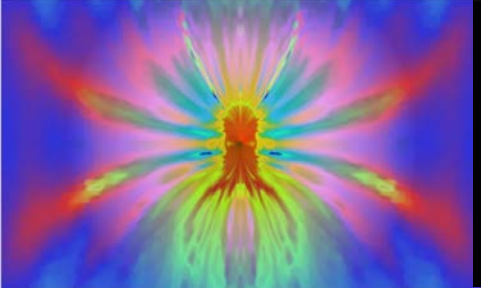

A Research Symposium – Tuesday 27th June, 2017
University of Derby
Markeaton Street Campus

UNIVERSITY of DERBY

Operas and Urban Soundscapes

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University of Parma (Italy)

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casadellamusica parma casadelsuono

UNIVERSITÀ DI PARMA

TEATRO REGIO PARMA

THE PROJECT

Collaboration between:

- University of Parma
- Casa della Musica (Casa del Suono)
- Teatro Regio di Parma

GOALS:

- Presenting a virtual tour of Parma's soundscapes to foreign visitors coming during **Festival Verdi 2016**

- Recording and reproduction of the 4 operas performed during **Festival Verdi 2016** making use of advanced panoramic sound and video capture and playback

Festival Verdi 2016:

Every year more than 80.000 tourists come to Parma for Festival Verdi, a multi-format kermesse for lovers of Verdi’s operas

Festival Verdi 2016:
The 4 operas

DON CARLO

FESTIVAL VERDI | Teatro Regio di Parma, from Saturday, October 01, 2016 to Tuesday, October 11, 2016

Daniel Oren and a new production by Cesare Lievi for the most complex and monumental opera by Giuseppe Verdi.

GIOVANNA D'ARCO

FESTIVAL VERDI | Teatro Farnese, from Sunday, October 02, 2016 to Thursday, October 20, 2016

Teatro Farnese embraces Luciano Ganci, Vittorio Vitelli, Vittoria Yeo, Cristiano Olivieri and Luciano Leoni in a new production by Saskia Boddeke and Peter Greenaway.

I MASNADIERI

FESTIVAL VERDI | Teatro Giuseppe Verdi di Busseto, from Friday, October 07, 2016 to Saturday, October 29, 2016

Artists of Voci Verdiane "Città di Busseto" play the rebels of Verdi in the setting by Leo Muscato from Festival Verdi 2013.

IL TROVATORE

FESTIVAL VERDI | Teatro Regio di Parma, from Friday, October 21, 2016 to Sunday, October 30, 2016

Massimo Zanetti conductos George Petean, Dinara Alieva, Enkelejda Shkosa and Murat Karahan in a new production by Elisabetta Courir.

Festival Verdi 2016:
Don Carlo
(Teatro Regio - Parma)

Festival Verdi 2016:
Giovanna D’Arco
(Teatro Farnese - Parma)

Festival Verdi 2016:
I Masnadieri
(Teatro Verdi - Busseto)

Festival Verdi 2016:
Il Trovatore
(Teatro Regio - Parma)

Urban Soundscapes:
Typical panoramic views of Parma

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Typical panoramic views of Parma

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Typical panoramic views of Parma

Urban Soundscapes:
Typical panoramic views of Parma

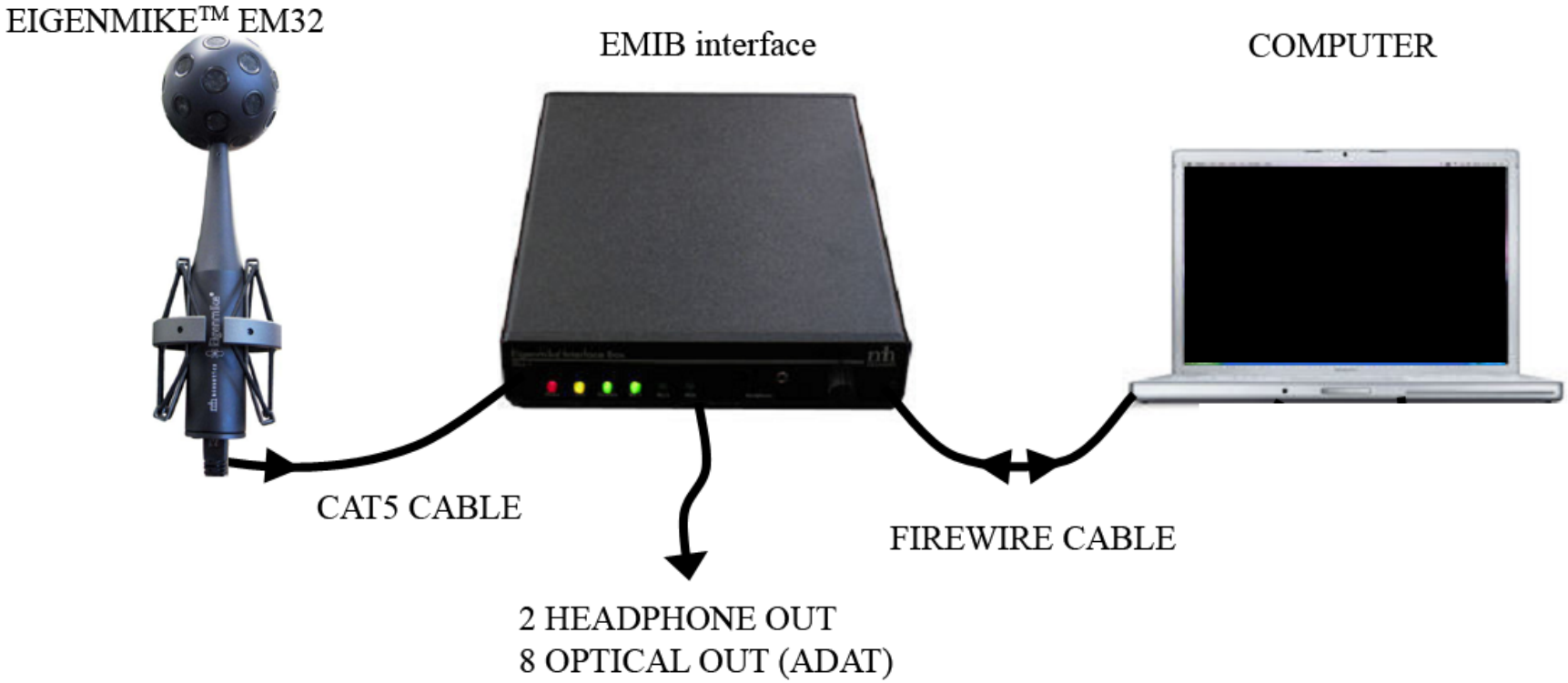
SOUND RECORDING EQUIPMENT

EIGENMIKE™ by MH Acoustics

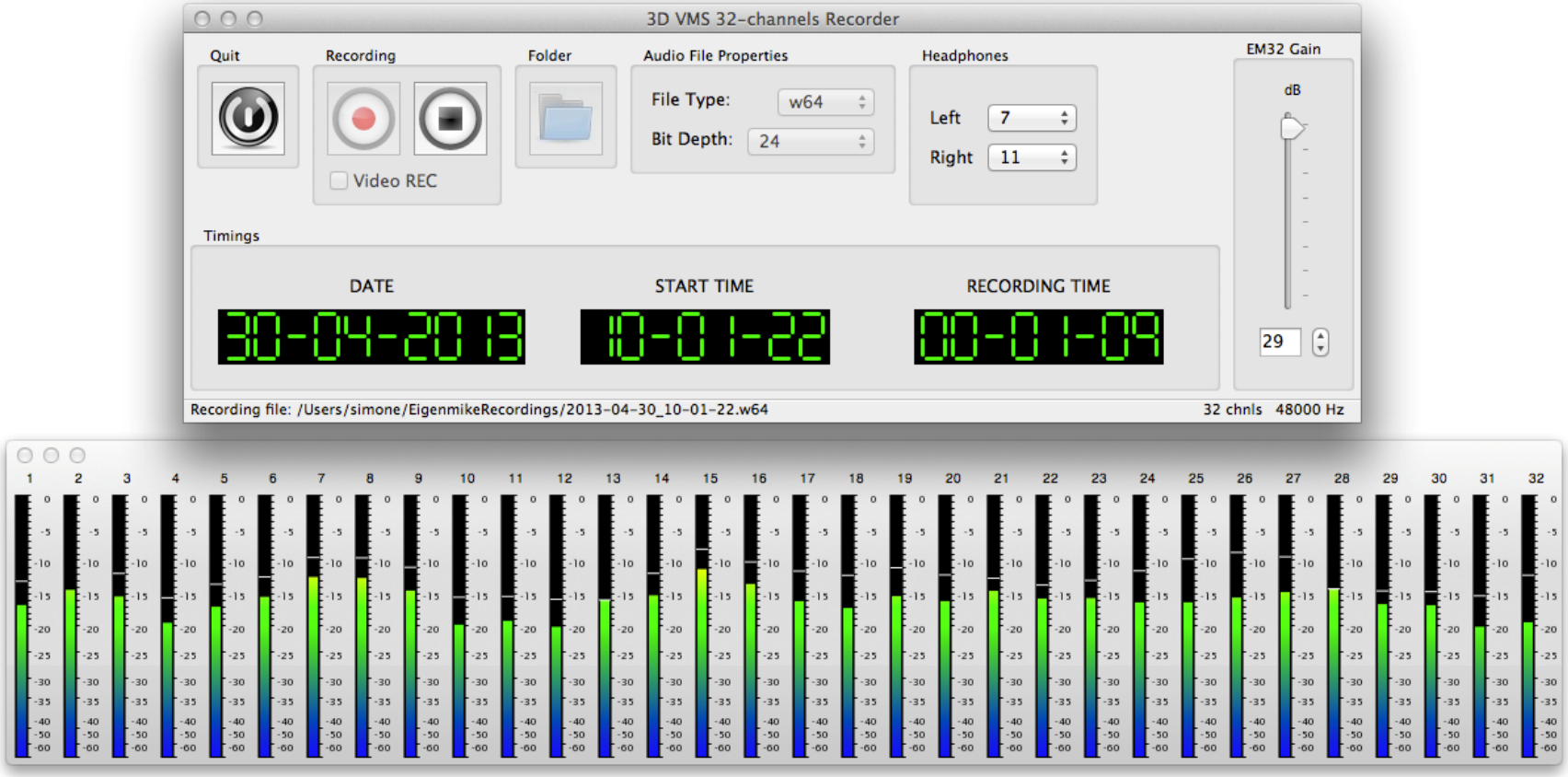
- Spherical Array with 32 condenser capsules of good quality, frequency response up to 20 kHz (14 mm each)
- Preamplifiers with digital gain control and A/D converters inside the sphere, with ethernet interface
- Large windshield for outdoor operation with camera support

