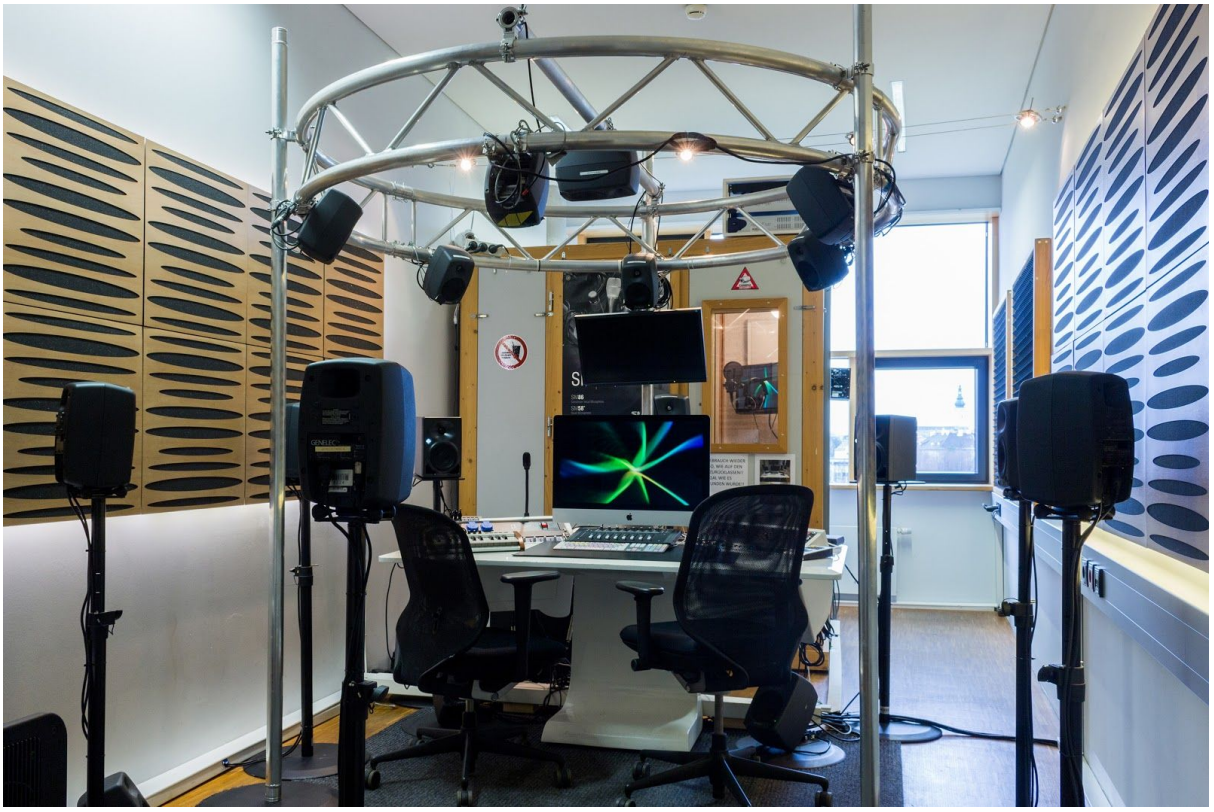

Ambisonics for Beginners

06/2020

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Basics

This tutorials' working environment (DAW, plugins)

This tutorial is intended for everybody, who wants to get started with 360° audio AND is on a budget, or just wants to mess around with this technology. This manual is a roadmap from your 360° recording to the final render.
As stated above, this tutorial is for everybody who is on a budget. The software packages used are mostly free, cheap or offer long demo times.

So - what will you need?

- The minimum requirement is macOS 10.10+ or Windows 7+ 64 bit
- https://www.reaper.fm/

This tutorial describes the workflow in **Reaper**, but if you want to use another DAW (such as Sequoia, Nuendo, Pro Tools Ultimate, Cubase), you can still scroll down to the plugin section, to learn more about great free plugins which work in other DAWs.

- https://facebook360.fb.com/spatial-workstation/

You don't need to start from scratch - Facebook offers its 360 Spatial Workstation for free. Under the URL above, you can choose the correct download for your system (it is offered as AAX and VST). If you need help while installing, you can turn to the manual which is provided by Facebook and also included in your FB360 download. You can find it in the folder "SpatialWorkstation-AAXAddon-~version number~-~yourOS~" (for instance "SpatialWorkstation-AAXAddon-3.3.3-macOS").
When everything is installed, you can open Reaper and launch the template which should be co-installed with the FB360 Spatial Workstation (filename: SpatialWorkstation.RPP) and you're ready to go. You can find this template in "Users → Shared → FB360 Spatial Workstation → Reaper → SpatialWorkstation".

That's basically it. You can also download all of the plugins in the plugin section down below and use them in your spatial audio project.

Structure

The following tutorial contains some heavy technological expressions BUT FEAR NOT, you do not need understand everything from scratch. You can start with the workflow in chapter 3 and slowly get familiar with everything. If you like to, you can also dive deeper into the fundamentals :-)

This tutorial is divided into 5 chapters. Here, you can check out a short summary of each chapter:

- Chapter 1: taking the very first steps in 360 degree audio production and downloading the software minimum
- Chapter 2: recording basics, First Order Ambisonics (FOA) and Higher Order Ambisonics (HOA) microphones and more detailed microphone descriptions
- Chapter 3: the whole production workflow in Reaper, from import to render
- Chapter 4: additional free plug-in solutions for 360 degree audio
- Chapter 5: video basics, which enable you to create a 360 degree audio-video file

You will also find additional information in each section when you click on the links provided in each chapter.

Fundamentals

- **Ambisonic:** a procedure to record, process and playback a soundfield which is not channelbased but scenebased and thus works on any number of speakers and headphones. Ambisonics enables 360 degree audio display. It is always recorded in A-format and converted to B-format for post production. The channels which are recorded include directional information.
- **A-format:** Ambisonics recording format. It needs to be converted to B-format for post production. Every microphone capsule represents one channel. (LFU - Left Front Up / LBD - Left Back Down / RFD - Rear Front Down / RBU - Rear Back Up) Depending on the capsule distance of the microphone, high frequency attenuation has to be compensated by equalization. Some conversion plugins offer this function (for instance “array2sh” by Sparta).

```
W = LFU + LBD + RFD + RBU

X = LFU - LBD + RFD - RBU

Y = LFU + LBD - RFD - RBU

Z = LFU - LBD - RFD + RBU
```

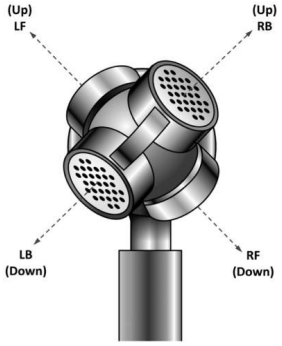


Figure 1: Spherical microphone array with tetrahedral arranged capsules (Nicol, 2018)

- **B-format:** Ambisonics post production format. When using 1st order, there are two different channel configuration possibilities, FuMa (WXYZ, channel order also called FuMa) and ambiX (WYZX, channel order also called ACN). Nowadays, ambiX is more widespread and compatible than FuMa since the industry seems to have largely settled on the ambiX convention. Some plugins give the choice of FuMa or ambiX - you need to make sure that you set the format as expected by your decoder. There are also plugins which make it possible to move back and forth between those two formats.
- **Normalization:** either maxN, N3D or SN3D. With rising order, the SPL of your project rises as well. To avoid clipping, normalization schemes were created. Those scale each Ambisonics components level depending on your projects order.
    - maxN: is used in the FuMa format. It applies a -3dB correction factor for W.
    - (S)N3D: is used in the ambiX format. With SN3D, unlike N3D, no component will ever exceed the peak value of the 0th order component (W) for single point sources. Although the common used normalization scheme is N3D, SN3D is easier to use when dealing with audio data, as clipping of higher order audio signals can be avoided.
- **First Order Ambisonics (FOA):** basic version of Ambisonics. Signals are compound in 4 channels (WXYZ) - the first of them contains the omnidirectional sound pressure component of the signal, the other 3 contain directional information of the 3 room axes. The picture below shows which channel contains which directional information.

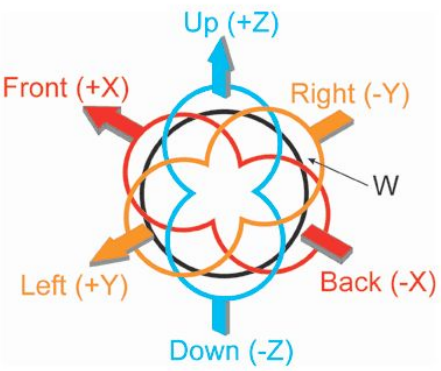


Figure 2: Directivity patterns for encoded B-Format channels W, X, Y and Z.
(SOS Sound On Sound, 2001)

- **Higher Order Ambisonics (HOA):** a format with more than 4 channels. 2nd order Ambisonics uses 9 channels, 3rd order Ambisonics uses 16 channels. The more channels, the higher the directional audio resolution. HOA microphones also record in A-format.
    - → to calculate, how many channels are usable in Ambisonics, following formula can be used: nth order uses $(n+1)^2$ channels.
      2nd order: $(2+1)^2$ channels = 9 channels
      3rd order: $(3+1)^2$ channels = 16 channels
      4th order: $(4+1)^2$ channels = 25 channels
      5th order: $(5+1)^2$ channels = 36 channels
      etc.

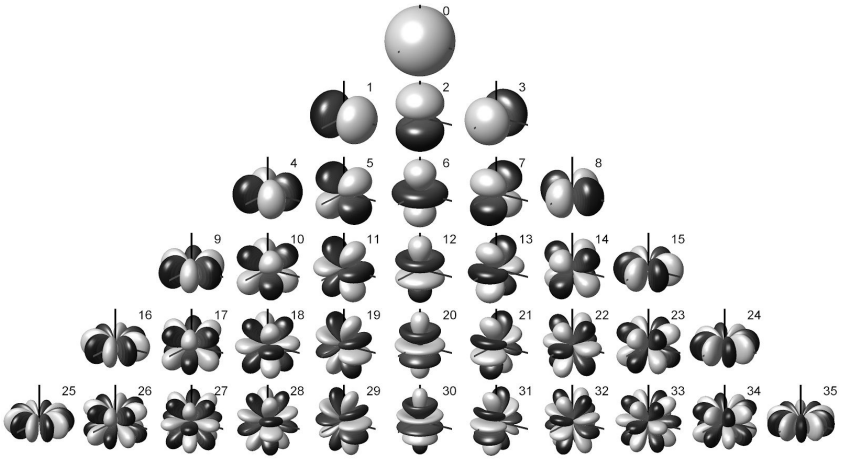


Figure 3: Spherical Harmonics up to degree 5, as used in fifth-order Ambisonics (Zotter, 2013)

- **Binaural:** binaural perception describes directional audio perception. It enables 360 degree perception through headphones. It differs from stereo by giving you a more natural aural impression offering accurate directional localization. To record binaural audio signals, you can for instance use a dummy head (such as the Neumann KU100 https://de-de.neumann.com/ku-100).

Resources

As Ambisonics technology becomes more widespread and easier to use, building a bigger online community, there are already lots of online resources available. In the following, we listed some of them:

Stock audio footage (from free to cheap):
https://www.freetousesounds.com/product/vr-ambisonic-sound-library/
https://library.soundfield.com/

Impulse responses (free):
https://openairlib.net/?fbclid=IwAR04BsIS96vZMKfX9rWh13-jFPwLsVvS2G97QLilE_iR80Mx0nRpQMErsnA

Recording

Sennheiser Ambeo

The Sennheiser AMBEO VR Mic is a small Ambisonics microphone with 4 KE 14 capsules in for first order recordings. It is very lightweight to allow portable recordings. As each capsule acts like an independant microphone, each and every capsule requires 48 V phantom power. To achieve this with a single connector, the AMBEO VR Mic uses a proprietary connector on the microphone's side with 4 male XLR plugs to be used with a recording device.

To start a recording with the AMBEO VR Mic it is necessary to create 4 input tracks for the corresponding 4 capsules. The front as well as the upper microphone is labeled on the mic itself. The recorded files will be in Ambisonic's A-format which can be converted to the B-format using the AMBEO A-B Converter Plugin.

The Sennheiser Ambeo VR Mic is available for ~ € 1500.

AMBEO A-B Converter Plugin

The plugin is available for macOS as well as Windows. It not only converts into the B-format but also gives you directional and output format settings with handy metering tools.

Settings

The **Ambisonics Correction Filter** applies a preset filter that should correct the mic's frequency response. However, no further documentation has been given so use it to your own liking. The **Low Cut Filter** should be self explanatory though its cut-off frequency also is not known.

You may also change the microphone's rotation based on a rotation knob if your front position isn't matching the front of the mic. Though, it is always a better choice to rotate the mic properly to begin with. If you need to mount the mic upside down or in an endfire position, you may as well select it in the plugin. The output format can also be changed from FuMa to ambiX.

The **A-format meters** give you metering options for the 4 capsules:

- FLU (front left up)
- FRD (front right down)
- BLD (back left down)
- BRU (back right up)

The **B-format meters** give you metering options for the different axis:

- W
- X
- Y
- Z

Download: https://de-at.sennheiser.com/ambeo-abconve

Sennheiser AMBEO VR Mic Set

Sennheiser's Proprietery Adapter With Channel Labeling

Sennheiser's Proprietary Connection On The Microphone

Zoom H3-VR

The Zoom H3-VR is a small and simple to use All-in-One portable solution to record ambisonics audio. The Zoom H3-VR allows to record in Ambisonics, Stereo Binaural or Standard Stereo up to 24bit/96kHz and features onboard Ambisonics A to B decoding (FuMa and AmbiX). The Ambisonics signal can be monitored and played back in Stereo binaural and Standard Stereo via the 3,5mm headphone- and line out output and mic-gain adjustments can be easily made with a dial on the side of the recorder. A 6-axis gyroscope allows a precise angle placement, which is viewable from the display, and detects the microphone position automatically (upfront, endfire, upside-down, endfire inverted). The microphone comes with a USB 2.0 Audio Interface Mode which supports live streaming and recording. The micro-USB port also allows powering via an AC-adapter. The recordings can be stored on a micro-SD card with up to 512GB storage.

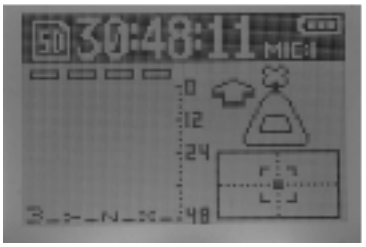
The recorder can be mounted on any tripod featuring a ¼" thread. The box contents include the Zoom H3-VR handy recorder, a foam windscreen, a dual mounting bracket as well as 2 AA-batteries. Optional accessories/software:

- Zoom PC/Mac post-production software to play, change a direction, and convert to binaural, stereo,and 5.1ch surround file
- BTA-1 Bluetooth Adapter for Wireless iOS remote control
- WSU-1 Hairy Windscreen

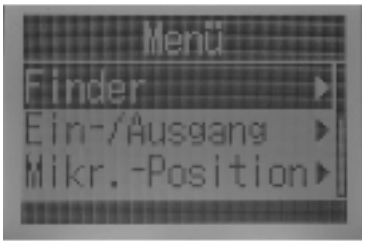
Price: ~ € 300

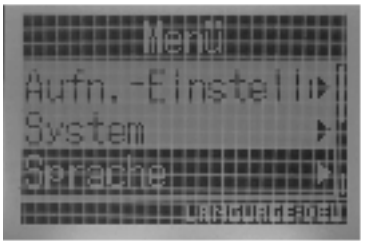
More features:
https://www.zoom-na.com/products/field-video-recording/field-recording/zoom-h3-vr-handy-recorder

Configuring the Zoom H3-VR



The main view of the display, which shows the levels of each mic-capsules, the orientation of the recorder and the angle placement.





The 3 pictures above show the menu options of the Zoom H3-VR.

