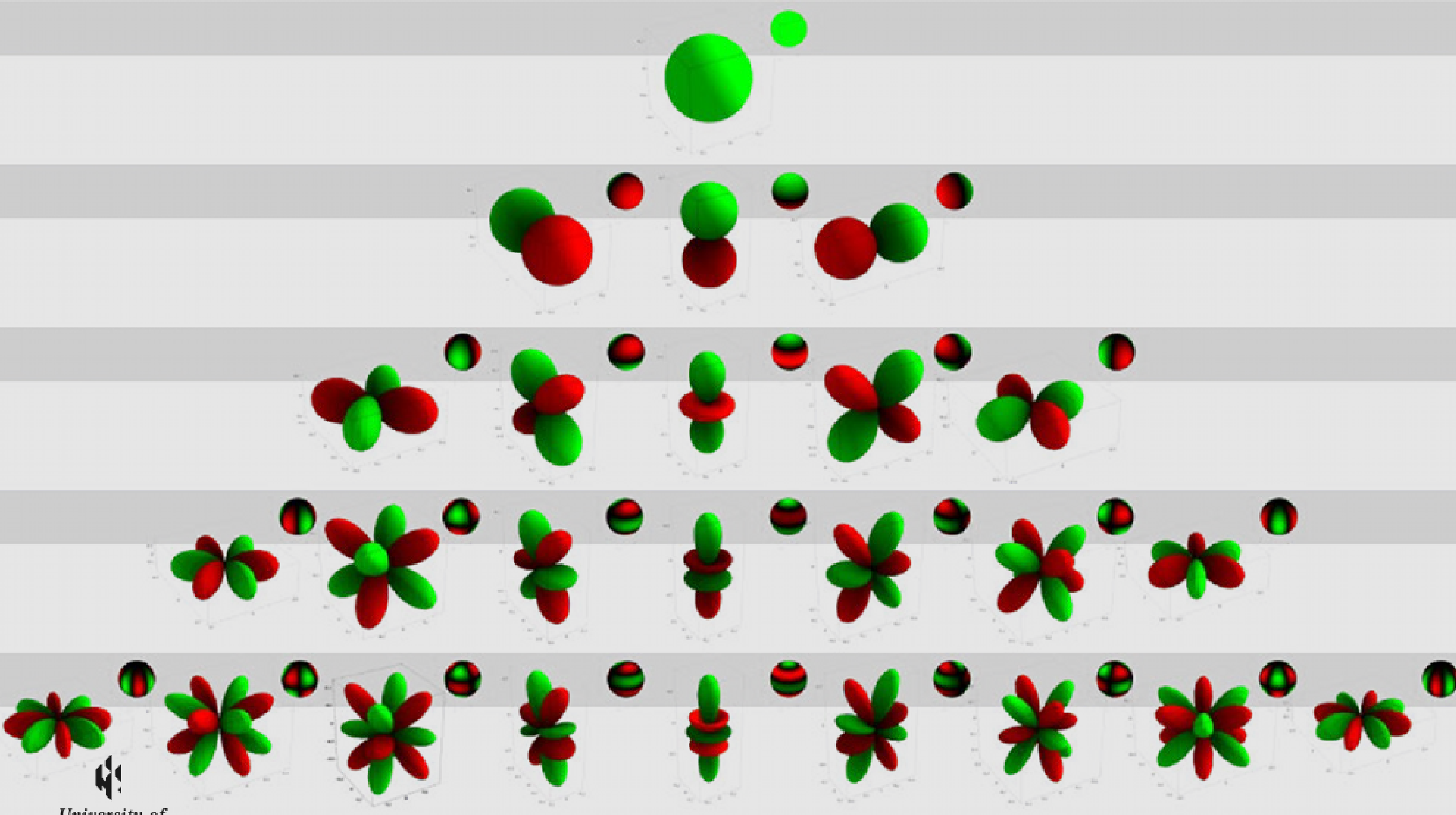
...and here they are:



