

Ambisonics impulse responses in ODEON

AR – September 26

This short note reviews the spatial analysis features available in the ODEON Room Acoustics Software for measured ambisonics impulse responses. The features include visually attractive 3D hedgehogs and impressive auralisation capabilities. The available tools are demonstrated with an example, available online. A more complete analysis can be found in [ODEON's application notes](#).

1. Prerequisites

1.1. ODEON software

The spatial analysis tools are available in:

- ODEON Auditorium
- ODEON Combined
- ODEON Combined Demo version (results limited to the 1 kHz octave band).

Find more information on ODEON's features and the difference between editions on [our website](#).

1.2. Measured impulse responses

The presented examples originate from [Reverbdata](#). Reverbdata is an extensive database containing measured 3D Ambisonics impulse responses of historical Portuguese spaces (churches, auditoria, theatres, etc.). The impulse responses are available in 1st, 2nd and 3rd order Ambisonics.



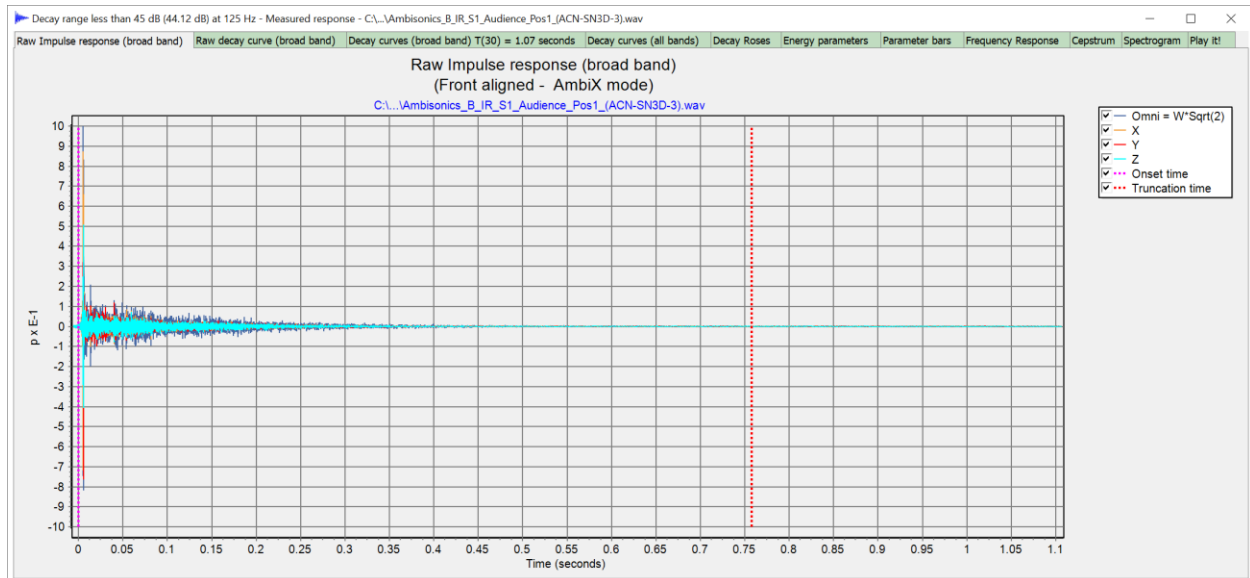
In ODEON, impulse responses must be available in the .wav format. In this note, we use an impulse response from the [São Carlos National Theatre](#), measured in 3rd order ambisonics. The impulse response is available directly in .wav format in the database.

Click on  and select the corresponding file, or simply drag-and-drop the wav file from Windows Explorer onto ODEON.

2. Available tools

2.1. Raw impulse response

Channels in use: ambisonics orders 0 and 1 (4 channels: W, X, Y, Z).