- **Finder**
  - Playback & delete already recorded files.
- **“Ein-/Ausgang” (In-/Output)**
  - configure a highpass, limiter, the Ambisonics Monitoring (Standard Stereo or Stereo Binaural) and the Line-Out-Level.
- **“Mikr.-Position” (Microphone-Position)**
  - configure your recorder position from Auto to Upright, Upside Down, Endfire and Endfire-Inverted.
- **“Aufn.-Einstellungen” (Rec. Settings)**
  - Recording-Mode: choose from FuMa, AmbiX, Ambisonics A and Standard Stereo and Stereo Binaural
  - Recording-Format: set the recording format from 44.1 kHz/16 bit up to 96 kHz/24 bit, recommended is 48 kHz/24 bit
  - Filename: set the file name automatically (date) or with a custom name
  - Sound-Marker: enable/disable a sound signal at the start of the recording for sync between image and sound
- **System, “Sprache” (Language)**
  - Configure the general settings like Date/Time, time display, LCD, batteries, SD-Card
  - Set the Language displayed on the device
- **USB**
  - Audio-I/F: Use the recorder as an audio interface with the settings: Stereo, 4ch Ambisonics or Stereo (iOS)
  - Card reader: Use the recorder as a card reader

Zylia ZM-1

The Zylia ZM-1 features 19 omnidirectional microphones in a MEMS capsule that is distributed on a sphere. It offers 48 kHz 24 bit recording and is powered via microUSB. It can be mounted the included Zylia ZM-1 stand or via an ¼" mount or a ⅜" mount with an adapter, respectively.

A small red dot indicates the front of the ZM-1 while its LED rings indicates its current state:

- ➔ White: USB powered but not connected to a USB host
- ➔ Blue: it is connected to a USB host
- ➔ Red: the microphones is active

Please Note!

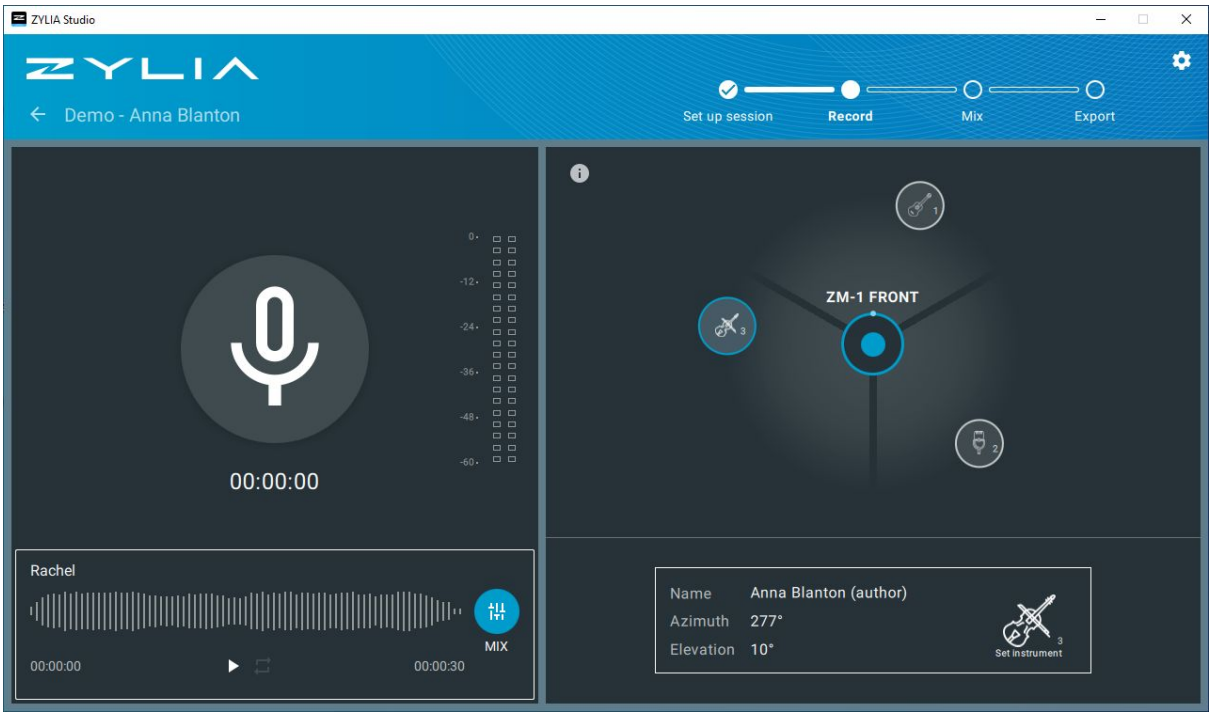
The microUSB connection to the Zylia ZM-1 can be very fragile. It is recommended to check the connection frequently and to ensure no stress is being force on the cable.

Drivers

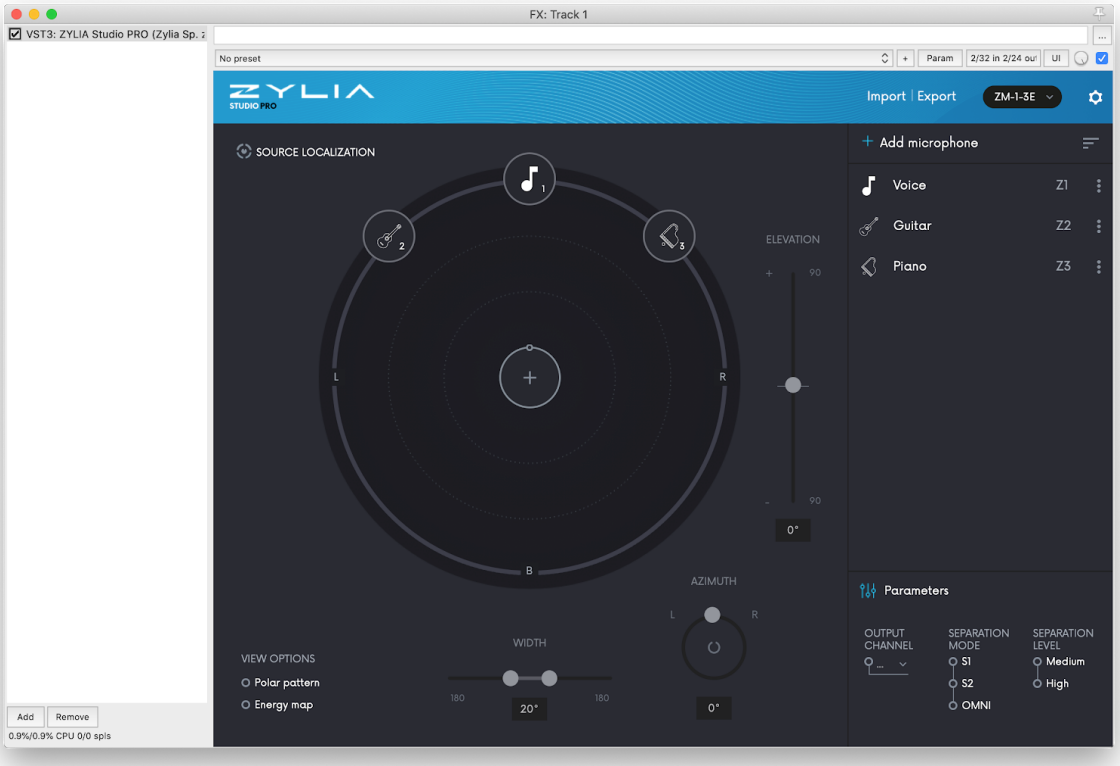
The driver are available for Windows, macOS as well as Linux and can be found here (it might require a restart): https://www.zylia.co/zylia-zm-1-drivers.html

Zylia Studio

Additionally, there is Zylia Studio available for all three platforms as well. This software allows you to record, manage and playback recordings with easy configuration options available. Alternatively, there is the Zylia Studio PRO plugin which allows to view and manage multiple polar patterns or characteristics in offline or in real time.



Zylia Studio Software



Zylia Studio Pro Plugin

The Zylia Studio Pro plugin allows to specify audio sources, change their icon as well as their name. First of all, select the correct Zylia model at the top right corner.

In order to distinguish between the several directions of your 3D soundfield you may add a audio source via the “Add microphone” button. Position the appearing icon to the corresponding direction of the microphone’s input signal. With this virtual microphone you record the chosen direction to a separate output channel.

The parameters “Elevation”, “Width” and “Azimut” define the position of the virtual microphone and help you narrow down the audio source. There are multiple options to enable, e.g. “Source Localization”, “Polar Pattern” and “Energy Map” to show you the directivity of the input signals.

Now select the “Output Channel”, “Separation Mode” and “Separation Level”:

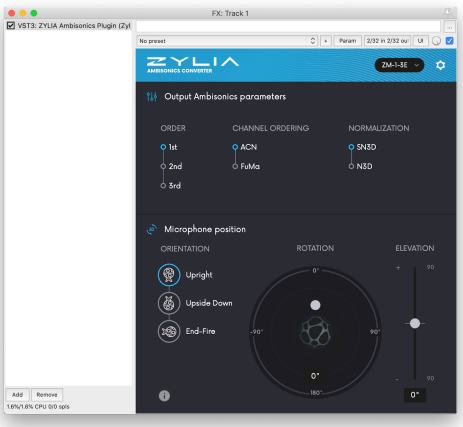
- **Output channel:** “-” means the mic is disabled. “Z1, Z2 etc.” mean that the selected virtual microphone is routed to the specified channel.
- **Separation Mode:** defines different polar patterns for the virtual microphones
  - “OMNI” has equal sensitivity in every direction
  - “S1” is used for few virtual microphones
  - “S2” is used automatically for mics that are closer than 15°
- **Separation Level:**
  - “Medium” a good setting to start with.
  - “High” requires additional computational power for calculating the microphone’s behaviour. Ambient noise is reduced and the source separation is better.

You can download the software from here:

- Zylia Studio (standalone): https://www.zylia.co/zylia-studio.html (Free)
- Zylia Studio Pro (plugin: VST2/3, AU, AAX): https://www.zylia.co/zylia-studio-pro.html (~ € 400)

Zylia Ambisonics Converter

The Zylia Ambisonics Converter is also available for Ambisonics B-format conversions. It can be downloaded as a standalone application or a plugin. It is compatible with ambiX, corrects the ZM-1’s microphones position in post-production and supports YouTube360 and Facebook360.



The Ambisonics Converter plugin offers different parameters for the conversion. You can change the Ambisonics order of the output (1st, 2nd or 3rd order), the channel ordering (ACN or FuMa) and the normalisation (SN3D or N3D).

Moreover, you can select the microphone’s position, its rotation as well as elevation.

- ➔ Zylia Ambisonics Converter (standalone): https://www.zylia.co/zylia-ambisonics-converter.html
- ➔ Zylia Ambisonics Converter Plugin (plugin, VST2/3, AU, AAX): https://www.zylia.co/zylia-ambisonics-converter-plugin.html (~ € 400)

Other Options

You may also use the Sparta plugins for the Zylia if you wish to do so. There is a preset for the Zylia available to easily get you started in Sparta.

Availability

Price: ~ € 550

Packaging of the Zylia ZM-1

Ring LEDs flash in the respective colours

Zylia ZM-1 with the ZM-1 stand and its microUSB port

Octava MK-4012 Mic

The Octava MK-4012 Mic consists of 4 MK-012 capsules with a windshield (Rycote BBG 20mm). The windshield can be opened by turning the upper part clockwise and can be closed by turning it counter clockwise.

It uses a proprietary connector with an adapter for 4 XLR inputs. Please note that every input requires 48 V phantom power to work.

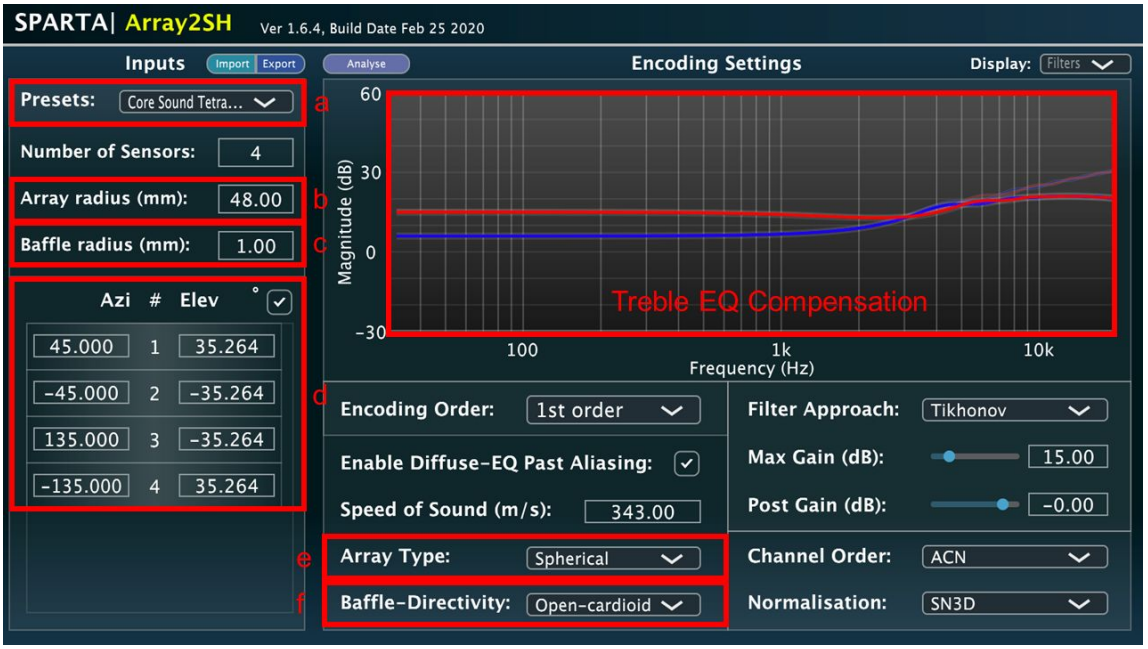
The front position as well as the position of every capsule is labelled on the outside with numbers ranging from 1 to 4. The front position is labelled by a red dot.

Oktava MK-4012 Set

Oktava's Proprietery Adapter With Channel Labeling

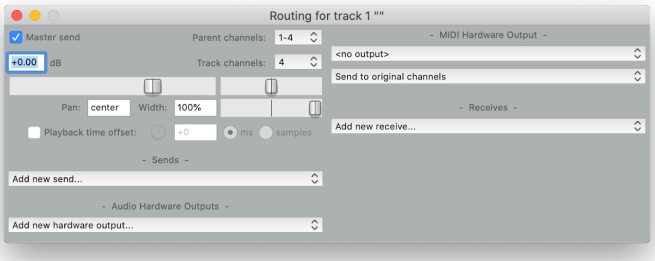
Oktava's Proprietary Connector On The Microphone

Configure the Oktava in Reaper



Array2SH SPARTA Plugin

1. Add a new empty track
2. Click on “Route”
3. Change “Track Channels” to 4



Track routing with 4 “Track channels”

4. Use the “sparta_array2sh (AALTO) (64ch)” plugin

   Important:

   If you see this message, you didn’t change the track channel selection to 4 input channels.

5. Now you may select the appropriate settings for the Oktava:
   a. Select the preset “Core Sound TetraMic” as a starting point
   b. Change the array radius to “48.00” (capsule distance to center in mm)
   c. Change the baffle radius to “1.00”
   d. Check that the azimut values are
      i. 45
      ii. -45
      iii. 135
      iv. -135
   e. Make sure the array type is set to “Spherical”
   f. Make sure the baffle directivity is set to “Open-cardioid”
   g. Leave the rest as it is. You may compare it to the screenshot above to make sure.

Production workflow in Reaper

Before starting in Reaper you need to make sure to have your 360°-video in the proper codec and format.

Converting - Video Format And Codec

It is recommended for Reaper to use the "DNxHR_LB" Codec because it works both on macOS and Windows and results in higher quality playback with quick frame-by-frame scrubbing and seeking. The video should be exported as a .mov file. For easy converting, FFmpeg is a good choice. Download and install FFmpeg from https://www.ffmpeg.org/download.html (macOS & Windows version available).

FFmpeg comes either as a .7z or .zip compressed file. Simply extract the contents to a folder specified by you.

To convert your video just drag it into the FFmpeg folder, start the terminal/cmd in the folder and execute the command below.