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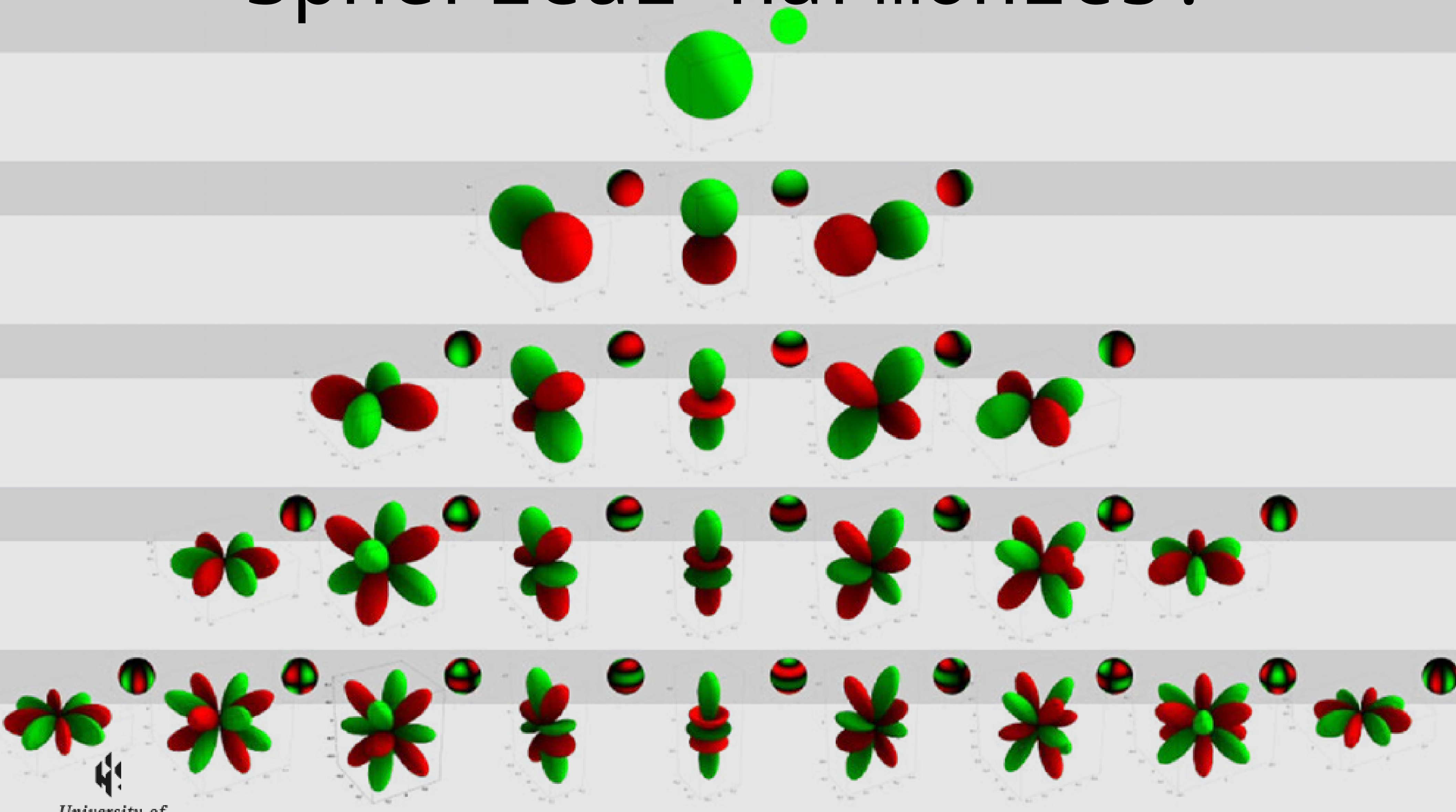
Ladies and Gentlemen: Spherical Harmonics!



