

Practical Ambisonics

Enrique Tomás & Manu Mitterhuber



This presentation was created in May 2023 for the workshop developed at Musrara School of Arts and Society in Jerusalem.

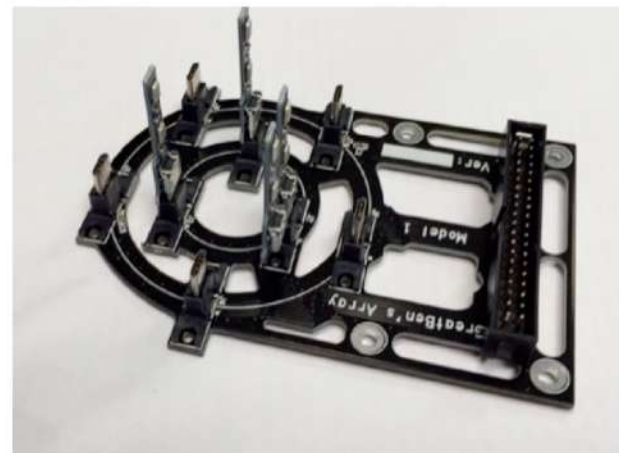
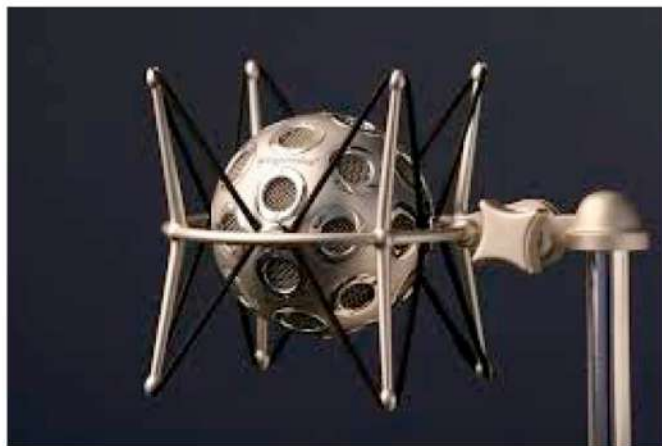
It contains screenshots of IEM Ambisonic Plugins and images from the open access book *Ambisonics: A Practical 3D Audio Theory for Recording, Studio Production, Sound Reinforcement, and Virtual Reality* by Franz Zotter and Matthias Frank published at Springer. These images are reproduced for educational use only.

Spatial Audio

*Can
we capture it?*

*Can we
reproduce it?*

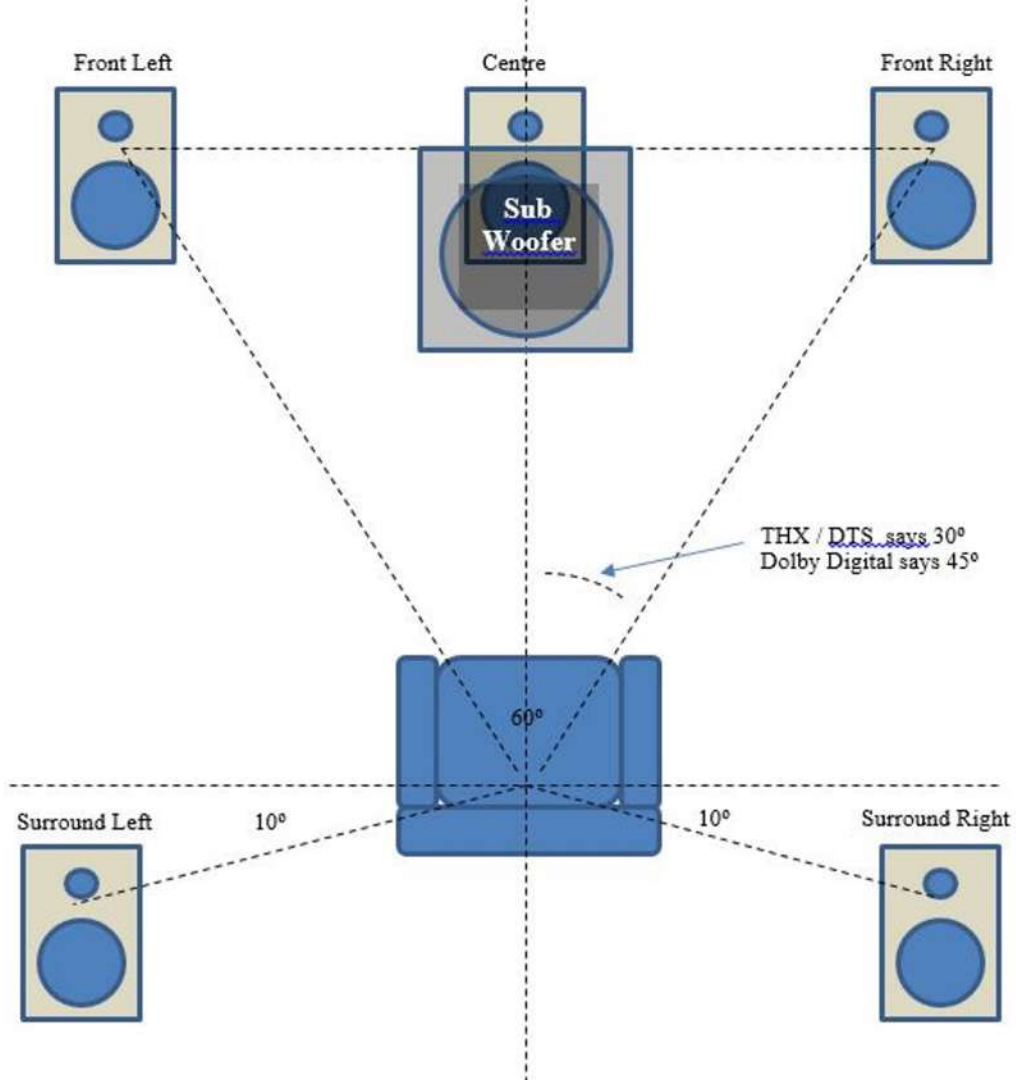




(a)

(b)

(c)





Dealing with Spatial Audio: Approaches

→ Channel Based

A channel-based mix, usually for a specific target loudspeaker

→ Object Based

Encoding each audio source independently with positional metadata, and letting the renderer at the reproduction side position the audio as best it can to the desired location.





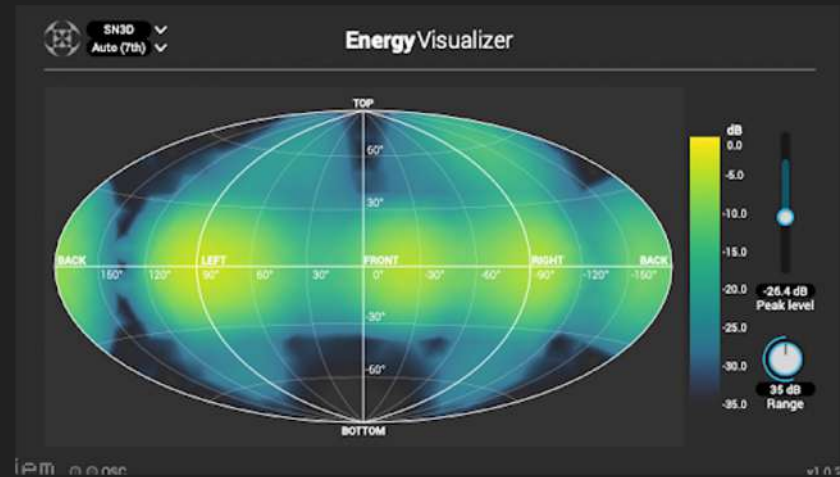
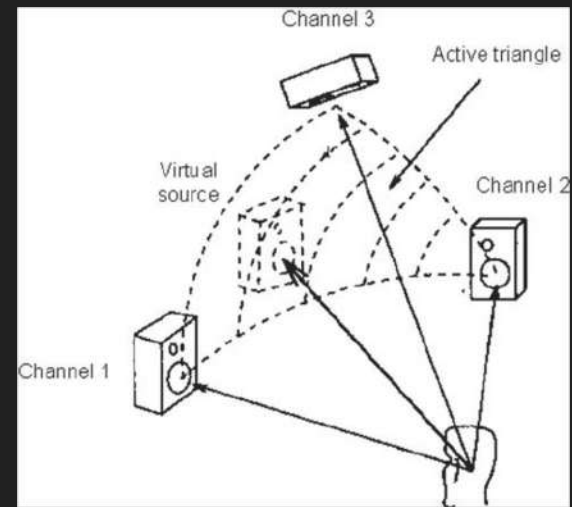
Modern Spatial Audio Renderers (Panners)

→ **VBAP** (Vector based amplitude panning)

Interaural level difference (ILD) based on triangles. Only three speakers are used at maximum.