Terminal-/cmd command:

```
ffmpeg -i INPUTFILE -map 0:v -an -c:v dnxhd -pix_fmt yuv422p -trellis 0 -profile:v dnxhr_lb -y OUTPUTFILE.mov
```

- **-c:v** Specifies DNxHD as the output codec
- **-profile:v dnxhr_lb** DNxHR LB profile
- **-an** Disables audio. Removing this option will retain the audio track in the video file (if present)
- **-pix_fmt yuv422p** Sets the pixel format to yuv422p
- **-trellis 0** disables trellis quantisation

4k scaled videos can cause a problem when working with Reaper. Add following command before specifying the outputfile name to rescale the resolution:

- **-vf scale=1920:-1** Rescale a video to the specified resolution without changing the aspect ratio
- **-vf scale=1920:1080** Rescale a video to the specified resolution disregarding the aspect ratio

The command would look like this:

```
ffmpeg -i INPUTFILE -map 0:v -an -c:v dnxhd -pix_fmt yuv422p -trellis 0 -profile:v dnxhr_lb -y -vf scale=1920:-1 OUTPUTFILE.mov
```

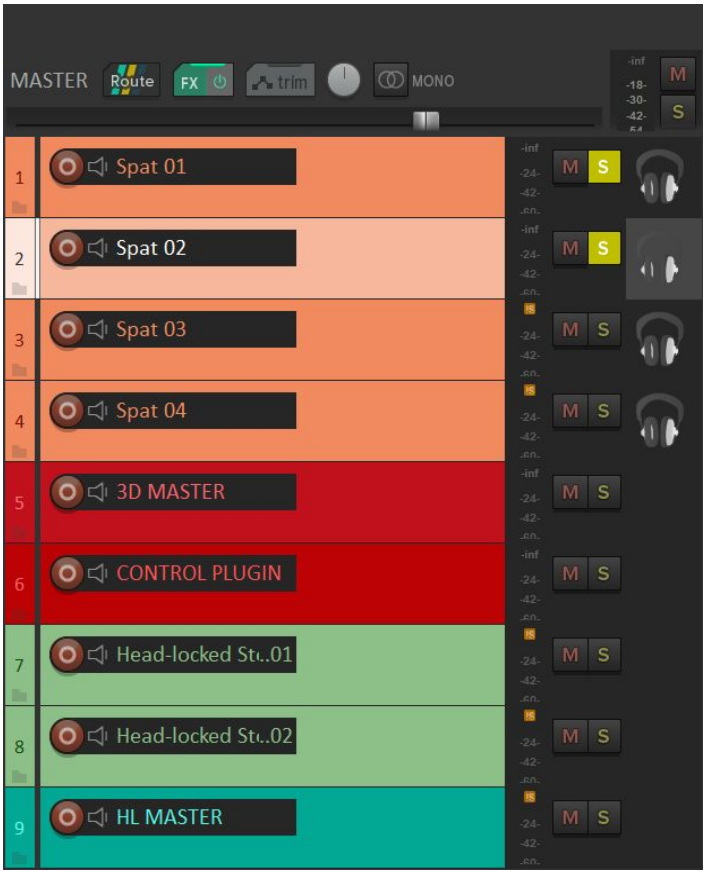
Starting the Reaper project

After converting the video you can go ahead, start Reaper and open the FB360-template (SpatialWorkstation.RPP).

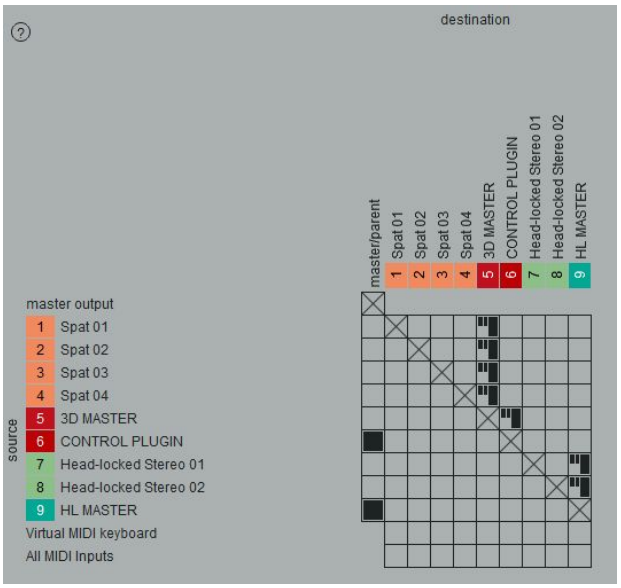
Using the template

The plugins used in the FB 360 workstation template will only be addressed briefly in this chapter but are described in detail in the chapter “Plugin possibilities”.

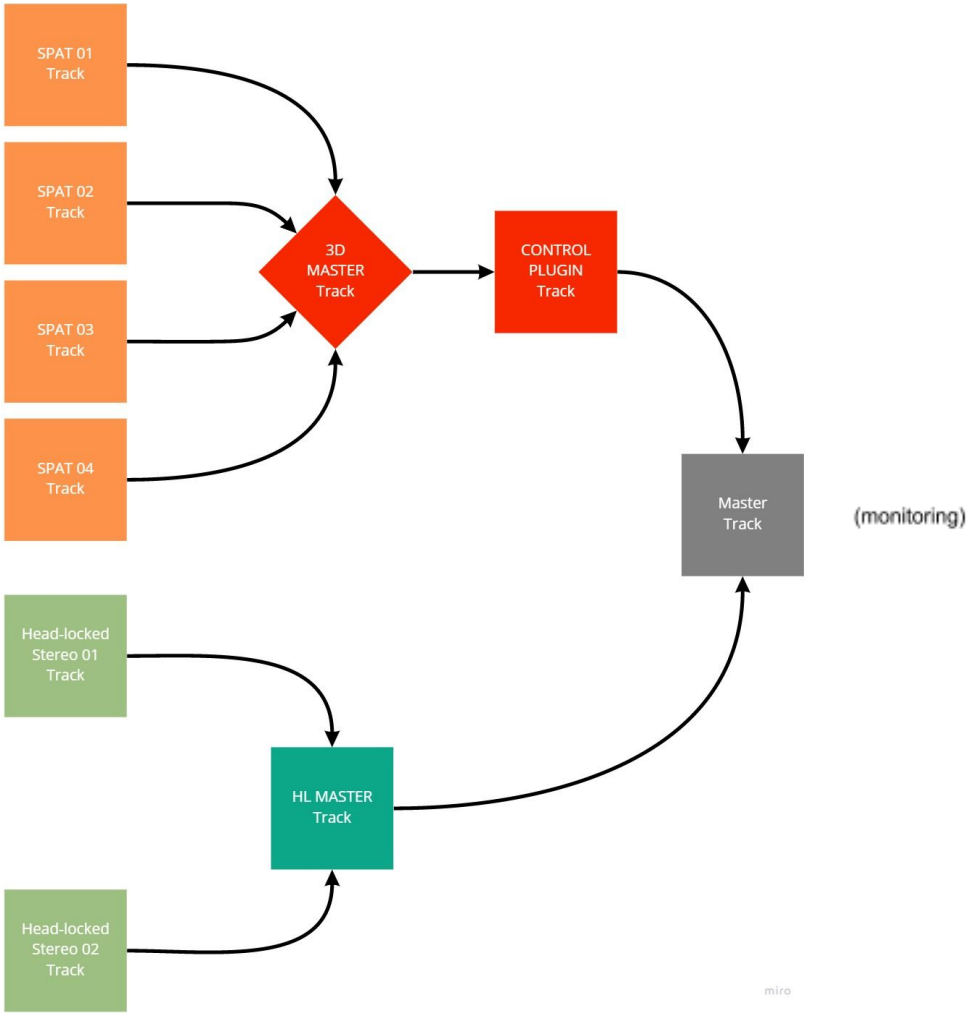
General Routing



Track overview of the FB 360 workstation template for quick reference



Routing Matrix in Reaper



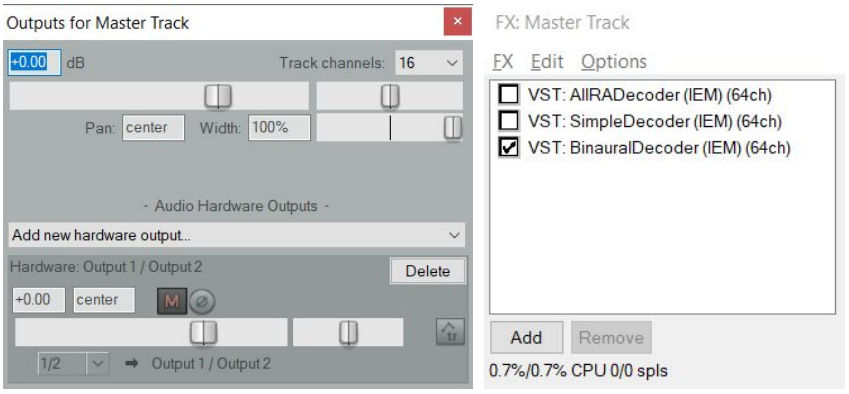
Routing of the template Tracks including the below added *Master Track*

Master Track (monitoring)

To start off, reveal the hidden master track (Windows: Ctrl+Alt+M, macOS Opt+Cmnd+M) in your Reaper project, click on

. If you are using a multi-speaker setup, set the Track channels equal to the hardware output channels of your audio interface. For binaural output only 16 channels are sufficient (TOA). After that open the effect chain by clicking on

. If you are using a multi-speaker setup to monitor the audio add the VST-IEM-Plugins `AllRADecoder(IEM)(64ch)` and `SimpleDecoder(IEM)(64ch)`. If you are using headphones to monitor the audio add the `BinauralDecoder(IEM)(64ch)` plugin.



Speaker Setup monitoring

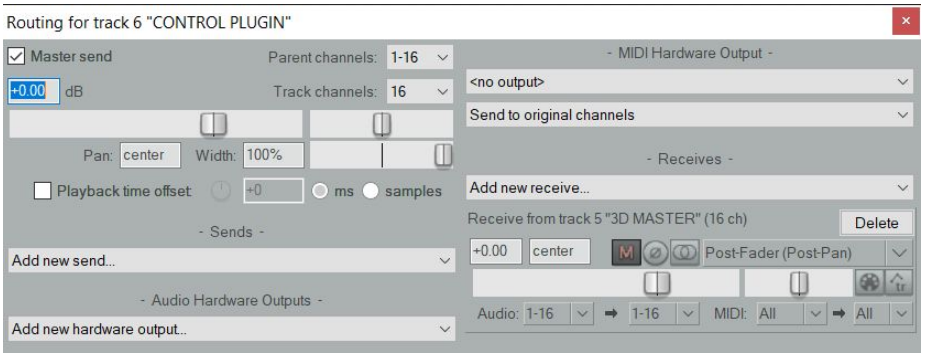
The `AllRADecoder` plugin lets you configure your speaker setup and export the configuration in a .json file. Make sure to setup your configuration with evenly placed triangles instead of 100% accurate measured because it generally sounds better. To get a better dimensional representation you should add an imaginary source at the center bottom. After that import the file in the `SimpleDecoder` plugin for correct playback. The `SimpleDecoder` plugin is used because it allows for the separation of low frequency contents to a discrete subwoofer channel.

Headphone monitoring

The `BinauralDecoder` automatically decodes the master signal to Stereo Binaural and lets you choose a headphone equalization for the most common studio headphones.

After setting up your Master Track go to the *CONTROL PLUGIN Track* and click

. There you need to check the “Master send” option to route the signal to the *Master Track*.



ATTENTION: If you use those plugins to monitor the audio you **MUST** disable "Decode Binaural" in the settings of the `FB360 Control(ambiX)(Two Big Ears)` plugin in the *CONTROL PLUGIN Track* or else it will be decoded twice.

HINT: You can also refrain from using the above proposed monitoring plugins and use the inbuilt Binaural Decoder of the `FB360 Control(ambiX)(Two Big Ears)` plugin but the IEM plugins result in better decoding quality. In this case "Master send" routing on the *CONTROL PLUGIN Track* has to be unchecked.

HINT 2: Using the inbuilt Binaural Decoder of the `FB360 Control(ambiX)(Two Big Ears)` plugin will give you a representation of how the finished video will sound when deployed to Facebook (since Facebook also uses the same Binaural Decoder).

Spat ## Tracks

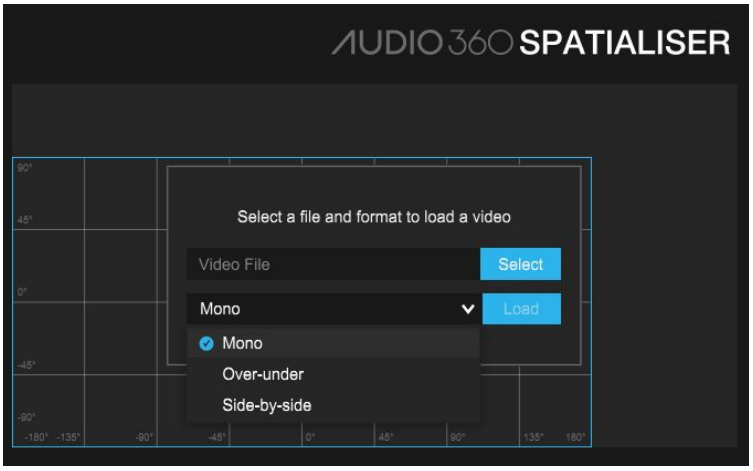
The *Spat ## Tracks* are where the magic happens - you insert your desired mono/stereo/FOA/TOA(Third Order Ambisonics) files and use the effect chain to work with them. The *Spat ## Tracks* effect chains must at least include the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin in order to work properly.

The *Spat ## Tracks* are routed to the *3D MASTER Track*.

HINT: To use FOA or TOA the separate signals need to be consolidated to a single .wav file containing either 4 channels (FOA) or 16 channels (TOA).

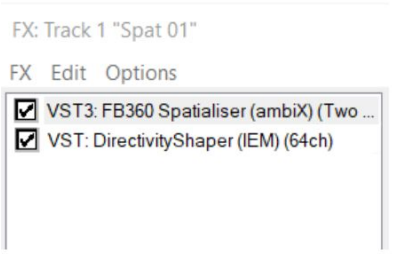
Importing the 360°-video

Before starting your work on the audio you'll first need to import the previously converted 360° video. Click the Select-button in the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin and select your video. In the dropdown-menu below you can specify if the 360°-video was shot monoscopic or in over-under/side-by-side stereoscopic.



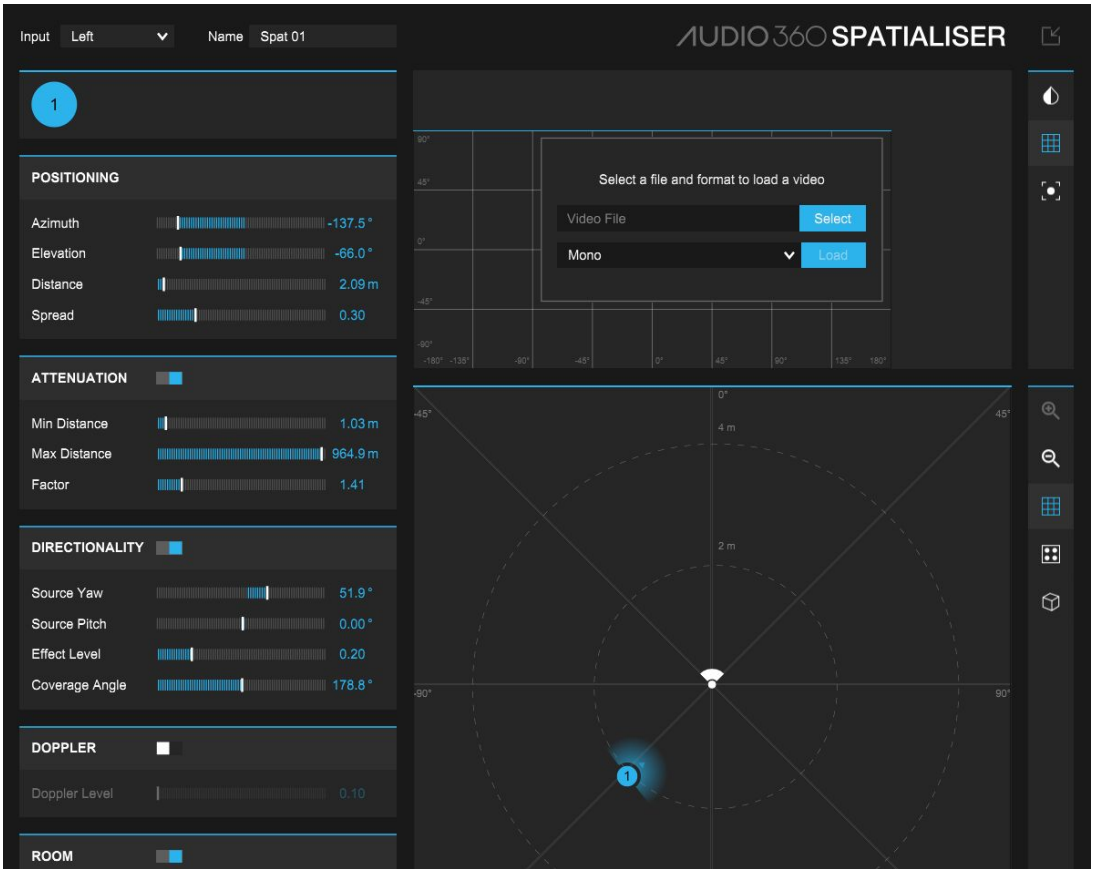
After pressing the Load-button the video loads into the plugin and will be automatically inserted into all the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin instances on other tracks.

