THREE-DIMENSIONAL ACOUSTIC DISPLAYS IN A MUSEUM EMPLOYING WFS (WAVE FIELD SYNTHESIS) AND HOA (HIGH ORDER AMBISONICS)

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ICSV14

Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

The “Casa del Suono”

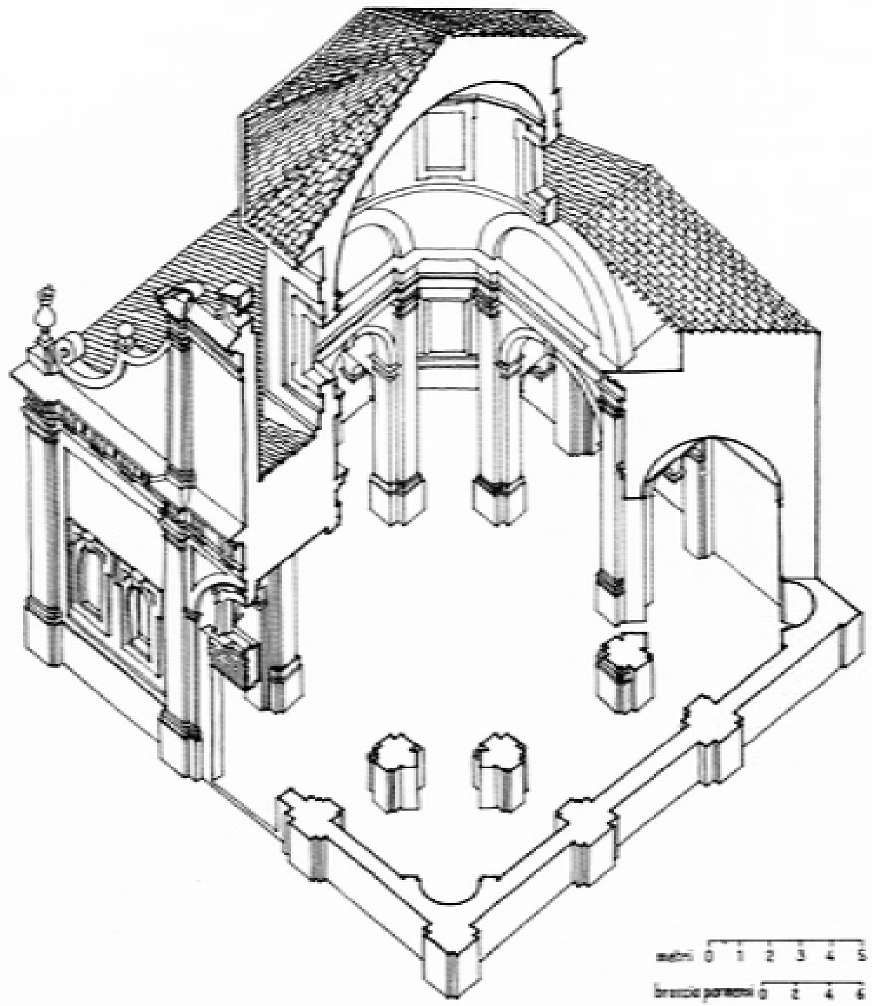
Presidenza del
Consiglio dei Ministri

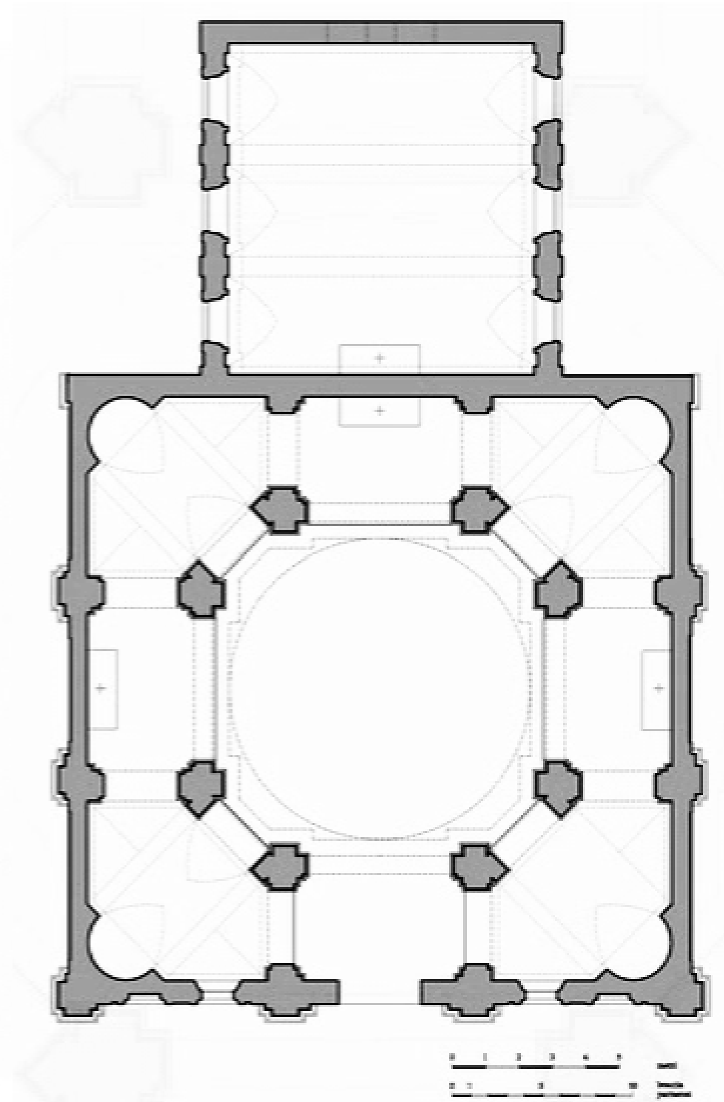
- It was born thanks to the cooperation of University of Parma, Comune of Parma, and with funds (approximately 2 million Euros) provided by Casa della Musica, Italian Governement and Cariparma Foundation
- The institutional goal is to display the famous Patanè’s Collection of vintage grammophones and radios, made available by CNIT (National Italian Consortium for Telecommunications)
- It is also a research lab about electroacoustics, equipped with the latest technologies for sound recording and reproduction employing a large number of channels