→ **Ambisonic Panning**

The audio scene is modelled as a sphere (non-preferred direction). There is always sound played in all speakers.



Find the differences between
these renderers



Energy Spread

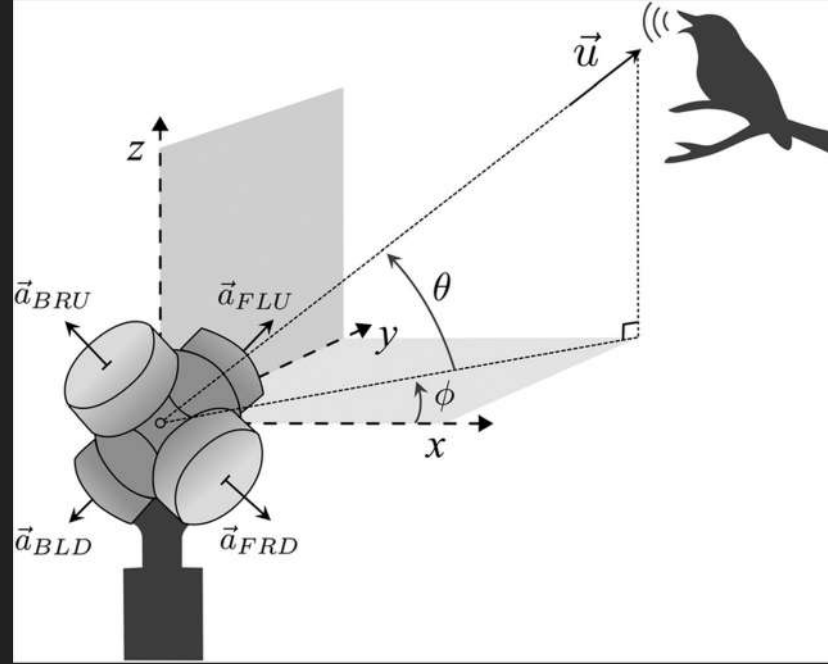
- VBAP maximizes sound accuracy at the expense of variability of the energy spread: it is maximal at the middle of a loudspeaker triangle.
- Ambisonics has a constant energy spread regardless of the source direction. The lower the ambisonic order, the greater the spread.



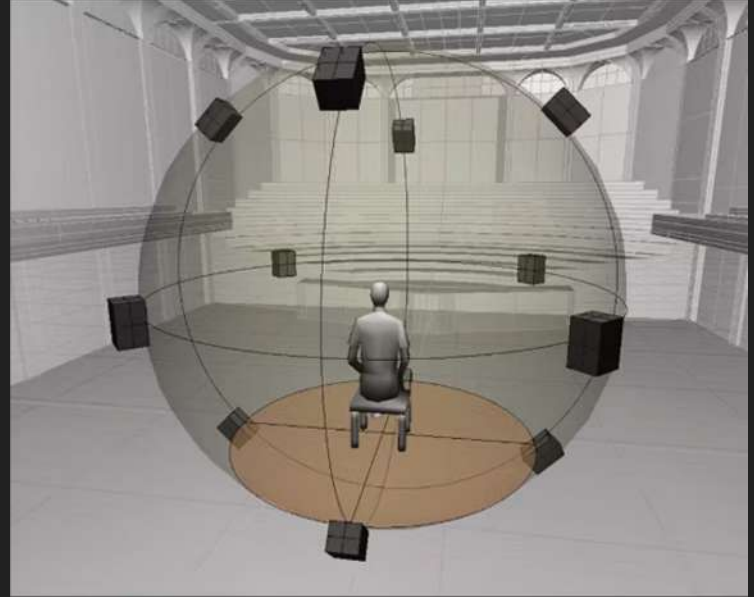
Playback Systems

- VBAP renderers need to know all speakers positions. They output the actual audio to be played at each of the speakers.
- The ambisonics signal is decoupled from the playback system. Audio is encoded in an intermediate format which is independent from speaker layouts. Playback requires a decoder to transform this ambisonic format to the final audio for each speaker.

Why encoding? For capturing a spatial soundfield in a way which is independent from playback layouts

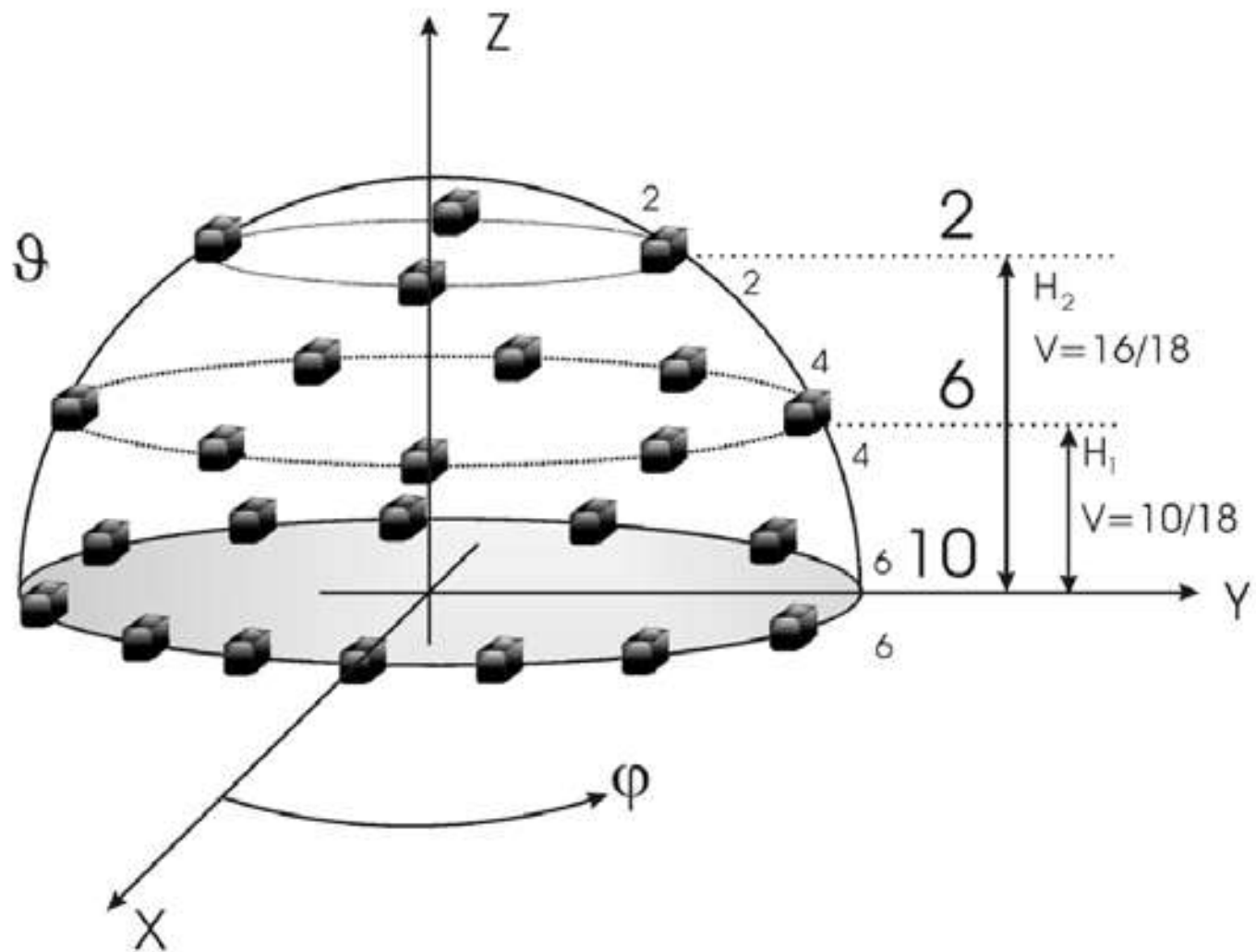


We can compose music independently from the speaker layout where it will be played.