Using a Mono - File



Spat Track Effect chain (mono)

In the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin on the top left you select the input to either left or right (it doesn't matter since it is a mono-file). In the plugin you can position the audio, track it to the video and adjust several spatialisation parameters.



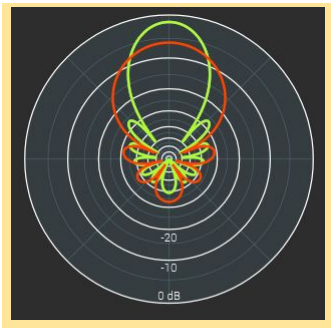
Input-option of the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin

To enhance the directivity you can add the `DirectivityShaper(IEM)(64ch)` plugin to the effect chain. This is optional but will allow you to position, adjust and enhance 4 filter bands as well as the order and shape.

HINT: You can also use the `DirectivityShaper(IEM)(64ch)` plugin in the first position of the effect chain. Then the Input of the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin needs to be set the Input-option to “B-format (3rd Order ambiX)”.

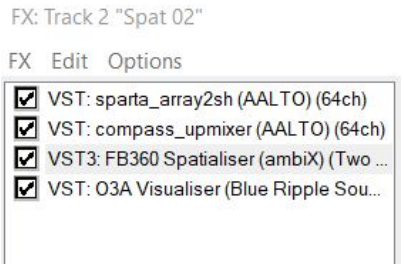
`DirectivityShaper(IEM)(64ch)` plugin overview

HINT: If the track you are working on is muted you won't see any change in the shape when adjusting the order and shape.



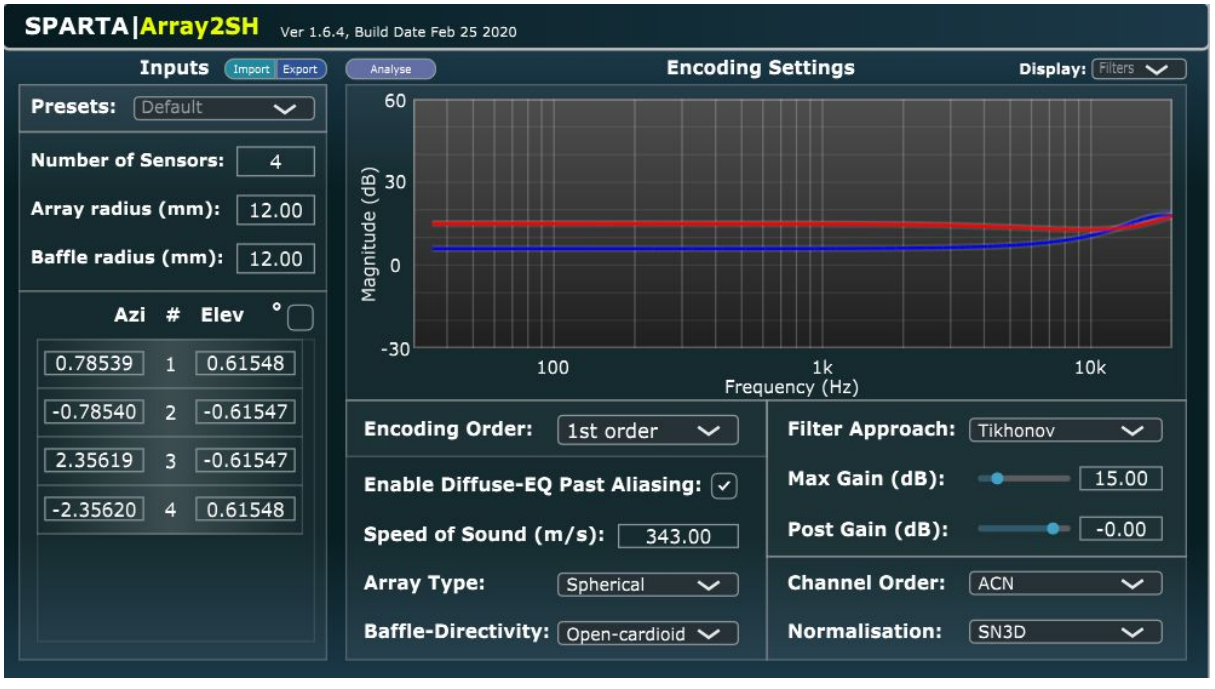
HINT: The `DirectivityShaper(IEM)(64ch)` plugin only supports mono audio signals. To use stereo you need to remove/uncheck it!

Using a FOA - File



FOA *Spat ## Track* effect chain

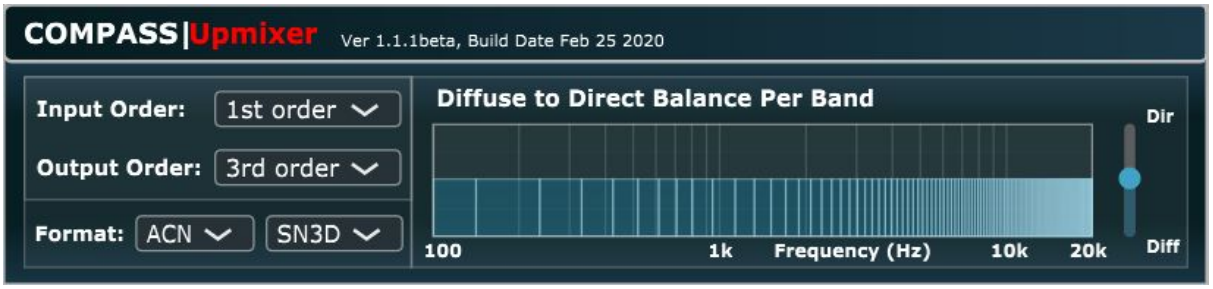
The effect chains first plugin is the `sparta_array2sh(AALTO)(64ch)`. In the plugin you can either choose a preset microphone or configure your own microphone setup by setting the number of sensors, array- & baffle radius. Make sure to set the encoding order to 1st order and adjusting the Array Type & Baffle-Directivity. Set the Channel Order and the Normalisation according to your recording configuration.



`sparta_array2sh(AALTO)(64ch)` overview

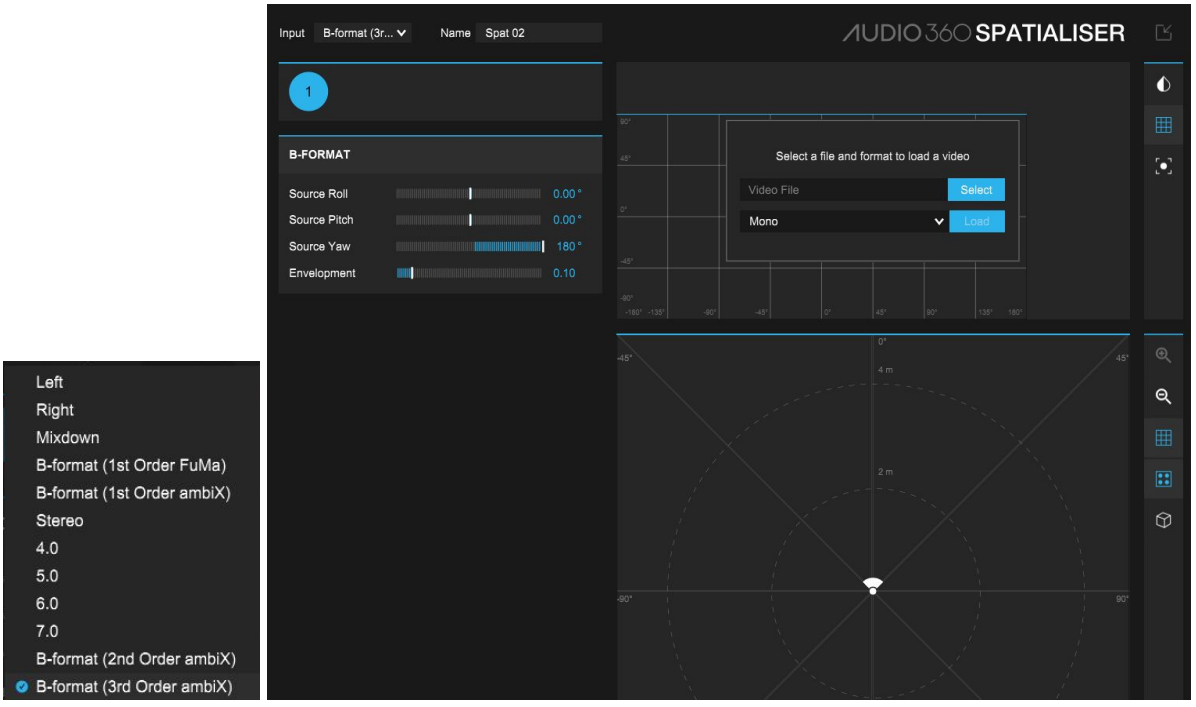
The next plugin is the `compass_upmixer(AALTO)(64ch)`. With this plugin you can upmix your FOA signal up to 7th order which will improve directivity (recording in HOA will still sound better). The `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin only

supports up to TOA - so the Output Order has to be set to 3rd order and set the Format to ACN & SN3D.



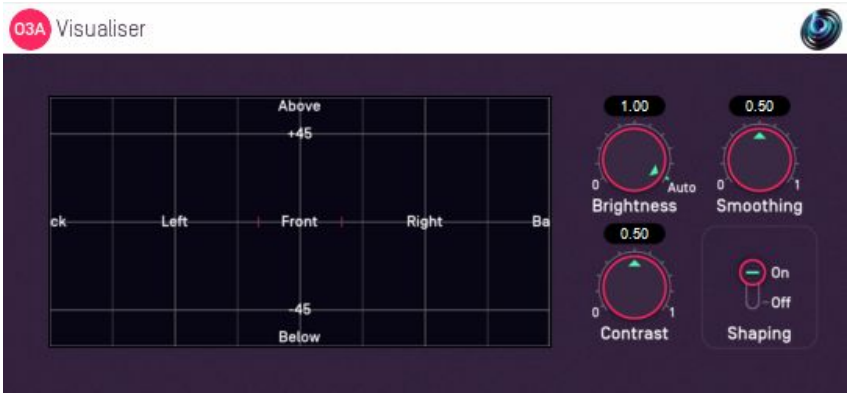
`compass_upmixer(AALTO)(64ch)` overview

In the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin you need to set the Input-option to “B-format (3rd Order ambiX)”. As you can see, the Interface changed from the mono signal view and now lets you adjust the B-format settings (Source-Roll,-Pitch,-Yaw & Envelopment).



Full Input-option & overview of the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin (TOA mode)

To make sure, the adjustment/orientation of your TOA are correct you can add the `O3A Visualiser (Blue Ripple Sound Limited)` plugin where you can compare the visualised representation of the monitored sound to the video in the `FB360 Spatialiser(ambiX)(Two Big Ears)` plugin. For this you will need to pop out one of those 2 plugins by double-clicking on the pluginname in the effect chain list.



`O3A Visualiser (Blue Ripple Sound Limited)` overview

Instead of the O3A Visualiser (Blue Ripple Sound Limited) plugin you can also use the `sparta_powermap(AALTO)(64ch)` which additionally enables you to place real time video of a camera behind the activity map to work as a makeshift acoustic camera.

HINT: To use TOA files you remove/uncheck the `compass_upmixer(AALTO)(64ch)` plugin from the effect chain. In the `sparta_array2sh(AALTO)(64ch)` plugin adjust the Encoding Order to 3rd Order and the Number of Sensors as well as the Array- & Baffle radius.

HINT 2: When using the `sparta_array2sh(AALTO)(64ch)` plugin make sure to import only A-format Ambisonics files since the plugin decodes them into B-format.

Head-locked Stereo ## Tracks

The *Head-locked Stereo ## Tracks* allow you to place any audio that you don't want to be spatialised. The audio is basically locked to the users head (movement). This can be used for music, narration and other kind of audio.

HINT: The *Head-locked Stereo ## Tracks* are only supported by Facebook (8+2ch) and Youtube (4+2ch). Youtube unfortunately only supports FOA.

Rendering/Export

To properly encode the audio you'll need to export the spatialised mix and the head-locked mix separately.

Spatialised Mix - Export

1. Use Reaper's Time Selection to specify the area you would like to bounce. Make sure the selection starts at 00:00:00:00 and open the Control plugin, disabling the Decode Binaural option.
2. Select the CONTROL PLUGIN track (and no other track)
3. Go to File -> Render in the menu bar
4. In the Render To File window that shows up, choose Stems (selected tracks) in the Source drop-down menu
5. In the Bounds drop-down menu, choose Time Selection
6. Specify the file name and output directory

7. Under Options, **type** in 9 or 16 in the Channels option for 2nd or 3rd order Ambisonics respectively
8. Click “Render 1 file..”
   The spatialised mix should now be exported.

Head-locked Mix - Export

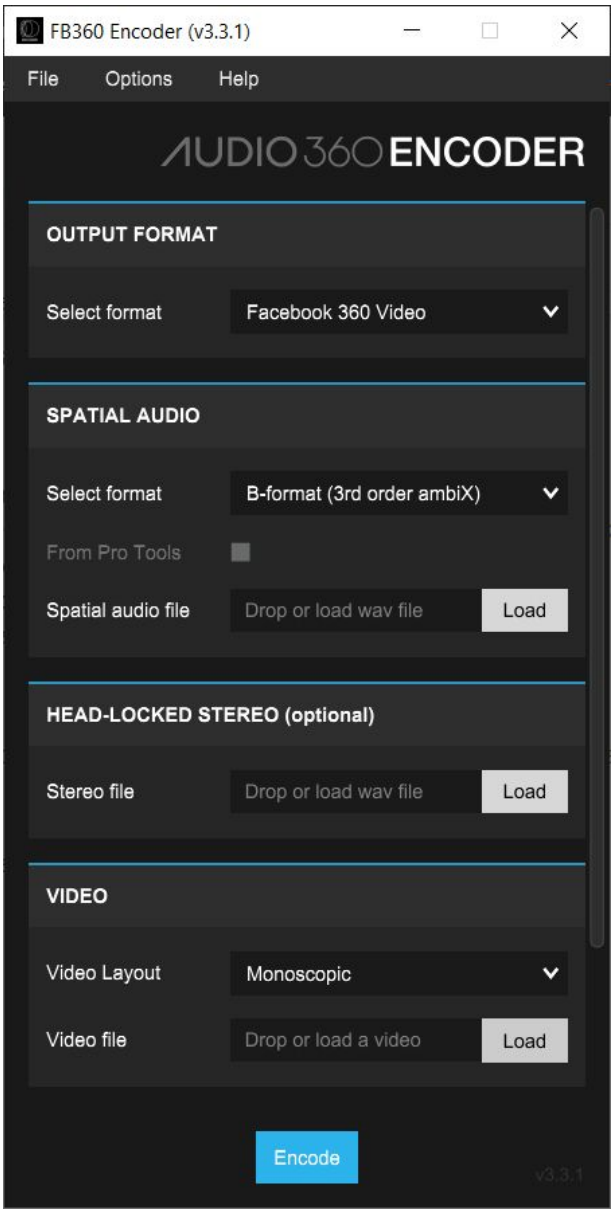
1. Select the HL MASTER track (and no other track)
2. Go to File ! Render in the menu bar again
3. In the Render To File window that shows up, choose Stems (selected tracks) in the Source drop-down menu
4. In the Bounds drop-down menu, choose Time Selection
5. Specify the file name and output directory
6. Under Options, specify 2 in the Channels option
7. Click Render 1 file..

Both files will now need to be processed and coded before being deployed to the app.

Encoder

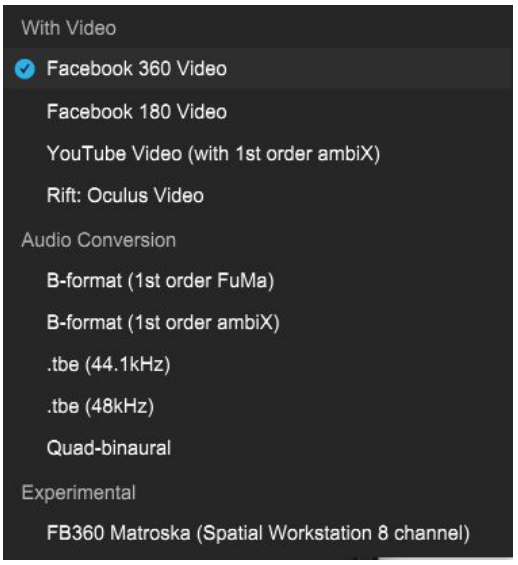
In order to encode the exported audio & video for deployment you need to start the FB360 Encoder. This is a seperate app which was installed with the FB360 Suite.

