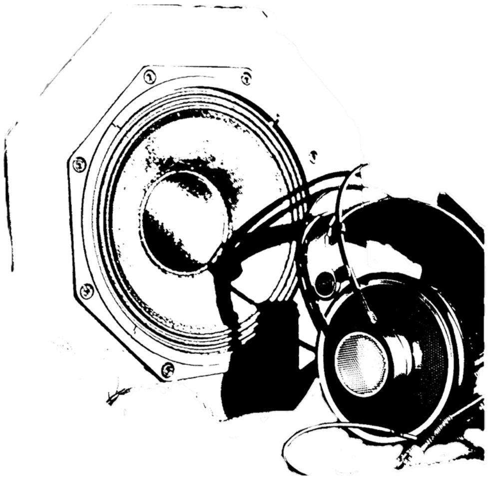


The Hybrid Audio Diffusion System (HADS) as a tool for the development of the Virtual Vienna Acousmonium

Documentation Phase I - July 22 to December 22

Researcher
Thomas Gorbach
Enrique Mendoza Mejia

THE ACOUSMATIC PROJECT

Overview

The goal of this artistic research project is the development of the Virtual Viennese Akusmonium. A system with a specific configuration of loudspeakers and headphones in a creative workflow, as well as the creation of a test system for the evaluation of the results by external users.
Through the developments during the first work phase and the analysis of the first test data, we were able to recognize the need for a precise definition of the requirements, possibilities and limitations as well as the features, assignments and feedback system of a virtual acousmonium. We are convinced that this can significantly improve spatial hearing and imagination, combined with acousmatic sound qualities. Thus, an ideal training system for spatial hearing as well as the creation of musical spatialization concepts for acousmatic music is created.
Furthermore, the possibility of integrating defined musical spatial parameters into the composition process of new works is enabled. We also raise the question of the minimum design of the virtual acousmonium for the home studio and the maximum design for the large concert hall, as well as the necessity of specific hardware development for the virtual acousmonium.

We performed the following steps in the first phase of work.

1. Installation and configuration of the research environment in the Praterstudio, 1020, Kurzbauergasse 6.

The Praterstudio - experimental studio for immersive multi-channel sound and acousmatic composition of The Acousmatic Project, opened in March 2022, we were able to expand as planned in July 2022 with two speaker arrays and two sub-basses to a 16.2 system.

There are two rings of eight channels arranged one above the other. One ring is placed at ear level and the second ring at the ceiling. In addition, two sub-basses are placed in the room in front and behind. With this arrangement in the form of a speaker dome, the sound can be moved three-dimensionally (horizontal, vertical, oscillating, axial, tangential, oblique, circular, spiral and mixed forms of these shapes).

The HADS system is equipped with ‚open' headphones. This allows listening to sounds from the speakers with very low filtering and as additional speakers they are integrated into the system. Depending on the configuration of the whole system, the headphones are recorded with their own audio channel. Due to their pronounced transparency, this type of headphones is suitable for accurate directional listening.

The filter and amplitude calibration of the system by IR (Impulse Responses) was done with the reference microphone DSP-mini and the REW software by John Mulcahy. The sound field of the entire system should be able to be measured and perceived as ‚balanced' after setting the audio levels and filtering.
All speakers including the headphones now provide an 18.2 audio system with discrete audio channels for research.

See Appendix 1

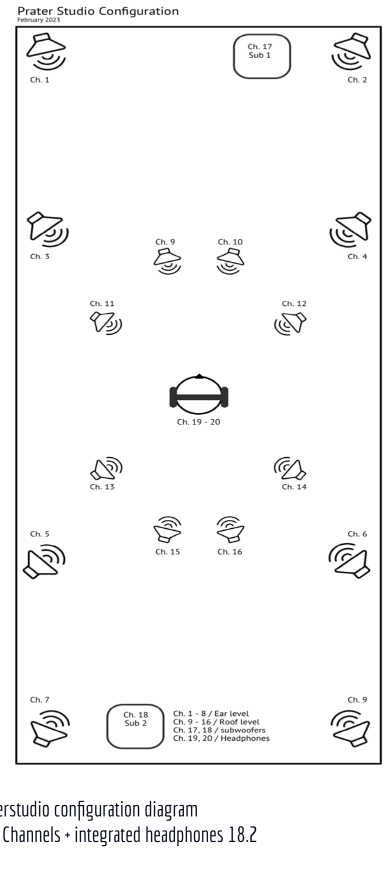


Fig. 1 Praterstudio configuration diagram
16.2 Channels + integrated headphones 18.2

2. Creative workflow - discrete, binaural and ambisonic channel configuration.

The special configuration of the audio routing in the DAW (Digital Audio Workstation) enables a workflow that provides a coherent, extended 3D sound field during composing as well as during the creation of a spatialization concept and during the preparation of the MUSHRA test files, which can also be re-initiated.
In an iterative approach, it is possible to alternate between compositional work and spatialization. Thus, mono- stereo- binaural or ambisonic sources can be combined with the modification of individual volumes of the loudspeaker channels or with ambisonic panners. The sum is then sent to the Ambisonic bus connected to the speaker array and to the Binaural bus connected to the headphones. In this configuration, the entire system is integrated.
The last step is now to match the Ambisonic bus with the Binaural bus in volume.
The described creative workflow is a key point in the development of the virtual acousmonium and has to be differentiated and modified more precisely in the further work in order to achieve the intended goal.

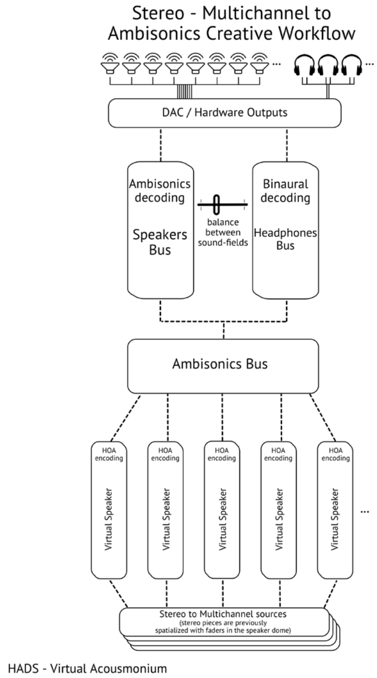


Abb. 3, discrete (stereo and multichannel) to ambisonics creative workflow

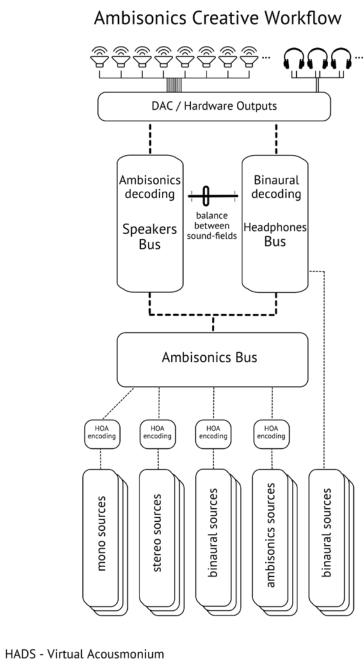


Abb. 2, Ambisonic creative workflow

3. The MUSHRA test environment - a method for the qualification of the test persons and the HADS system.

MUSHRA testing is a method for subjectively evaluating the quality of audio systems. It is a multi-stimulus test with hidden references (as comparison data) and anchors (for testing the test subject), which not only evaluates the system, but also distinguishes the test subjects as suitable or unsuitable participants.
This method has been verified and officially released by the International Telecommunication Union ITU, based in Geneva.

We use it to evaluate the subjective perception between the egocentric and the allocentric sound field with respect to defined musical spatialization parameters. Thus, we obtain data describing the subjective characteristics of the extended immersive sound experience of the test subjects.

An essential step is now to perform the test with specific sound samples. These must depict the musical-spatial parameters particularly clearly. For this purpose, we selected work excerpts with a duration of between 12 and 30 seconds from the acousmatic repertoire.

3.1 Procedure of a test

The testing was always carried out in the same procedure.

1. the subject does not receive any information about the test or the test environment in advance. She enters the test environment.

2. he sits down at the place of testing and receives the headphones.

3. the use of the test tool is explained.

4. the test person listens to one minute of acousmatic music, using the whole system.

5. before the test starts, the person is informed about the maximum duration of 30 minutes for the entire test run.

6) The person is also informed that in the case of a neutral evaluation, the set value (zero) should not be changed.

7. the person is also informed that this is a subjective assessment and that he/she cannot therefore give a ‚false' assessment and that, in case of doubt, he/she can either give a ‚zero' or an ‚estimated' assessment.