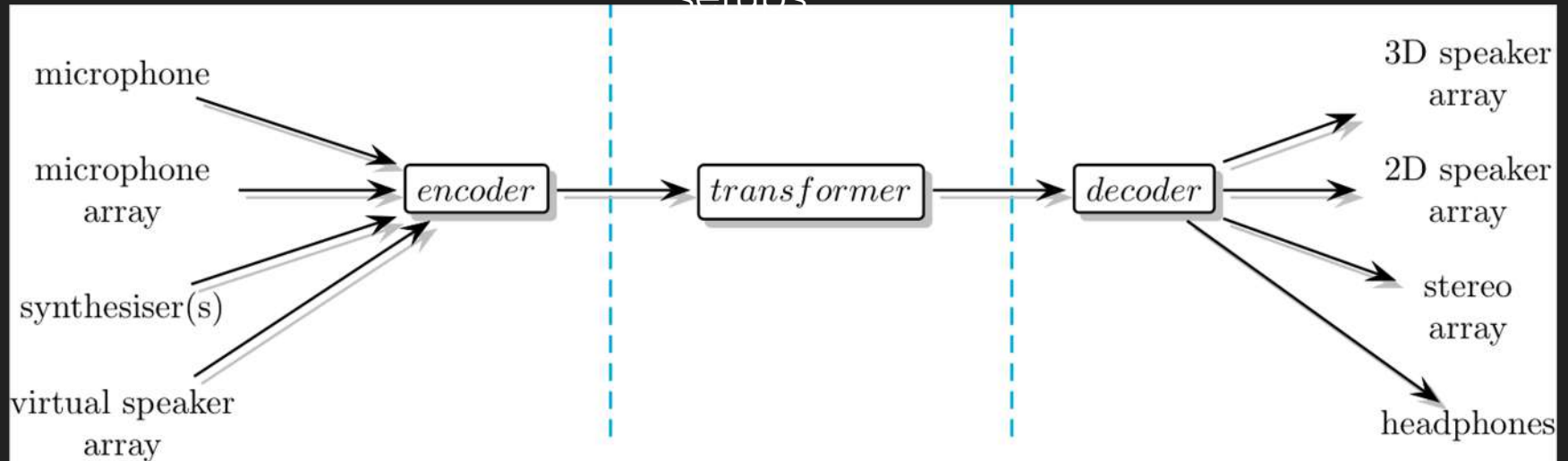
Which layouts?
Ambisonics benefit from spherical and
isomorphic layouts, but not necessarily...



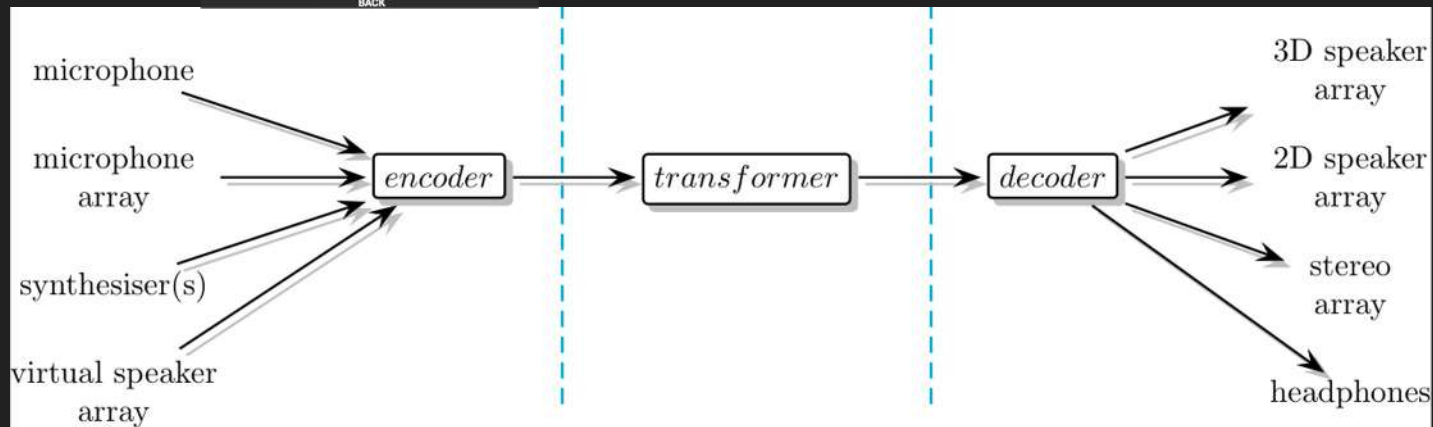
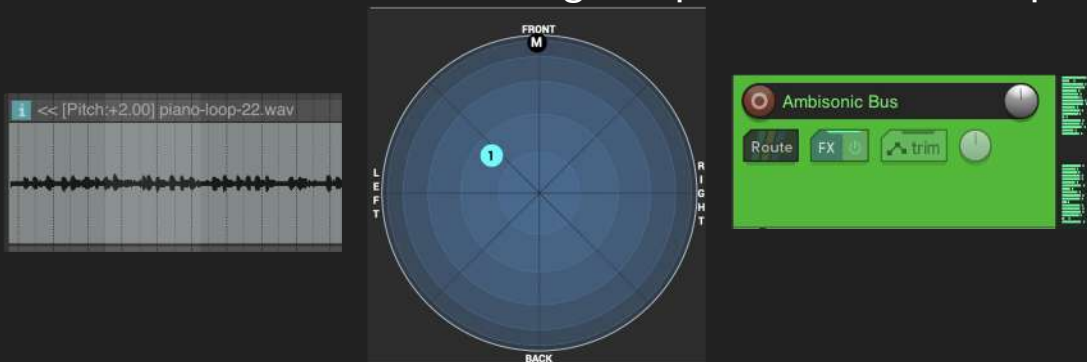


Ambisonics Workflow

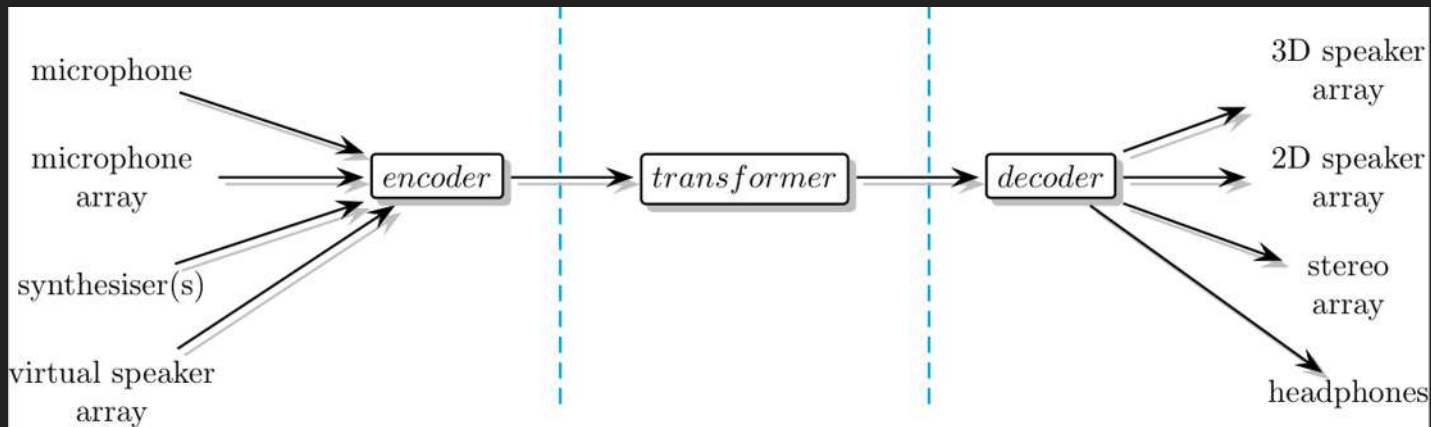
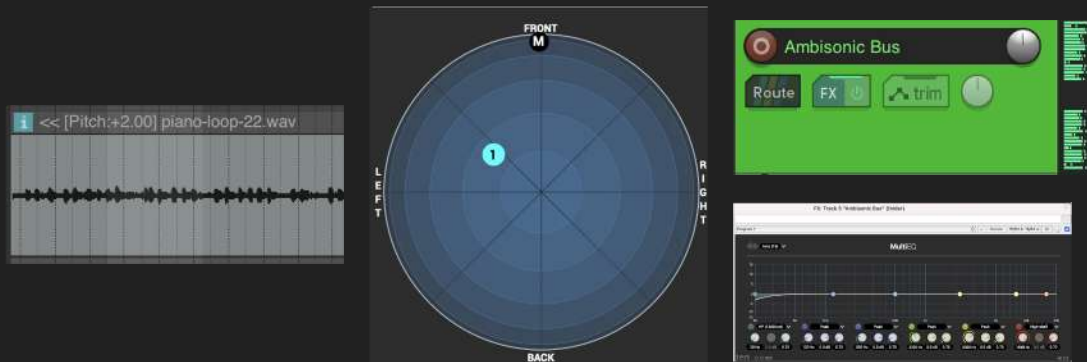
Audio contents are first encoded in ambisonic format and later decoded to a particular speaker layout. Therefore, we produce ambisonic scenes which can be played at different setups