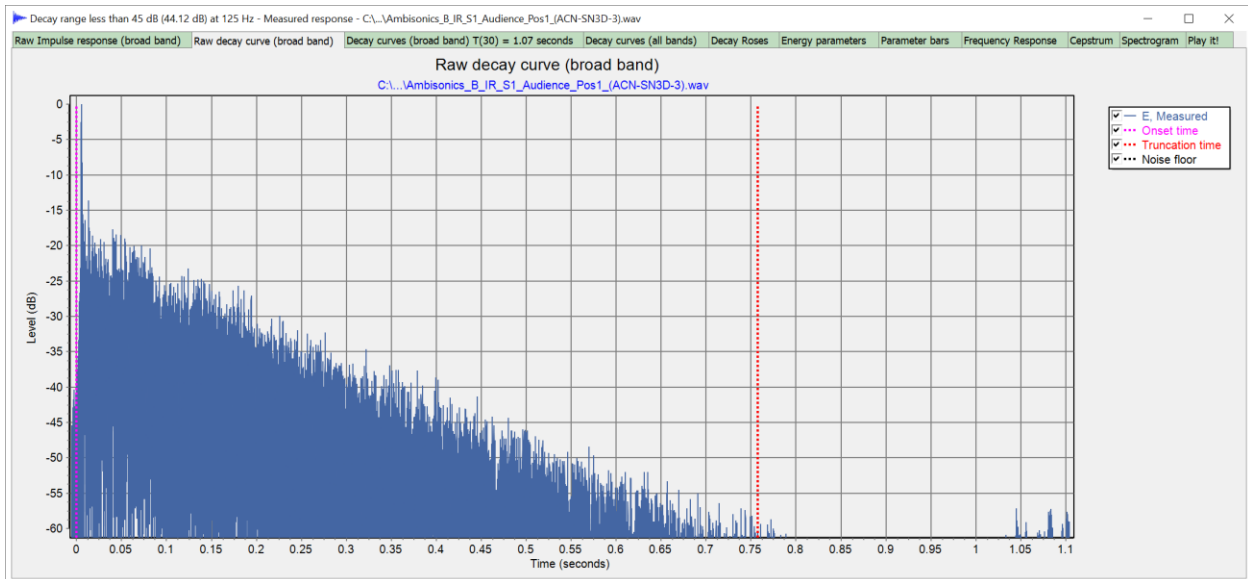
The first channel W (order 0) corresponds to the pressure that would be measured by an omnidirectional microphone. The 3 other channels X, Y, Z (order 1) correspond to the measurement with figure-of-eight microphones in the X, Y and Z directions. Higher orders are not displayed.

ODEON can read ambisonics impulse responses in **B-format** (W, X, Y, Z) and in **AmbiX** ($W \cdot \sqrt{2}$, Y, Z, X), but the Raw impulse response will always be displayed in B-format ordering, with an additional scaling for W ($W \cdot \sqrt{2}$, X, Y, Z).

The response can either be displayed in its original orientation or be rotated so that it is aligned to the direct sound.

2.2. Raw decay curve

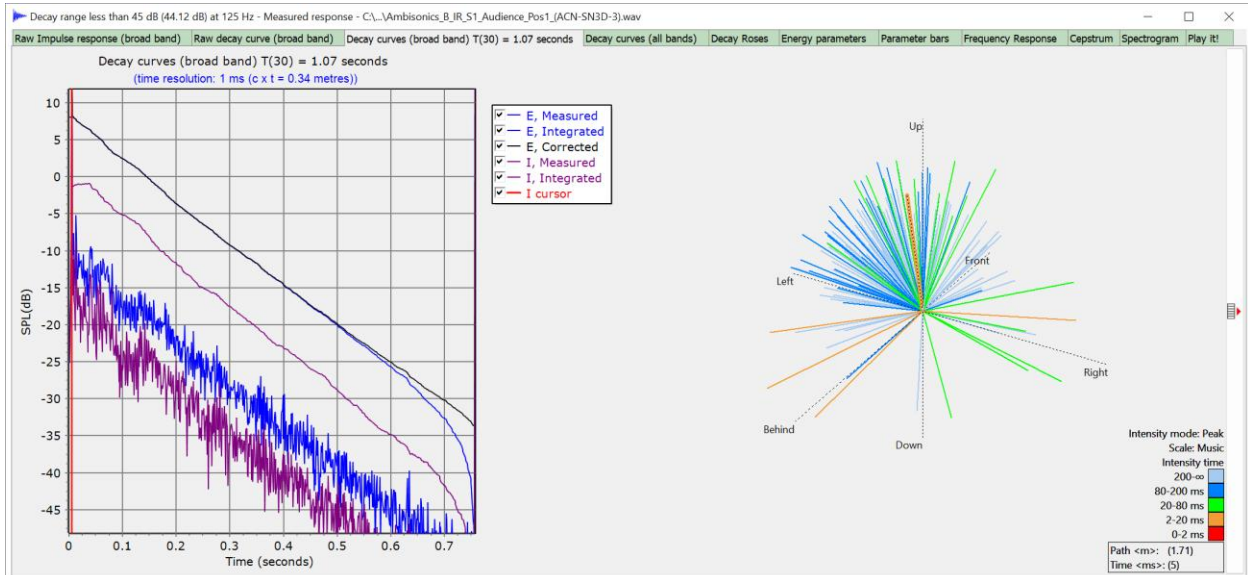
Channels in use: ambisonics order 0.