3.2 Description of the MUSHRA Test Tool

According to the MUSHRA recommendation, the test files must be available in different multi-channel formats and in different processing. To perform the tests, a special computer program was written that can play these formats.
A continuous quality scale from 0 to 100 (poor to excellent) is provided for comparison. The data collection can now be carried out and the results stored in a data set for evaluation.

Fig. 4, User interface to the test program of the MUSHRA test.

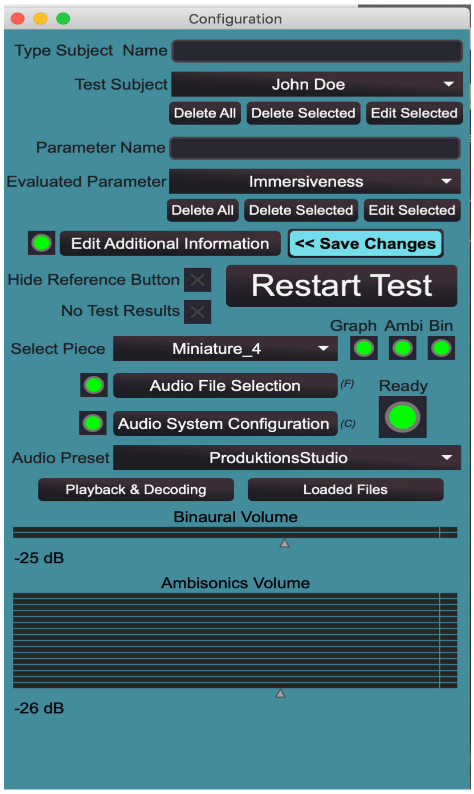


Fig. 5, Configuration window for the MUSHRA test. Here the name of the evaluated room parameter, the name of the tester, the selection and loading of the test signal and the calibration of the amplitude ratio between the binaural and the ambisonic test file can be set.

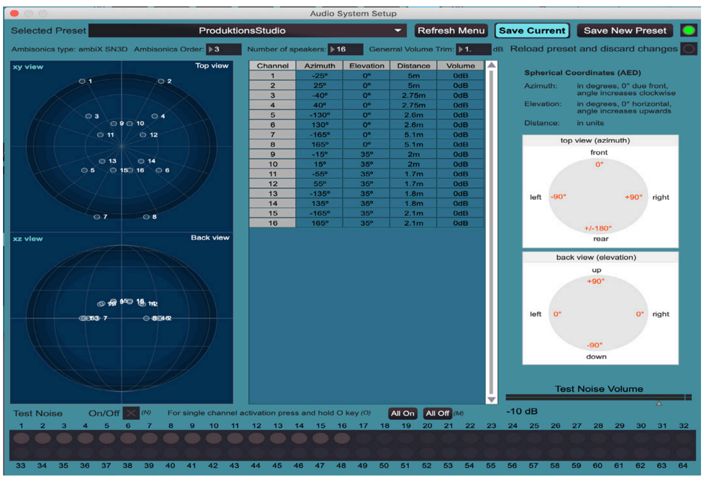


Fig. 6, Audio system configuration window. In this window, the speaker dome is calibrated for Ambisonic playback. With the programmed software, listening tests can be performed with differently configured speaker domes.

3.3. The number and formats of test files

Seventeen signals must be generated for each test file, which are compared during the tests. Eight signals are Ambisonic files, another eight signals are Binaural files and one non-sounding Mono file serves as visual feedback for the test subjects.

According to the MUSRAH recommendation, the following signals are created to be compared with the reference signal.

- reference signal
- three impaired signals
- one low anchor
- one hidden middle anchor
- one hidden reference

The three impaired signals are used to systematically test the sonic qualities of the HADS as a listening system. The remaining edits of the test signal are used to check the suitability of the test subjects.

Signal	Content	Ambisonics File	Binaural File
Reference	Full bandwidth stimuli	Yes (File 1)	Yes (File 7)
Impaired Signal 1	Only headphones listening with speaker's sound field and room acoustics rendered to the binaural sound field.	No (File 2)	Yes (File 8)
Impaired Signal 2	Only headphones listening without rendering the speaker's sound field and room acoustics.	No (File 3)	Yes (File 9)
Impaired Signal 3	Only speakers without the binaural sound field.	Yes (File 4)	No (File 10)
Hidden low anchor	The Reference files with a low-pass filter. (cut-off frequency at 1750 Hz. with 24/oct slope)	Yes (File 5)	Yes (File 11)
Hidden mid anchor	The Reference files with a low-pass filter. (cut-off frequency at 3.5 kHz. With 24/oct slope)	Yes (File 6)	Yes (File 12)
Hidden Reference	Full bandwith stimuli	Yes (same file as Reference)	Yes (same file as Reference)
Graphic (File 13)	Mix collapsed in mono to be only used as graphic.	No	No

Table 1, description of the content and impairments of each test signal.

The analysis of the collected data is performed using a parametric statistical model to obtain the median values. This information gives us information about the spatial qualities of the system.

The Mushra test program generates a text file with the correspon-ding values from the data entered by the test subjects. These are evaluated statistically in the following.

```
Date: 27-1-2023

Time: 14:45

Test Subject: John Dow

Evaluated Parameter: Inside - Outside the Head

Tested Signal: Miniature_8

Test Results:

        Fader 1: 0
        Fader 2: 28
        Fader 3: 84
        Fader 4: 0
        Fader 5: 14
        Fader 6: 28
        Fader 7: Inactive
        Fader 8: Inactive

Loaded Signals:

        Fader 1: ImpSig2 VDA
        Fader 2: LowAnchor
        Fader 3: Hidden Reference
        Fader 4: ImpSig1 VDA
        Fader 5: ImpSig3 VDB
        Fader 6: MidAnchor
        Fader 7: Inactive
        Fader 8: Inactive

Audio System Preset Name: ProduktionsStudio

Audio System Configuration Data:

        Ambisonics Type: ambiX SN3D
        Ambisonics Order: 3
        Number of Speakers: 16
        General Volume Trim: 1.00dB
        Binaural Volume: -11.41dB
        Ambisonics Volume: -20.61dB

        Channel   Azimuth   Elevation   Distance  Volume
        1        -25.00º      0.00º     5.00m    0.00dB
        2         25.00º      0.00º     5.00m    0.00dB
        3        -40.00º      0.00º     2.75m    0.00dB
        4         40.00º      0.00º     2.75m    0.00dB
        5        -130.00º     0.00º     2.60m    0.00dB
        6         130.00º     0.00º     2.60m    0.00dB
        7        -165.00º     0.00º     5.10m    0.00dB
        8         165.00º     0.00º     5.10m    0.00dB
        9        -15.00º     35.00º     2.00m    0.00dB
        10        15.00º     35.00º     2.00m    0.00dB
        11       -55.00º     35.00º     1.70m    0.00dB
        12        55.00º     35.00º     1.70m    0.00dB
        13       -135.00º    35.00º     1.80m    0.00dB
        14        135.00º    35.00º     1.80m    0.00dB
        15       -165.00º    35.00º     2.10m    0.00dB
        16        165.00º    35.00º     2.10m    0.00dB

Additional Information:

Speakers dB(c) SPL: 70
Headphones dB(c) SPL: 54
Number of Subs: 2
Binaural Config Patch Level: -5.500 dB
Ambisonics Config Patch Level: -13
```

Fig. 7, Example of a data set of a test person and a room parameter created by the MUSHRA test program.

4. Selection of the three musical room parameters for testing

In different works of acousmatic music we have identified three musical spatial parameters that produce clearly recognizable sound space movements with the HADS system. When processing the sound excerpts as test files, we did not interfere with the already existing spatialization by the composers.
This also means that in the current phase of the project, we have not used the inherent possibilities of the system to spatialize or interpret the acousmatic works.

4.1 Immersiveness

This parameter can be described as the subjective feeling of being integrated into the musical event.
This includes both the intensity of the spatial directions and the integration of the sound space movements from the loudspeakers to the headphones. Thus the movement of a sound through one's own head or one's own body can be experienced. But also the movements within the loudspeaker circle at ear level to the upper circle of loudspeakers are recognizable.

4.2 Proximity / Distance

This parameter distinguishes between signals that are played either through the speakers or through the headphones and/or switch between these two sources, thus clearly emphasizing the proximity / distance aspect.
The immersivity is hardly perceptible here and the sound space movements are stable to little active.

4.3 Horizontal / Vertical

This parameter distinguishes sounds that move either on one of the horizontal planes (circle & headphones at ear level or speaker circle on the ceiling) or from one to the other, emphasizing the vertical axes of space. The frequency progression and the type of granularity play a significant role in the morphological progression of the music.