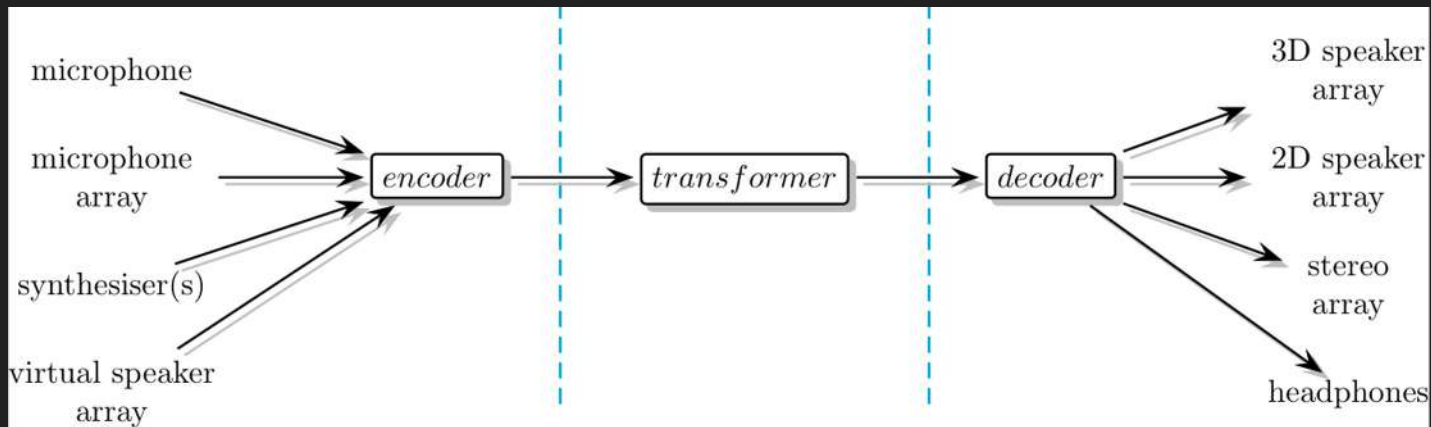
The ambisonics encoded audio scene is the decomposition of an audio signal into a number of spherical directions. For example, here a mono track is encoded at a position in space (see blue sphere) resulting into a 25 channels audio signal. That means the mono file is encoded using 24 spherical directions plus an omni channel.



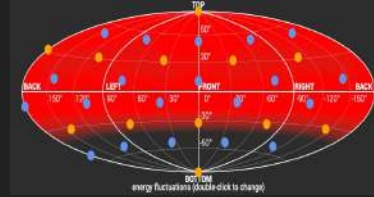
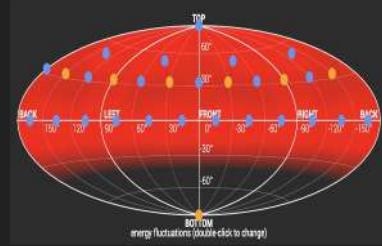
The transformer can be any **ambisonics effect or processing**: reverbs, EQ, rotations, spread effects, room effects, etc which are **applied to the ambisonics signal** (not to the signal we will decode later).



The number of ambisonics audio channels usually does NOT coincide with the number of speakers used (output channels). It depends on the ambisonic order. Here we add a decoder for rendering the output audio channels to be played at the actual speaker layout.



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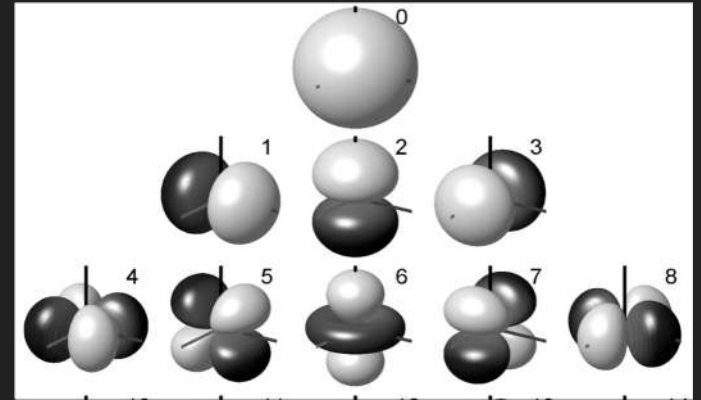
Spatial Order

We can define the number of spatial directions in the ambisonics mix. The smaller the order, the more “pixelated” our spatial resolution will be.

Ambisonics sounds good if order is 3 or bigger.

Spatial Order

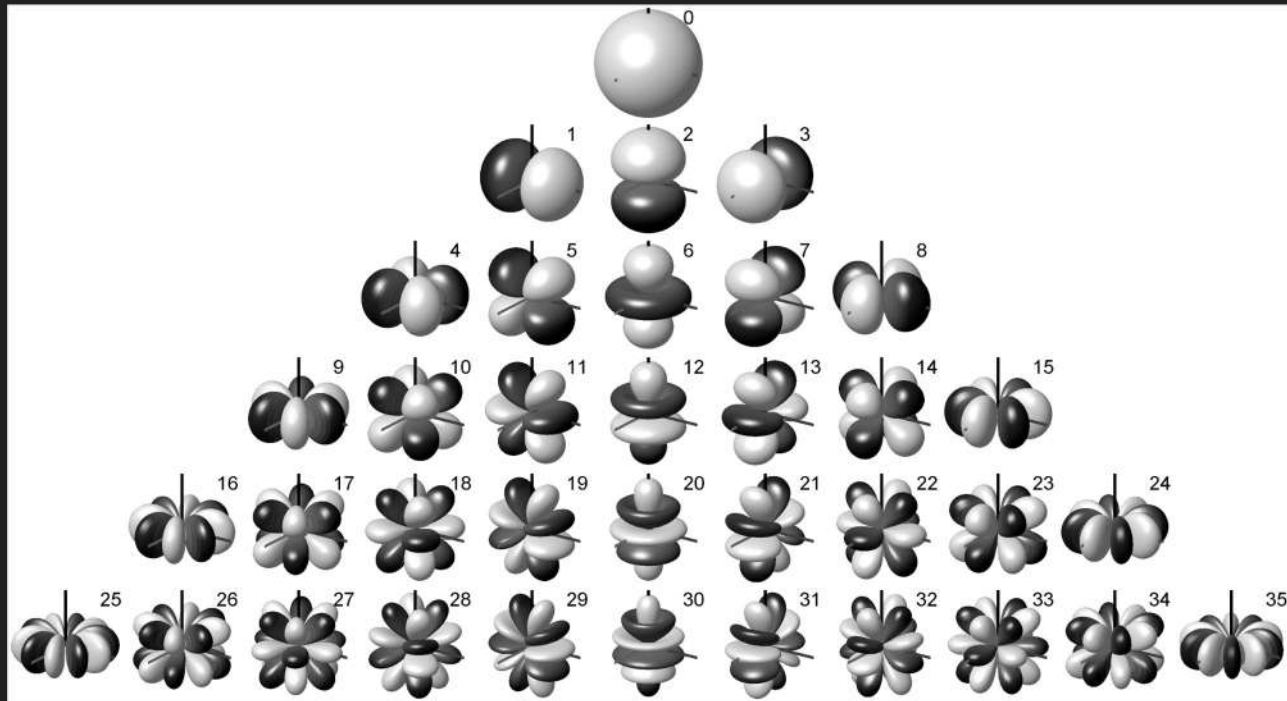
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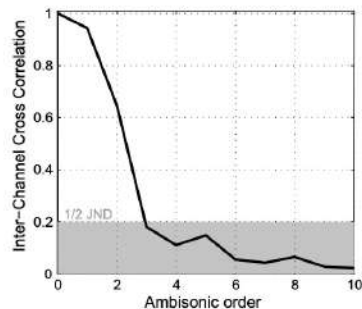