This view shows the squared pressure impulse response, corresponding to the 0th order.

2.3. Decay curve and 3D hedgehogs

Channels in use: ambisonics orders 0 and 1.



The decay curves are available per octave band and in broadband (for the demo version, only the 1 kHz band is available). They are truncated at the noise floor, and the Schröder integrated versions are also displayed. The intensity norm is also included, as well as its Schröder integration. The intensity curve can indicate echo phenomena (visible as spikes in the measured response).

The 3D hedgehog is another representation of the intensity decay. Each spike corresponds to a local maximum of the intensity norm. The direction of the spike corresponds to the direction of the intensity

vector, its length is related to the intensity norm, and its colour to the time of arrival. The hedgehog is a useful tool to identify strong early reflections.

Various settings are available to adjust the hedgehog display:

- **Time resolution (R or Shift+R shortcut):** a coarser resolution will cluster more sound events together, thus lead to fewer peaks. A time resolution of 10 ms is appropriate for studying echo problems and a resolution of 1 ms or finer can be used to analyse individual reflections.
- **Scale colors (Alt+S shortcut):** multiple scales are available; optimised for music, speech or studio, as well as an automatic scale.
- **Peak detection (Ctrl+P shortcut):** if deactivated, all intensity components at each time frame will be displayed in the hedgehog.

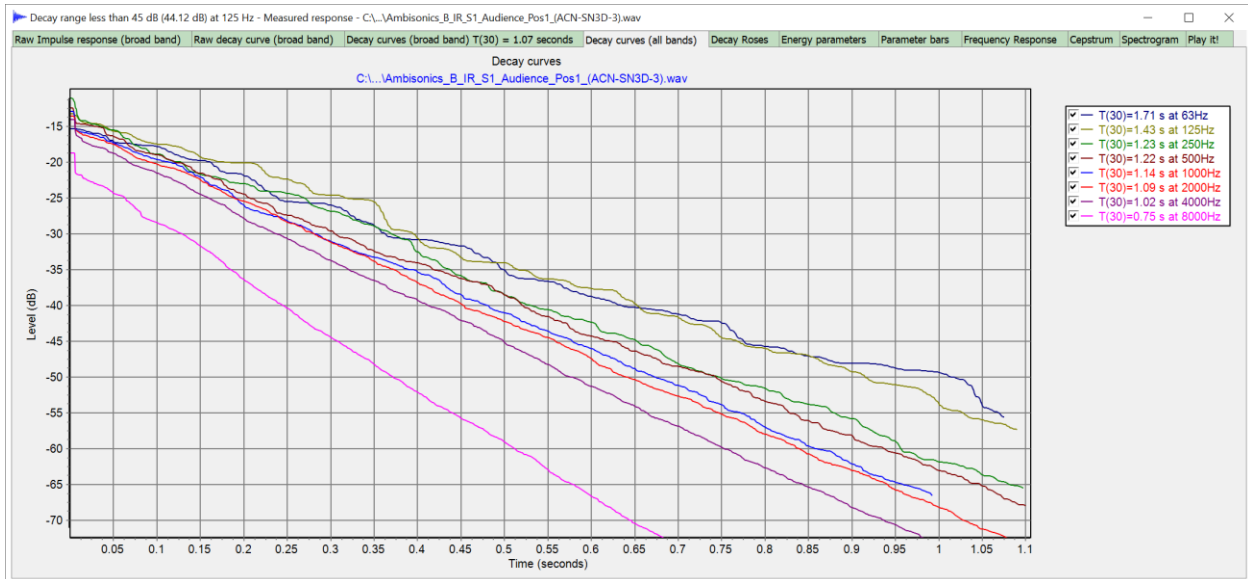
The following options can be used to browse through the hedgehog:

- Clicking on a hedgehog spike will highlight the corresponding time in the Intensity decay curve and vice-versa.
- The P and Shift+P shortcuts move to the next/previous intensity peak in time.