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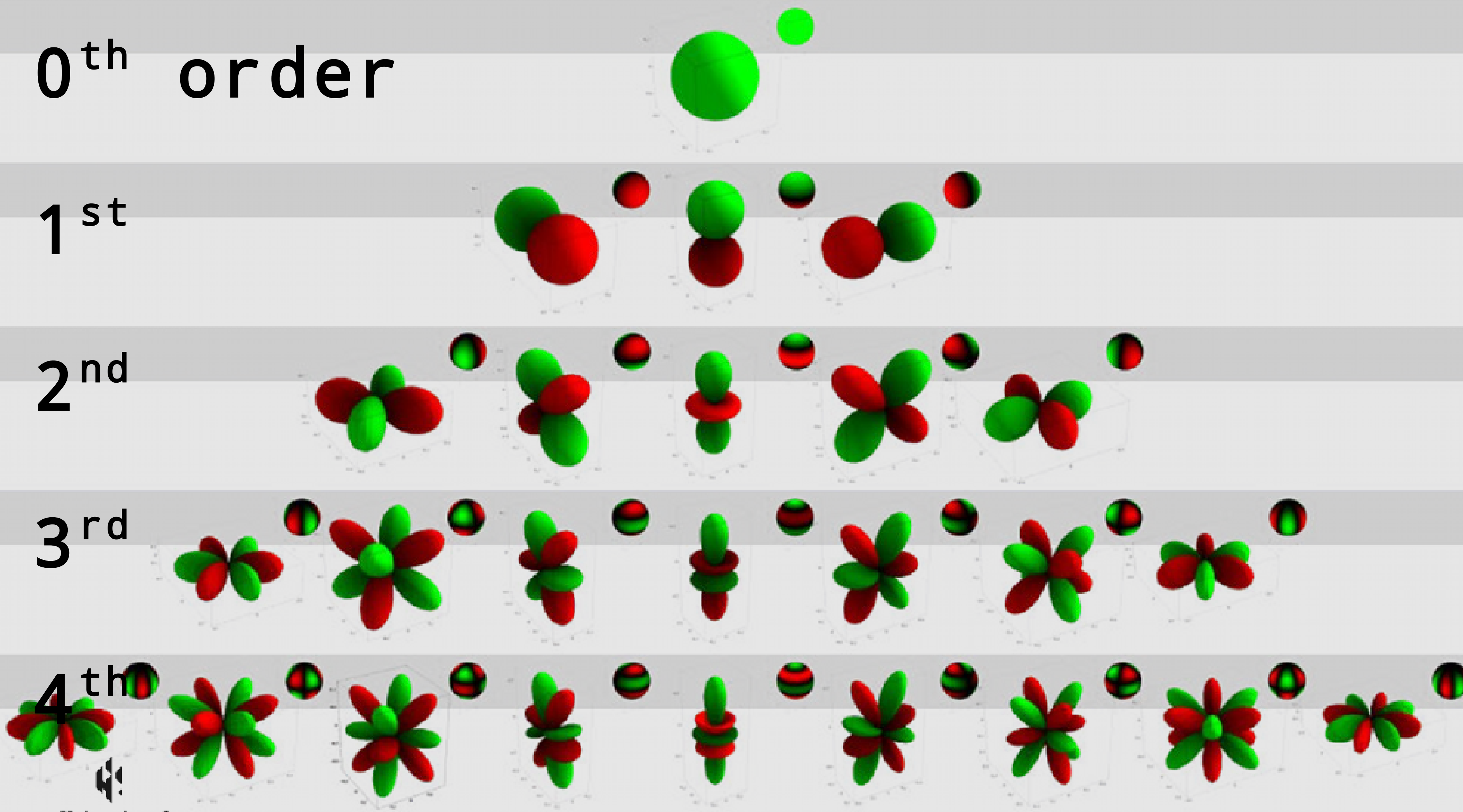
Higher-order Ambisonics