SOUND RECORDING EQUIPMENT

- Computer: Mac Book Pro 13”
- Software: Plogue Bidule, or our own 3DVMS Recorder software
- 12V lead-acid battery powering the EMIB and the computer



THE RECORDING SOFTWARE: 3DVMS



- Works as front-end for Ecasound (partially customized...)
- Embedded gain control for the Eigenmike EM32
- VU meters with true peak indicators
- Output as W64 (WAV file with 64-bit header) for very long recordings (more than 2^{32} samples)

VIDEO RECORDING EQUIPMENT

Array of 8 GoPro cameras

- 1920x1440 pixels, 29.97 FPS, H264 x 8
- Autopano Video software for stitching
- Resulting resolution for mono: 5648x2824
- Resulting resolution for stereo: 5648x5648

Samsung Gear 360 camera

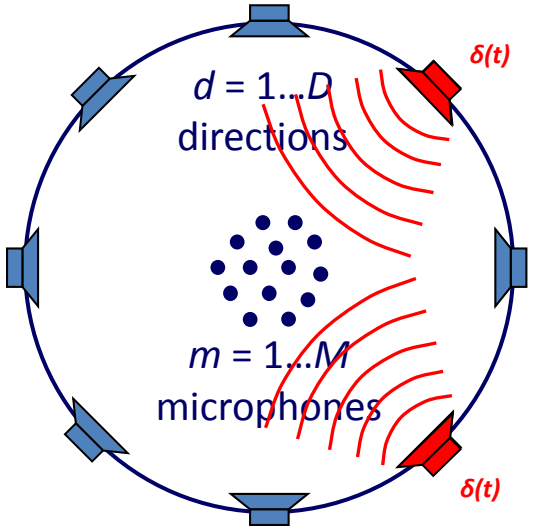
- 3840x1920 pixels, 29.97 FPS, H265
- Samsung S7 smartphone for stitching
- Resulting resolution for mono: 3840x1920

PROCESSING OF THE AUDIO RECORDINGS

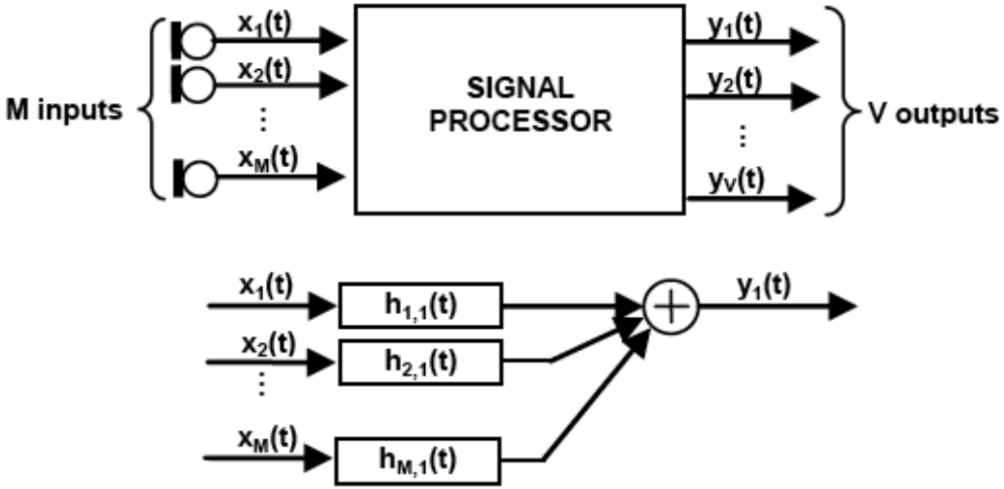
VIRTUAL MICROPHONES

The 3DVMS processing technique was developed by the RAI Research Center in Turin and by AIDA, a spinoff of the University of Parma.

We don't assume any theory for computing the filters: they are derived directly from a set of anechoic measurements.

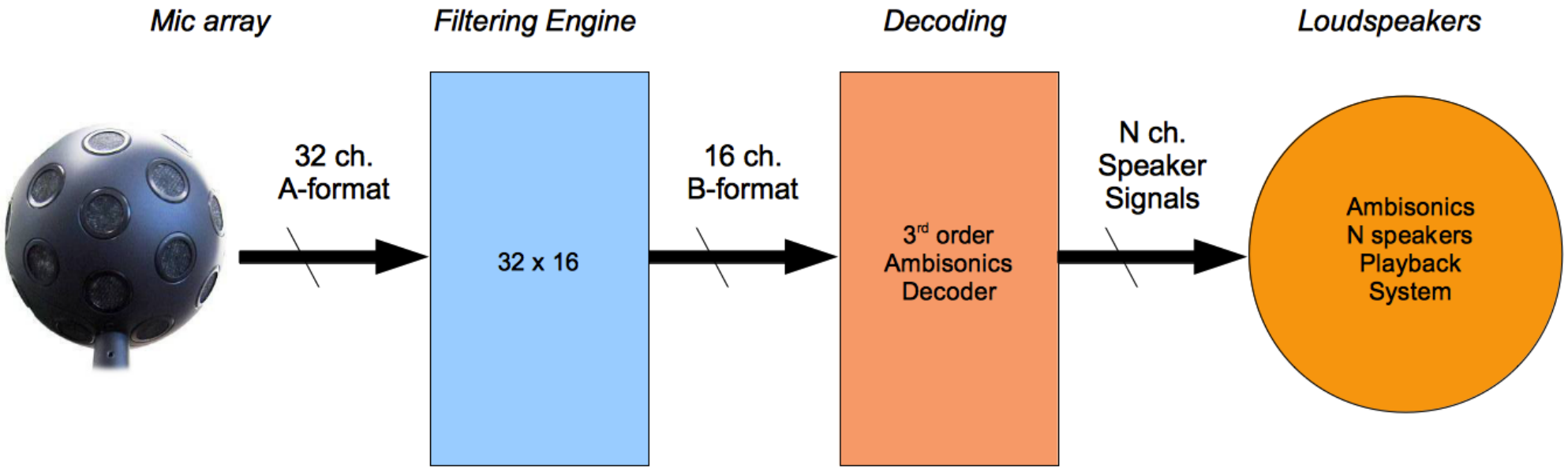


A matrix of measured impulse response coefficients is formed and the matrix has to be numerically inverted



V = 16 virtual microphones

Method 1: 3rd Order AMBISONICS

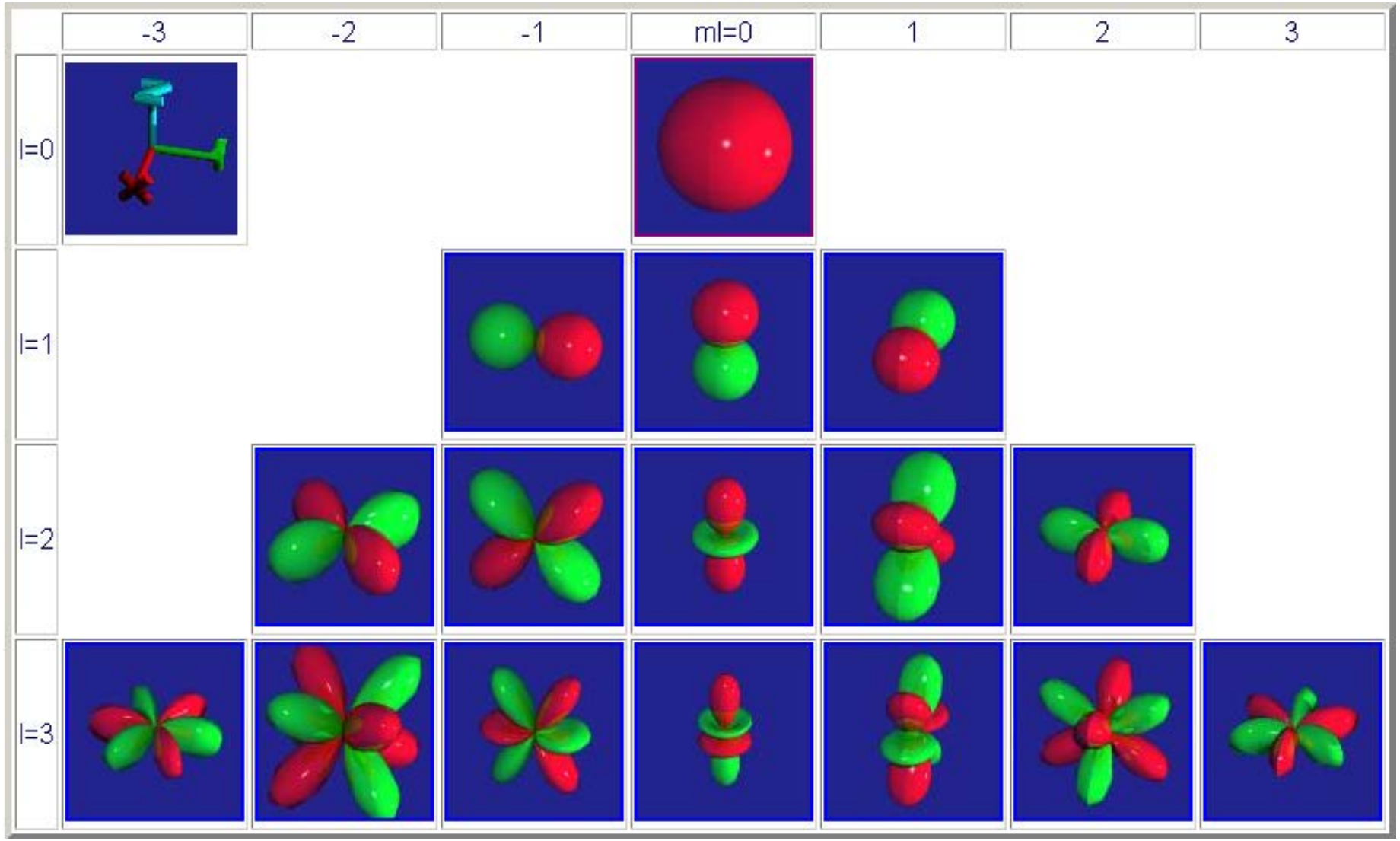


The 32x16 A to B-format filter matrix has been calculated with Matlab starting from a measurement set of 362 directions in the anechoic room