2.4. Decay curves for all bands

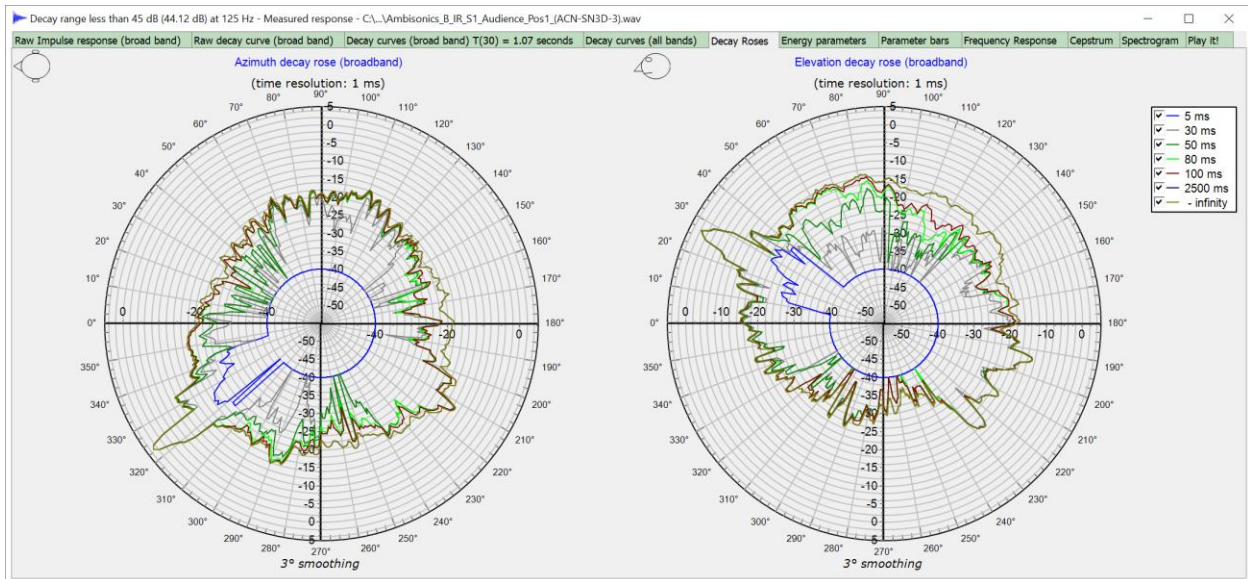
Channels in use: ambisonics order 0.

All octave band decay curves are plotted on the same graph, allowing for a quick comparison between the octave bands.



2.5. Decay roses

Channels in use: ambisonics orders 0 and 1.



The decay roses represent the distribution of the cumulative sound energy on an azimuth plane and an elevation plane over time. They illustrate the spatial distribution of sound in the response. The decay roses are available per octave band as well as in broadband – except in the demo version which only shows the 1 kHz result.

2.6. Room acoustic parameters

Channels in use: ambisonics orders 0 and 1.