WINDOWS-HINT: The Encoder requires Mp4Box and Python 2.7 installed on your Windows computer. The Python 2.7 installer can be downloaded from here. Follow the instructions with the installer. Mp4Box can be installed using the GPAC installer from here. The GPAC installer includes Mp4Box and other components. Installing the additional components is optional.



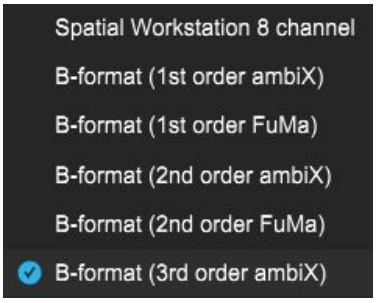
FB360 Encoder overview

First, select the Output Format. In this guide we will go with the Facebook 360 Video.



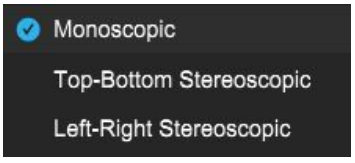
Full Output Format list

Afterwards select the Spatial Audio format. Because you exported TOA (ambiX) in the B-Format choose “B-format (3rd order ambiX)” and load the previously exported spatialised audio file.



Full Spatial Audio Format list

Next up you load the previously exported head-locked audio file if you had one. Last but not least is the video. This time you take the high quality video, select the Video Layout corresponding to how the video was shot and load the video.

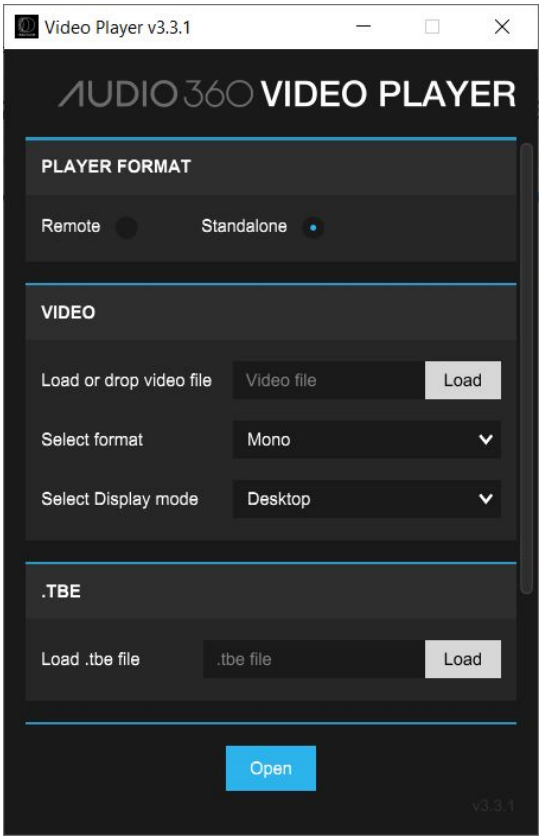


Full Video Layout list

By clicking “Encode” you start the encoding process and save your file. After that you have successfully finished your 360° Audio project.

Video Player

To view your successfully saved video you can load it in the Video Player that comes with the FB360 Suite. Select the format and Display mode and you are good to go! Additionally you can add a .tbe file if you encoded audio only.



Plugin possibilities

IEM

Download and additional information:

- https://plugins.iem.at/
- https://plugins.iem.at/faq/

Bullet points:

- Plugins work up to 7th order (although, the only DAW which can handle up to 7th order is Reaper)
- Created at the Institute of Electronic Music and Acoustics Graz by staff and students
- Works on macOS, Windows and Linux
- Free
- 20 Open-Source VST(2) plugins

The IEM plugin suite offers a broad range of audio processing tools which work up to 7th order Ambisonics. Every plugin has the same design principles. On top of the UI you can usually choose your projects Ambisonic order and its normalisation type (N3D or SN3D).

All of the following plugin descriptions are only condensed versions of the descriptions, provided by IEM under the links in each description.

This tutorial addresses plugins, which are essential for the Ambisonics Workflow, but you can find more of them on the IEM website.

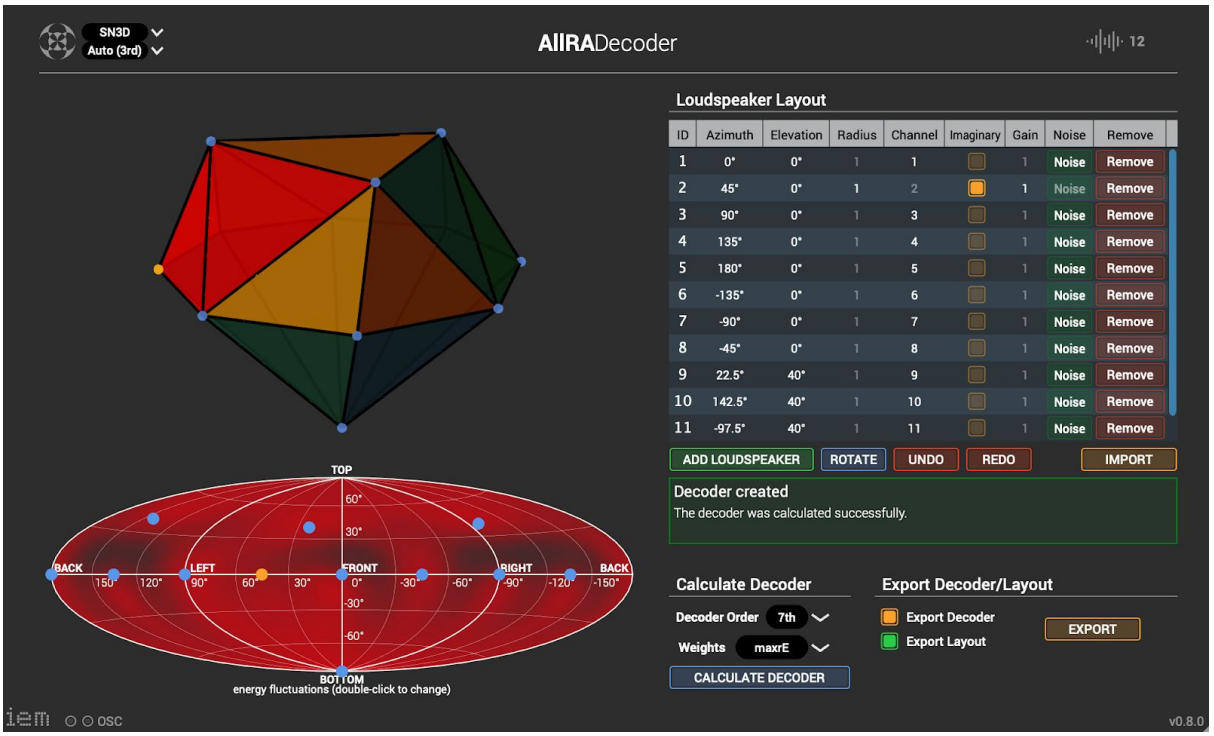
IEM - **AllRA**Decoder

https://plugins.iem.at/docs/allradecoder/

The **AllRA**Decoder can be use to design your own Ambisonic decoder. It enables you to create a decoder for every speaker setup and save it as JSON file. This way, the decoder can also be used in other plugins. It is usually inserted in your projects Master track.

Functions:

- Re-create your own speaker setup.
- Optionally add imaginary speakers, so that your speaker setup can be triangulated.
- Check out your setups energy distribution and source width.
- Export your own speaker layout and decoder.

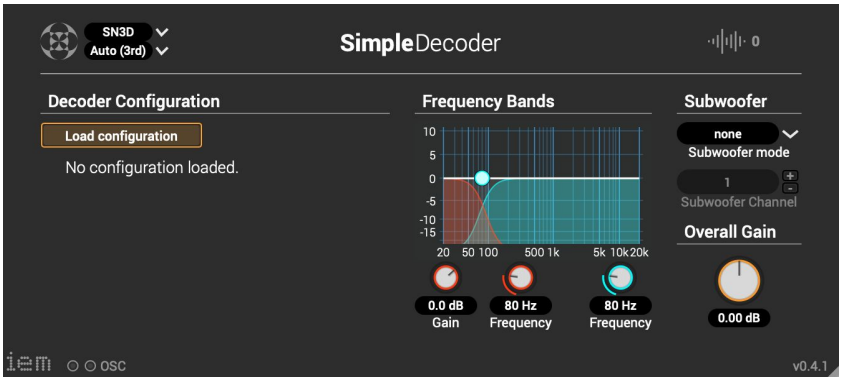


IEM - **Simple**Decoder

https://plugins.iem.at/docs/plugindescriptions/#simpledecoder

https://plugins.iem.at/docs/configurationfiles/

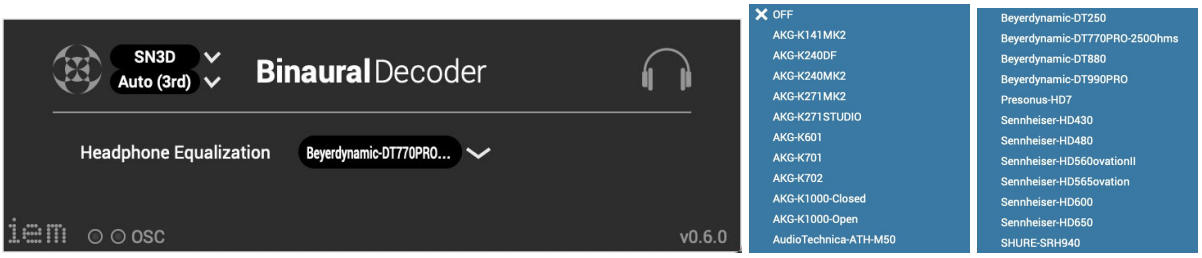
The **Simple**Decoder can load JSON configuration files and thus decodes Ambisonic input files to loudspeaker signals (JSON files can, for instance, be designed within the **AllRa**Decoder).
You can change the subwoofer setting to discrete or virtual. When you do so, the input signal is filtered into two bands. The upper band is always decoded according to the loaded configuration file. When the setting is discrete, the lower band is sent to the defined subwoofer channel. If the setting is virtual, the lower band signal is passed to all the loudspeakers, creating a virtual subwoofer.



IEM - **Binaural**Decoder

https://plugins.iem.at/docs/plugindescriptions/#binauraldecoder

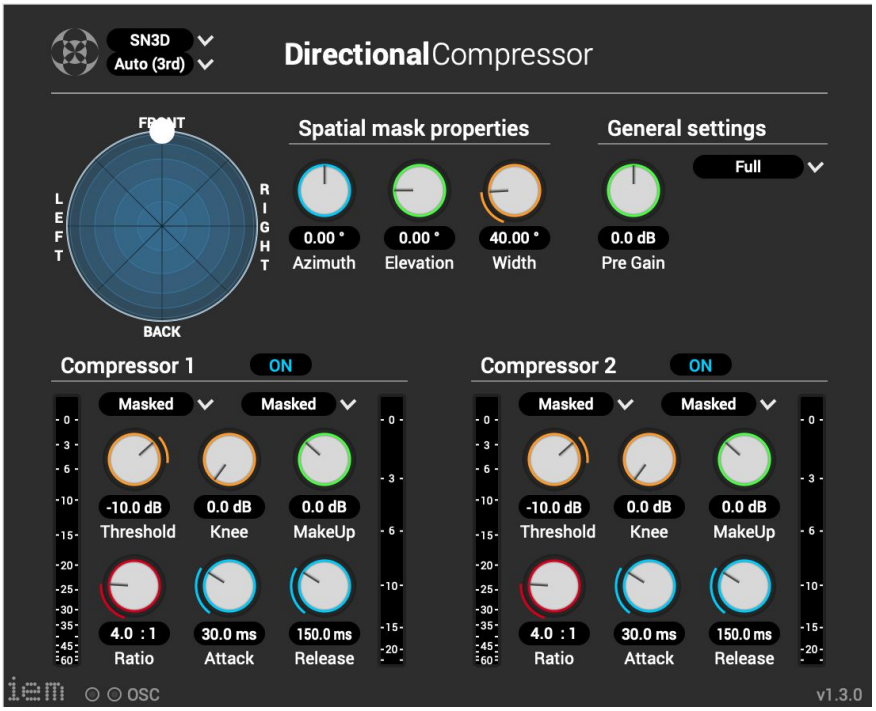
The **Binaural**Decoder converts an Ambisonics input signal to a binaural headphone signal. It uses pre-processed HRTFs from the Neumann KU 100 dummy head. In the configuration windows, you can choose your own headphones (if available).



IEM - **Directional**Compressor

https://plugins.iem.at/docs/plugindescriptions/#directionalcompressor

The **Directional**Compressor enables you to compress/limit dynamics for different spatial regions. You can also use it to activate a ducking effect. Use the sphere panner and width settings to create a spatial mask. It is also possible to use target compression.



IEM - **Directivity**Shaper

https://plugins.iem.at/docs/directivityshaper/

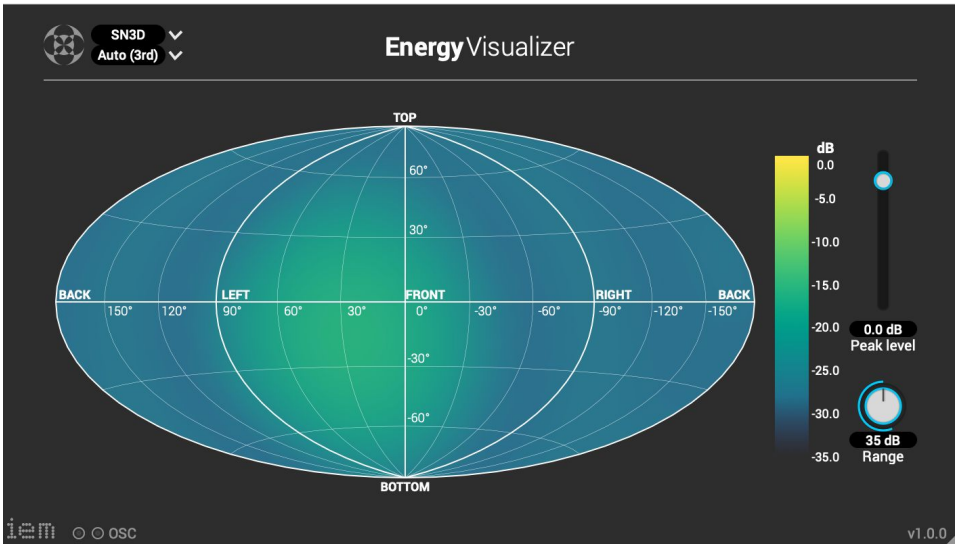
The **Directivity**Shaper divides a mono input signal into four separate frequency bands and color codes those. Thus, it also acts as a frequency dependent Ambisonic encoder. Each frequency band can independently be assigned to an Ambisonic order and also be placed separately from the others. You can choose from four different filter designs (all pass, low pass, band pass, high pass) and the progression between Ambisonic orders is smooth/continuously. There are three normalization settings: basic decode, on-axis and constant energy.

As this plugin can do many things and is quite complicated, I suggest you take a look at its official manual, written by its creator. You can find it under the link above.

IEM - **Energy**Visualizer

https://plugins.iem.at/docs/plugindescriptions/#energyvisualizer

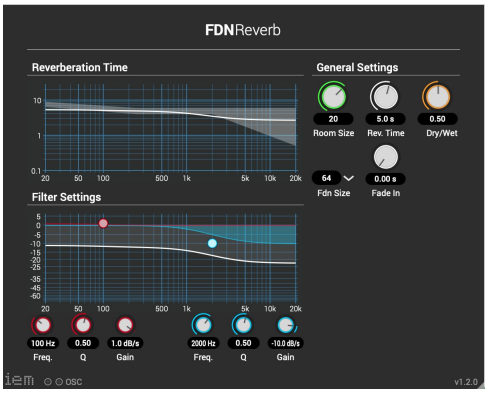
The **Energy**Visualizer can be used to represent spatial signals visually in form of their energy distribution. You can set your desired range and the highest depictable peak level.