The Ambisonics decoder is Rapture3d by Richard Furse

Method 1: 3rd Order AMBISONICS

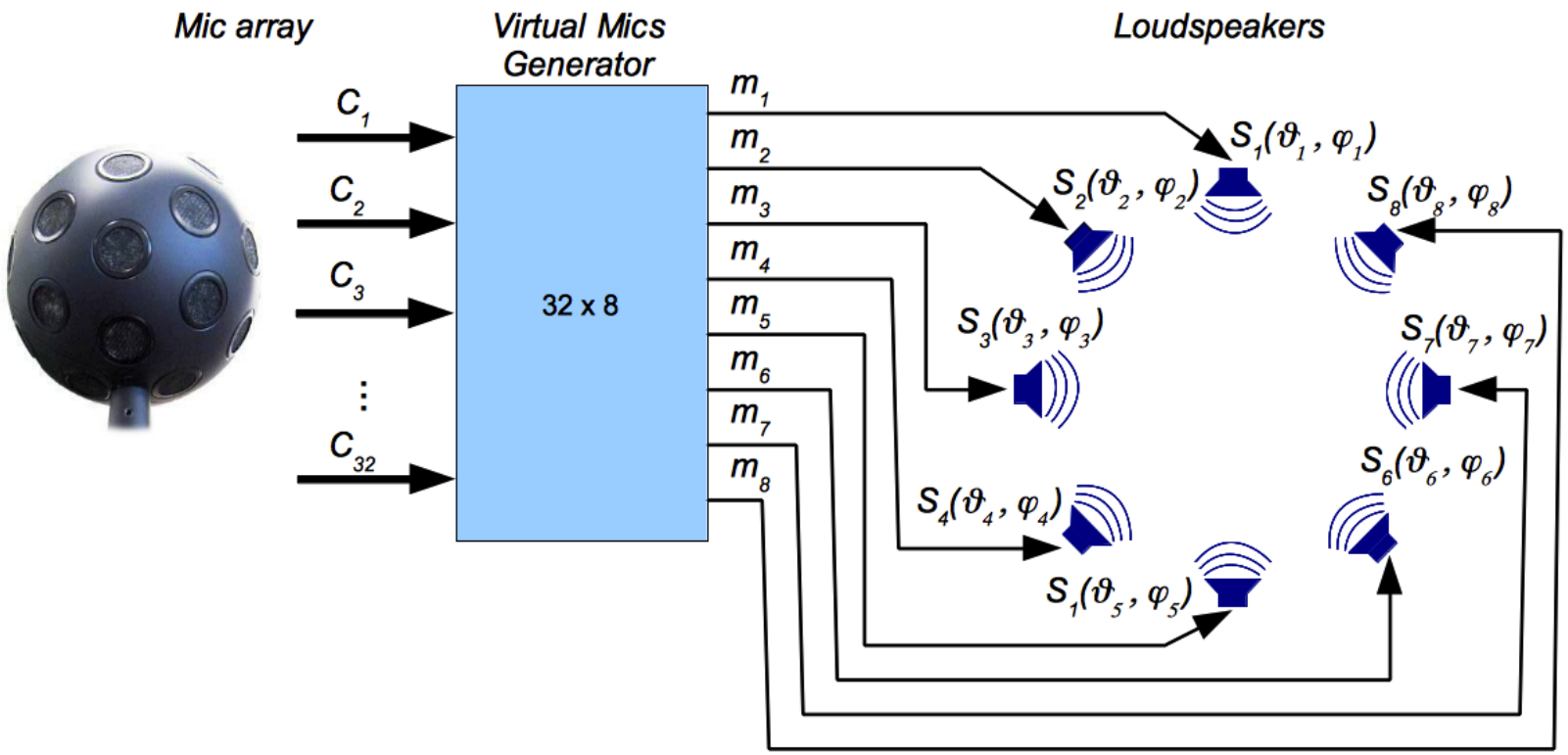
- The patterns of the 16 virtual microphones correspond to spherical harmonics of orders 0, 1, 2 and 3:



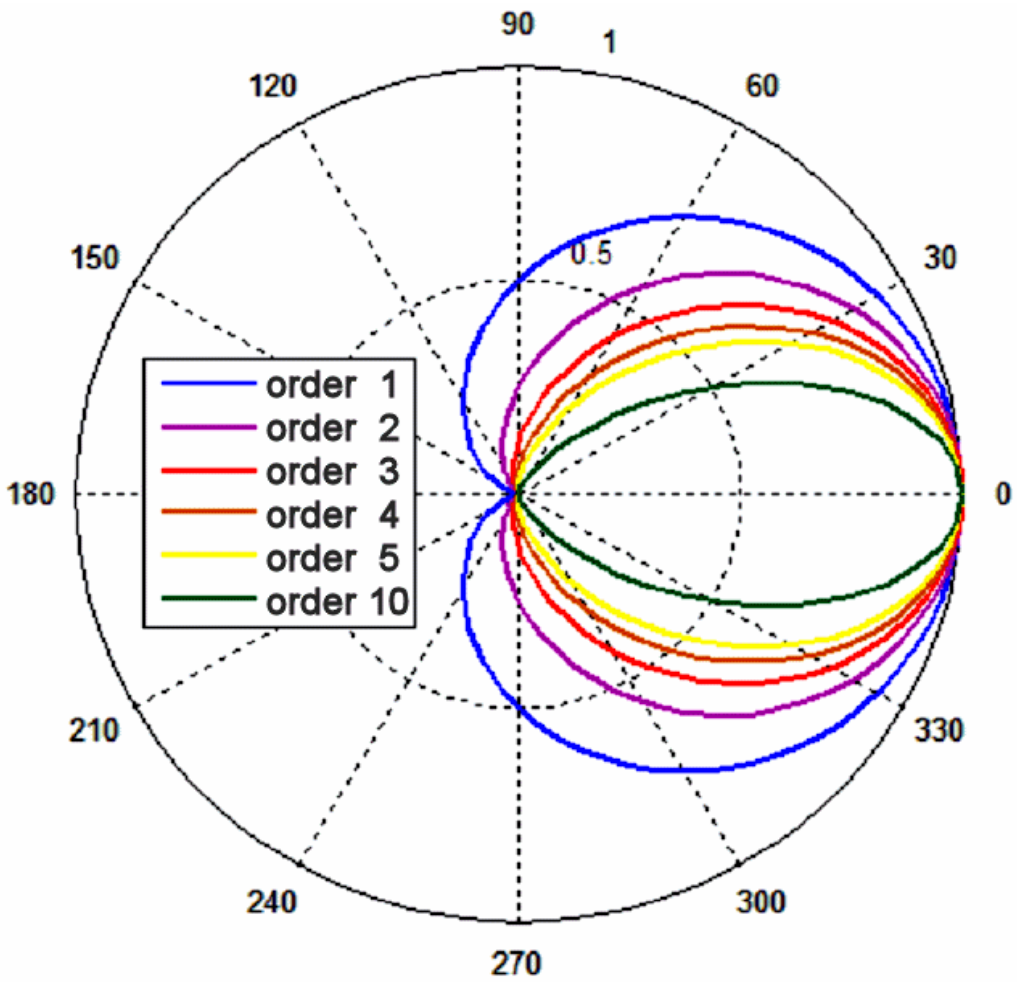
METHOD 2:
DIRECT SYNTHESIS OF VIRTUAL MICROPHONES

Feed every speaker with a single (virtual) microphone.

- Define the (regular) layout of the V loudspeakers
- Create an ultradirective virtual microphone focused in the direction of every speaker



METHOD 2: TARGET DIRECTIVITY



Our synthetic, “virtual” microphone is chosen among a family of cardioid microphones of various orders:

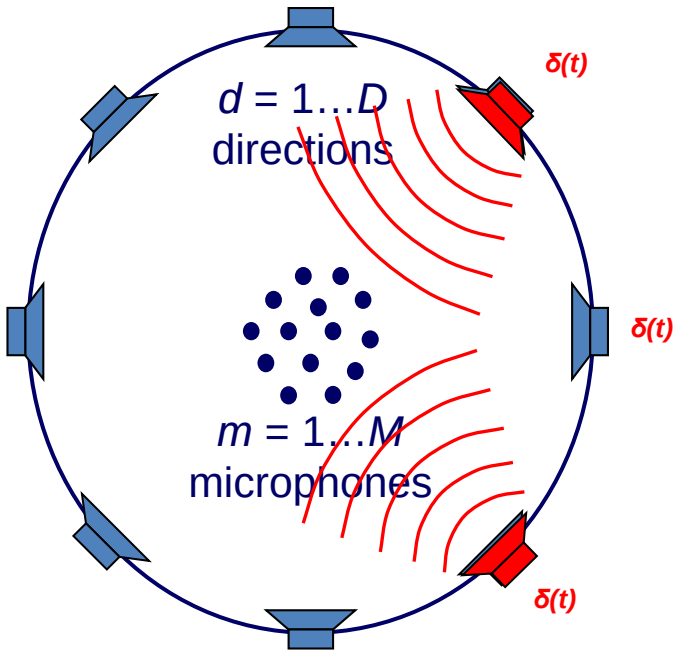
$$P_D(\vartheta,\varphi) = \left[0.5 + 0.5 \cdot \cos(\vartheta) \cdot \cos(\varphi)\right]^n$$