Topics

- Restoration of the S.Elisabetta church
- Exhibit of Patanè's Collection
- Sound system for the exhibit
- The SONIC CHANDELLIER, an innovative planar WFS installation
- 30-seats listening room (linear WFS)
- The single-seat listening room (Binaural, Ambisonics, Ambiophonics)

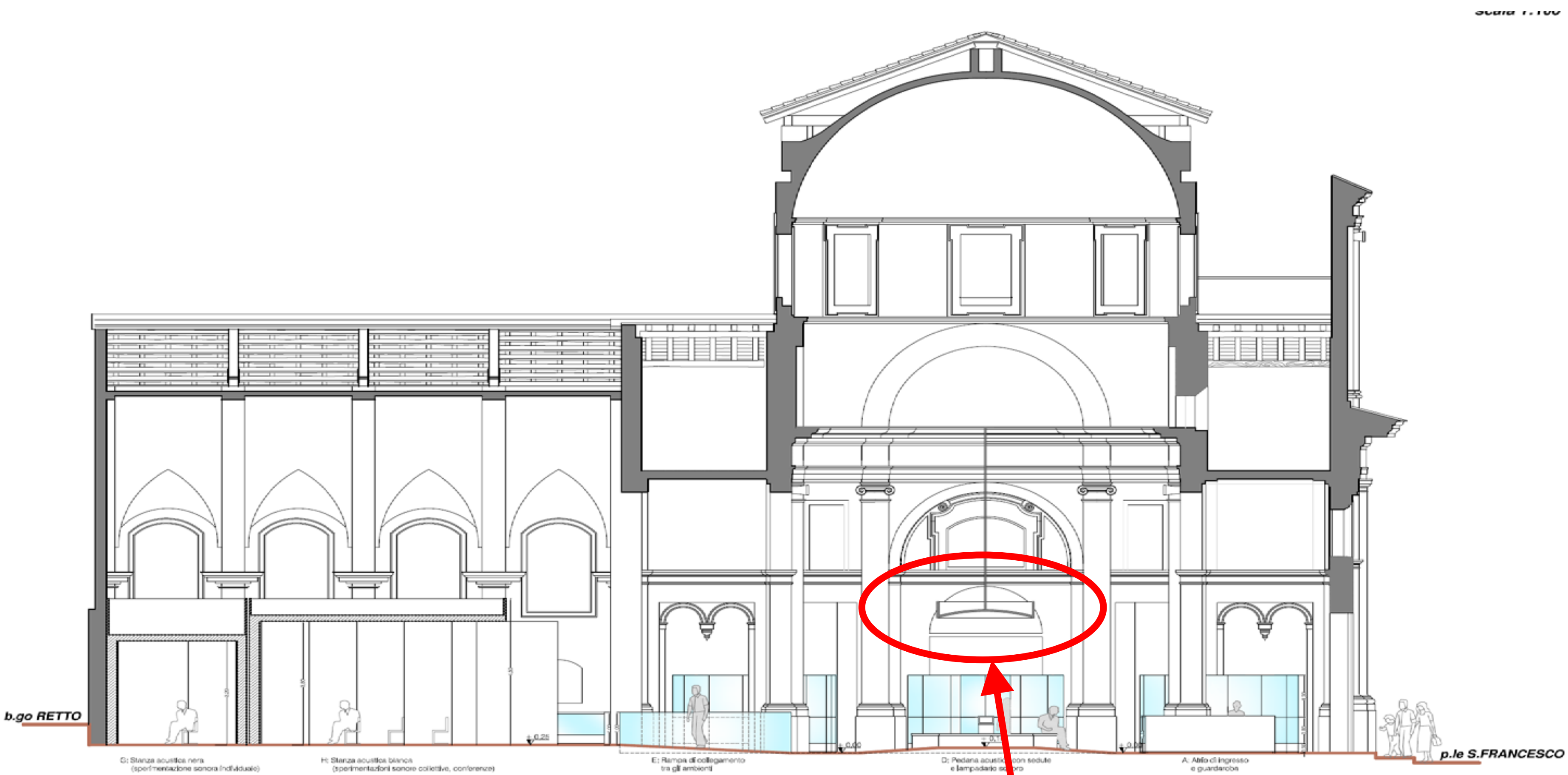
The S.Elisabetta Church





A Baroque square church, with annexed rectangular chapel

The S.Elisabetta Church



The main room is characterized by a very tall dome,with a lot of light thanks to many windows; in the center of the dome the SONIC CHANDELLIER was installed