Decay range less than 45 dB (44.12 dB) at 125 Hz - Measured response - C:_Ambisonics_B_IR_S1_Audience_Pos1_ACN-SN3D-3).wav									
Raw Impulse response (broad band) Raw decay curve (broad band) Decay curves (broad band) T(30) = 1.07 seconds Decay curves (all bands) Decay Roses Energy parameters Parameter bars Frequency Response Cepstrum Spectrogram Play It!									
Band	(Hz)	63	125	250	500	1000	2000	4000	8000
EDT	(s)	1.59	1.75	0.98	1.15	1.23	1.19	1.04	0.72
EDT(2)	(s)	1.47	1.63	0.82	1.03	0.96	0.99	0.86	0.63
T(15)	(s)	1.51	1.28	1.49	1.13	1.06	1.10	0.99	0.75
T(20)	(s)	1.49	1.35	1.35	1.22	1.13	1.08	1.00	0.74
$\xi(T(20))$	(%)	8.4	19.2	20.5	6.0	6.2	1.7	1.0	3.1
T(30)	(s)	1.71	1.43	1.23	1.22	1.14	1.09	1.02	0.75
$\xi(T(30))$	(%)	12.7	9.0	8.4	2.5	2.0	0.9	0.7	1.0
Curvature(C)	(%)	15.3	5.7	-8.8	0.4	1.1	0.5	2.2	1.4
Ts	(ms)	130	107	53	61	56	59	50	38
SPL	(dB)	-11.3	-11.8	-10.6	-11.8	-12.3	-13.0	-13.7	-17.7
G	(dB)	19.7	19.2	20.4	19.2	18.7	18.0	17.3	13.3
G(early)	(dB)	18.4	17.4	19.3	17.9	17.4	16.8	16.2	*
G(late)	(dB)	14.0	14.5	13.8	13.2	12.8	12.0	10.7	13.3
SPL(Af)	(dB)	-37.5	-28.0	-19.3	-15.1	-12.3	-11.8	-12.7	-18.8
SPL(Direct)	(dB)	-73.7	-73.7	-73.7	-74.0	-74.8	-79.0	-75.1	*
D(50)		0.70	0.55	0.65	0.59	0.63	0.60	0.66	0.00
C(7)	(dB)	-7.8	-9.6	-5.6	-1.3	-1.0	-2.2	-1.6	*
C(50)	(dB)	3.7	0.8	2.6	1.7	2.3	1.8	2.9	*
C(80)	(dB)	4.4	2.9	5.5	4.7	4.6	4.8	5.5	*
U(50)	(dB)	-12.9	-14.5	-12.7	-14.2	-14.4	-15.3	-15.5	*
U(80)	(dB)	-12.7	-13.7	-11.8	-13.2	-13.7	-14.3	-14.8	*
MTI(corrected)		*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LF(80)		0.021	0.075	0.163	0.184	0.168	0.290	0.325	*

The energy parameters tab includes classic standardized parameters, such as reverberation (EDT, T_{20} and T_{30}). For spatial impulse responses, additional spatial parameters can also be displayed:

- **Lateral energy fraction (LF_{80} , LFC_{80}):** these parameters indicate the source's perceived width and are based on the early part of the response.

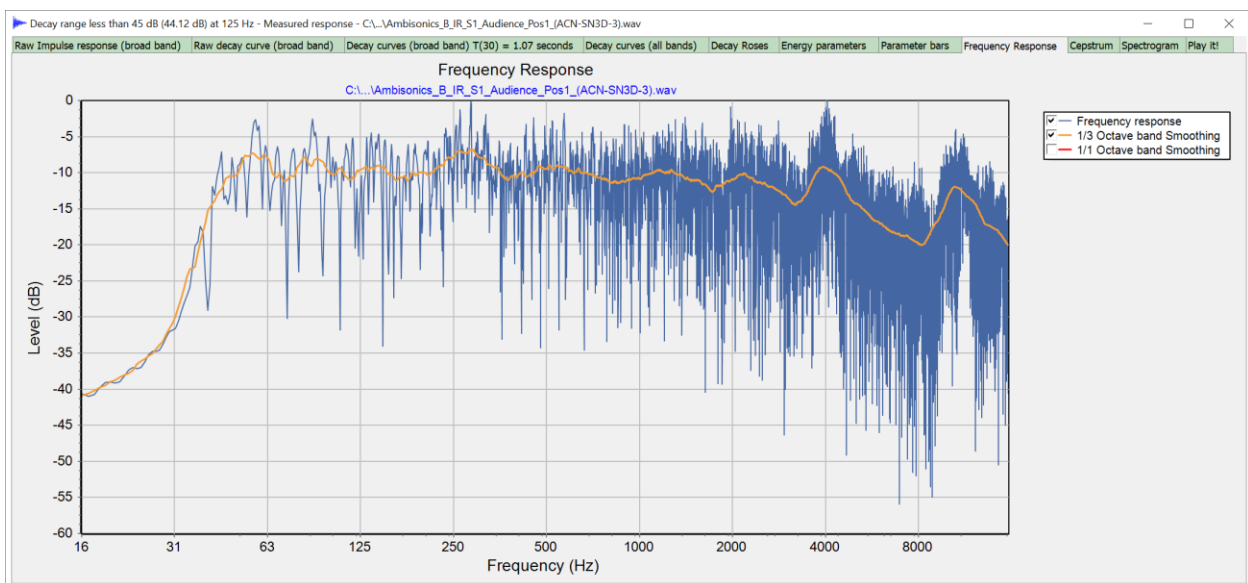
- **Late lateral G (L_l):** represents listener's envelopment and the room's spaciousness. It is based on the late part of the response.
- **Diffusivity:** compares sound energy with the intensity norm. If the two quantities are equal, the diffusivity is 0 and the sound field is entirely directional.