5.1 Listening test : Parameter : Immersivity

- Hypothesis. The combination of Ambisonic 3D sound fields over the loudspeaker array and Binaural 3D sound fields over open headphones enhances the impression of an extended immersive 3D sound field.

- Premise: Six test signals with different configurations of the monitoring system are compared to a reference and evaluated. The results are the statistical representations of the subjectively perceived impression of immersivity.

- Independent variables: Test signal, monitoring systems, configuration of the studio, calibration of the equipment, signal flow of the whole audio chain (see above).

- Dependent variable: ten test subjects

- Control variable: the MUSHRA test

	Hidden Reference	Impaired Signal 1	Impaired Signal 2	Impaired Signal 3	Mid Anchor	Low Anchor
Assesor 1	45	15	0	60	40	11
Assessor 2	45	21	14	50	44	50
Assessor 3	50	26	24	32	69	50
Assessor 4	50	26	21	50	39	33
Assessor 5	59	28	20	25	39	10
Assessor 6	66	29	21	70	50	36
Assessor 7	68	34	25	43	63	45
Assessor 8	71	41	27	69	74	78
Assessor 9	80	52	10	41	37	27
Assessor 10	90	56	41	50	35	16

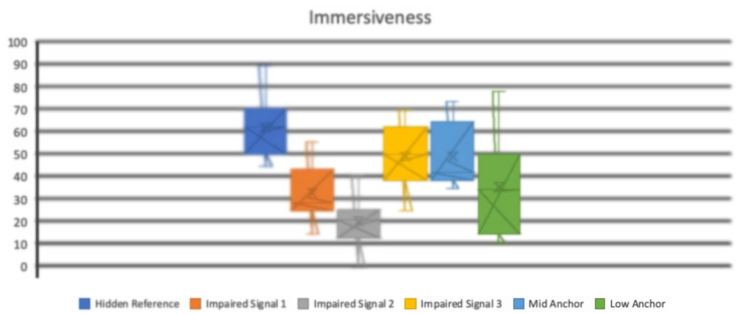
Tab 2, Summary of the evaluations

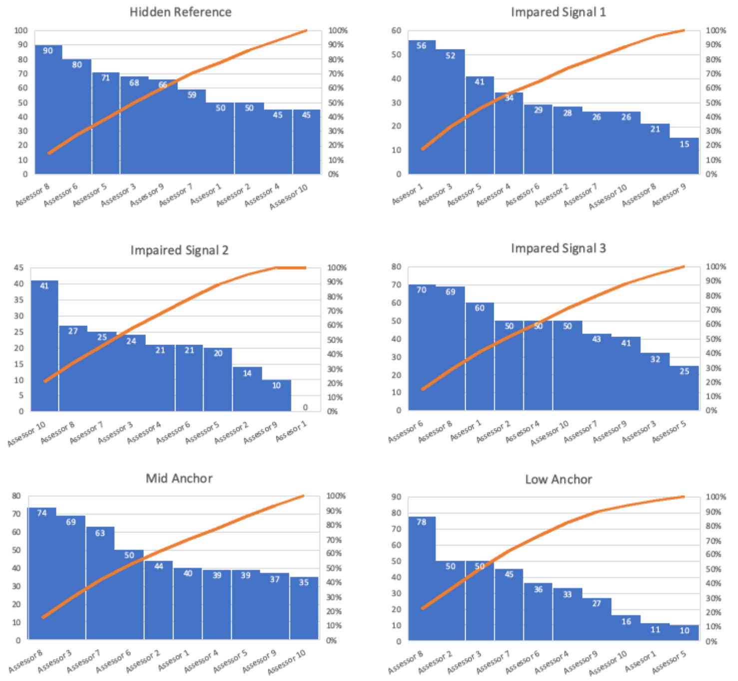
Descriptive Statistics

	Hidden Reference	*Impaired Signal 1*	*Impaired Signal 2*	*Impaired Signal 3*	*Mid Anchor*	*Low Anchor*
Mean	62.4	32.8	20.3	49	49	35.6
Typical Error	4.8470	4.1655	3.4450	4.6308	4.5558	6.6886
Median	62.5	28.5	21	50	42	34.5
Mode	50	26	21	50	39	50
Standard Deviation	15.33	13.17	10.89	14.64	14.41	21.15
Variance	234.93	173.51	118.68	214.44	207.56	447.38
Kurtosis	- 0.73	- 0.32	1.38	- 0.59	- 0.92	0.32
Skewness	0.50	0.73	- 0.04	- 0.04	0.88	0.63
Range	45	41	41	45	39	68
Minimun	45	15	0	25	35	10
Maximum	90	56	41	70	74	78
Sum	624	328	203	490	490	356
Count	10	10	10	10	10	10
	Platykurtic	Platykurtic	Leptokurtic	Platykurtic	Platykurtic	Leptokurtic

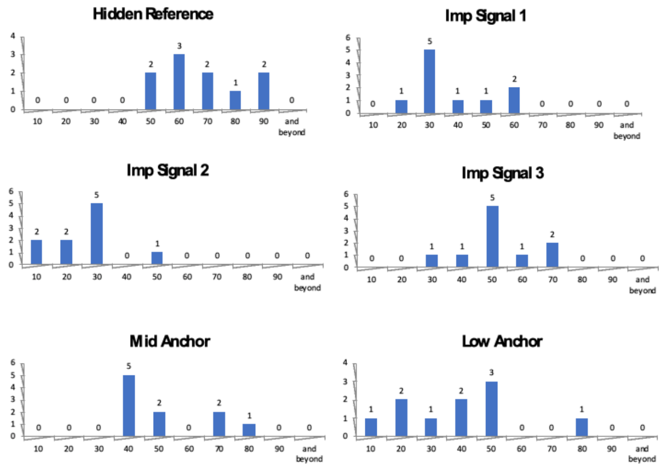
	Assesor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9	Assessor 10	Mean	Median	Standard Dev.
Hidden Reference	50	50	68	45	71	80	59	90	66	45	62.4	62.5	15.3
Impaired Signal 1	56	28	52	34	41	29	26	21	15	26	32.8	28.5	13.2
Impaired Signal 2	0	14	24	21	20	21	25	27	10	41	20.3	21.0	10.9
Impaired Signal 3	60	50	32	50	25	70	43	69	41	50	49.0	50.0	14.6
Mid Anchor	40	44	69	39	39	50	63	74	37	35	49.0	42.0	14.4
Low Anchor	11	50	50	33	10	36	45	78	27	16	35.6	34.5	21.2

Mean, median, and standard deviation calculation





Median and Pareto distribution



Class and frequency

SUMMARY	Count	Sum	Mean	Vaiance
Hidden Reference	10	624	62.40	234.93
Impaired Signal 1	10	328	32.80	173.51
Impaired Signal 2	10	203	20.30	118.68
Impaired Signal 3	10	490	49.00	214.44
Mid Anchor	10	490	49.00	207.56
Low Anchor	10	356	35.60	447.38

ANALYSIS OF VARIANCE

Origin of variance	Sum of the squres	Freedom degrees	Mean of the squares	F	Probability	Critical value for F
Test signals	11092.4833	5	2218.497	12.490	0.000	2.422
Error	7993.01667	45	177.623			
Total	23660.9833	59				

Result of Analysis of variance
Rejects H_0 The means are not equal
Which means that the ratings given to each of the coders are independent and it can be seen that the rating given to the Hidden Reference is higher than the rest.

ANOVA Analysis

5.2 Hearing test : Parameters : Near / Far

- Hypothesis. The combination of Ambisonic 3D sound fields over the loudspeaker array and Binaural 3D sound fields over open headphones enhances the impression of proximity and distance.

- Premise: Six test signals with different configurations of the monitoring system are compared with a reference and evaluated. The results are the statistical representations of the subjectively perceived impression of near and far.

- Independent variables: Test signal, monitoring systems, configuration of the studio, calibration of the equipment, signal flow of the whole audio chain (see above).

- Dependent variable: ten test subjects

- Control variable: the MUSHRA test

- Statistical model: parametric statistical analysis and analysis of variance.