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The S.Elisabetta church

Before the restoration the building was in miserable conditions

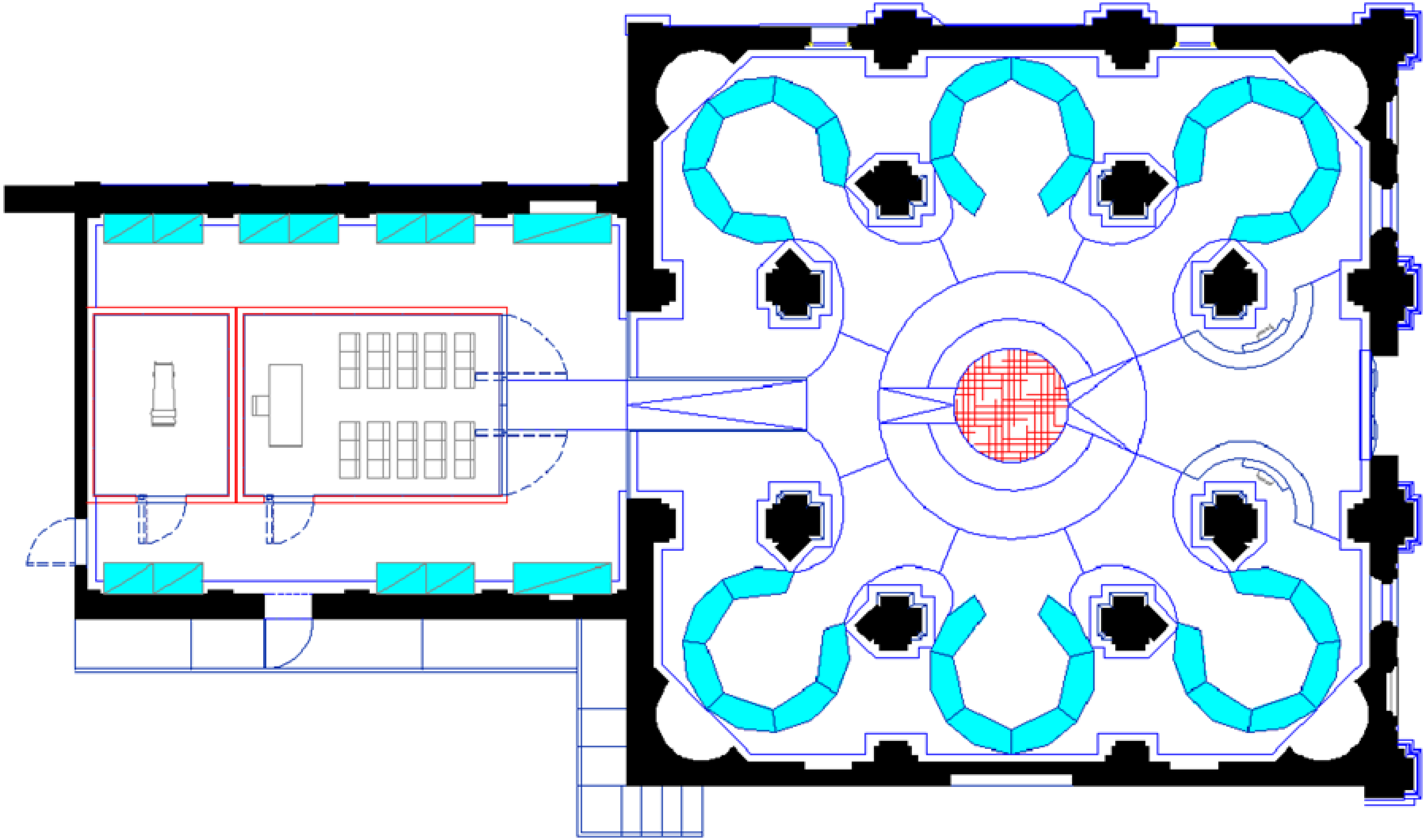
The S.Elisabetta church

Advanced restoration techniques revamped the original beauty

The S.Elisabetta church

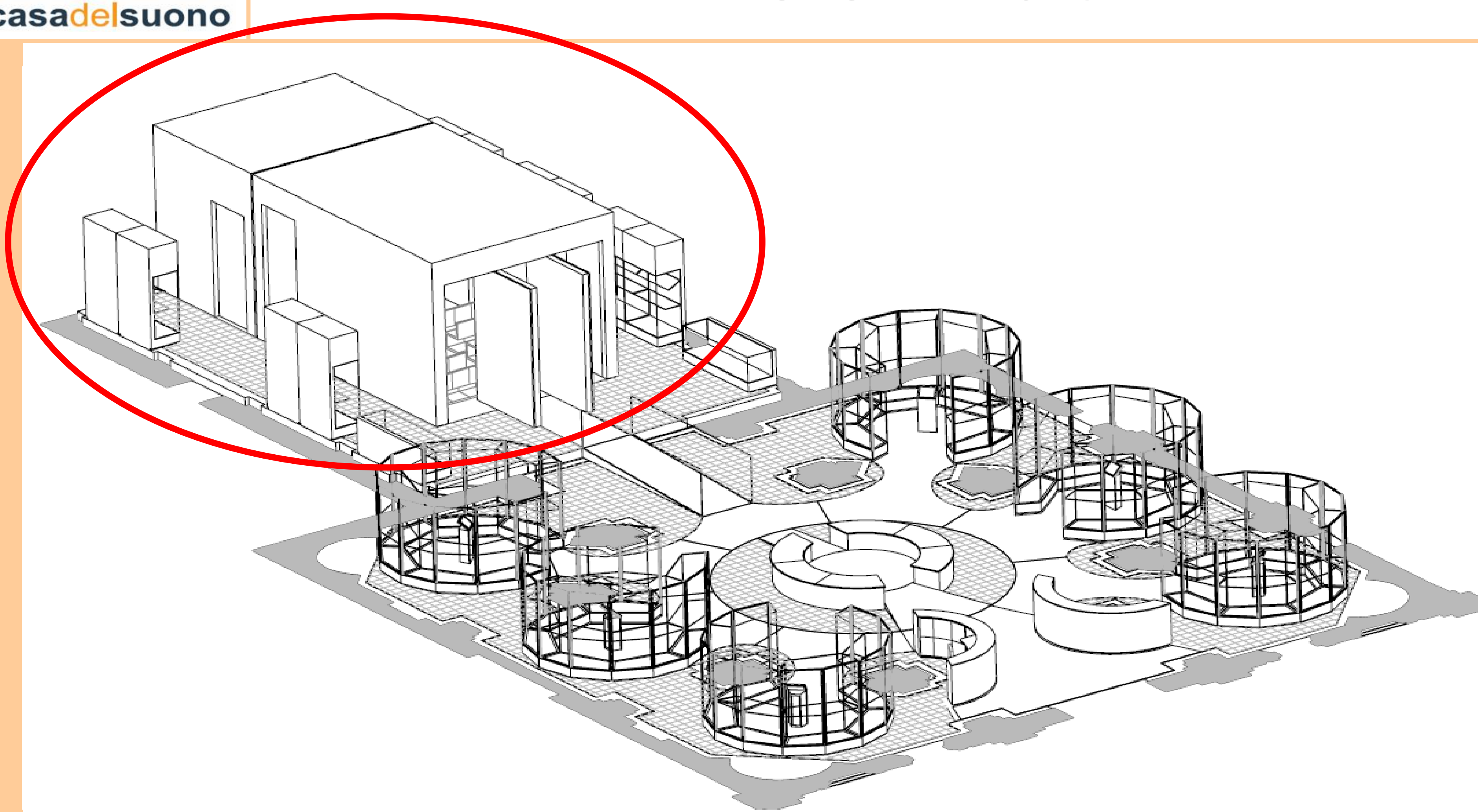
However, these restoration and consolidation techniques caused the acoustical behaviour of the church to worsten significantly, raising the reverberation time of the empty room from 2.3 s to more than 4.0 s

The exhibit



6 circular niches in glass and steel, located in the 6 chapels of the main church, contain the major part of the "pieces" being exposed

The exhibit



In the rear chapel, the two “surround” listening rooms are located

Patanè’s Collection

- The collection was donated to CNIT by don Giuseppe Patanè, a priest and a collector, who employed his entire, long life for searching, purchasing and repairing valuable pieces.
- The collections contains approximately 400 pieces, ranging from the first phonographs, to Galen radios and extends to domestic and military radios of 20’s, 30’s, 40’s up to the first years after WWII. All pieces have been carefully maintained and serviced, most of them are working as new....
- There are also some particularly rare pieces, such as a cryptographic “Enigma” machine, employed by the German army for transmitting encoded informations during WWII.