Spatial Orders

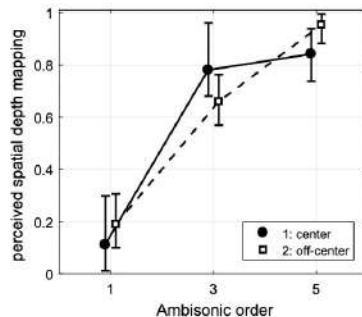
Higher Order:

decomposition into more spatial directions (harmonics)





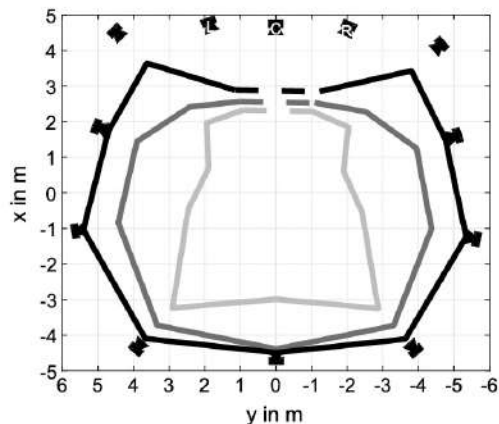
(a) Inter-channel cross correlation of two Ambisonically driven loudspeakers spaced by 60°



(b) Perceived depth in dependence of Ambisonics playback order for two listening positions

Fig. 1.21 Relation between the Ambisonic order, decorrelation, and perceived depth

Fig. 1.22 Perceptual sweet area of Ambisonic playback from the front at first (light gray), third (dark gray), and fifth order (black). It marks the area in which the perceived direction is plausible, i.e., does not collapse into a single loudspeaker other than C



To remember

→ Spatial harmonics

The more spatial harmonics (the higher the order), the less “spatially pixelated” your soundfield will be.

→ Which order?

We would love to use 1000th order but we do not count with pragmatic software or hardware. From 4th order or more (HOA – High Order Ambisonics), the quality improves substantially.

→ Number of channels pro Order

Formula: $(\text{order} + 1)^2$
i.e. 4th order = 25 channels

Spatial Orders

Extending the M-S format

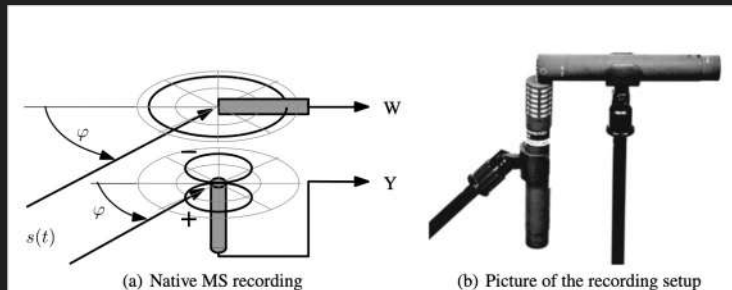


Fig. 1.2 Native mid-side recording with the coincident arrangement of an omnidirectional microphone heading front and a figure-of-eight microphone heading left

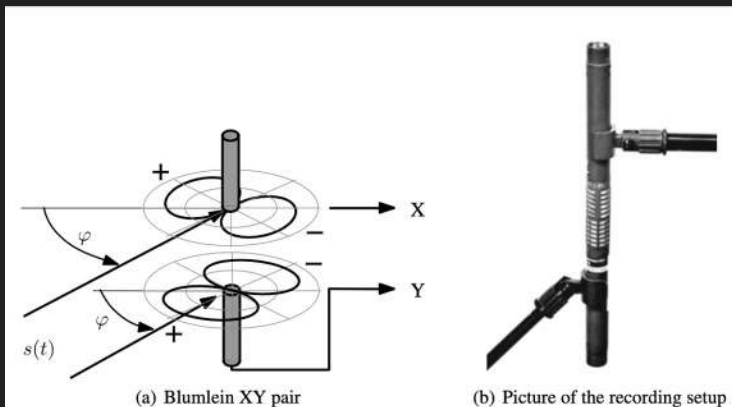


Fig. 1.1 Blumlein pair consisting of 90°-angled figure-of-eight microphones

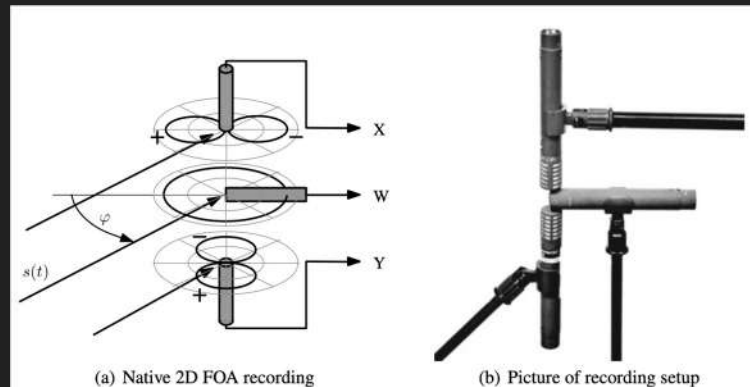


Fig. 1.5 Native 2D first-order Ambisonic recording with an omnidirectional microphone heading front, and a figure-of-eight microphone heading left; photo shown on the right

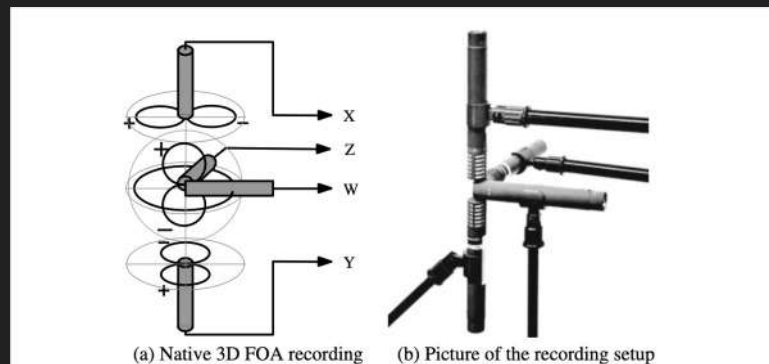
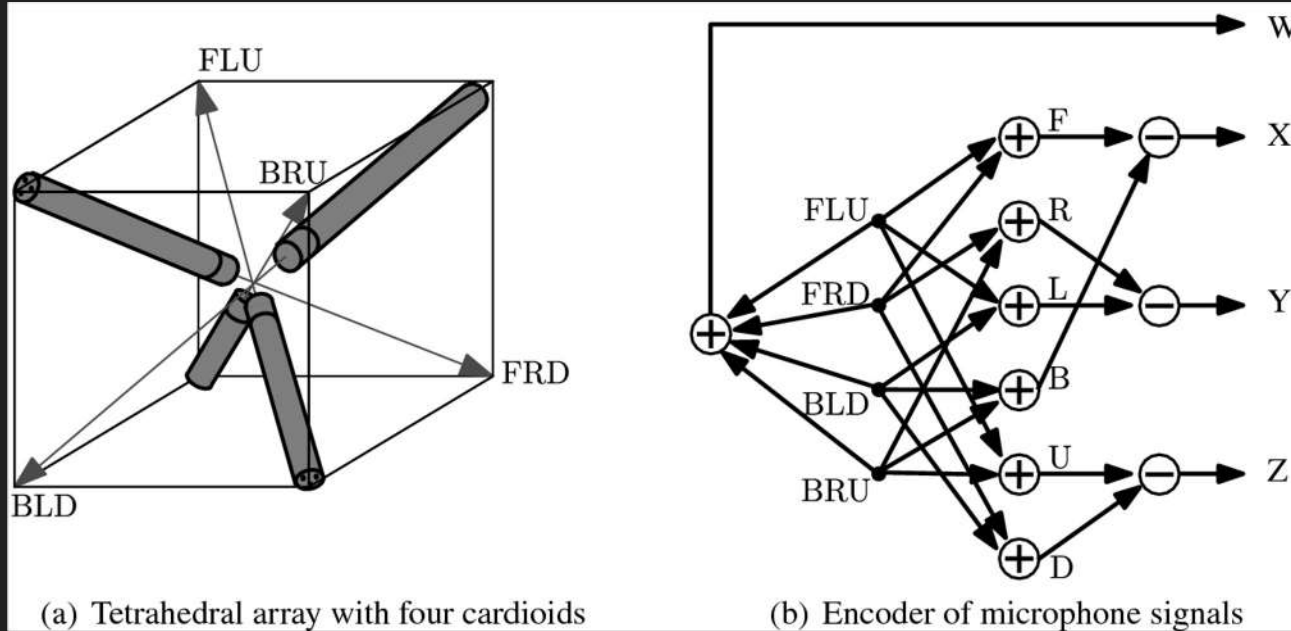