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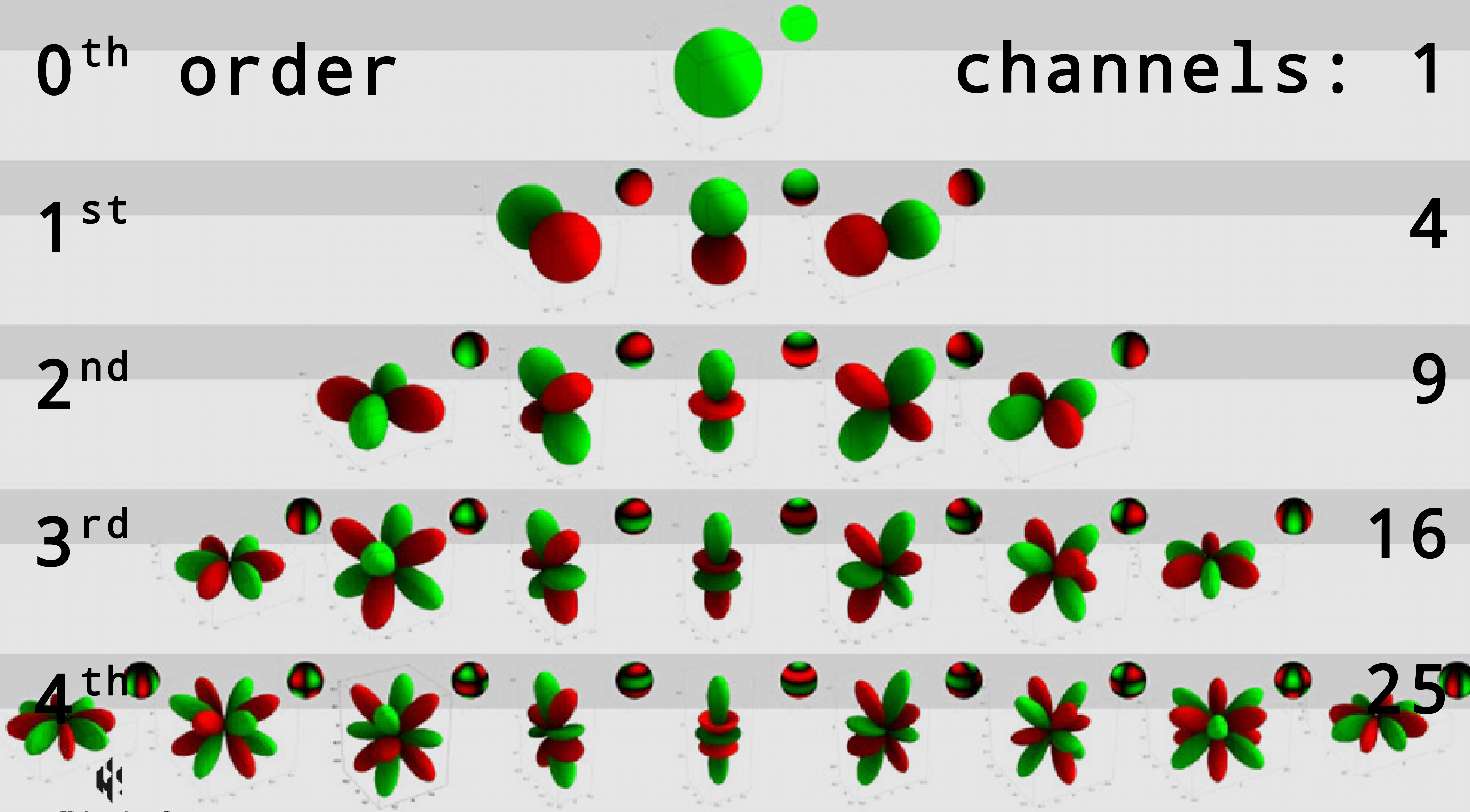
Higher-order Ambisonics