	Hidden Reference	Impaired Signal 1	Impaired Signal 2	Impaired Signal 3	Mid Anchor	Low Anchor
Assesor 1	58	0	11	60	22	7
Assessor 2	68	0	34	50	68	21
Assessor 3	77	35	50	20	64	50
Assessor 5	84	0	0	14	28	28
Assessor 6	50	70	40	45	60	20
Assessor 7	50	42	9	70	50	25
Assessor 8	82	9	10	71	78	50
Assessor 9	78	37	40	6	28	12
Assessor 10	47	5	0	50	61	54

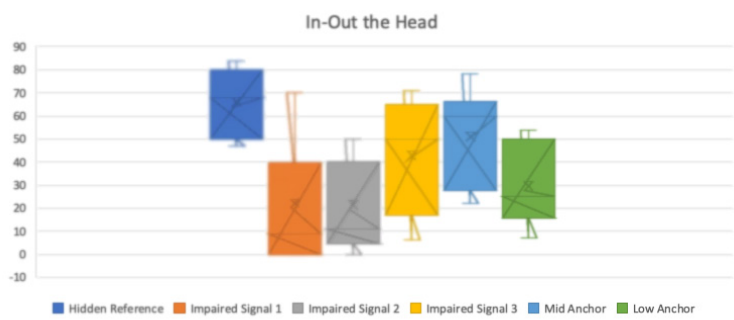
Tab 2, Summary of the evaluations

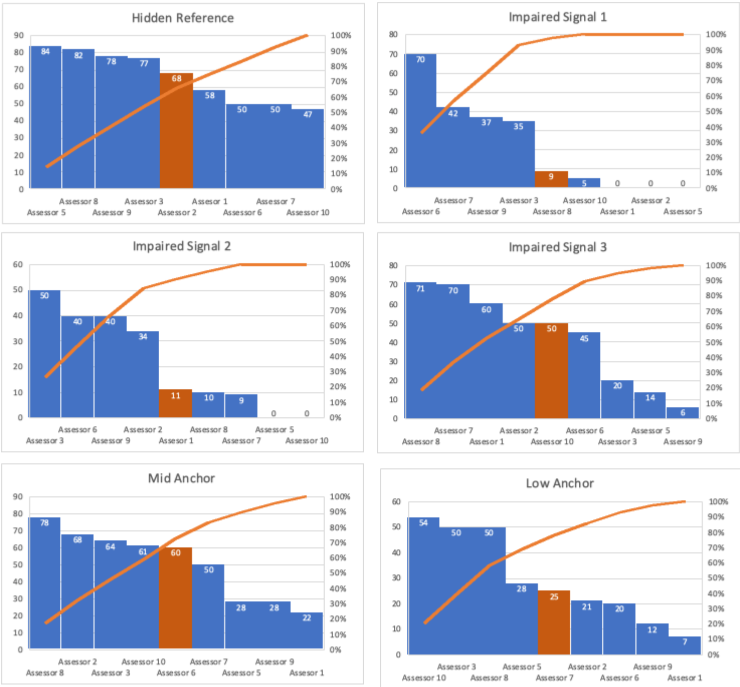
Descriptive Statistics

	Hidden Reference	*Impaired Signal 1*	*Impaired Signal 2*	*Impaired Signal 3*	*Mid Anchor*	*Low Anchor*
Mean	67	24.75	22.875	40.75	54.625	32.5
Typical Error	5.532	8.928	7.135	8.776	6.439	5.763
Median	72.5	22	22	47.5	60.5	26.5
Mode	50	0	0	50	28	50
Standard Deviation	15.648	25.252	20.181	24.824	18.213	16.301
Variance	244.857	637.643	407.268	616.214	331.696	265.714
Kurtosis	-2.122	-0.449	-2.128	-1.523	-0.705	-1.873
Skewness	-0.358	0.695	0.061	-0.195	-0.676	0.354
Range	37	70	50	65	50	42
Minimun	47	0	0	6	28	12
Maximum	84	70	50	71	78	54
Sum	536	198	183	326	437	260
Count	8	8	8	8	8	8
Confidence Level	13.082	21.111	16.872	20.753	15.226	13.628
	Platykurtic	Platykurtic	Platykurtic	Platykurtic	Platykurtic	Platykurtic

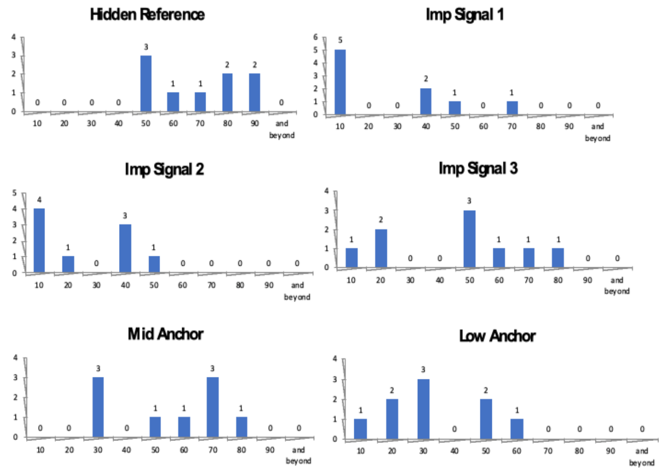
Variables	Assesor 1	Assessor 2	Assessor 3	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9	Assessor 10	Mean	Median	Standard Dev.	
Hidden Reference	58	68	77	84	50	50	82	78	47	66	68	14.9	
Impaired Signal 1	0	0	35	0	70	42	9	37	5	22	9	25	
Impaired Signal 2	11	34	50	0	40	9	10	40	0	22	11	19	
Impaired Signal 3	60	50	20	14	45	70	71	6	50	43	50	24	Assessor 4
Mid Anchor	22	68	64	28	60	50	78	28	61	51	60	20	didn't make
Low Anchor	7	21	50	28	20	25	50	12	54	30	25	17	the test.

Mean, median, and standard deviation calculation:





Median and Pareto distribution



Class and frequency

SUMMARY	*Count*	*Sum*	*Mean*	*Vaiance*
Hidden Reference	9	594	66.00	223.25
Impaired Signal 1	9	198	22.00	626.00
Impaired Signal 2	9	194	21.56	372.03
Impaired Signal 3	9	386	42.89	580.36
Mid Anchor	9	459	51.00	408.50
Low Anchor	9	267	29.67	304.75

ANALYSIS OF VARIANCE

Origin of variance	*Sum of the squres*	*Freedom degrees*	*Mean of the squares*	*F*	*Probability*	*Critical value for F*
Assessors	4090.1481	8	511.268519	1.27586175	0.283263799	2.18017045
Test signals	14115.704	5	2823.14074	7.04509892	8.34939E-05	2.44946643
Error	16028.963	40	400.724074			
Total	34234.815	53				

Result of Analysis of variance
Rejects H_0 The means are not equal
Which means that the ratings given to each of the coders are independent and it can be seen that the rating given to the Hidden Reference is higher than the rest.

ANOVA Analysis

Conclusion

From the box plot and the median graphs, we can see that the hidden reference in both tests have almost the same mean and median values which means that there is a better distribution of the subjects' ratings for this variable.
Together with the Anova analysis, we can say that the results are statistically representative of the tester:s preferences, and we can draw the following conclusions:

The use of a multichannel loudspeaker array together with open headphones enhances the impression of the two musical space parameters ‚immersiveness' and ‚near/distant'.

Moreover, the HADS was preferred compared to Ambisonic only or Binaural only sound fields as well as compared to the anchors (filtering).

Thus, we can conclude that the initial hypothesis holds.

6. Activities

9.9.2023 Presentation & Workshop
Anton Bruckner University Linz : Sonic Lab
Digital Music Focus 2022 @ Ars Electronica 2022

„Perceiving augmented sound fields : the Hybrid Audio diffusion System" Immersive Sounds - External Worlds Research student meeting.

26.1.2023 Pilot Test, Praterstudio, 1020 Vienna
27.1.2023 Listening tests with 10 participants, Praterstudio, 1020 Vienna

27.1.2023
Concert with the HADS System
Praterstudio, Kurbauergasse 6, 10 20 Vienna
Works by Annette Vande Gorne, François Bayle, Enrique Mendoza, Thomas Gorbach

28.2.2023 Presentation & Workshop
University of Music and Performing Arts Vienna, Sound Theater
„Perceiving augmented sound fields: the Hybrid Audio diffusion System."

7. Results of the first work phase and outlook

The results of the first work phase are more far-reaching than initially thought. Many aspects have emerged that stimulate further research.
The following is a list of activities and research results at the current time.

- In the Praterstudio of TheAcousmaticProject we could set up an ideal test environment. The space is quiet, soundproofed, and acoustically well optimized.

- The 18.2 system in the combination of open headphones and two loudspeaker circuits as well as the hardware and software configuration allow for specific sound and room acoustics measurements as well as exact volume calibration.

- The system's configuration and playback capabilities allow processing, combining and mixing of discrete, binaural and ambisonic file formats. This results in a creative workflow with which to modulate at each of these levels depending on the application.

- The MUSHRA test could be adapted according to the ITU specifications and a special software could be programmed to perform the test and to store the obtained data.

- The structure and the procedure of the hearing tests are coherent and the evaluation of the results has confirmed the originally established thesis of the subjectively perceived higher quality of the HADS system by ten test persons.