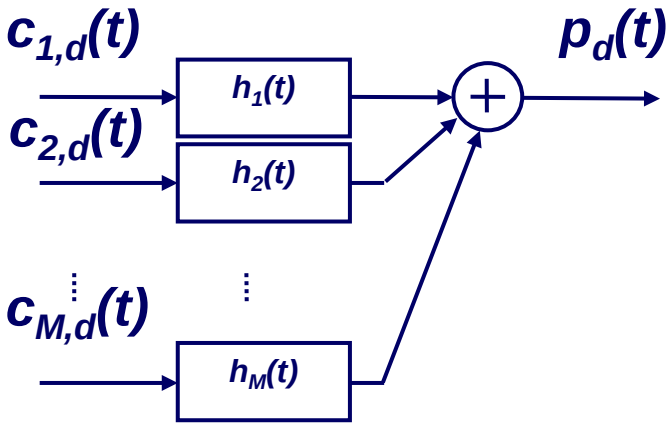
Where ***n*** is the directivity order of the microphone – normal cardioid microphones are just 1st-order…

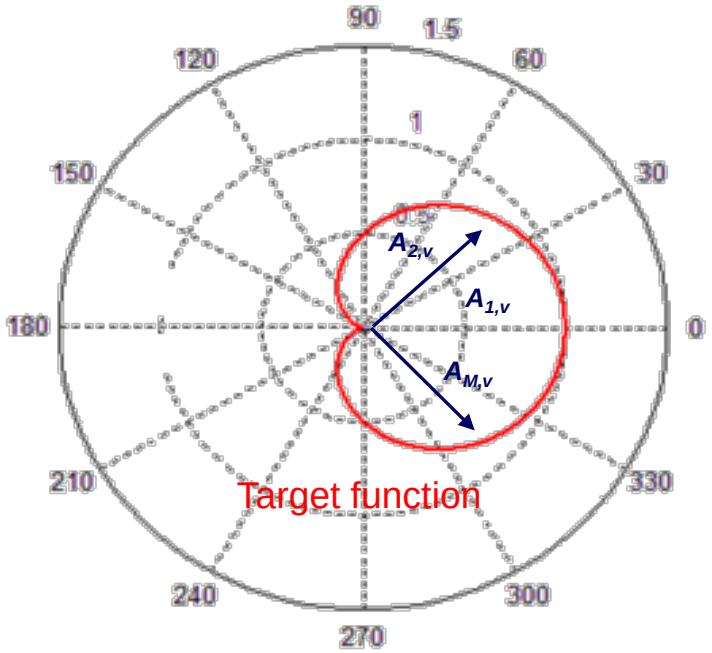
4th-order microphones are typically used for a ring of 16 virtual cardioids

LEAST-SQUARES METHOD FOR FILTER COMPUTATION

We impose that applying the filter matrix H to the measured impulse responses C, the system should behave as a virtual microphone with wanted directivity





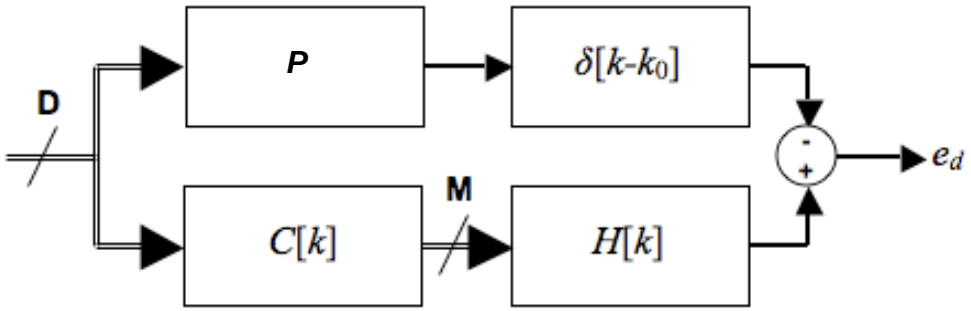


$$\sum_{m=1}^{M} c_{m,d} * h_m \Rightarrow p_d \qquad d = 1..D$$

But in practice the result of the filtering will never be exactly equal to the prescribed directivity functions p_d…..

LEAST-SQUARES METHOD FOR FILTER COMPUTATION

We compare the results of the numerical inversion with the theoretical response of our target microphones for all the D directions, properly delayed, and sum the squared deviations for defining a total error:



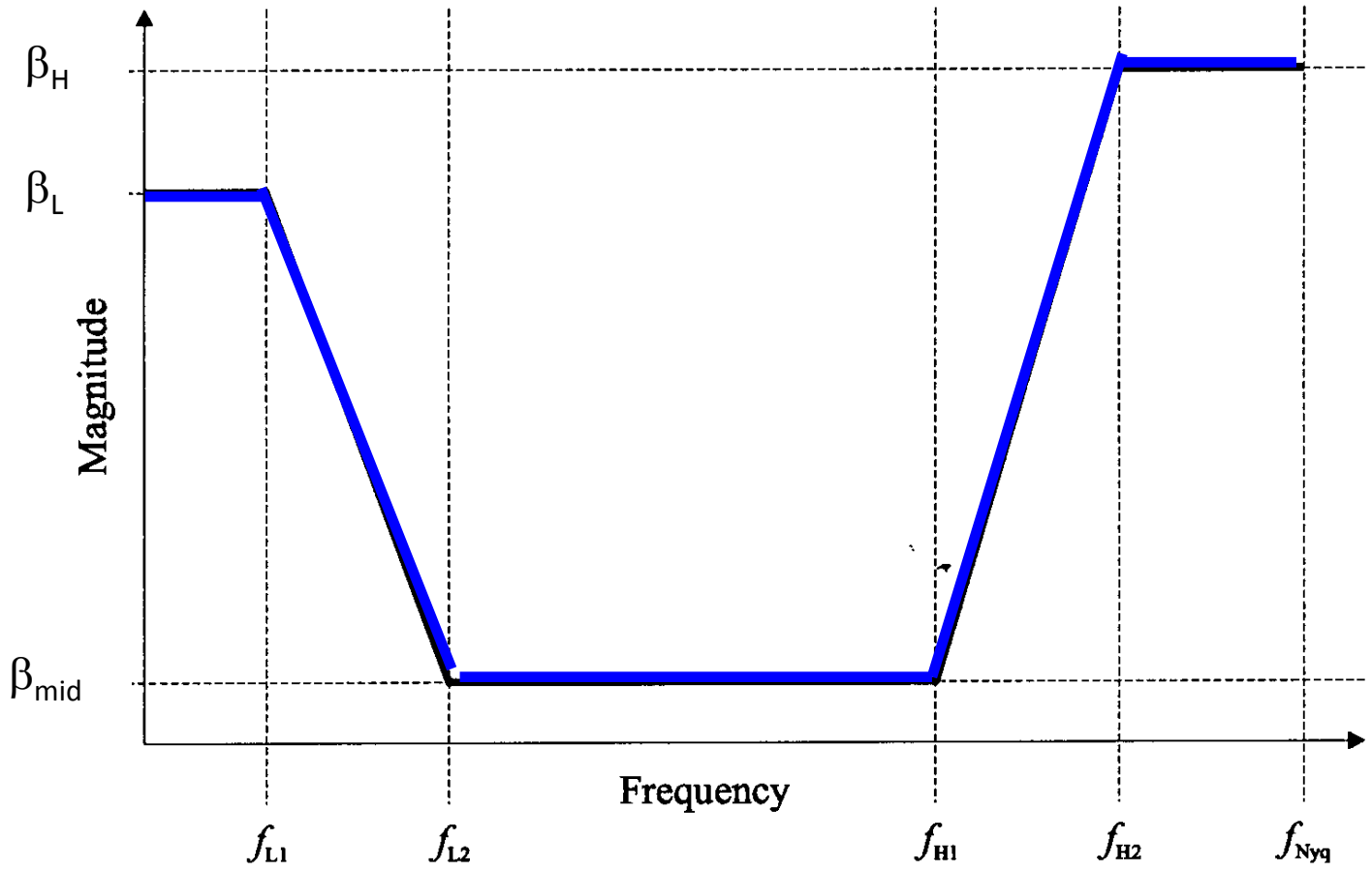
The inversion of this matrix system is performed adding a regularization parameter β, in such a way to minimize the total error (Nelson/Kirkeby approach):

$$[H_k]_{MxV} = \frac{e^{-j\pi k} \cdot [C_k]^*_{MxD} \times [Q]_{DxV}}{[C_k]^*_{MxD} \times [C_k]_{DxM} + \beta_k \cdot [I]_{MxM}}$$

It revealed to be advantageous to employ a frequency-dependent regularization parameter β_k.