IEM - **Fdn**Reverb

https://plugins.iem.at/docs/plugindescriptions/#fdnreverb

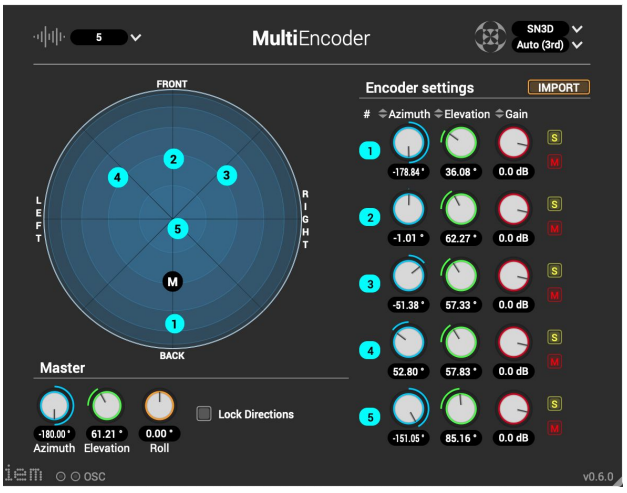
The **Fdn**Reverb is an Ambisonics appropriate reverb plugin (although it also works on mono and stereo signals) which is based on a feedback-delay-network. The fade-in control can make the effect even more diffuse by employing a second network in parallel. You need to make sure that the fade-in time is below the overall reverberation time. The overall settings are similar to a conventional reverb plugin, but here, you can set the size of the feedback-delay-network.



IEM - **Multi**Encoder

https://plugins.iem.at/docs/plugindescriptions/#multiencoder

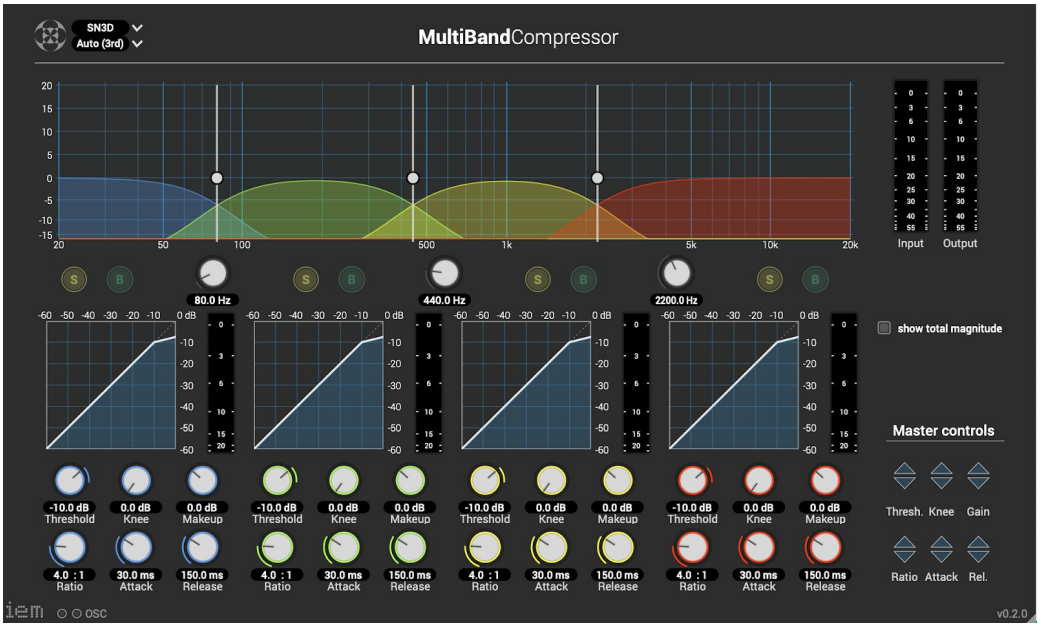
The **Multi**Encoder enables you to encode multiple sources (select your desired number in the upper left corner, up to 64 sources are possible) with just one plugin. It is an alternative to the Facebook 360 spatializer. You can pan, mute, solo, control its gain and label color every source individually. With the button “Lock Directions”, you can stick all sources to a Master-Panner, and control them simultaneously. The blue sphere represents the linear elevation of your sources.



IEM - **MultiBand**Compressor

https://plugins.iem.at/docs/plugindescriptions/#multibandcompressor

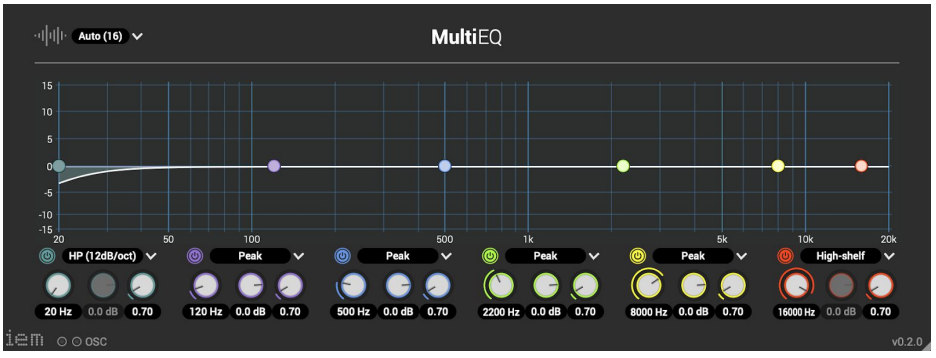
The relatively new **MultiBand**Compressor works just like a common multiband compressor. It splits the incoming Ambisonic signal into four bands and compresses them individually. Your spatial mix image will be retained, by analyzing the omnichannel (W) of each band and applying the same gain reduction to all channels.



IEM - **Multi**EQ

https://plugins.iem.at/docs/plugindescriptions/#multieq

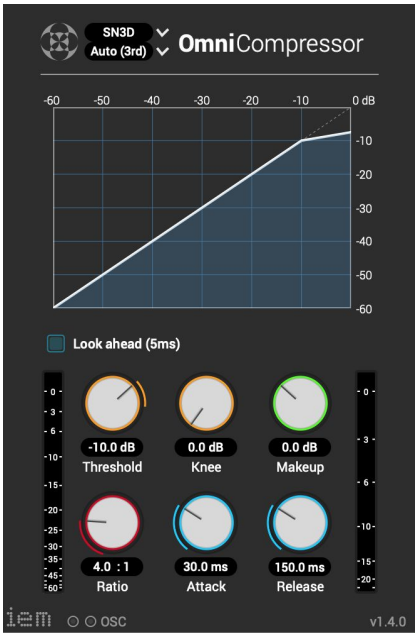
The **Multi**EQ is a common multi-channel equalizer, enabling filtering up to 64 audio channels. There is also the possibility to create a Linkwitz-Riley crossover, which can be used to split audio into two bands, with a constant magnitude response when added together.



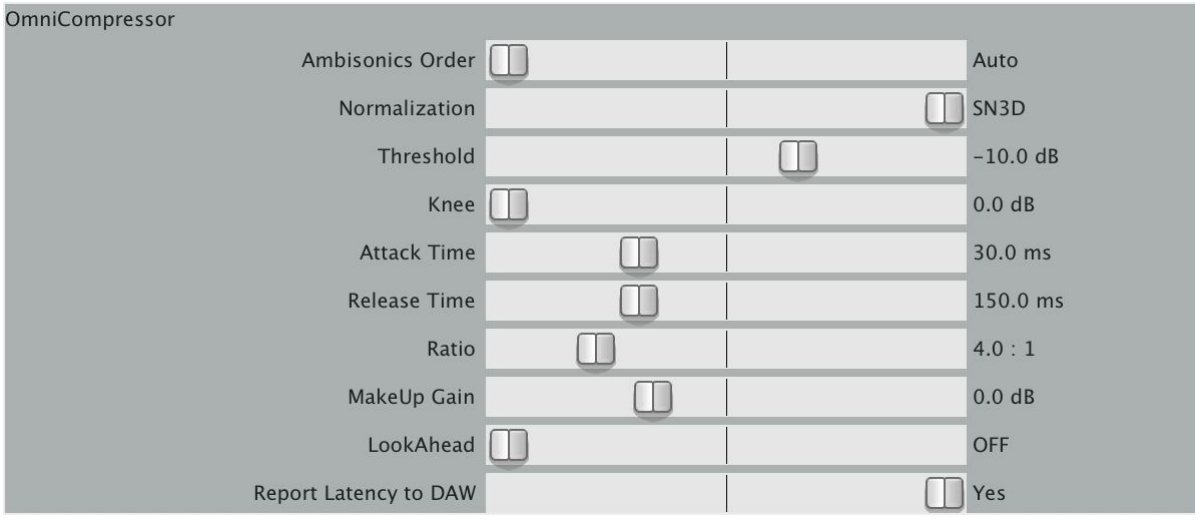
IEM - **Omni**Compressor

https://plugins.iem.at/docs/plugindescriptions/#omnicompressor

The **Omni**Compressor works like a common compressor, and can also be used as limiter. The used driving signal is the first input channel (W ⇒ omni). It applies the calculated gains to the whole Ambisonic signal. There is also the possibility to use the lookahead feature (introduces 5 ms latency) to avoid distortion when limiting.



When you disable the plugins UI by clicking the “UI” button, you can deactivate latency reporting to your DAW. This improves the playback performance, but the delay won’t be compensated for with that setting.

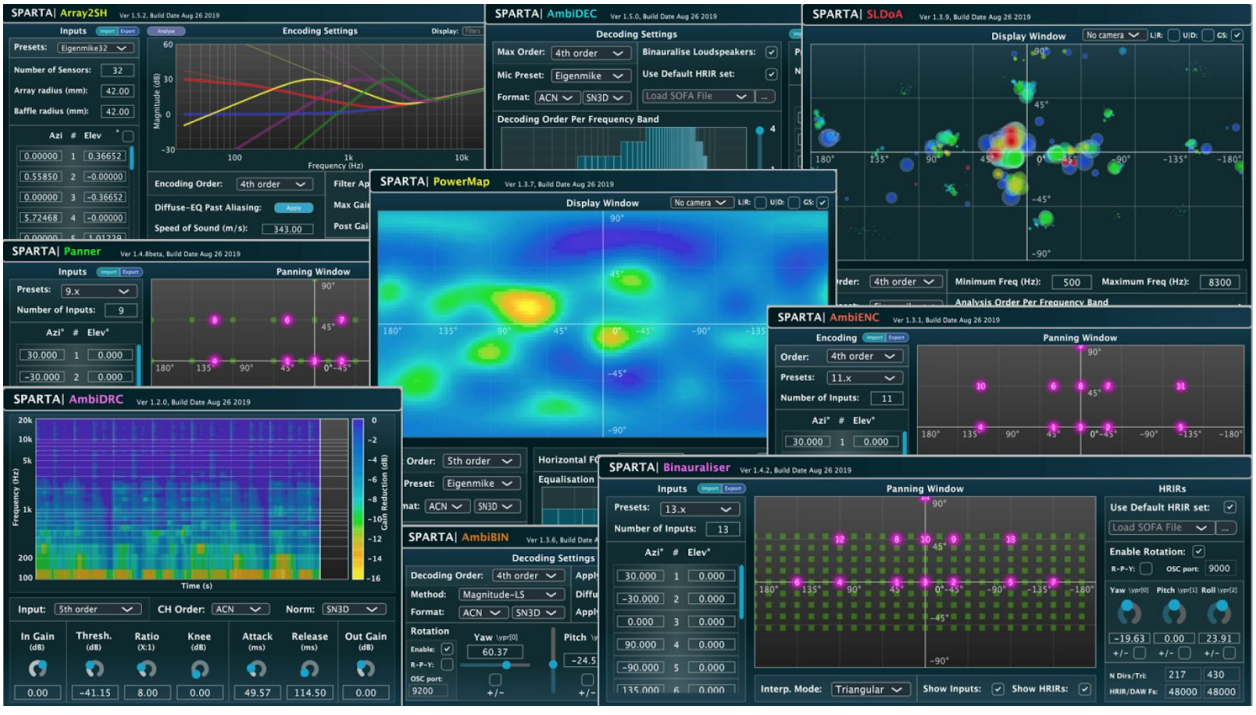


SPARTA

Well, this is SPARTA, a collection of flexible VST audio plugins for spatial audio production, reproduction and visualisation, which was primarily developed by members of the Acoustics Lab at the Aalto University in Finland. SPARTA is also a clever abbreviation for *Spatial Audio Real-time Applications*; Makes sense, doesn't it? For whom it might concern: All plug-ins covered in this section were developed using the Spatial_Audio_Framework (SAF), an open-source and cross-platform framework in C/C++. So in case you feel extra adventurous, the source code for the plug-ins is available.For more info, visit: http://research.spa.aalto.fi/projects/spatial_audio_framework/.

Aalto University
School of Electrical
Engineering

When **downloading** the SPARTA Installer, which you will find under the following link: http://research.spa.aalto.fi/projects/sparta_vsts/, you are about to cram a host of different plug-in suites onto your hard drive and into the DAW(s) of your choice. The SPARTA Installer installs the SPARTA plug-in suite, as well as the COMPASS suite, and a few other single plug-ins, including HOSIRR and the cropac_decoder. And if you like them, you should put a… Okay, I'll stop.



You made it this far, so I do not want to furthermore confuse you, dear reader and sonic explorer of audio technologies that embody the idiom *those believed dead live longer* more than anything else, so we'll just look at a few of the SPARTA plug-ins before taking a brief look at its companions with compassion.

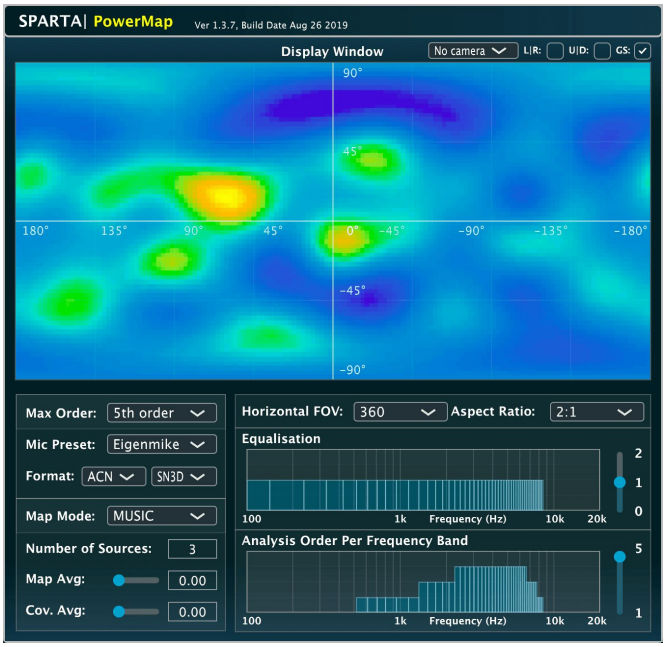
The SPARTA Suite

sparta_array2sh

The array2sh is a spatial encoder that works with up to 7th order ambisonics. The best part is, that It already comes with presets for quite a lot of commercially available microphone arrays in A-format or HOA. Furthermore, the Array2SH plug-in is able to present objective evaluation metrics for selected configurations, giving you a little more insight into what's underneath the hood.

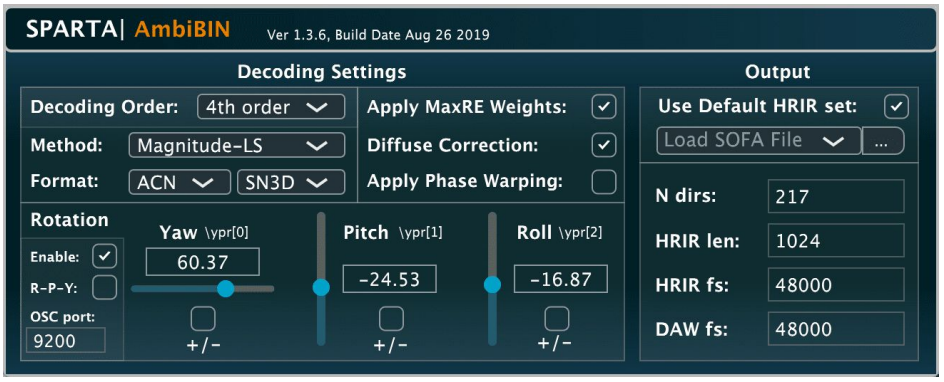
sparta_powermap

The Powermap is a sound-field visualizer reminiscent of heat cameras. It's a handy tool to check the location of audio in conjunction to video based on ambisonic signals (again up to 7th order), with PWD/MVDR/MUSIC/Min-Norm options.