Fig. 1.10 Native 3D first-order Ambisonic recording with an omnidirectional and three figure-of-eight microphones aligned with the Cartesian axes X, Y, Z

Spatial Orders

Relationships between order and channels



Result: **4 channels** -> three spherical axis X, Y, Z plus an omnidirectional component W ->> First Order Ambisonics

Spatial Orders

Example First Order: decomposition in three spatial directions



(a) Tetrahedral array of 4 cardioids



(b) SPS200



(c) MK4012



(d) ST450

Result: 4 channels -> three spherical axis X, Y, Z plus an omnidirectional component W

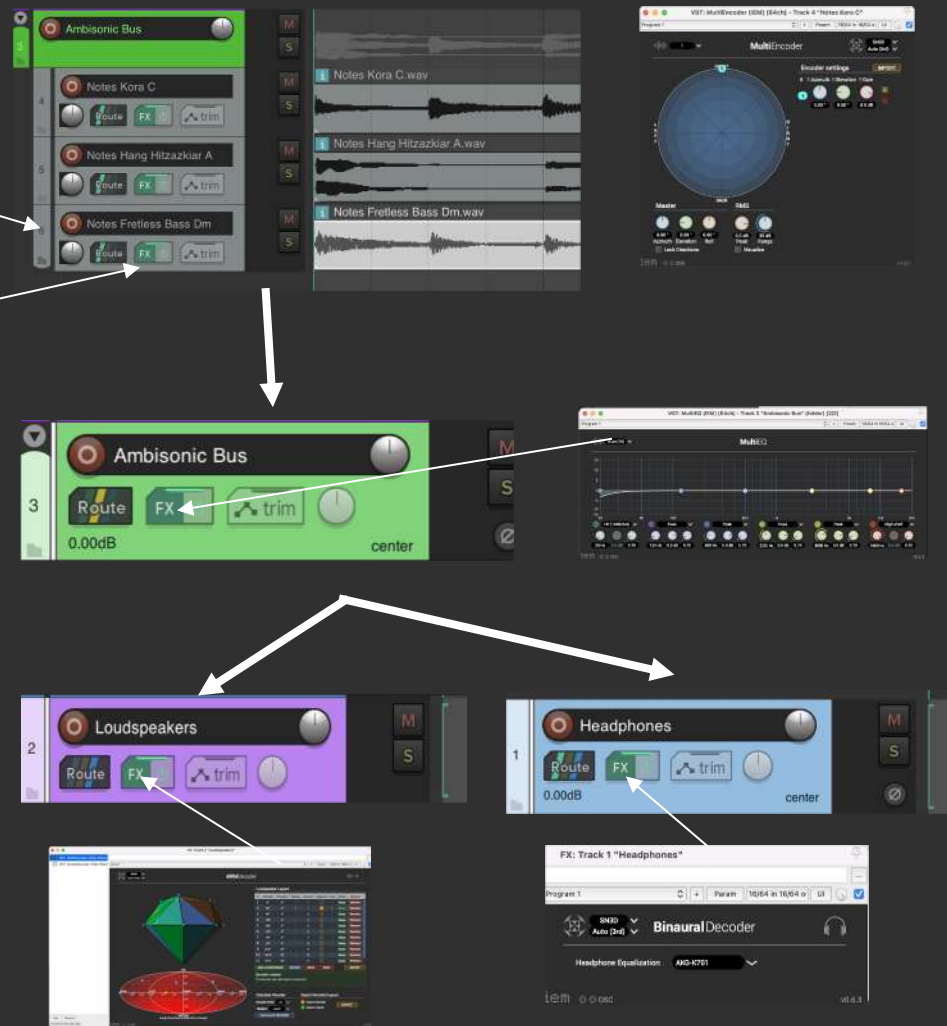
Let's practice ambisonics!

Open Reaper and the example project



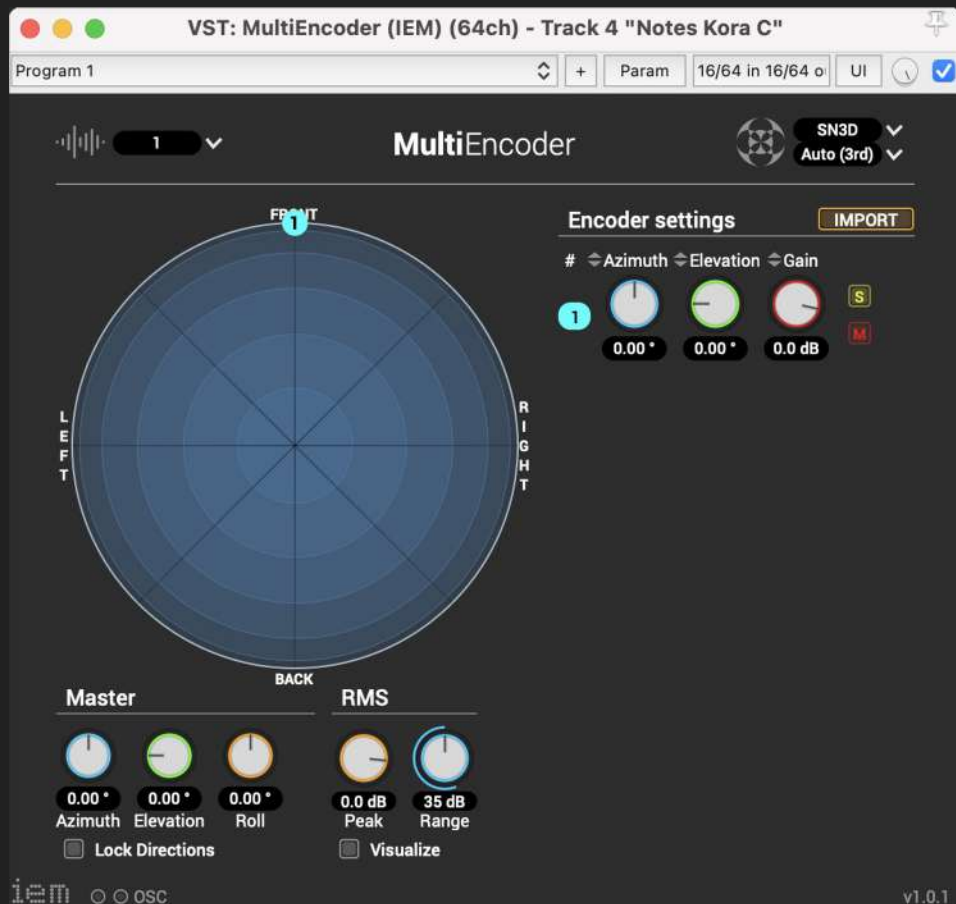
Workflow Encoder-Decoder

- Add “source” tracks as children of the **Ambisonics Bus** (mono /stereo/ multichannel)
- Each “source” track must have its MultiEncoder VST in FX.
- The “**Ambisonics Bus**” track receives and mixes all source tracks which are already ambisonic after their MultiEncoders.
- At the “**Ambisonics Bus**” you can add ambisonics effects (reverb, compression, EQ, etc).
- The “**loudspeakers**” track receives audio channels from the “**Ambisonics Bus**” and decodes them to the actual speaker rig.
- The “**Binaural Decoder**” track receives from the “**Ambisonics Bus**” and produces binaural decoded version of the mix.