- Through detailed analysis of different acousmatic works, we have been able to extract three sound space parameters that are particularly salient due to the nature of the system. These are immersivity, proximity and distance, and horizontal-vertical listening.

Some tasks we could only perform conditionally.

- The Horizontal-Vertical parameter could not be evaluated during the tests, because the initially selected acousmatic work did not show this parameter clearly enough. This was already visible after the first two test listeners, who were confused by the question. They had thus clearly exceeded the test time.

- The question regarding the minimum and maximum system could not be tested and verified due to time constraints. This needs a new configuration of the system and the MUSHRA test.
We assume that with clear-space composition less loudspeakers are needed to better evaluate the effect of spatiality. In the comparison of the work Déplacement by François Bayle with the work VoxAllia II by Annette Vande Gorne we could notice this difference.

Prospects

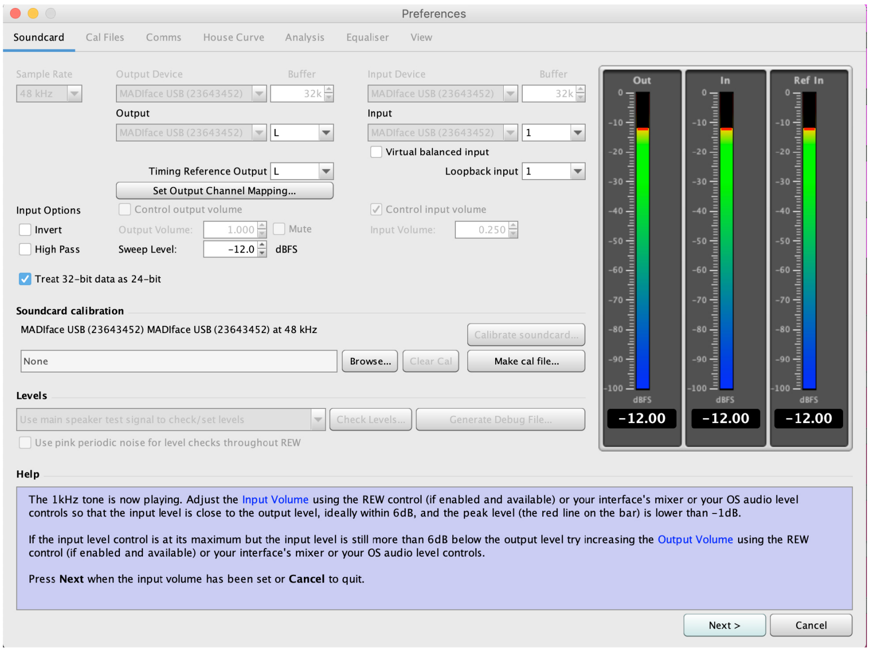
The Virtual Vienna Acousmonium was until now an idea that I, Thomas Gorbach, in the knowledge of the complexity and the lack of experience, could not define to a sufficient extent.
With this work, in the first phase, we are an important step further in the combination with the HADS system of Enrique Mendoza. The developed 18.2 HADS system with the MUSHRA testing method has shown that, based on the experience gained, a precise definition of the requirements, the possibilities and constraints, as well as the controls, mappings and feedback system can be carried out in the next iterative step of the project.

- During the execution of the tests, we were repeatedly asked by the test subjects for an assessment of their spatial listening abilities, since the spatial listening ability of a test subject is integrated in the test. We would therefore like to investigate the question of whether the test can be used to make a qualitative statement about spatial hearing ability. If this is possible, the adaptation of the test would be possible and a spatial hearing training could also be designed.
- We would like to advance the extraction of sound spatial parameters from the acousmatic repertoire by analyzing more works and testing even more parameters.
- Further elaboration of the MUSHRA test into an application-oriented design is necessary.
- Further testing on the minimum and maximum size of the system is needed. This includes a re-adapted configuration of the hardware and software in the studio as well as in the creative workflow.
- Moving forward, we would like to increase the number of headphones to enable the results tested in the studio with a larger number of concertgoers and TheAcousmaticProject's large acoustic monium. This also requires the conversion of the headphones to Bluetooth operation.

Appendix 1

Praterstudio calibration

Soundcard calibration: MADIface USB at -12dBFS
Info from REW calibration:
Input device: MADIface USB (23643452)
Input: MADIface USB (23643452)
Channel: Left
Output device: MADIface USB (23643452)
Output: MADIface USB (23643452)
Input RMS target: -12.0 dB
Actual RMS at 1 kHz: -18.0 dB
Sample rate: 48000 Hz
Input volume: no control, Sweep level: -12.0 dB
20 Hz .. 20 kHz flatness: +0.0, -0.2 dB
-3 dB points: 3.7 Hz, 23.457 kHz

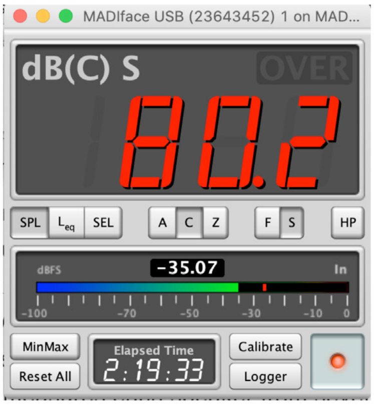


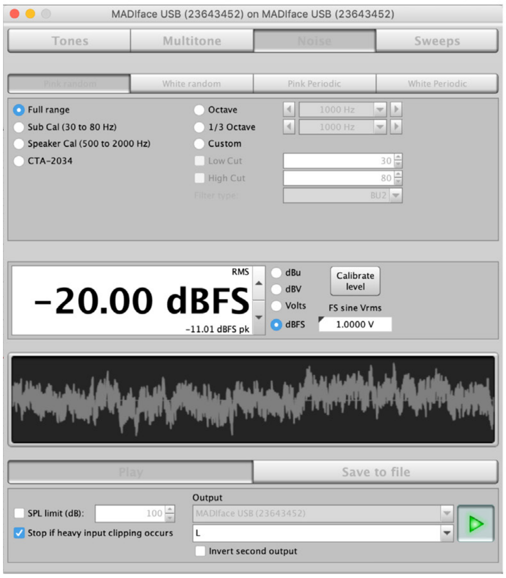
Volume Calibration
Made with PinkNoise at -20dBFS to match 80dB SPL on each speaker
Measured with SPL dB(C) / SoundID Reference microphone on the sweet spot.
All calibration was made with the microphone in 90° axis

Speaker array measurement and calibration

Levels check at -27.3 dBFS / 82 dB SPL

Sweep at -12 dBFS



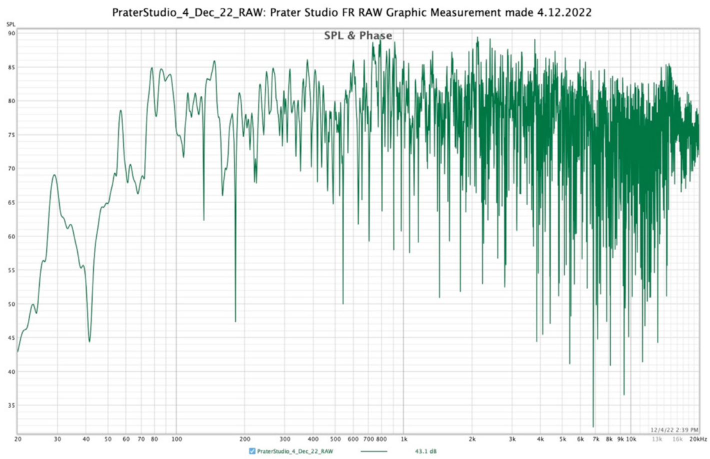


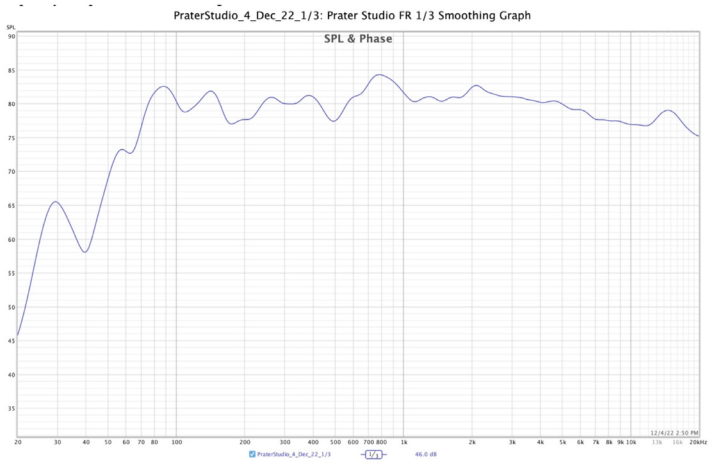
Speaker array measurement and calibration