Patanè's Collection

- Some samples from the collection

APPARECCHIO A REAZIONE
3 valvole - Francia - 1925

RADIO "RADIEX"
4 valvole esterne, a reazione , Francia

RADIO FRANCESE
4 valvole esterne

FRANCESE A REAZIONE
valvole esterne - 1923

Patanè's Collection

- Some samples from the collection

RCA RADIOLA 26
6 valvole - supereterodina - 1925

RAMAZZOTTI tipo RD8
8 valvole - 1927

STROMBERG-CARLSON mod. 654 - A
1929

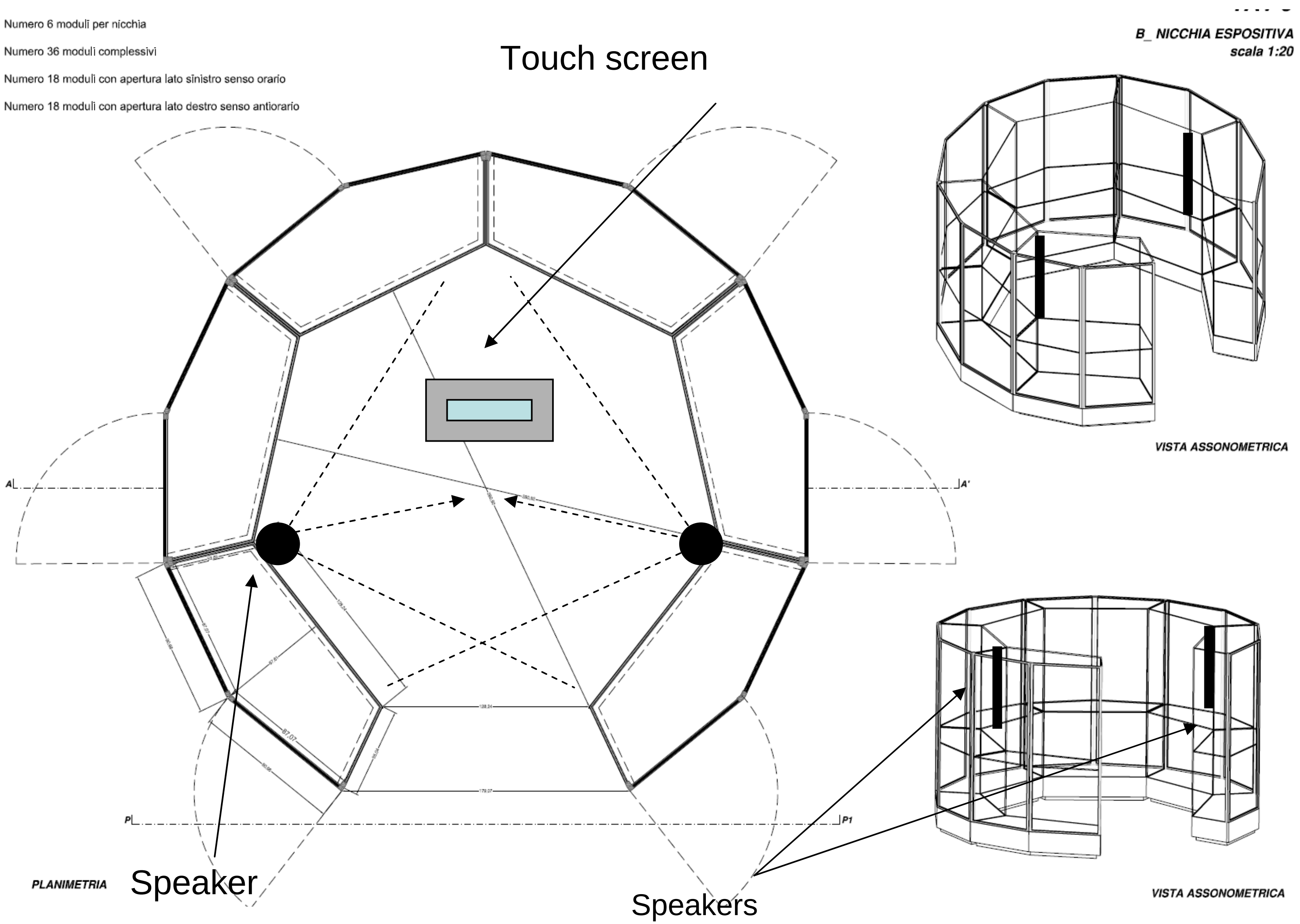
Patanè's Collection

- Some samples from the collection

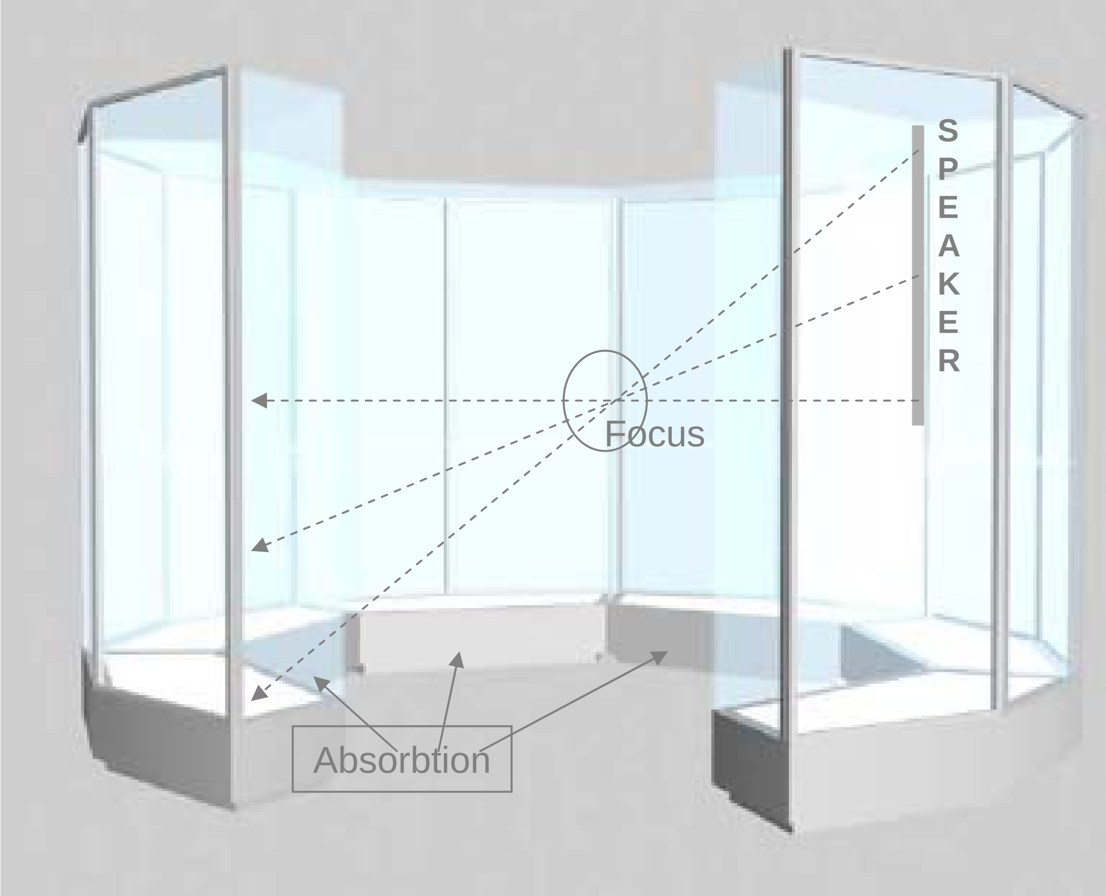
IMCA RADIO MULTIGAMMA IF 71
Alessandria - 1941