0th order	channels: 1
1st	4
2nd	9
3rd	16
4th	25

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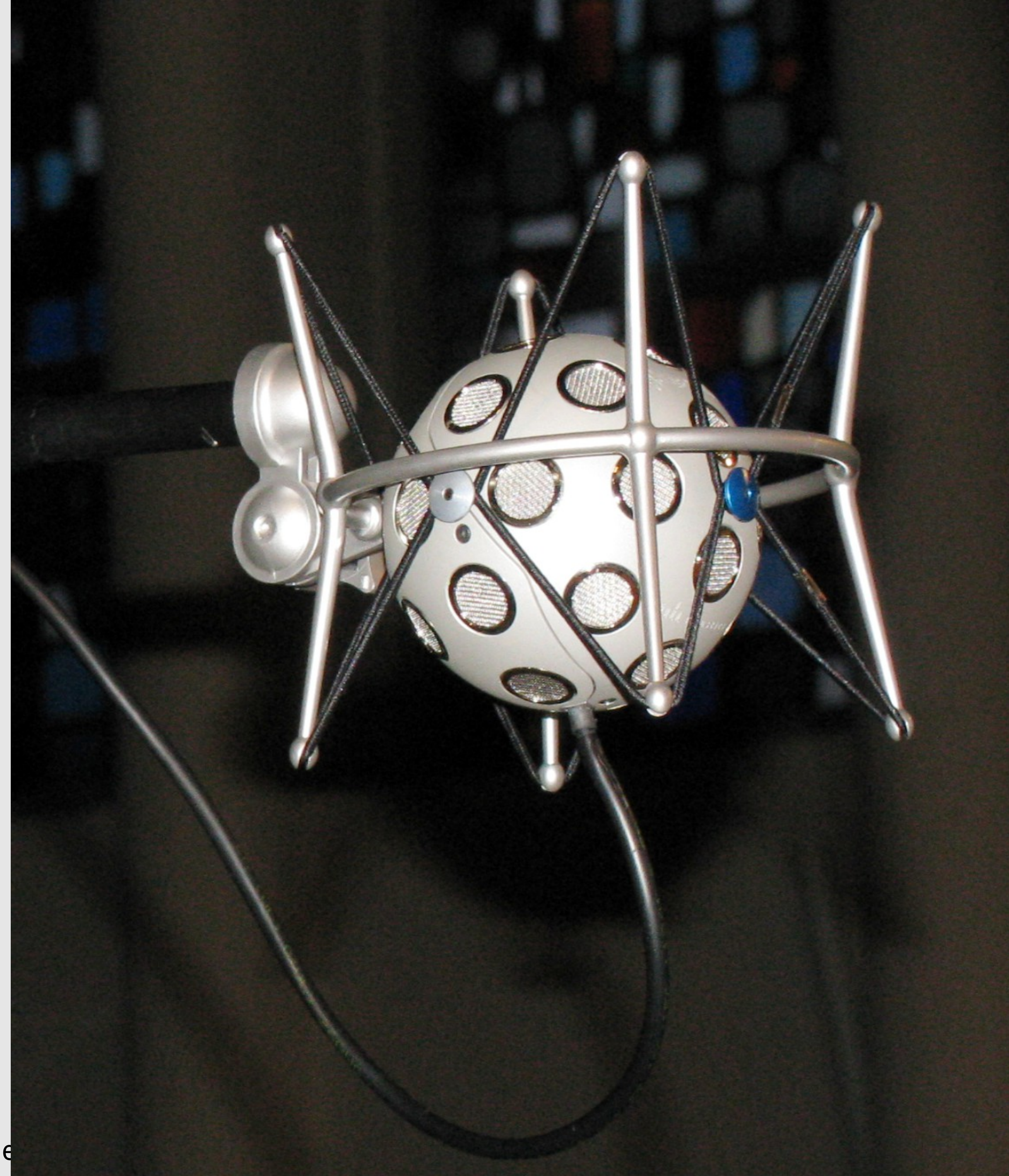
“Native” higher order microphones do not exist.

But we can use the same trick as the tetrahedral mic:



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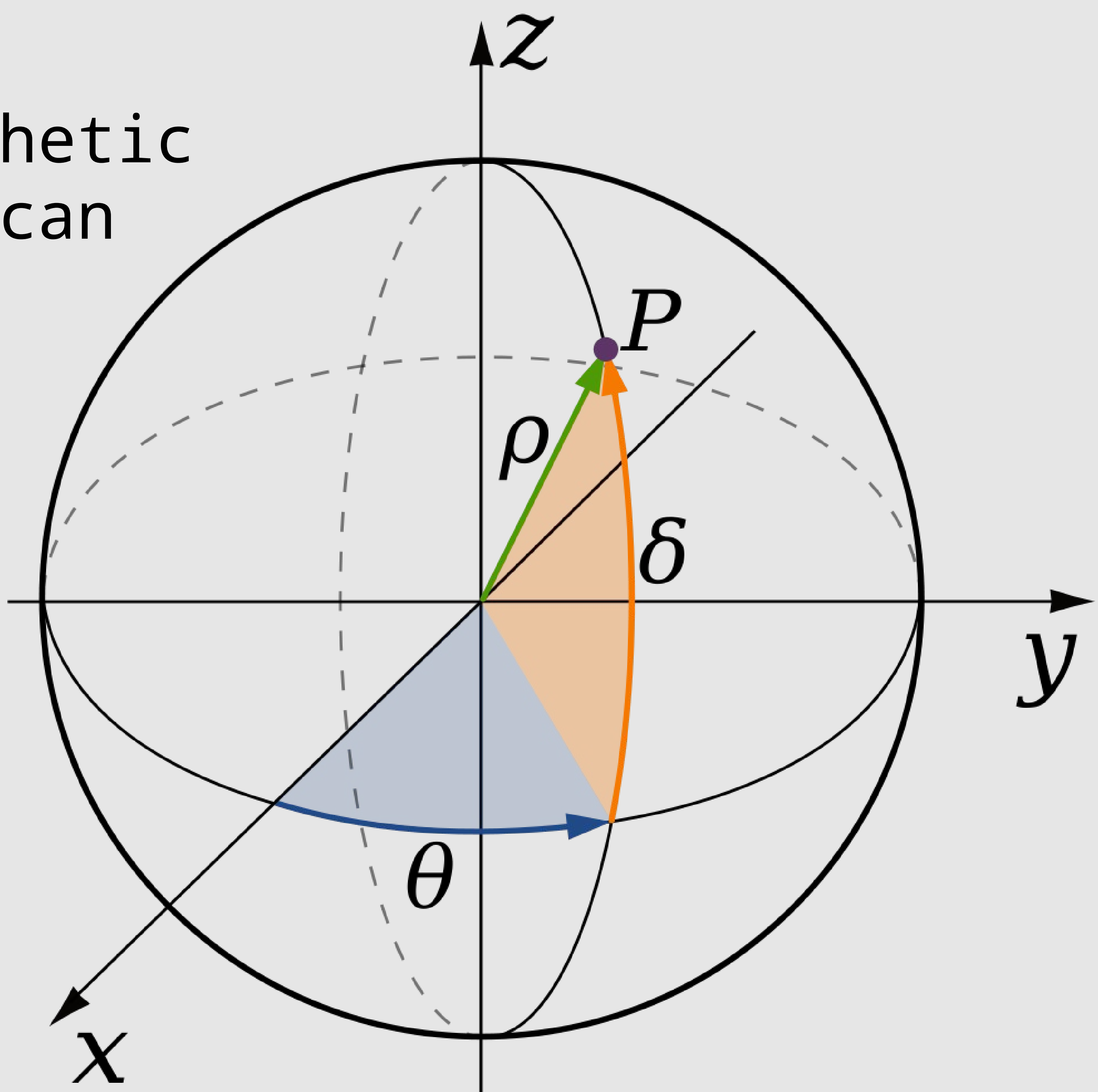
And for synthetic sources, we can use panning functions that yield higher-order components.



Higher-order Ambisonics

For reproduction, we need at least as many speaker as we have B-format channels, preferrably a few more.

$$N_{chans} = (order + 1)^2$$

$$N_{speakers} >= N_{chans}$$

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Using Ambisonics

Using Ambisonics

- Decide which order you want to work in (use the highest you can!).

Using Ambisonics

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- Your master bus will become B-format.