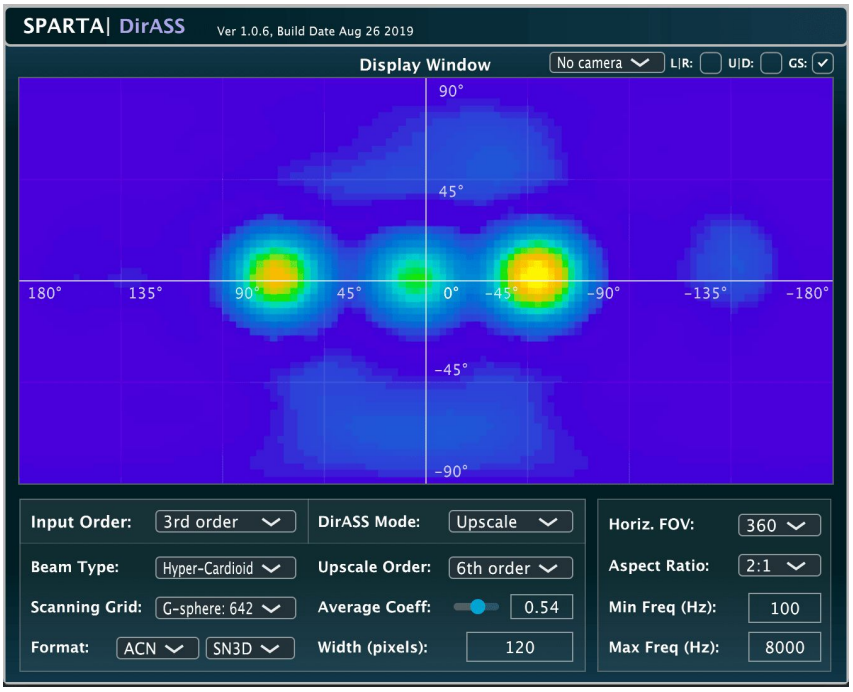
//sparta_ambiBIN - optional & advanced

The BIN in ambiBIN stands for binaural, as it is a ambisonic decoder working up to 7th order ambisonics. The plug-in features a built-in SOFA loader and head-tracking support via OSC messages. SOFA is a format for saving your head related transfer functions (HRTFs). As a quick explanation: A HRTF is your ear's very personal frequency response. The ambiBin plug-in includes options for Least-Squares (LS), spatial re-sampling (SPR), time-alignment (TA), and magnitude least-squares (Mag-LS) decoding.



//sparta_dirass - optional

Dirass is another sound-field visualiser, this time based on re-assigning the energy of beamformers. This re-assignment is based on DoA estimates extracted from "spatially-constrained" regions, which are centred around each beamformer look-direction.

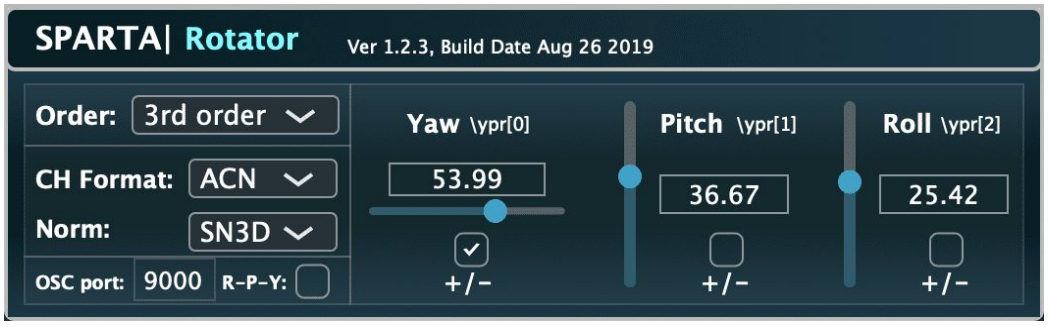


//sparta_sldoa - optional

SLDOA is a frequency-dependent sound-field visualiser. Low frequency estimates are shown in blue, mid-frequencies are green, and high-frequencies are represented in red.

//sparta_rotator - optional

The rotator is a flexible ambisonic rotator that works up to 7th order ambisonics with head-tracking support.

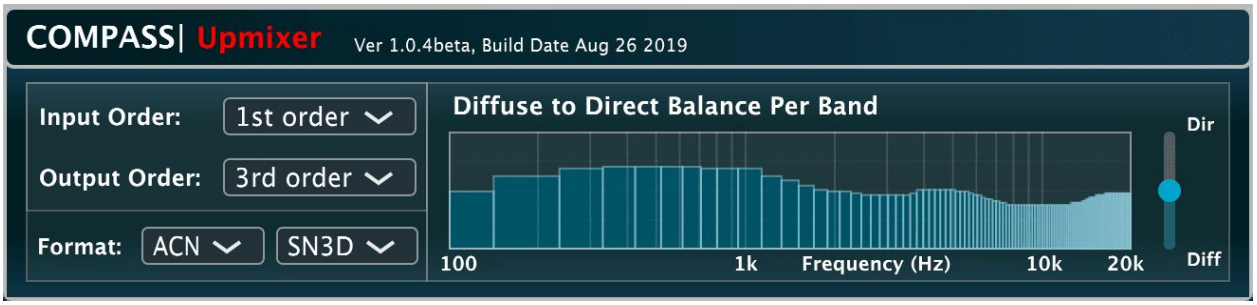


The COMPASS Suite

Before we briefly dive into the plug-ins, you might ask yourself: Does COMPASS also stand for something? Yes, it does, maybe not in a political sense, but it is (yet another) abbreviation and it reads *Coding and Multidirectional Parameterisation of Ambisonic Sound Scenes*. COMPASS comes with a handful of plug-ins, but for now we would recommend sticking to the following:

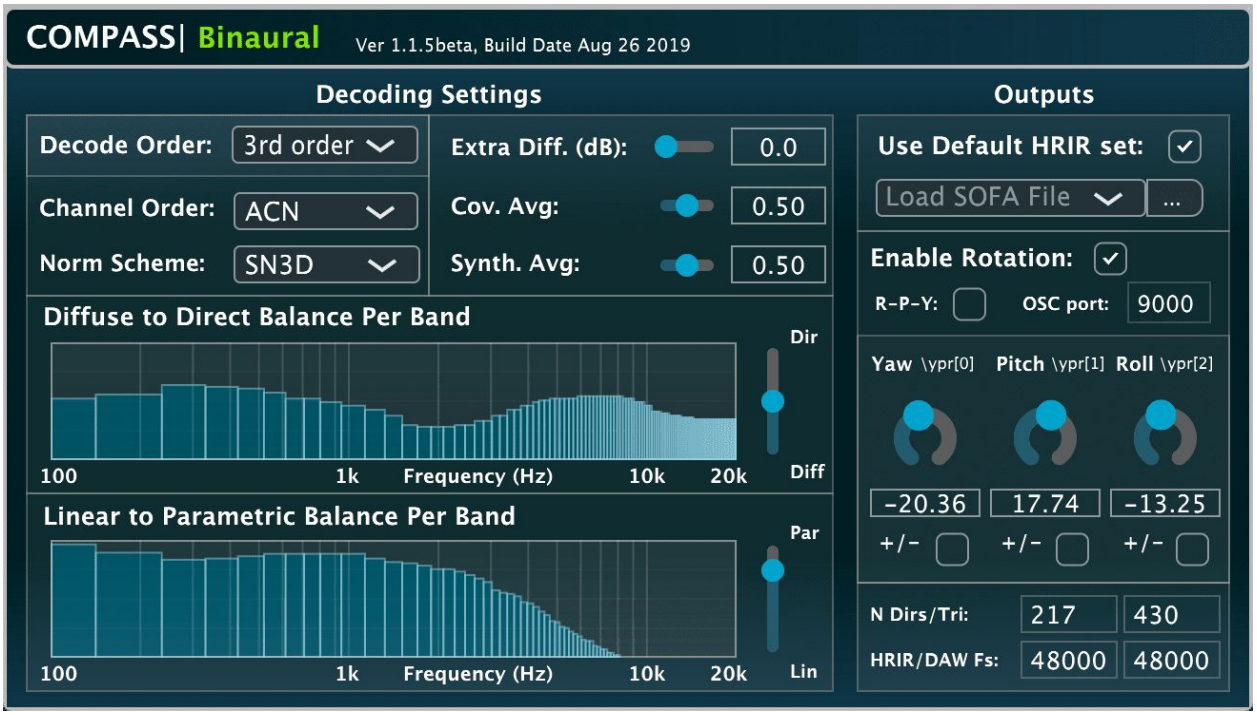
compass_upmixer - `essential`

An Ambisonic upmixer with an first ro 3rd order input and a second to seventh order output.



//compass_binaural - `optional & advanced`

A binaural ambisonic decoder with an input for up to 3rd order ambisonics. Also comes with a SOFA loader and head-tracking supported via OSC messages.



Facebook 360°

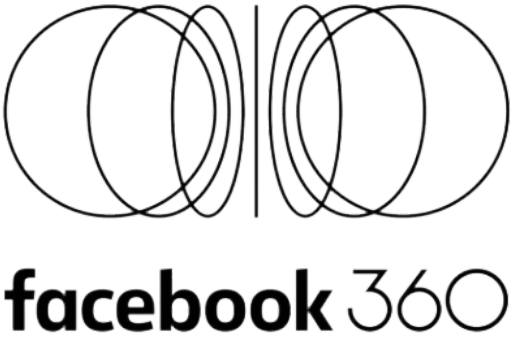
Whether you like the social media giant or not, Facebook is one of the biggest players in spatial audio. The audio division of *Facebook 360* is disguised as the *spatial workstation*, which adds the following plug-ins to your library:

- FB360 Control
- FB360 Converter
- FB360 Mix Loudness
- FB360 Spatializer
- FB360 Stereo Loudness

Dowload and more info: https://facebook360.fb.com/spatial-workstation/

I would also recommend visiting the website above for tutorials held directly by those people who brought you the software.

If that is not enough, here is all the info you could possibly need and more:
https://facebookincubator.github.io/facebook-360-spatial-workstation/index.html

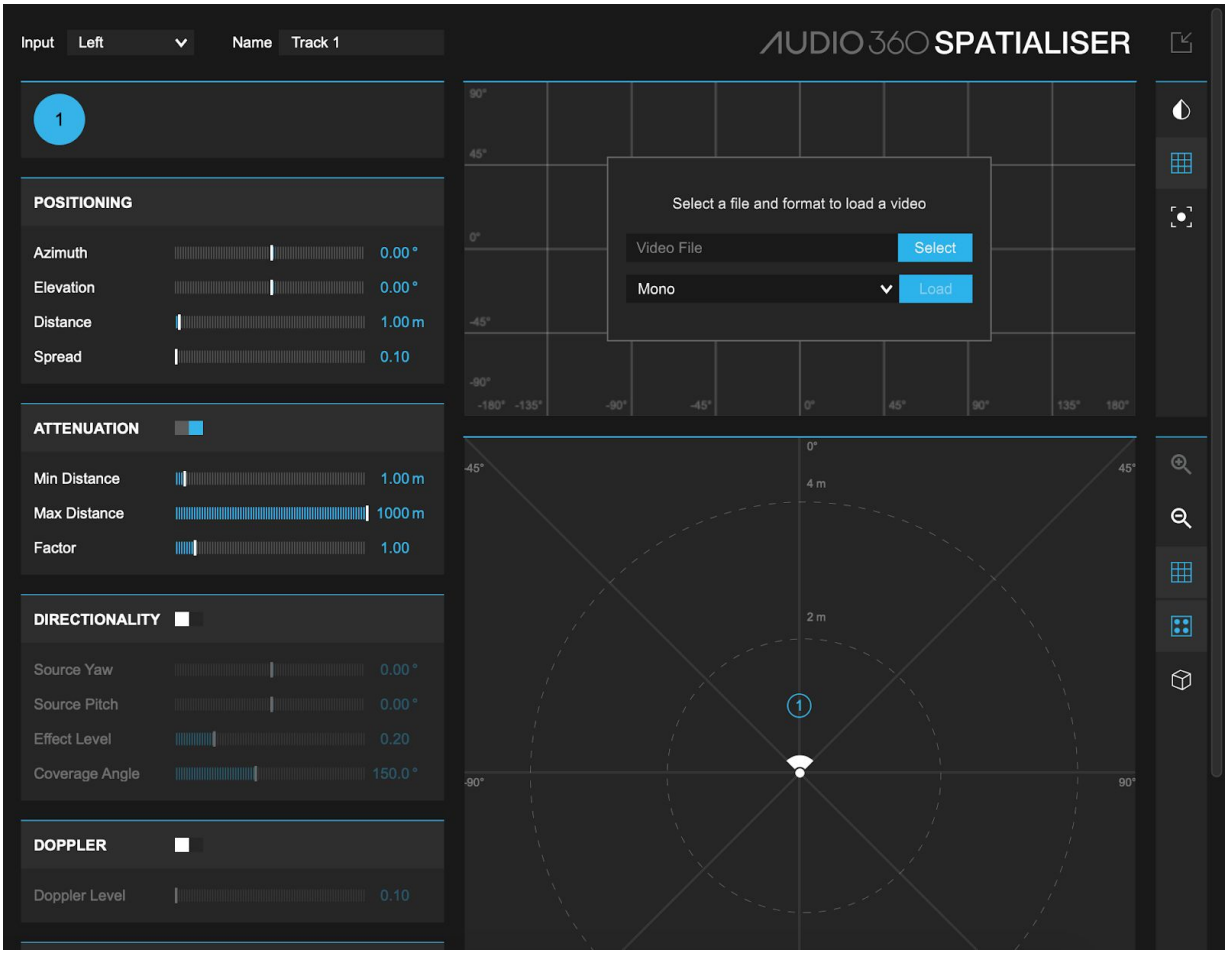


After strolling through our very own little guide to Ambisonics, you will probably be familiar with a few of the following plug-ins already. But, for a quick refreshment, here we go again...

FB360 Spatialiser

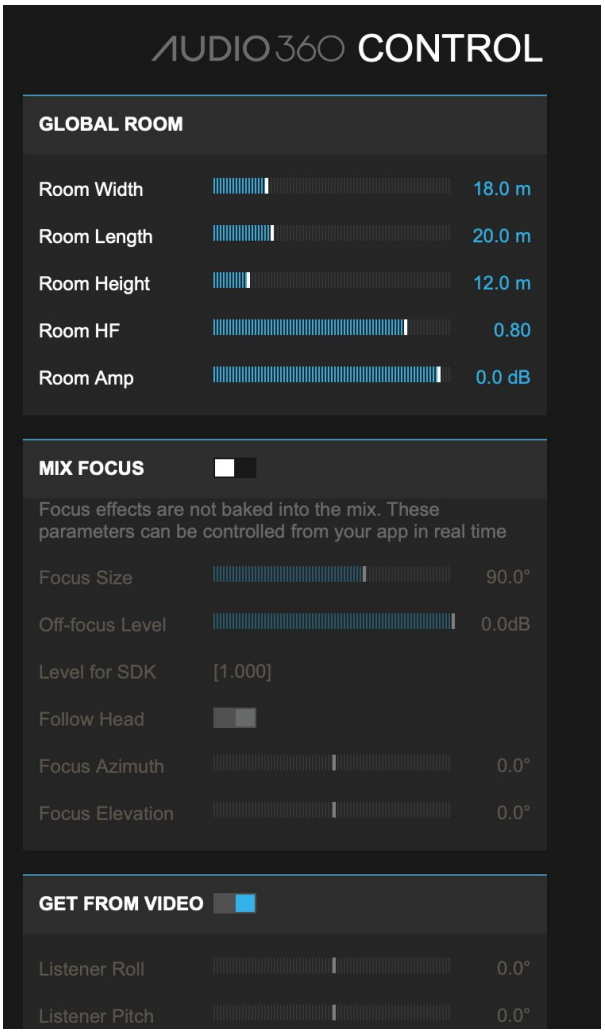
This one should look familiar. It allows you to place a sound source in space. The source may vary: It can be mono, an Ambisonics recording, or a multi-channel recording. Non-mono sources act as a “bed,” which can be described as a static scene, while diegetic mono sources, such as dialogue and sound effects, are usually placed on certain positions in a scene. Everything that is under the category of non-diegetic audio, i.e. narration or background music, is usually routed to the head-locked stereo bus. Head-locked does what it says: It locks the position of the affected audio source to the head of the listener, so you could theoretically headbang without strange rotary effects happening... In other words, they will not rotate as the user looks around in a VR scene.