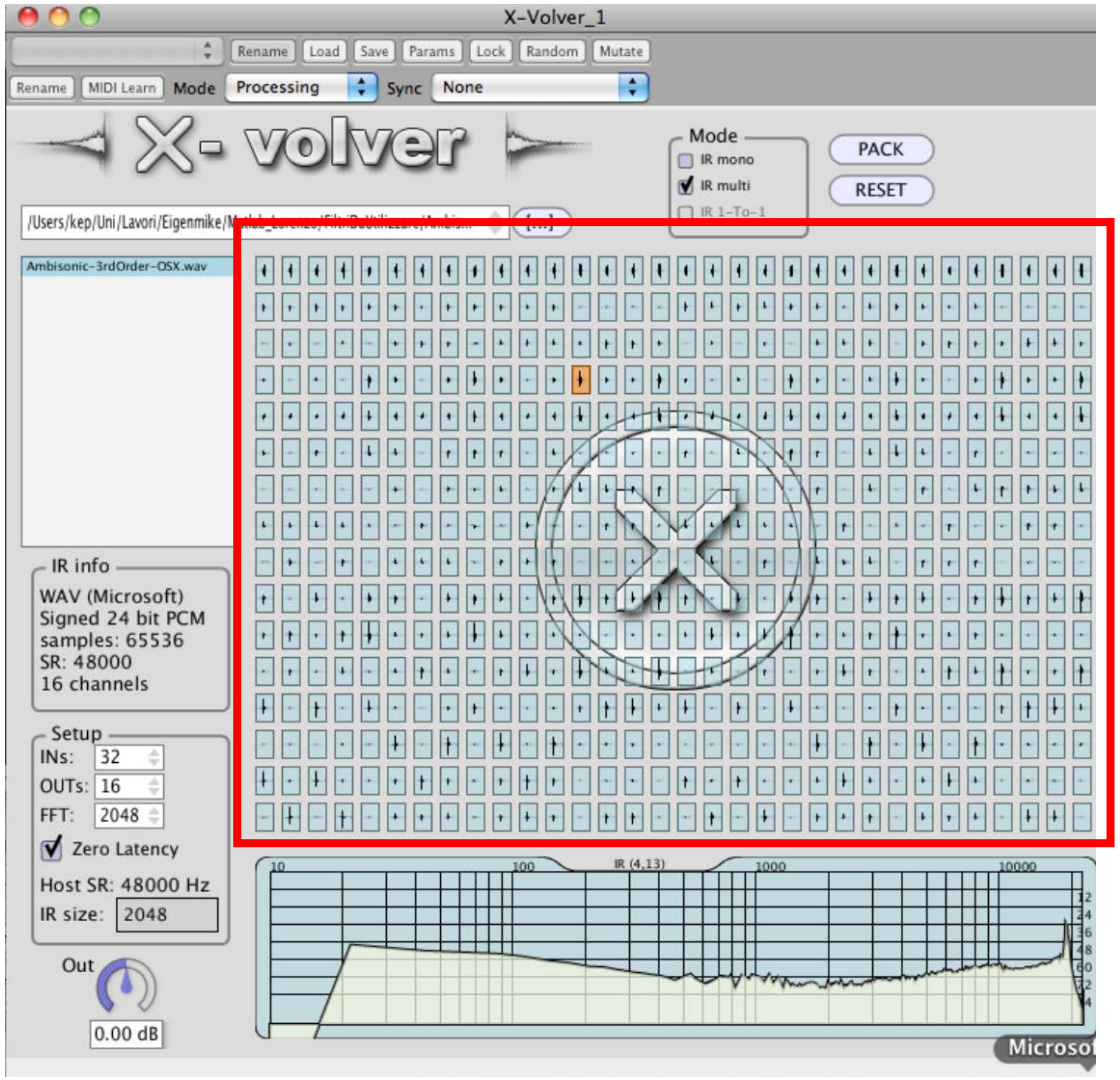
Spectral shape of the regularization parameter β_k

- At very low and very high frequencies it is advisable to increase the value of β.



X-Volver VST plugin for realtime FIR filtering

- Realtime fast convolution of the 32 microphone signals with the matrix of 32x16 FIR filters



32x16 FIR Matrix:

- 2048 samples
- 48kHz – 24bit

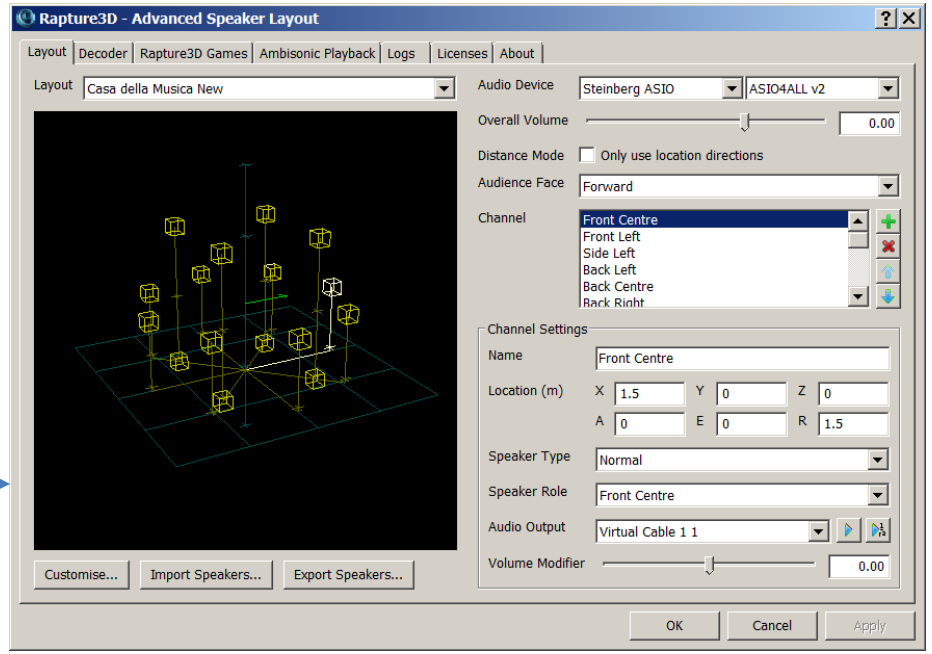
Playback system #1: 3D Ambisonics room

Performed in a threated room equipped with:

- Desktop PC
- RME Hammerfall audio interface
- Apogee DA-16x digital-to-analog converter
- N.2 QSC CX168 power amplifiers
- N.16 Turbosound Impact 50 speakers

PLAYBACK SOFTWARE:

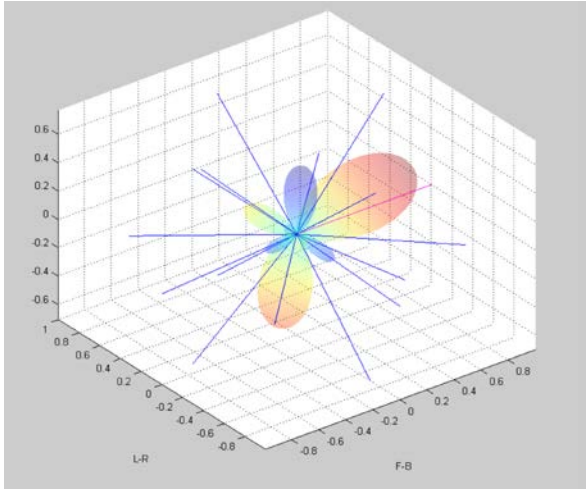
- Windows 7
- Plogue Bidule
- Rapture3D decoder by Richard Furse
- Novel alternative decoder based on Filippo Fazi's theory



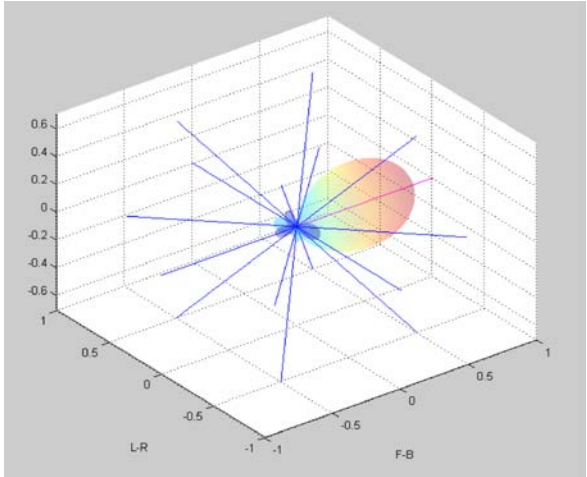
Playback system #1: 3D Ambisonics room

New frequency-independent 3rd order decoder:

- Modifying the geometry of the loudspeaker array, it became possible to employ a simpler Ambisonics decoder, with frequency-independent coefficients, providing better reconstruction



Original Geometry



Modified Geometry

Playback system #2: the WFS «white room»

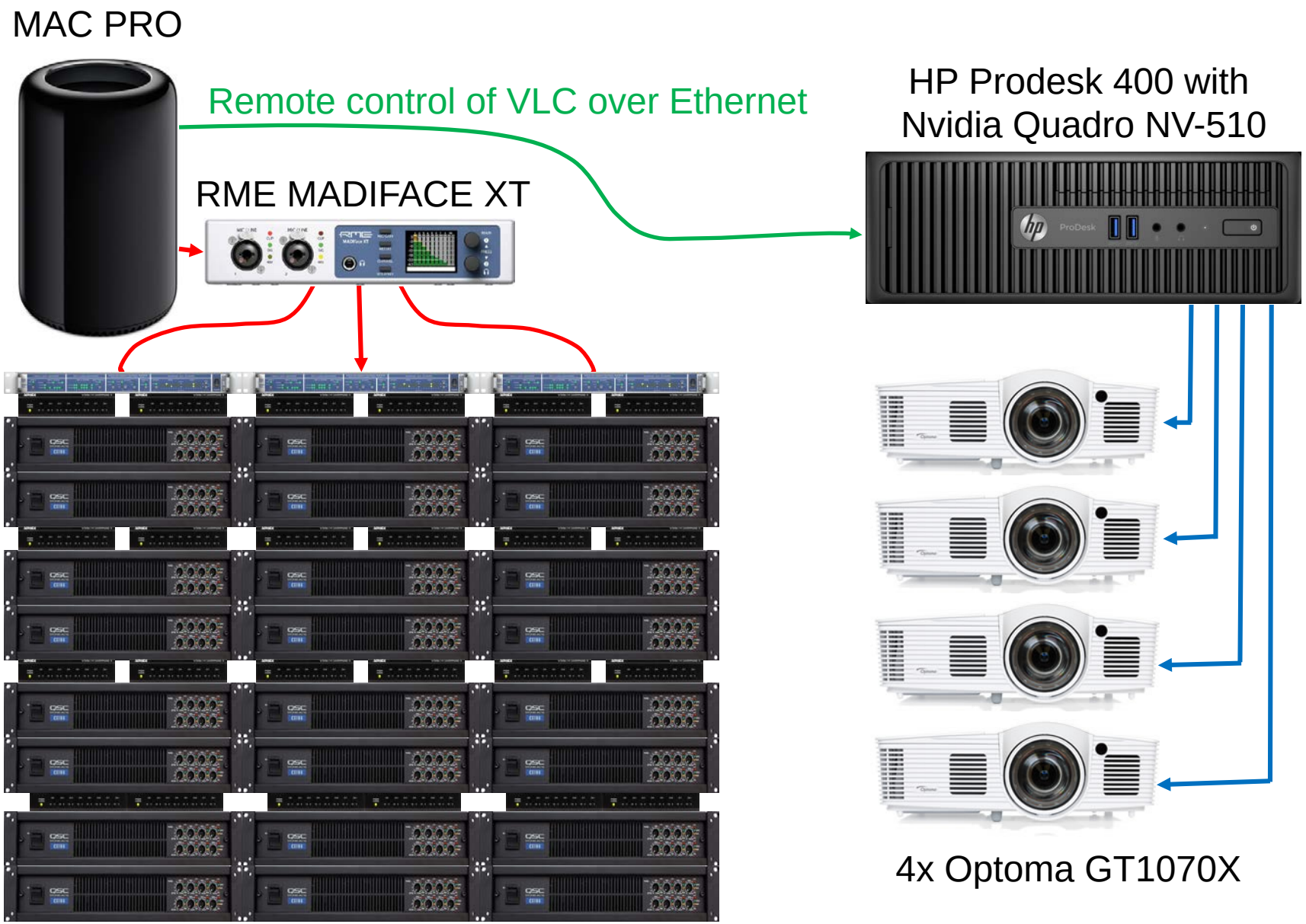
Wave Field Synthesis room, named “Sala Bianca”, in “Casa del Suono” museum.