Levels check at -27.3 dBFS / 82 dB SPL

Sweep at -12 dBFS

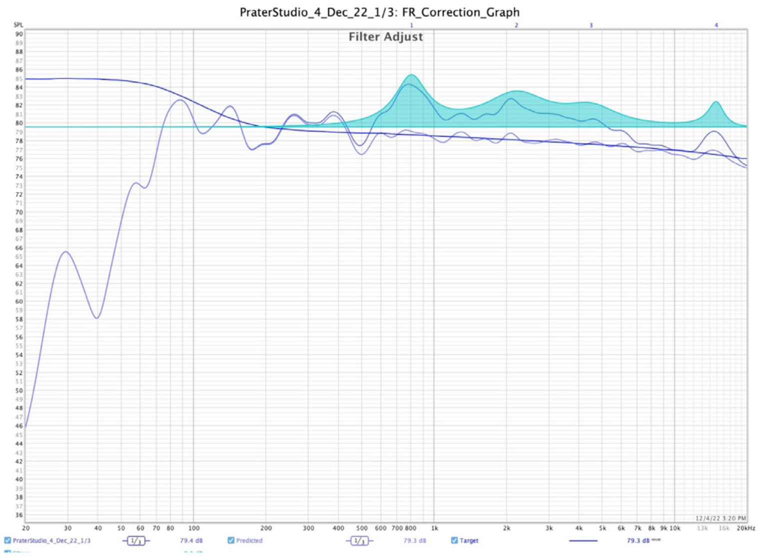
Frequency Response RAW Graph





Frequency Response 1/3 Smoothing

Frequency Response Correction Graph



The correction was made using the Harman graph as target.
Filters Information:

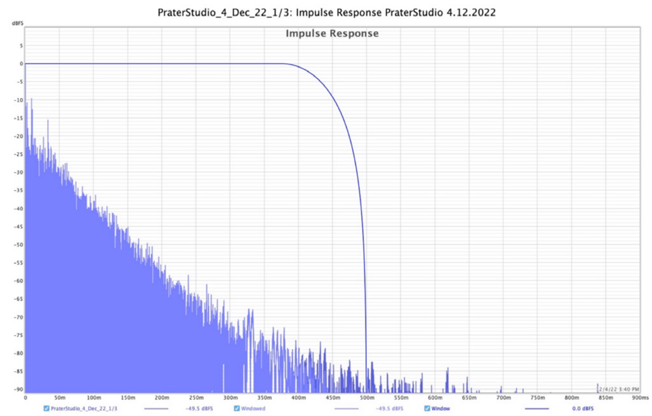
Filter Settings file

Room EQ V5.20.13
Dated: Dec 4, 2022 3:09:52 PM

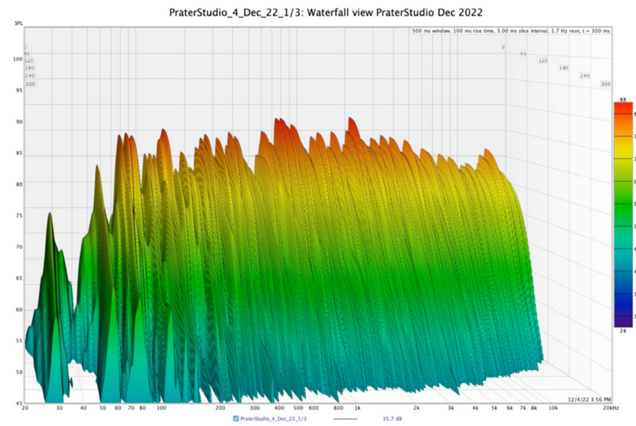
Notes:FR_EQ_Correction_PraterStudio_4-12-2022

Equaliser: Generic
PraterStudio_4_Dec_22_1/3
Filter 1: ON PK Fc 802.0 Hz Gain -5.50 dB Q 2.597
Filter 2: ON PK Fc 2192 Hz Gain -3.60 dB Q 1.301
Filter 3: ON PK Fc 4493 Hz Gain -2.00 dB Q 1.488
Filter 4: ON PK Fc 14864 Hz Gain -2.80 dB Q 2.546

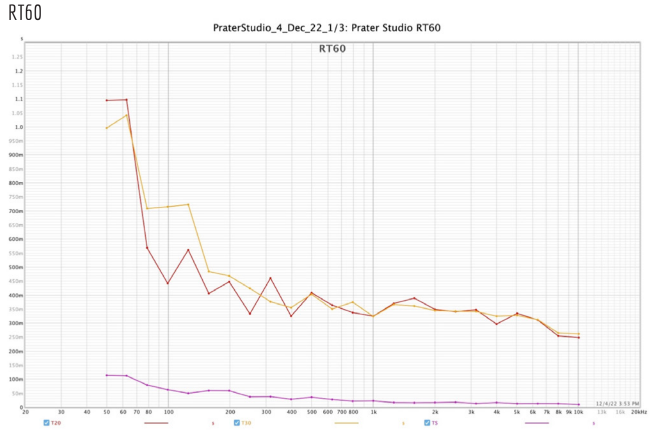
Impulse Response



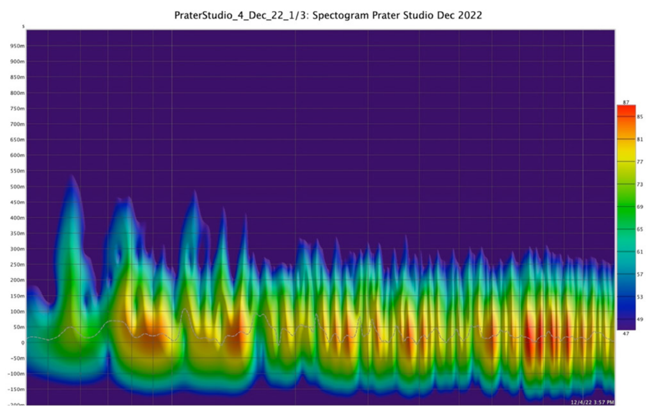
Waterfall



RT60



Spectogram

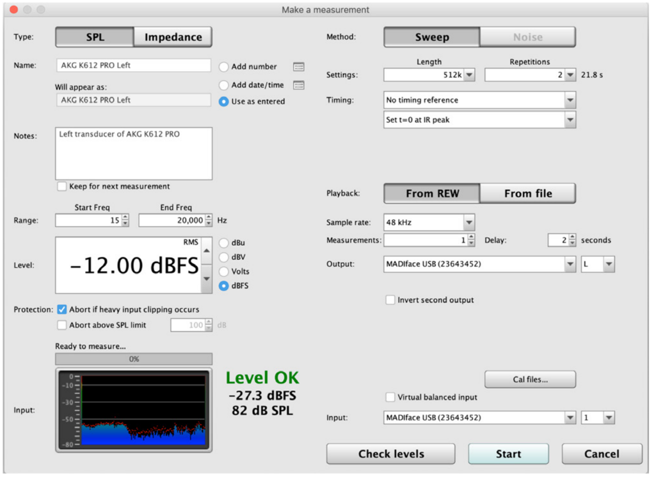


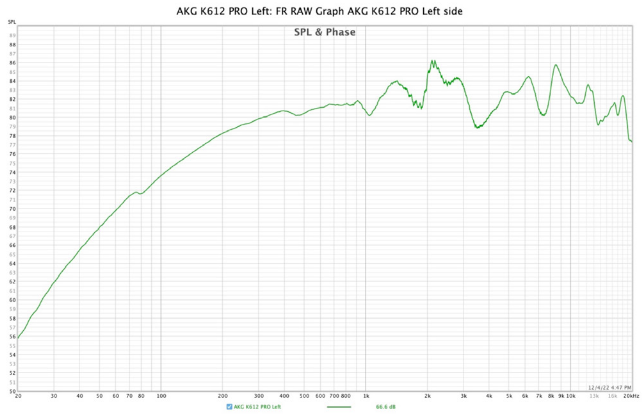
Headphone's measurement and calibration

Headphones: AKG K612 PRO

Microphone: SoundID Reference / Measured at 0° with Cal file

Frequency Response Left (RAW Graph)