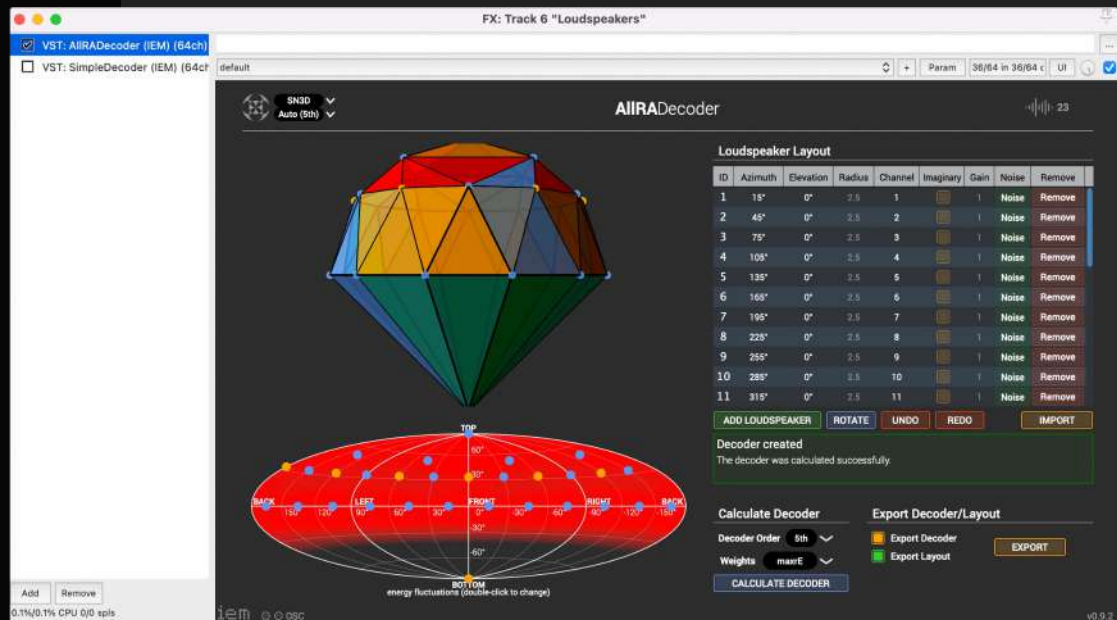
Using the Encoder

- Select number of sound sources
- Select SN3D format and the ambisonics order



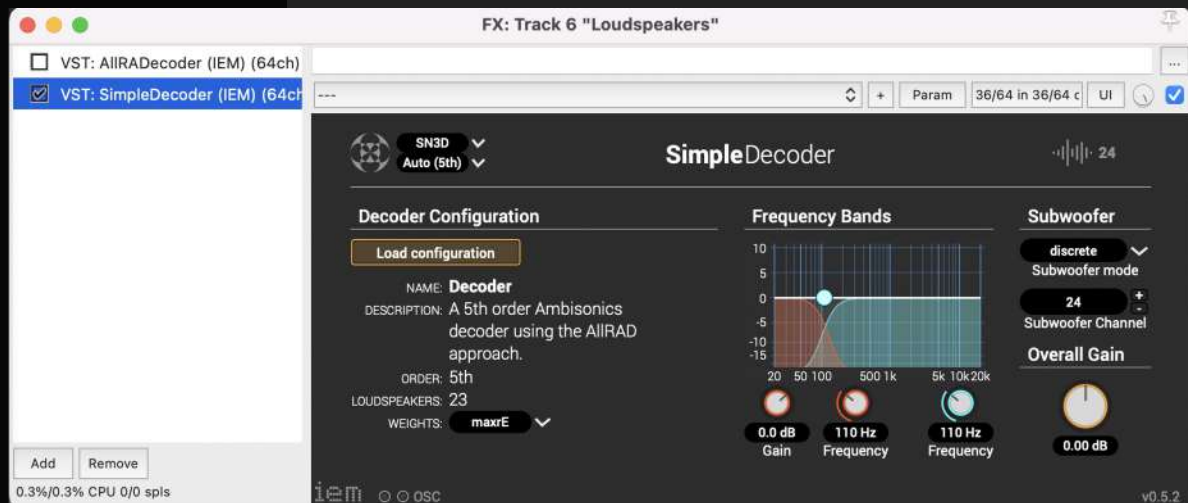
Defining a decoder

- Select order
- Introduce your speaker positions
- Introduce “imaginary” speakers for helping the decoder algorithm
- Export to save your decoder
- Import to load new ones



Using the decoder

- We create decoders with “AllRad” but we prefer using the “SingleDecoder” (after loading a decoder) because it incorporates subwoofer output and frequency band control.



Using several types of sources: mono, stereo, multichannel, B-Format

- Practically, you will need to mix different types of sound sources, their encoded versions, and other ambisonic native audio files.