- Dimensions: 7.5 x 4.5 x 4.5 meters
- Number of speakers: 189
- 4 Optoma Full-HD projectors

The Wave Field System is used for simulating 16 “virtual” speakers placed on a regular octagon at a distance of 15 meters from the centre of the room.
A set of 16 4th-order virtual cardioid microphones are synthesized for feeding these 16 virtual loudspeakers

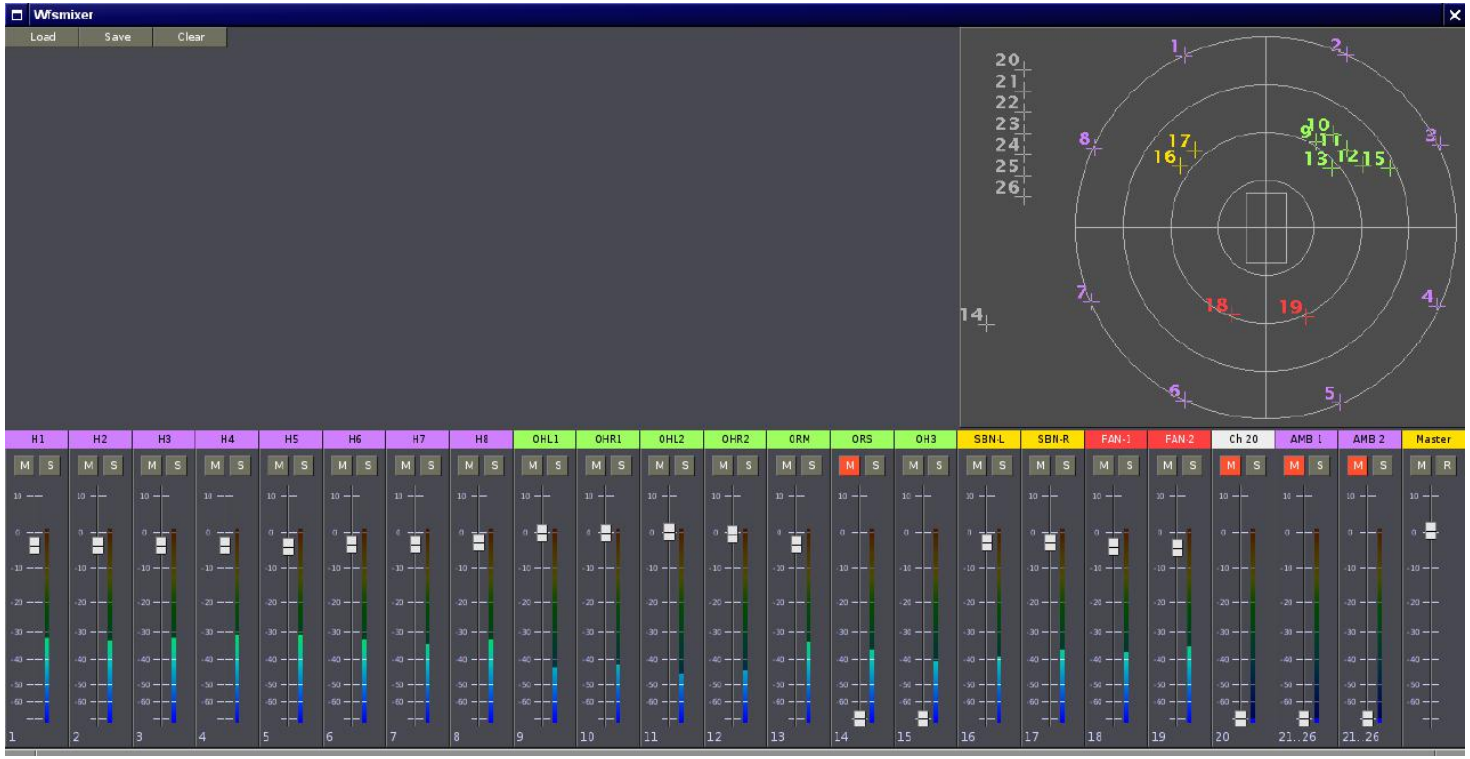
Playback system #2: the WFS «white room»

Hardware:



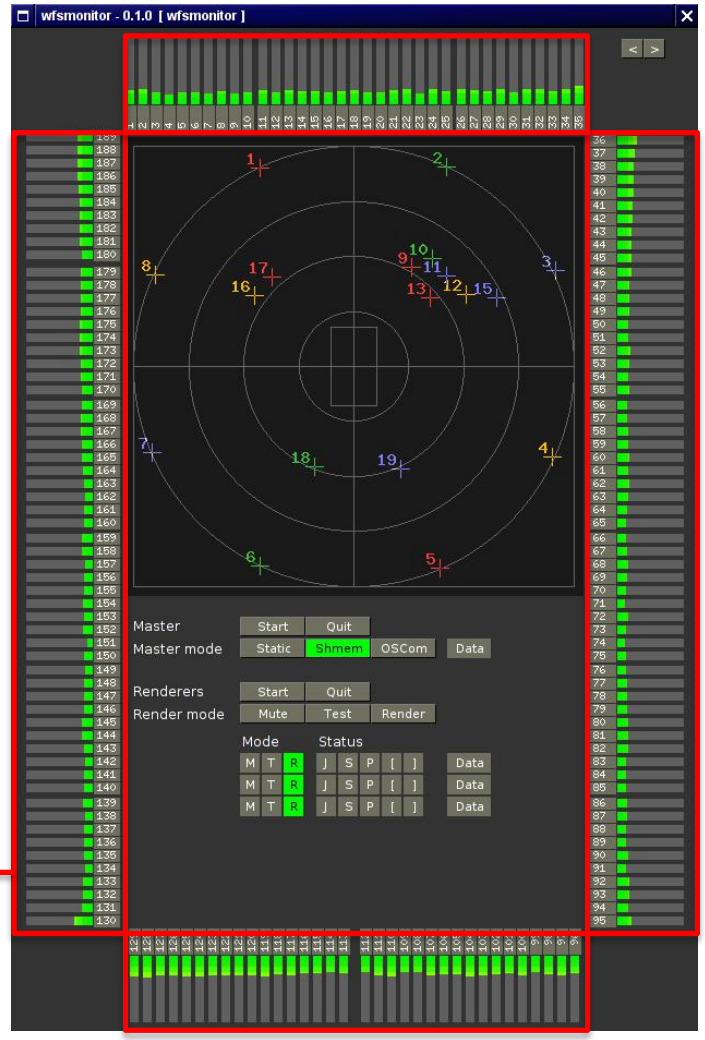
3x RME ADI 648
24x Aphex 141 D/A
24x QSC CX 168 amplifiers