SAFAR mod. 846
1939

Exhibit's sound system

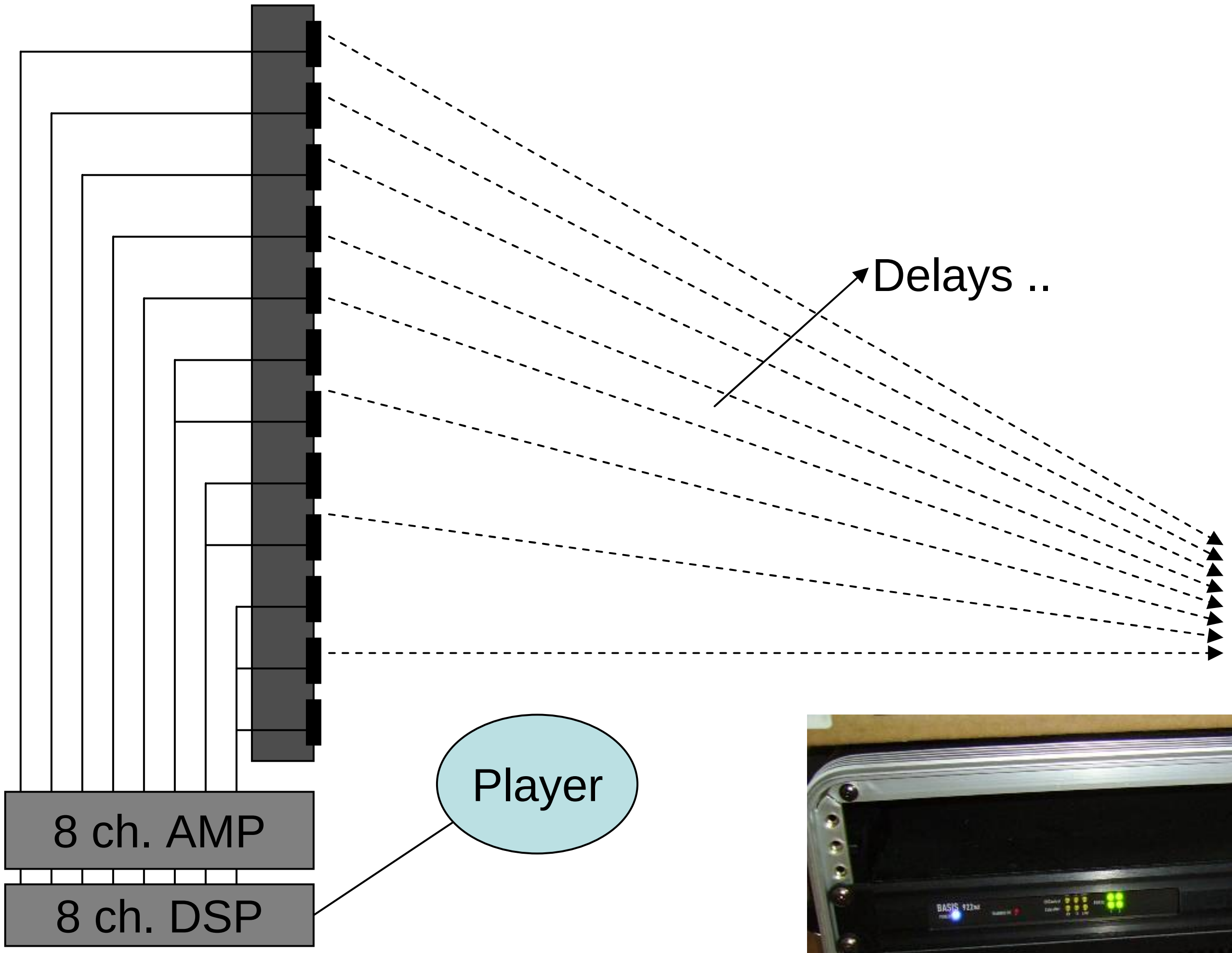


Exhibit's sound system



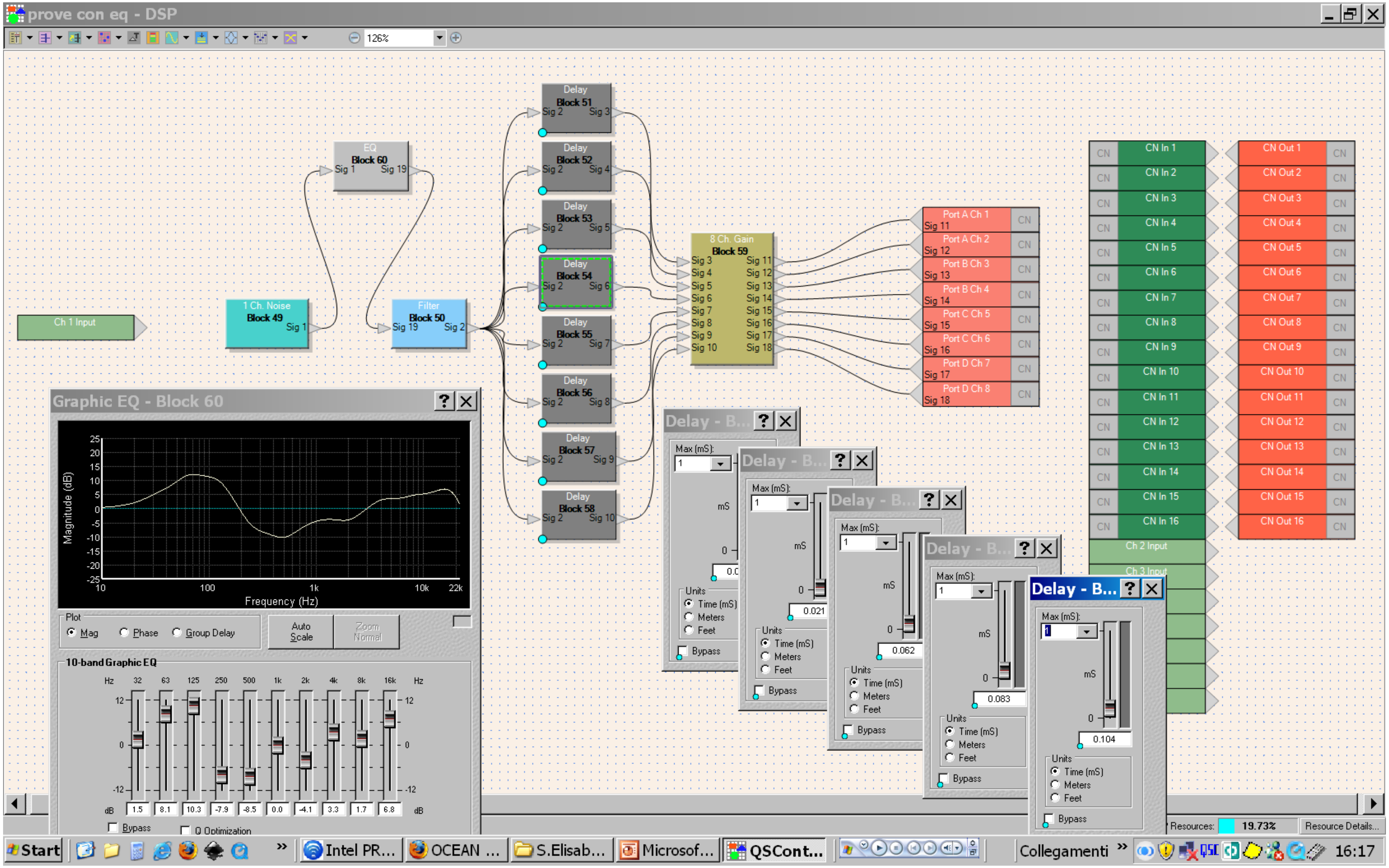
Two vertical 13-speakers line-arrays are employed. A DSP unit focalizes the sound downwards, where absorptive “sound traps” are located, for avoiding to spread the sound all around the church