IMPORTANT: these parameters assume that there is only one omni directional source and that the receiver is facing the sound source. Make sure that the response is front-aligned.

Most parameters can also be studied graphically in the "Parameter bars" tab.

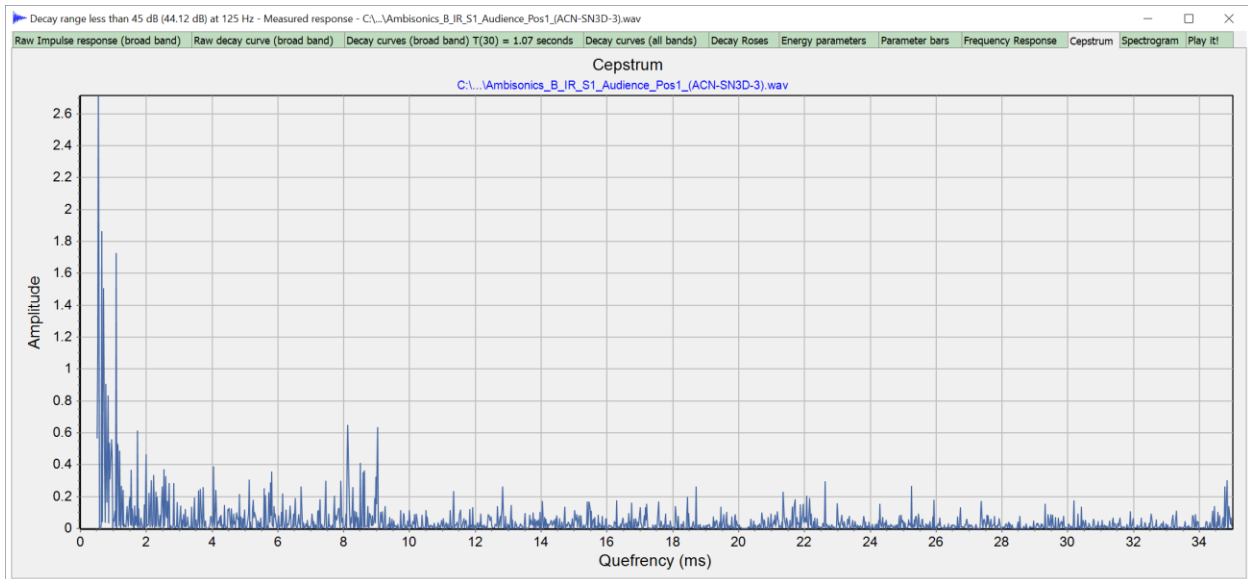
2.7. Frequency response

Channels in use: ambisonics order 0.



2.8. Cepstrum

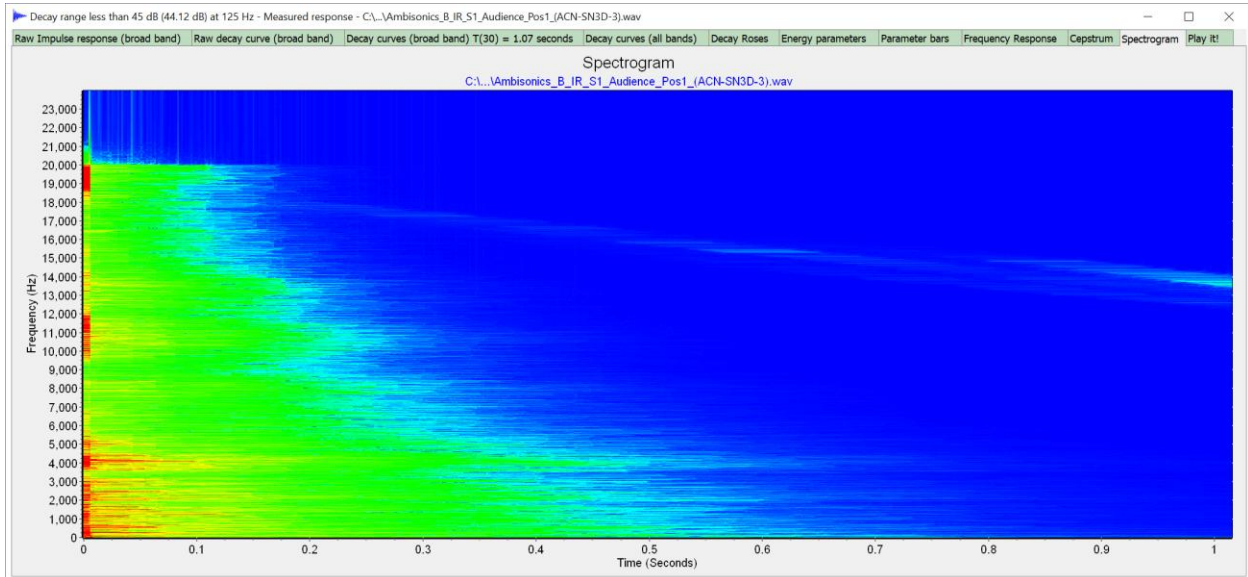
Channels in use: ambisonics order 0.