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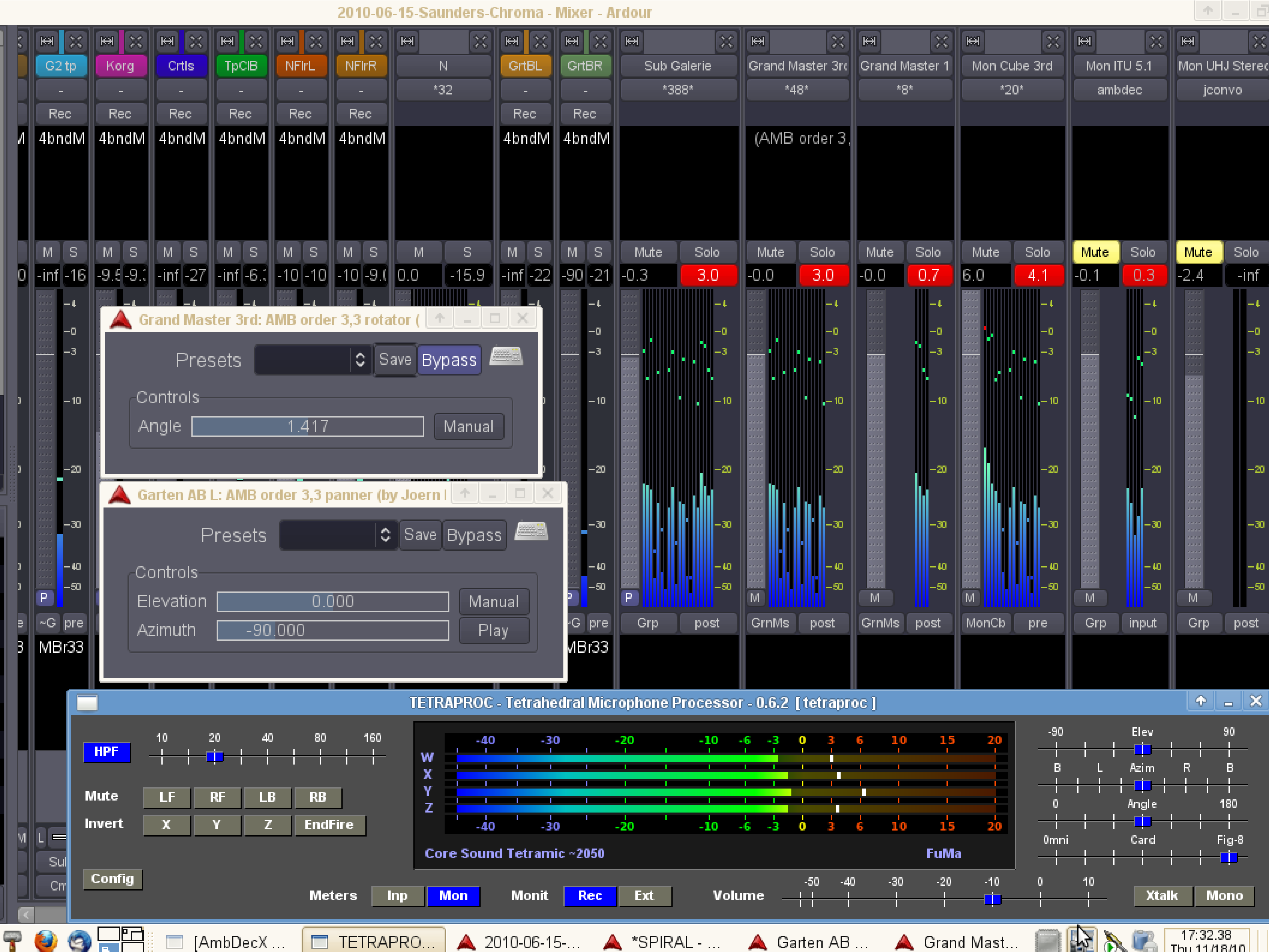
- Your master bus will become B-format.
- Your panners will become Ambisonic encoders.
- You deliver either native B-format or pre-decode for a given layout.

Using Ambisonics

Oh, and did I mention you can start composing with

height information

today?


2010-06-15-Saunders-Chroma - Mixer - Ardour
G2 tp
Korg
Crtls
TpClB
NFlrL
NFlrR
N
GrtBL
GrtBR
Sub Galerie
Grand Master 3rd
Grand Master 1
Mon Cube 3rd
Mon ITU 5.1
Mon UHJ Stereo
*32
388
48
8
20
ambdec
jconvo
Rec
4bndM
(AMB order 3,
Mute
Solo
Grand Master 3rd: AMB order 3,3 rotator (
Presets
Save
Bypass
Controls
Angle
1.417
Manual
Garten AB L: AMB order 3,3 panner (by Joern I
Elevation
0.000
Azimuth
-90.000
Play
Grp
post
GrnMs
MonCb
pre
input
MBr33
TETRAPROC - Tetrahedral Microphone Processor - 0.6.2 [tetraproc]
HPF
Mute
LF
RF
LB
RB
Invert
X
Y
Z
EndFire
Config
W
Core Sound Tetramic ~2050
FuMa
Elev
Azim
Angle
Omni
Card
Fig-8
Meters
Inp
Mon
Monit
Rec
Ext
Volume
Xtalk
Mono
[AmbDecX ...
TETRAPRO...
2010-06-15-...
*SPIRAL - ...
Garten AB ...
Grand Mast...
17:32.38


Thanks for your attention!
Any questions?

Acknowledgements:

Polar pattern graphs:
Wikimedia Commons
Microphone, kid w/ phones, grand piano and speaker clipart:
openclipart.org
Spherical harmonics chart:
Robin Green, Spherical Harmonic Lighting:The Gritty Details, 2003