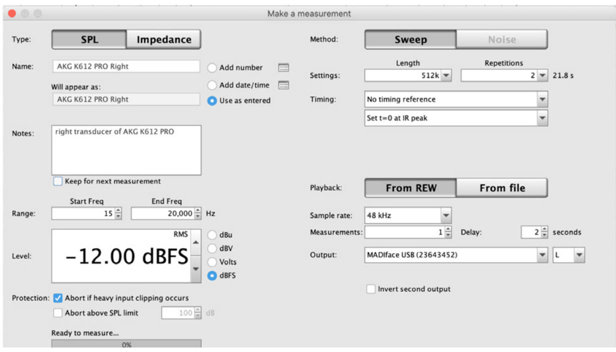
Measurement

LEFT

Levels check at -27.3 dBFS / 82 dB SPL

Sweep at -12 dBFS

ART Headamp at 5



RIGHT

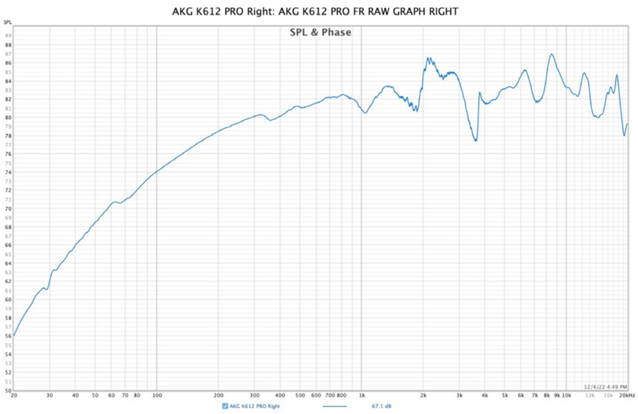
Levels check at -27.3 dBFS /

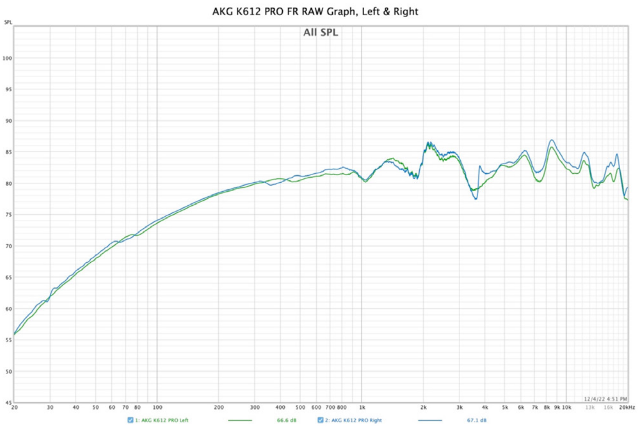
82 dB SPL

Sweep at -12 dBFS

ART Headamp at 5

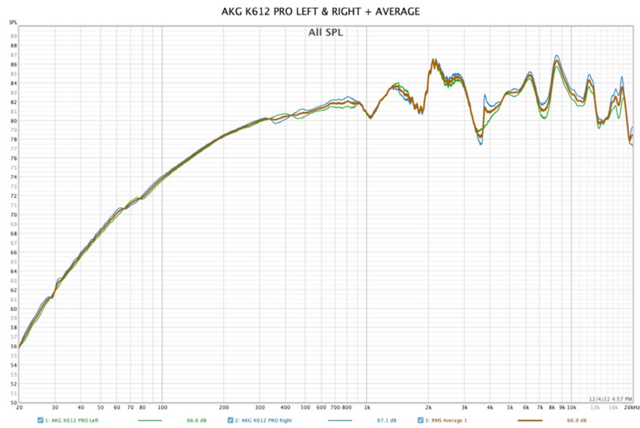
Frequency Response Right (RAW Graph)

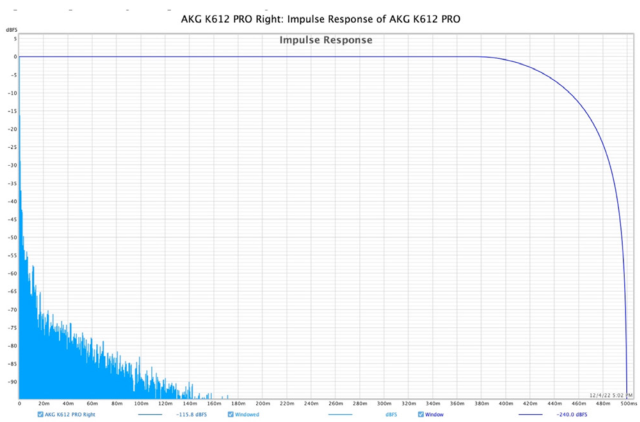




Frequency Response Left & Right (RAW Graph)

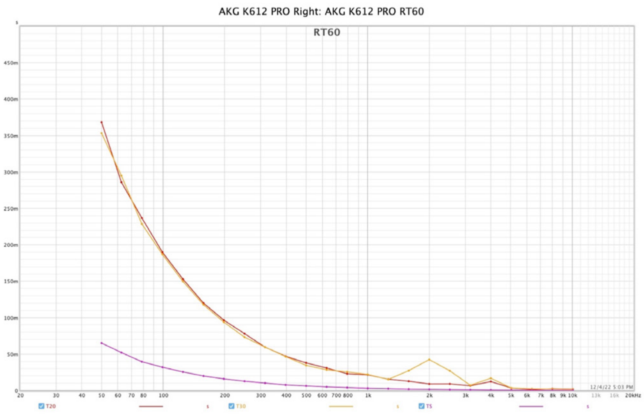
Frequency Response Left + Right + Average (RAW Graph)



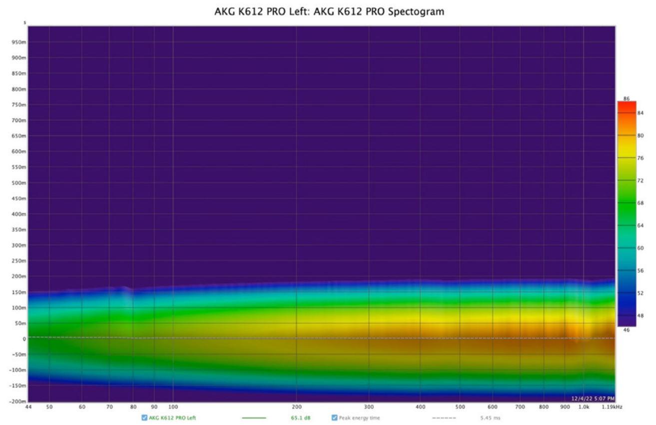


Impulse Response (Right Graph but Left & Right measured the same)

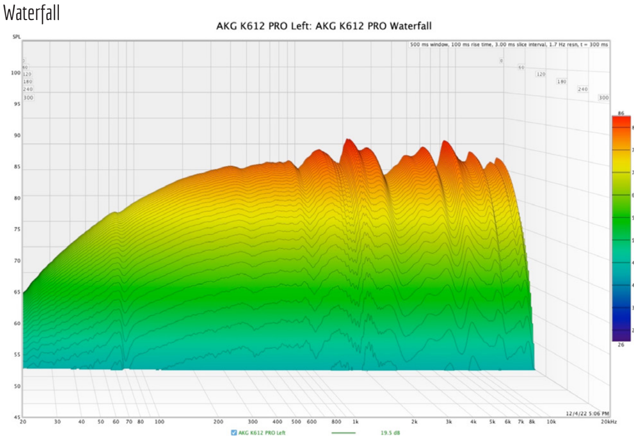
Impulse Response RT60 (Right Graph but Left & Right measured the same)



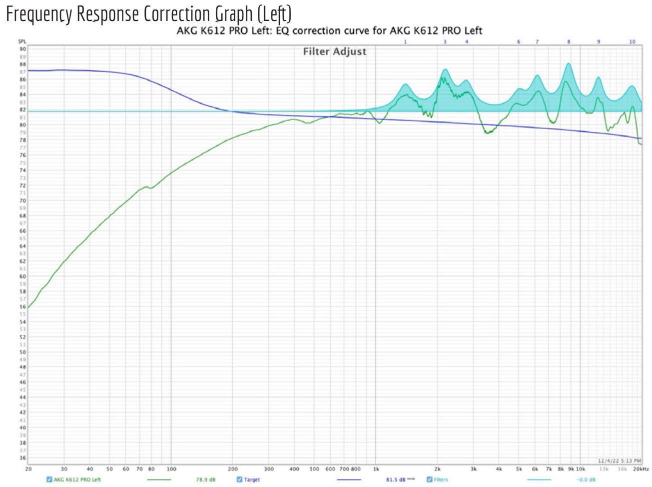
Spectogram



Waterfall



Frequency Response Correction Graph (Left)