THE WFS SOFTWARE by Fons Adriaensen



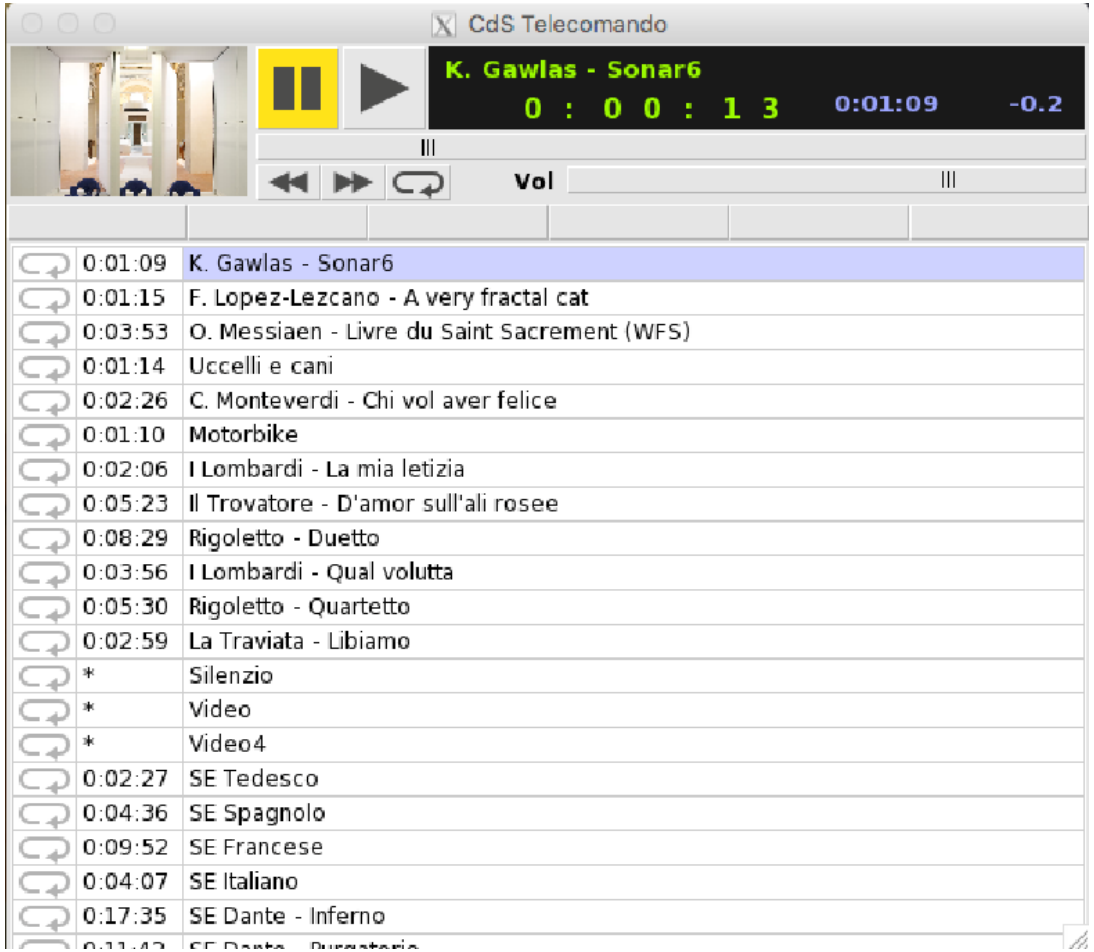
Virtual Sources Mixer

WFS Realtime Monitoring

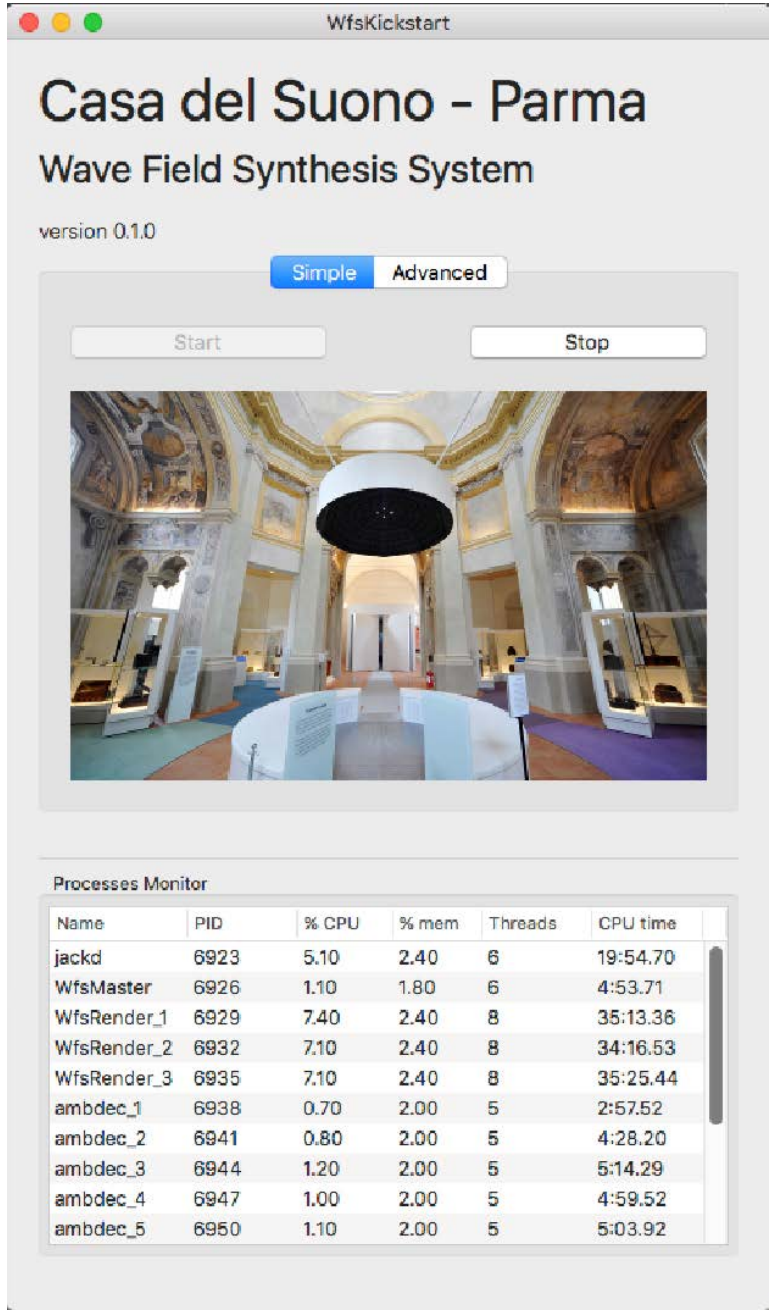


WFS system VU Meters

THE WFS SOFTWARE by Fons Adriaensen



Remote Control



WFS Kickstarter

Playback system #3: Samsung Galaxy S7 + Gear VR

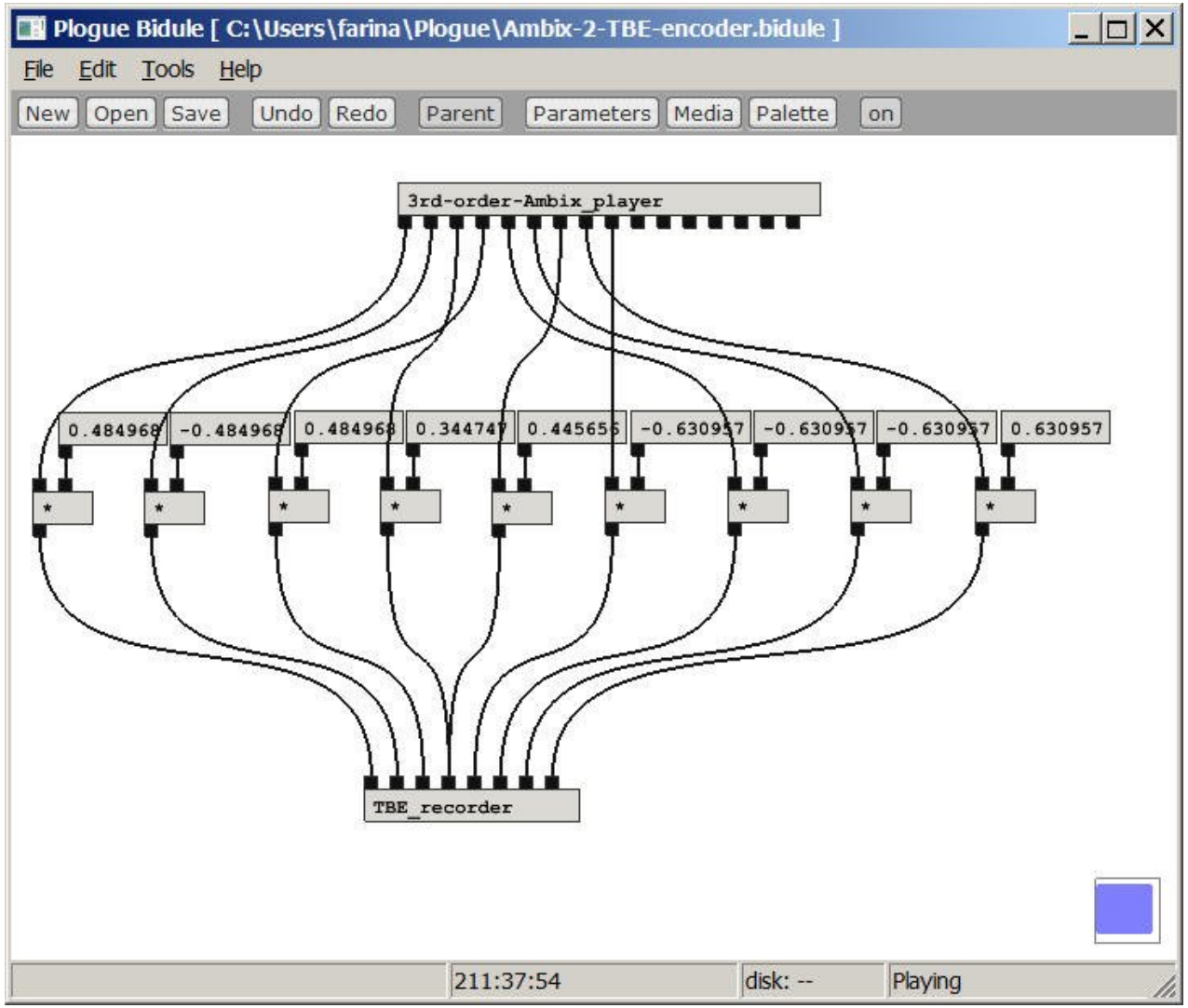
Details:

- No inter-pupillar distance compensation
- Viewing angle: 90 degrees
- Head tracking employing fast sensors inside the visor
- Samsung original earbuds
- Oculus Video Player
- MP4 file container
- 4096x2048 mono video
- 8-channels soundtrack in TBE format (2nd order Ambisonics format with channels Z and R mixed)

Conversion from 16-ch Ambix to 8-ch TBE

The conversion formulas from Ambix to TBE, obtained by trial and errors, are the following:

```
TBE(1) =  0.486968 * Ambix(1)
TBE(2) = -0.486968 * Ambix(2)
TBE(3) =  0.486968 * Ambix(4)
TBE(4) =  0.344747 * Ambix(3) +
0.445656 * Ambix(7)
TBE(5) = -0.630957 * Ambix(9)
TBE(6) = -0.630957 * Ambix(5)
TBE(7) = -0.630957 * Ambix(6)
TBE(8) =  0.630957 * Ambix(8)
```



Playback system #4: Samsung Galaxy S7 + BoboVR Z4

Details:

- Inter-pupillar distance compensation
- Viewing angle: 105 degrees
- Head tracking employing slower sensors inside the smartphone (but S7’ sensors are indeed very fast)
- Visor incorporates headphones
- Jump Inspector video player
- MOV file container
- 4096x2048 mono video
- 16-channels soundtrack in Ambix 3rd order format (ACN / SN3D)