Building a Scene

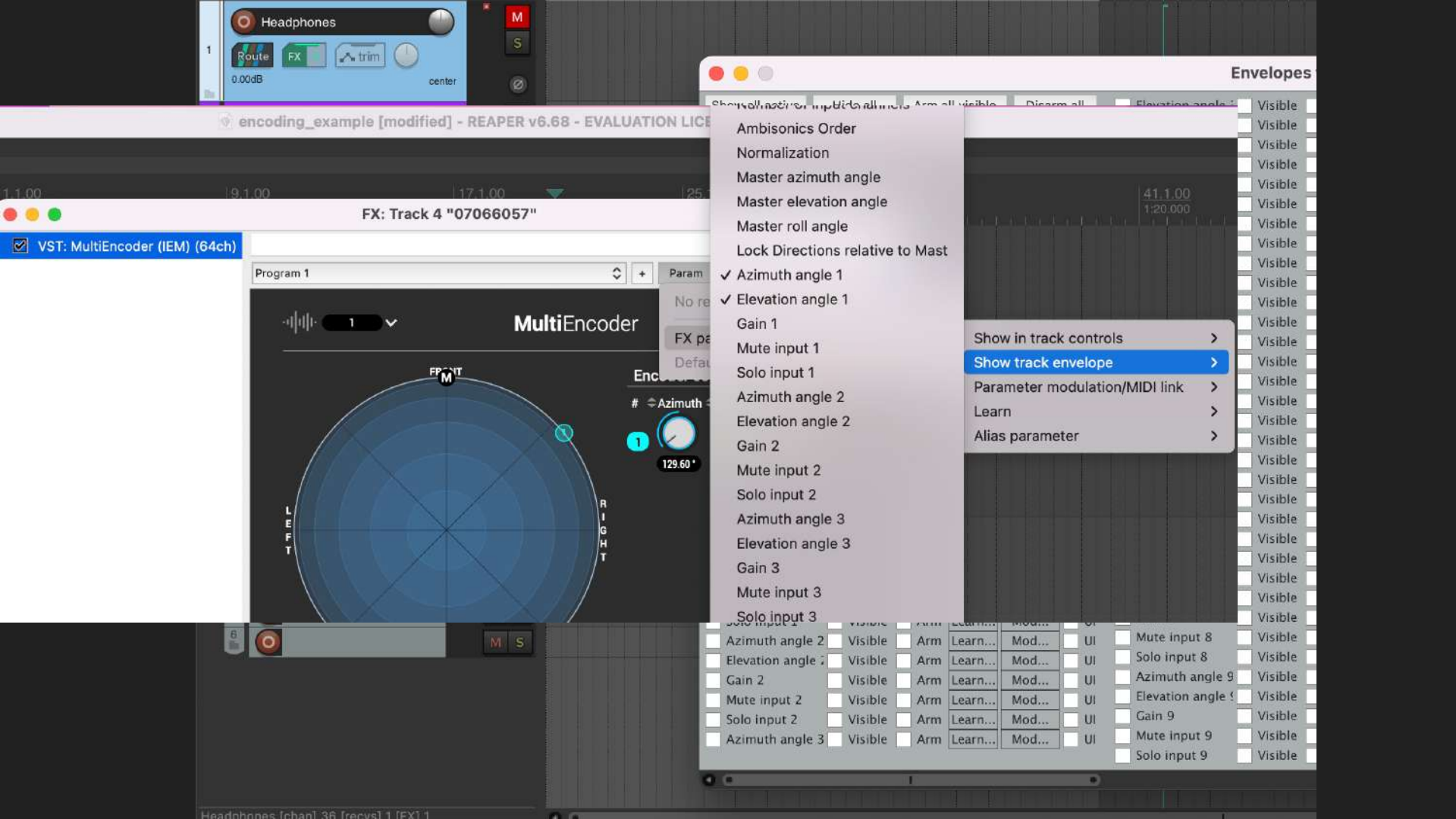
Case study: The Murder of Crows

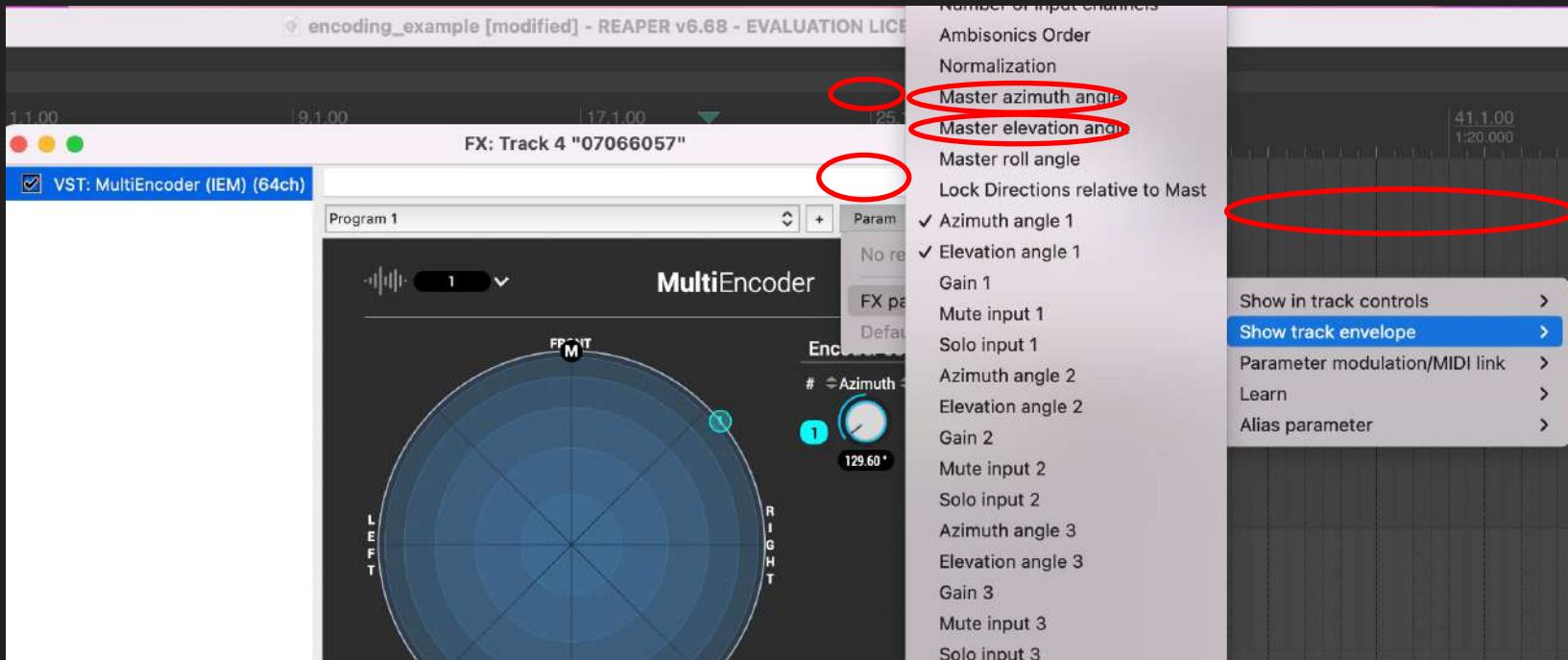


Automation in Reaper

- Control multiEncoder and record each source's position with automation







1 Headphones
Route FX trim 0.00dB center

2 Loudspeakers
Route FX trim

3 Ambisonic Bus
Route FX trim

4 07066057
Route FX Latch

Azimuth angle 1 / MultiEncoder

Elevation angle 1 / MultiEncoder

5

6

Envelopes for track 4 "07066057"

Show all active Hide all Arm all visible Disarm all

Automation mode **Latch** Highlight:

Track Envelopes

<input type="checkbox"/> Volume	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Pan	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Width	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Volume (Pre-FX)	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Pan (Pre-FX)	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Width (Pre-FX)	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Trim Volume	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm
<input type="checkbox"/> Mute	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm

☐ Show last touched FX parameters only

☐ VST: MultiEncoder (IEM) (64ch) Filter:

<input type="checkbox"/> Number of input	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Ambisonics Ord	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Normalization	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Master azimuth	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Master elevation	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Master roll angle	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Lock Directions	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input checked="" type="checkbox"/> Azimuth angle 1	<input checked="" type="checkbox"/> Visible	<input checked="" type="checkbox"/> Arm	Learn...	Mod...	UI
<input checked="" type="checkbox"/> Elevation angle 1	<input checked="" type="checkbox"/> Visible	<input checked="" type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Gain 1	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Mute input 1	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Solo input 1	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Azimuth angle 2	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
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<input type="checkbox"/> Solo input 2	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Azimuth angle 3	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Elevation angle 3	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Gain 3	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Mute input 3	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Solo input 3	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Azimuth angle 4	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Elevation angle 4	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Gain 4	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Mute input 4	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Solo input 4	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Azimuth angle 5	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
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<input type="checkbox"/> Mute input 5	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
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<input type="checkbox"/> Elevation angle 6	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
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<input type="checkbox"/> Mute input 6	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Solo input 6	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Azimuth angle 7	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Elevation angle 7	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Gain 7	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Mute input 7	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
<input type="checkbox"/> Solo input 7	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI
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<input type="checkbox"/> Solo input 9	<input type="checkbox"/> Visible	<input type="checkbox"/> Arm	Learn...	Mod...	UI

Ambisonic Effects

EQ

Energy Visualiser

Compressor

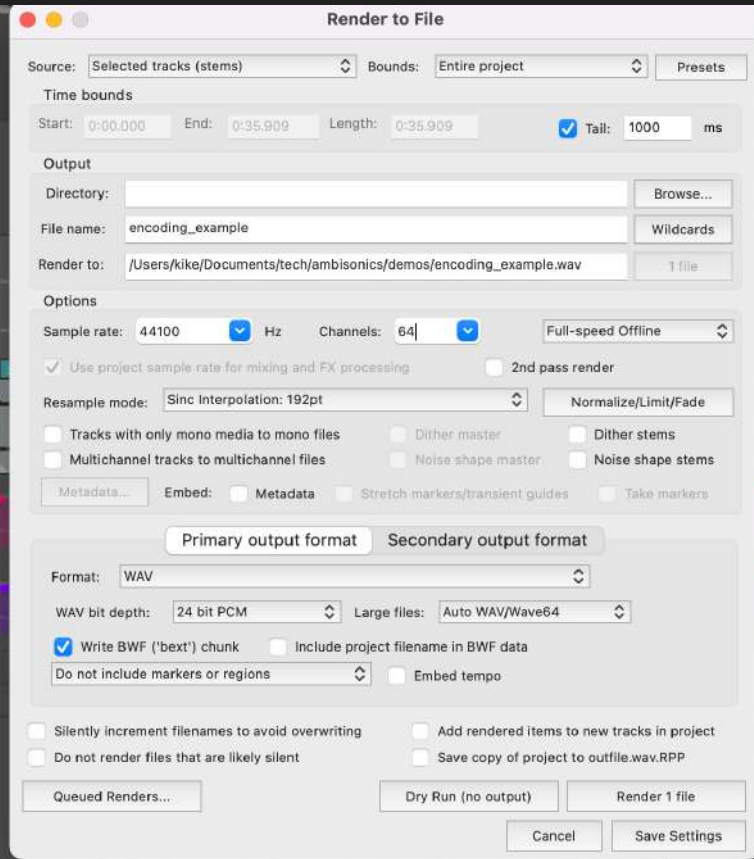
FDN Reverb

Room Encoder

Etc

Exporting your project

Render the ambisonics bus with a number of channels



Alternatives in SPARTA plugins suite

IR impulse (matrix convolver)

Encoder/Decoder

Upmixer

Practice!

Work Analysis!