If, by now, you have forgotten how the FB360 Spatialiser looks like, here’s a screenshot:



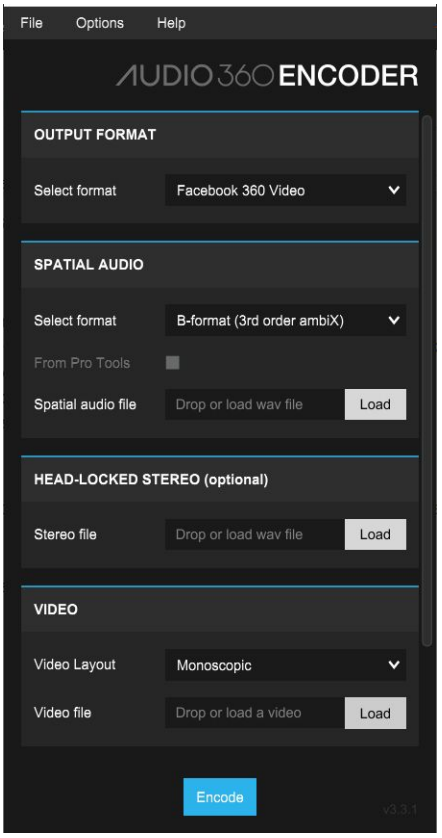
FB360 Control

The Control plug-in is utilized as command center by controlling audio routing for real-time binaural playback through headphones and also managing the global attributes of your production for example by modelling early reflections. You can also control the mix focus.



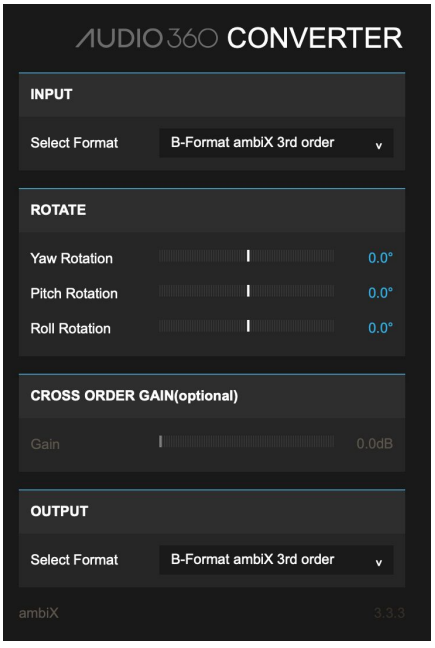
FB360 Encoder

The Facebook 360 Encoder plug-in combines the video file with the audio files and creates a video container, suited for playback on Facebook and other supported platforms. It is also possible to cross-convert between different audio formats. The encoder also adds metadata to the file describing values for the Mix Focus feature, as well as relevant spatial metadata, making the final asset ready for upload. Sounds familiar? You already used this tool in the Encoder chapter.



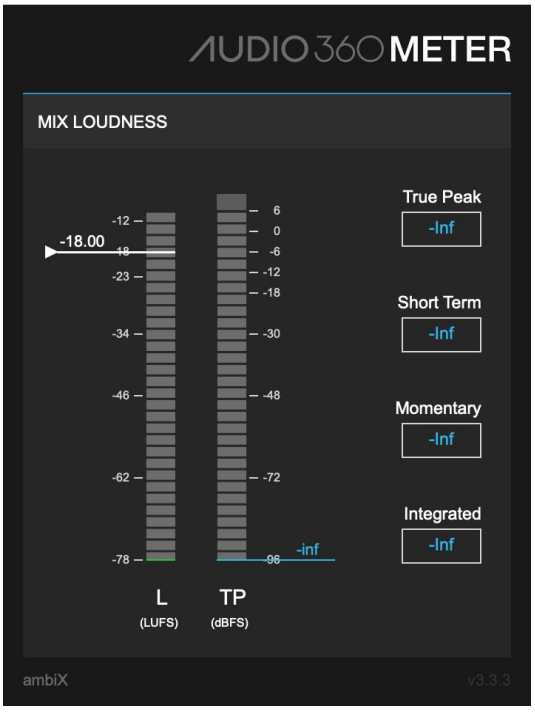
FB360 Converter

The Facebook 360 Converter is a utility plug-in that can rotate a mix after the fact, or output audio to other formats.



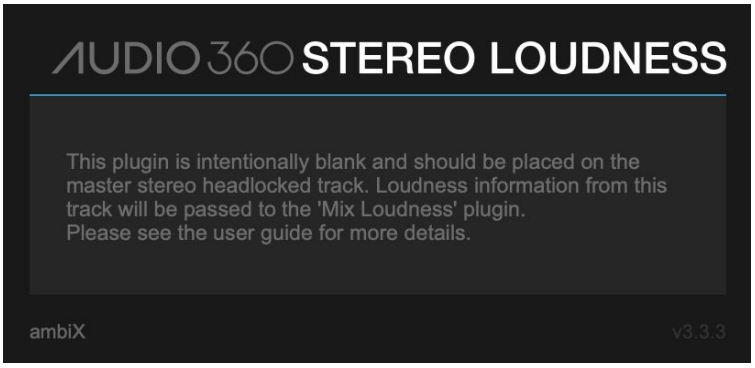
FB360 Mix Loudness

The Loudness meter shows you the loudness of your complete mix. Loudness for spatial mixes is considerably different and more complex than the usual channel-based formats. This meter is said to provide useful data to prevent the final published content from clipping when played back on the targeted device.



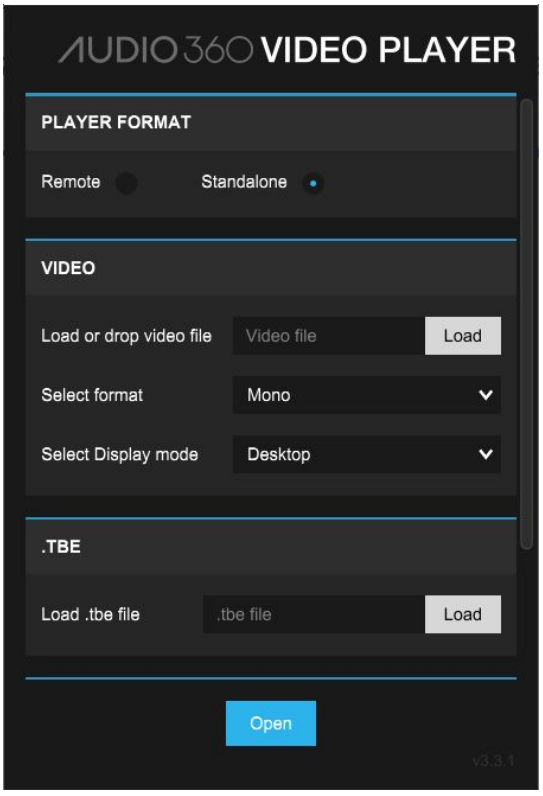
FB360 Stereo Loudness

A little utility plug-in with no controls to possibly mess up. The instructions speak for themselves, and “please see the user guide for more details,” but details are details.



VR Video Player

The essentials about this tool were already covered, but it basically allows you to load and play a video file.



Kronlachner

Immersing ourselves in Ambisonics, there's one name you just can't ignore: Matthias Kronlachner. A lot can be said about him, but most importantly, he is from Austria - you guessed it - just like us. So, you could call him the Arnold Schwarzenegger of Ambisonics. For an overview of Matthias Kronlachner's expansive portfolio, as well as more first-hand infos about his tools, visit his webpage: http://www.matthiaskronlachner.com.

For now, let's take a brief look at the two audio plug-in suites he developed for the process of working with spatial audio:

ambiX v0.2.10 – Ambisonic plug-in suite

The *Ambisonic plug-in suite* is a set of plug-ins developed by Matthias Kronlachner. It includes quite the bunch of applications that can either be used standalone or - how we roll - in a host DAW.

Download and some info: http://www.matthiaskronlachner.com/?p=2015

Following plug-ins are included into the Ambisonic plug-in suite:

- **ambix_converter**
  An on-the-go converter between different ambisonic standards as well as between 2D/3D
- **ambix_encoder**
  A plug-in for panning with varying numbers of input channels.
- **ambix_mirror**
  Inverts or mirrors soundfield along the X, Y, or Z axis.
- **ambix_rotator**
  Rotates around the X, Y & Z axis.
- **ambix_vmic**
  Simulates a virtual microphone that will not be output as an ambisonics signal.

If you feel like familiarizing yourself a tad more with this suite, check out the following paper written by the developer himself: http://www.matthiaskronlachner.com/wp-content/uploads/2013/01/kronlachner_aes_studentdesigncompetition_2014.pdf.

mcfx v0.5.11 – multichannel audio plug-in suite

The *multichannel audio plug-in suite* is a handy set of essential tools created to make batch processing of multiple channels possible. The suite was also developed by Matthias Kronlachner.

Download and more info: http://www.matthiaskronlachner.com/?p=1910

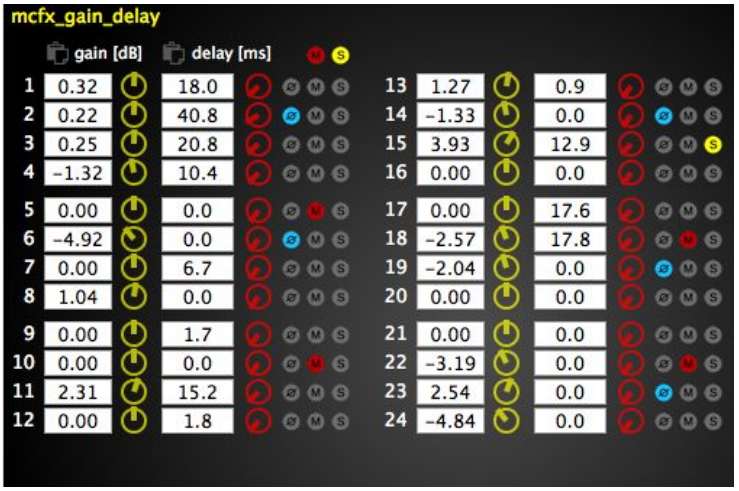
Finding information about the plug-ins themselves can be quite tricky, yet I did it;
Thank me later: https://github.com/kronihias/mcfx

The *multichannel audio plug-in suite* includes:

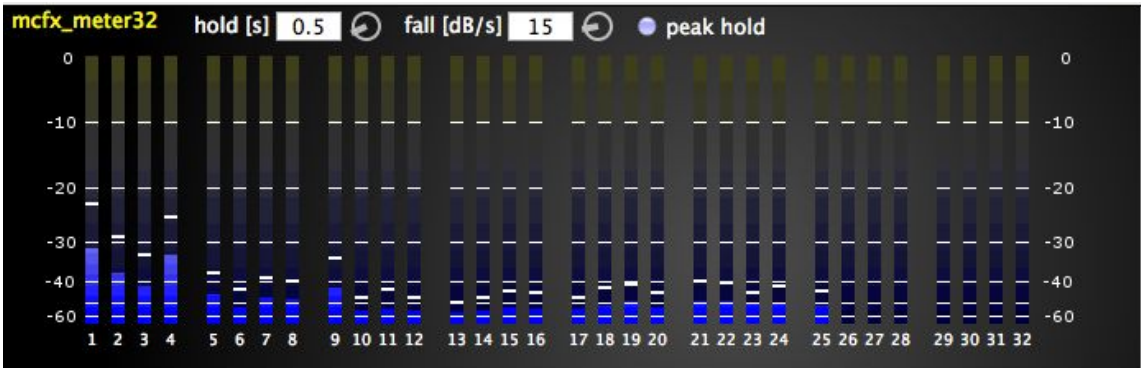
- **mcfx_convolver**
  A convolution plug-in.
- **mcfx_filter**
  A multi-channel filter.

- **mcfx_delay**
  Delays each channel with the same delay time.

- **mcfx_gain_delay**
  Varying delay time and gain setting for each individual channel. Also comes with a signal generator for testing individual channels. A nifty tool for setting up multi-channel systems.



- **mcfx_meter32**
  A multi-channel level meter displaying RMS, peak and peak hold.



Blue Ripple Sound

The company Blue Ripple Sound brings you the free O3A Core library, a bundle of essential tools for audio production in higher-order Ambisonics.

Download and more info:
https://www.blueripplesound.com/products/o3a-core

The bundle includes the following:

Essentials

- O3A Decoders (Mono, Stereo and 5.1 Basic)

  Simple 16 in/1, 2 or 6 out plug-ins.

- O3A Converters

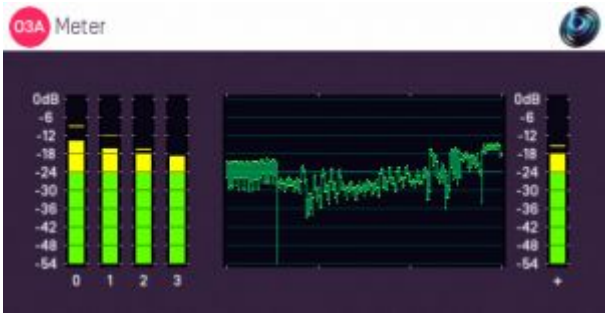
  Convert to/from FuMa or classic ambisonics and between orders

- O3A Virtual Microphone

  Simulates a stereo-mic in an Ambisonic scene

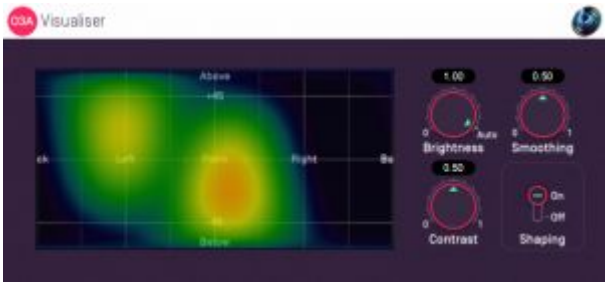
- O3A Metering (Standard and Signal)

  The meters do what meters do, they show you the energy of your mix.



- O3A Visualisers (Standard, Hemisphere, Colourizer and Flare)

  Different visualizers for different visualization purposes, all working in real-time.



Useful but maybe not essential

- O3A Panners
  (Standard, Classic, Hemisphere, Large, Two Channel and Eight Channel)
- O3A Beamer
- O3A Gain
- O3A Look and O3A Rotation
- O3A Spatial Delay

360° video details

Distribution platforms:
YouTube, Vimeo, VeeR, Visbit, Facebook

Camera possibilities:
Insta360 One X, GoPro Max, Insta360 Evo, Insta360 One R, Vuze XR Dual VR 360 5.7K, Vuze 3D 360 4K VR, GoPro Fusion, Insta360 One, Ricoh Theta V, Samsung Gear 360, Garmin VIRB 360, Insta360 Pro, KODAK PIXPRO 4KVR360, YI-360VR Camera

Common formats:

- https://headjack.io/blog/best-encoding-settings-resolution-for-4k-360-3d-vr-videos/

Video stock resources (please review these platforms terms):
- https://www.kandaovr.com/gallery/

- https://www.mettle.com/360vr-master-series-free-360-downloads-page/

Tutorials:

Stitching

https://www.youtube.com/watch?v=1idjcc2X_FU

https://www.youtube.com/watch?v=uRYbPYjQDDA

General information for getting started with VR A/V

http://www.immersiveshooter.com/2019/01/11/16-beginner-tips-for-shooting-360-degree-video/

https://www.cnet.com/how-to/360-cameras-comparison-video-things-to-know-before-you-buy/

https://www.bbc.com/academy-guides/how-do-i-make-360-videos

Glossary

MEMS...Micro-Electro-Mechanical Systems

omnidirectional...no directional information, omnidirectional microphones receive the same sound pressure from every side of the capsule

SPL...sound pressure level

dB...decibel; a relative unit for measurements

List of figures

Figure 1: Nicol, R. (2018). *Spherical microphone array with tetrahedra arranged capsules* [Sound Field. In A. Roginska & P. Geluso (Hrsg.), Immersive Sound: The Art and Sience of Binaural and Multi-Channel Audio (1. Aufl., S. 276-311). Oxford, New York: Routledge.].

Figure 2: SOS Sound On Sound. (2001). *Directivity patterns for encoded B-Format channels W, X, Y and Z.* [Https://www.soundonsound.com/techniques/surround-sound-explained-part-3]. https://www.soundonsound.com/techniques/surround-sound-explained-part-3

Figure 3: Zotter, D. F. (2013). *English: Spherical Harmonics up to degree 5, as used in fifth-order Ambisonics*. Dr Franz Zotter <zotter@iem.at>. https://commons.wikimedia.org/wiki/File:Spherical_Harmonics_deg5.png