CONCLUSIONS

- A complete workflow for panoramic audio and video recording / processing / playback has been set up and successfully employed
- The resulting quality has been judged perfectly satisfying by opera lovers
- The recordings can be released in various formats and are compatible with many platforms:
  - Youtube (Ambix 1st order, 4 channels)
  - Facebook (TBE 2nd order, 8 channels)
  - Jump Inspector (Ambix 3rd order, 16 channels)
  - 3DVMS (WFS, ring of 16 “sound objects”, 4th order)
  - SPS (Spatial PCM Sampling, 32 channels/objects, 4th order)

Web Links

- YOUTUBE: https://www.youtube.com/channel/UCD7_UQQs4a3k7nxSqDBzhxA
- FACEBOOK: https://www.facebook.com/SpatialAudioParma/
- JUMP INSPECTOR: http://www.angelofarina.it/Public/Jump-Videos/
- UNREAL ENGINE: to be released soon…

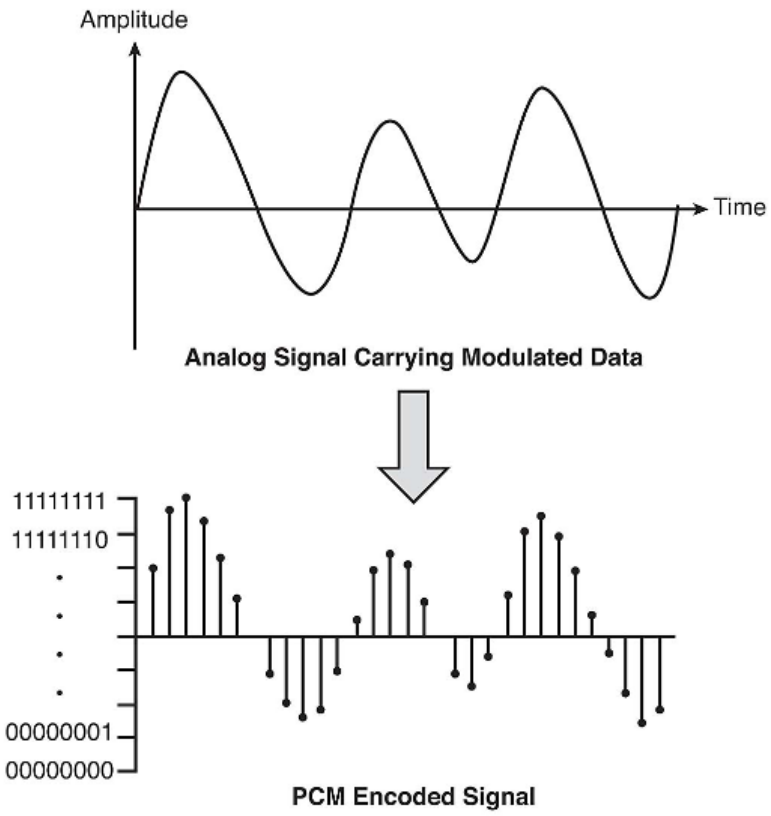
Current Development

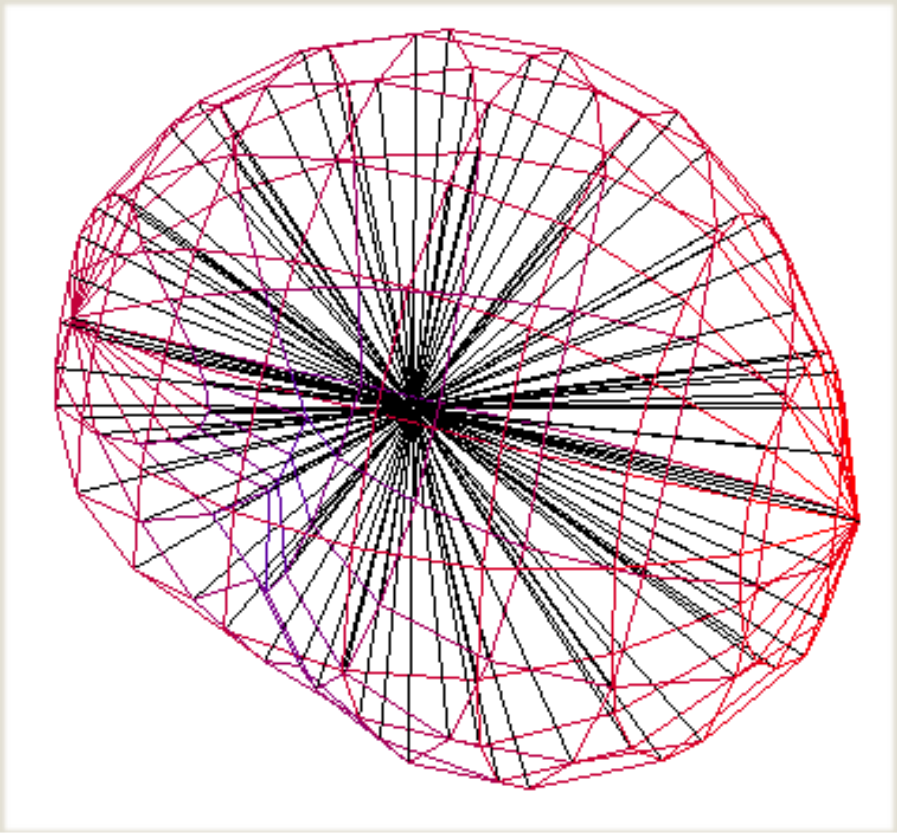
- SPS (Spatial PCM Sampling) rendered over the **HTC Vive** with “room scale”:

Alienware Aurora R7
with Nvidia GTX 1080
video card

Spatial PCM Sampling

Pulse Code Modulation used for modelling
a waveform in time domain or a *balloon* in spatial domain

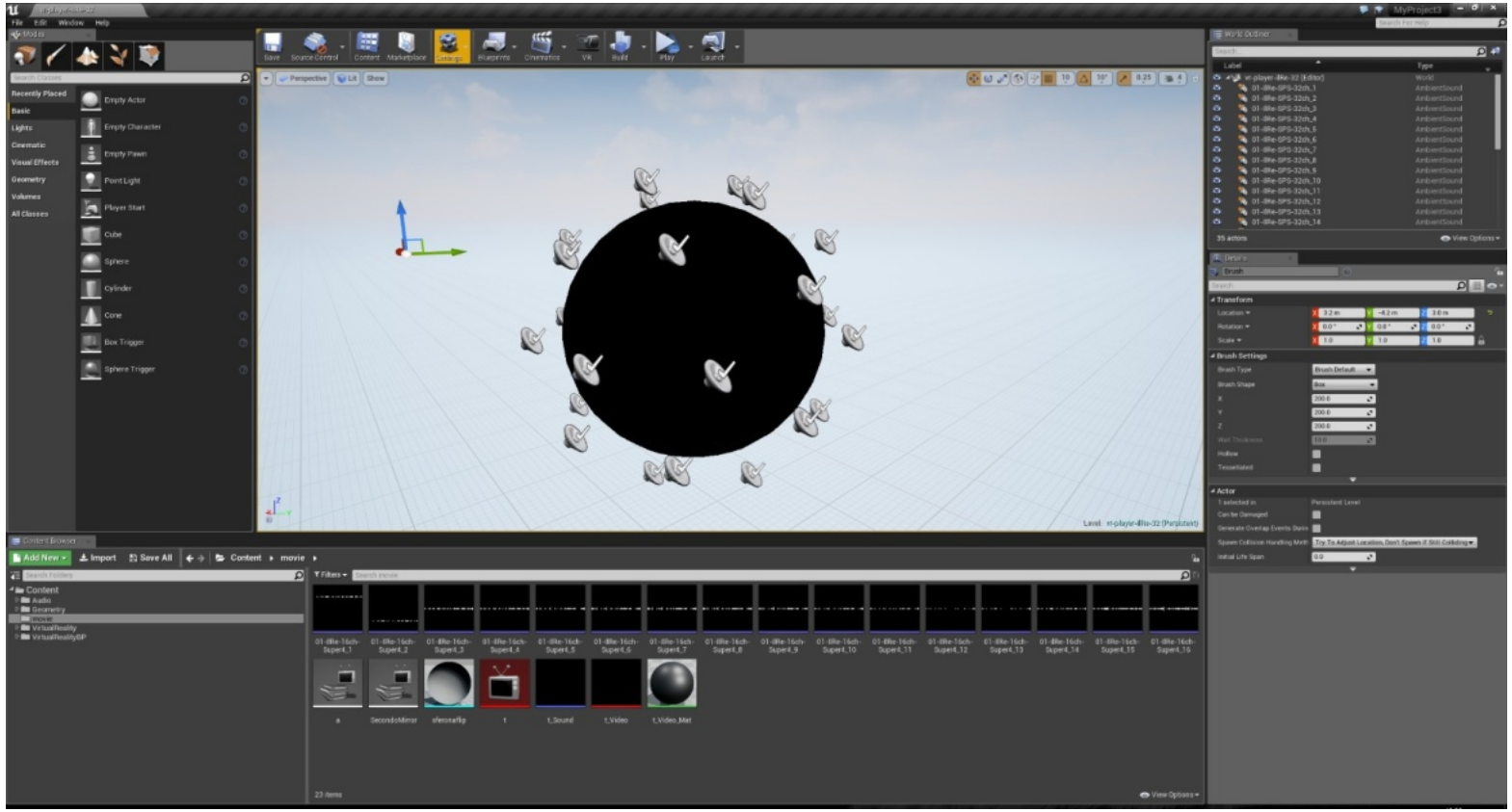




A waveform is represented by a sequence of pulses, a balloon is a “sea urchin” of spikes
Mathematically, these are all approximations to Dirac’s Delta functions

SPS playback on the HTC Vive using Unreal Engine

A spherical screen carries the panoramic video,
surrounded by 32 “sound objects” playing the 32 SPS signals



The software (**which will be released publicly very soon**) renders the panoramic recordings with increased realism, as the system reacts also to body translation, and not just head rotations (6 DOFs)