The cepstrum can be used to identify colouration effects, which appear as large peaks in the graph.

2.9. Spectrogram

Channels in use: ambisonics order 0.

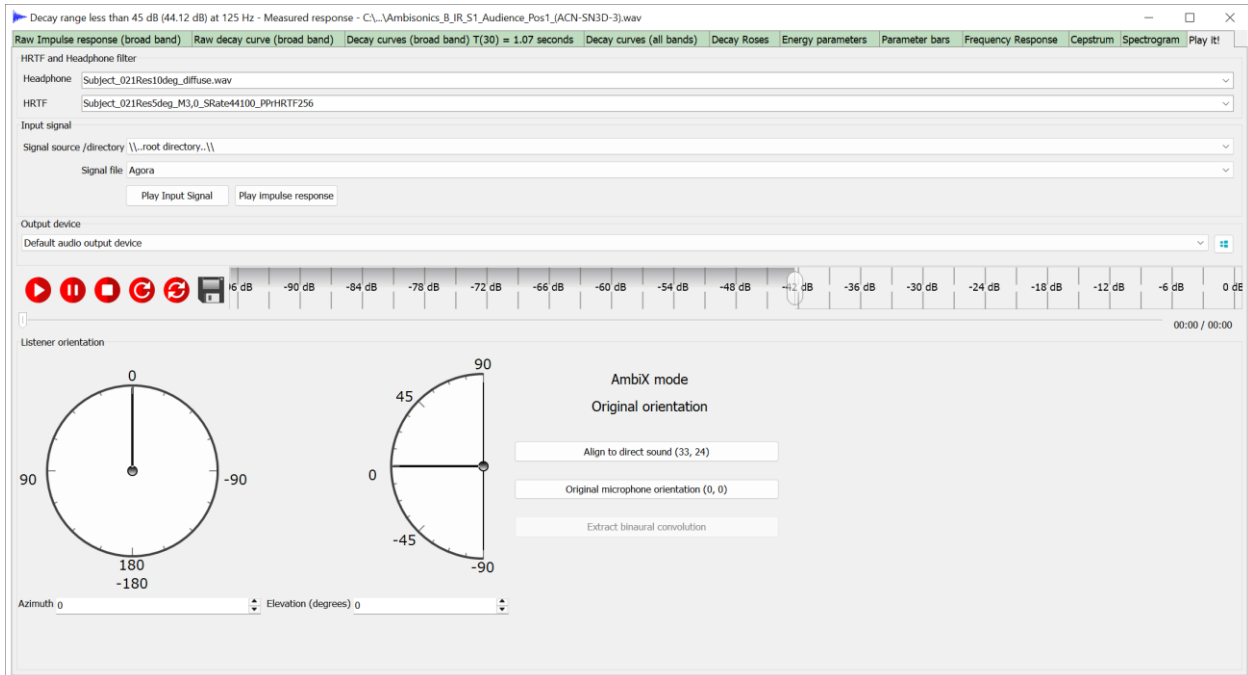


The spectrogram is a time-frequency representation of the impulse response.

2.10. Play it!

Channels in use: all ambisonics orders.

Last but not least, the PlayIt! Tool allows to convolve the full spatial impulse response with an anechoic signal of your choice and auralise it in 3D via headphones. The listener's orientation (azimuth and elevation) can be changed in real time.



The ODEON Play It! supports up to third-order ambisonics, which means that the 2nd and 3rd order channels will also be used in the rendering. A higher order leads to a more precise localization and better out-of-head experience.