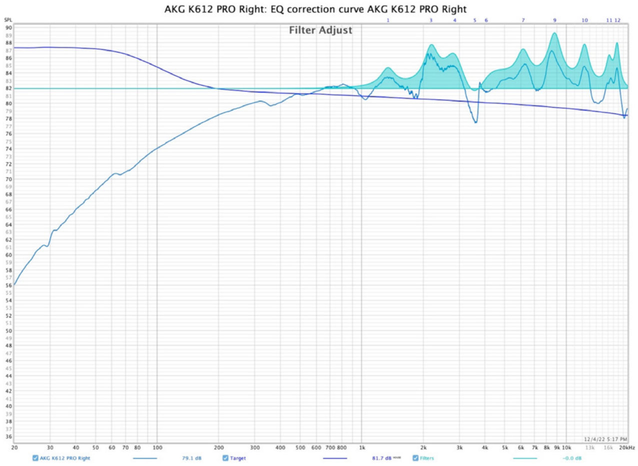
Filter Settings file

Room EQ V5.20.13
Dated: Dec 4, 2022 5:10:40 PM

Notes: Correction EQ for AKG K612 PRO

Equaliser: Generic
AKG K612 PRO Left
Filter 1: ON PK Fc 1392 Hz Gain -3.30 dB Q 4.527
Filter 2: ON PK Fc 1843 Hz Gain 0.00 dB Q 4.904
Filter 3: ON PK Fc 2179 Hz Gain -4.90 dB Q 4.999
Filter 4: ON PK Fc 2781 Hz Gain -3.20 dB Q 4.996
Filter 5: ON PK Fc 4175 Hz Gain 0.00 dB Q 4.352
Filter 6: ON PK Fc 4984 Hz Gain -2.00 dB Q 4.996
Filter 7: ON PK Fc 6156 Hz Gain -3.90 dB Q 4.998
Filter 8: ON PK Fc 8752 Hz Gain -5.80 dB Q 4.399
Filter 9: ON PK Fc 12256 Hz Gain -3.80 dB Q 4.802
Filter 10: ON PK Fc 17883 Hz Gain -3.30 dB Q 1.523

Frequency Response Correction Graph (Right)



Filter Settings file

Room EQ V5.20.13
Dated: Dec 4, 2022 5:19:20 PM

Notes:EQ correction curve for AKG K612 PRO Right

Equaliser: Generic
AKG K612 PRO Right
Filter 1: ON PK Fc 1340 Hz Gain -2.40 dB Q 4.921
Filter 2: ON PK Fc 1630 Hz Gain 0.00 dB Q 4.905
Filter 3: ON PK Fc 2181 Hz Gain -4.70 dB Q 4.999
Filter 4: ON PK Fc 2843 Hz Gain -4.80 dB Q 3.412
Filter 5: ON PK Fc 3564 Hz Gain 6.00 dB Q 2.191
Filter 6: ON PK Fc 4048 Hz Gain -4.70 dB Q 1.592
Filter 7: ON PK Fc 6145 Hz Gain -3.70 dB Q 4.904
Filter 8: ON PK Fc 7240 Hz Gain 0.00 dB Q 4.903
Filter 9: ON PK Fc 8755 Hz Gain -6.60 dB Q 3.997
Filter 10: ON PK Fc 12274 Hz Gain -5.10 dB Q 4.702
Filter 11: ON PK Fc 16149 Hz Gain -3.20 dB Q 4.918
Filter 12: ON PK Fc 17704 Hz Gain -5.50 dB Q 4.438

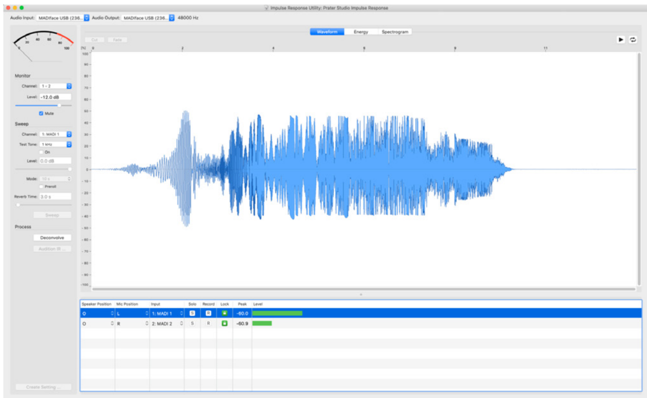
Binaural Impulse Response of room acoustics

Software: Impulse Response Utility, Logic's Space Designer

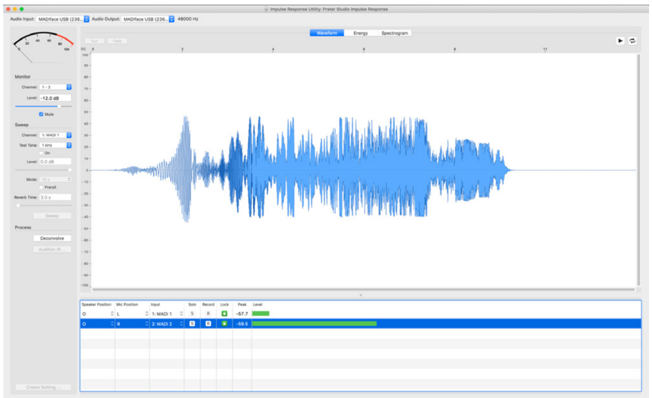
Microphone: Roland Binaural Microphone CS-10EM

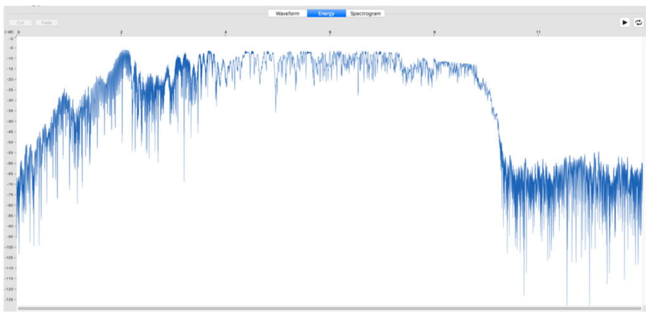
Sine sweep original

Impulse Response Waveform Left channel



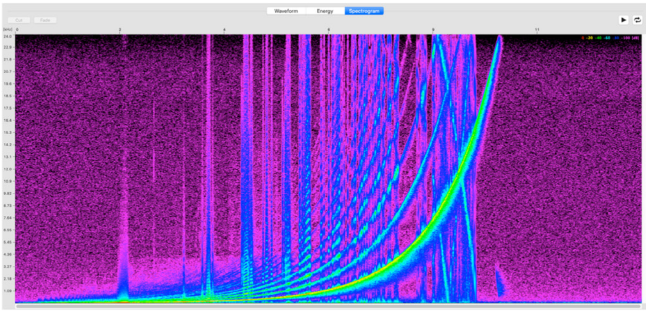
Impulse Response Waveform Right channel



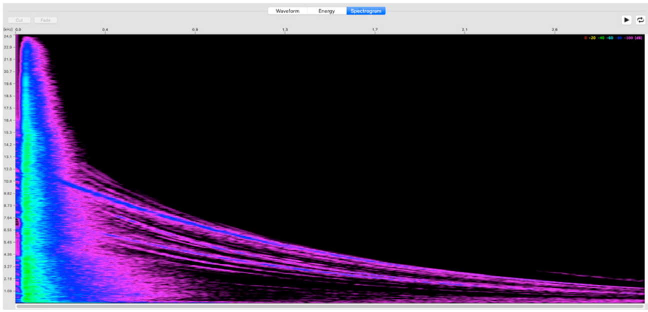


Energy (Left channel)

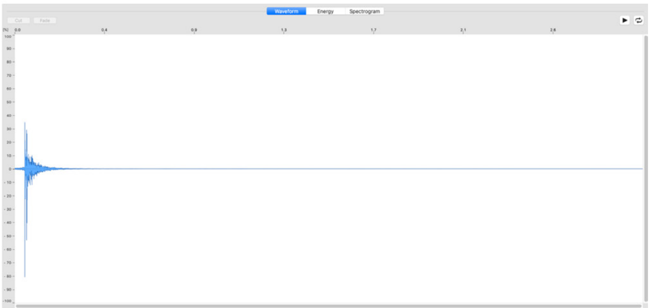
Spectrogram (Left channel)

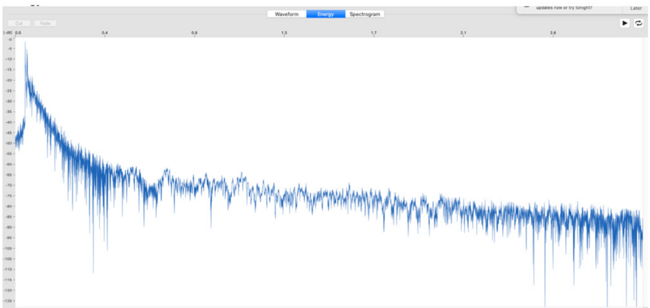


Spectrogram



Deconvolved Impulse Response (from sine sweep) Waveform





Energy