DSP control of line arrays



QSC 8-channels amplifier + BASIS DSP controller / Cobranet interface

DSP control of line arrays



The Niches

Niche n. 1 - PHONOGRAPHS AND GRAMMOPHONS
1897-1923

The Niches

Niche n. 2 - RADIO
1921-1926

The Niches

Niche n. 3 - RADIO and GRAMMOPHONS
1926-1929

The Niches

Niche n. 4 - RADIO
1930-1935

The Niches

Nicchia n. 5 - RADIO AND RADIOGRAMMOPHONS
1935-1954

The Niches

Nicchia n. 6 - RADIO, TURNTABLES, AMPLIFIERS, STEREO
1950 - 2007

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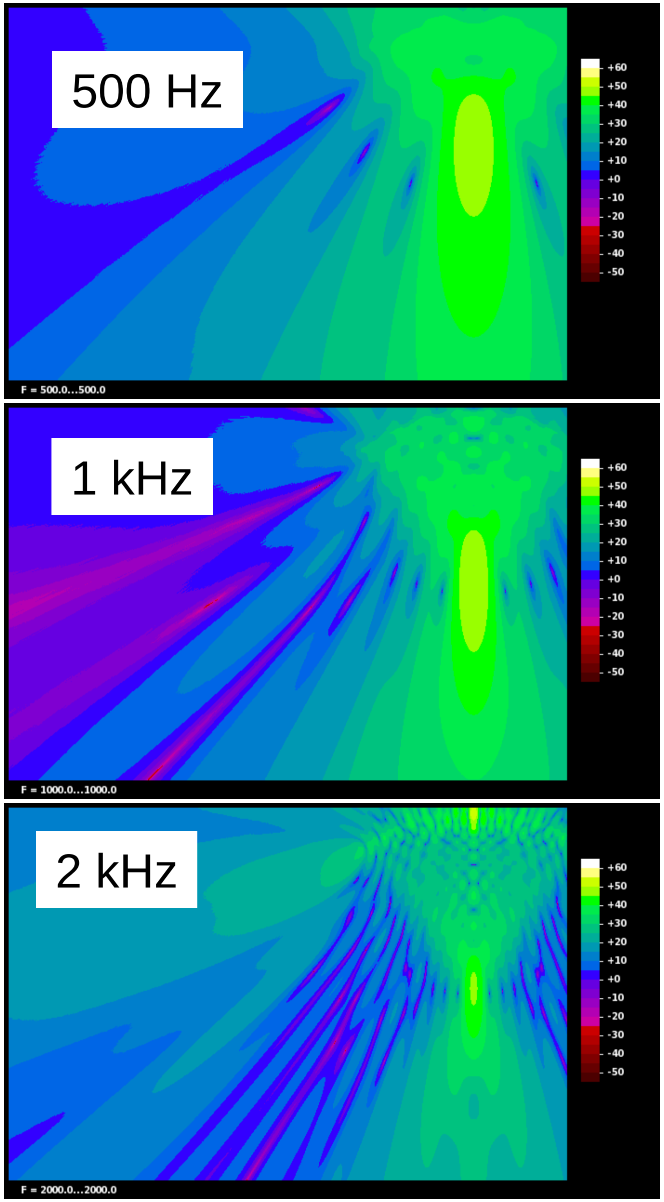
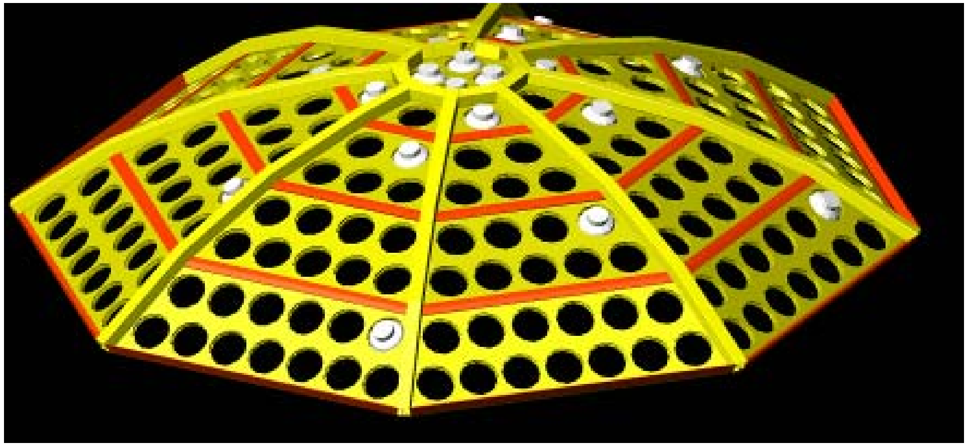
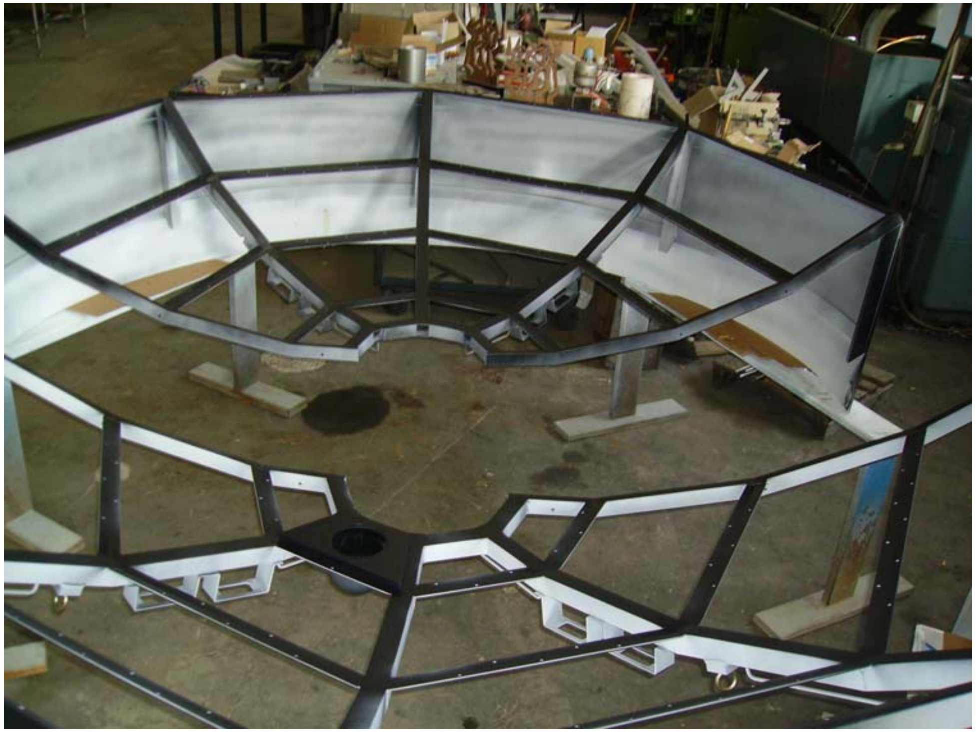
The “Sonic Chandellier”

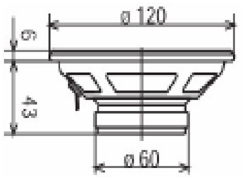


Design and Construction

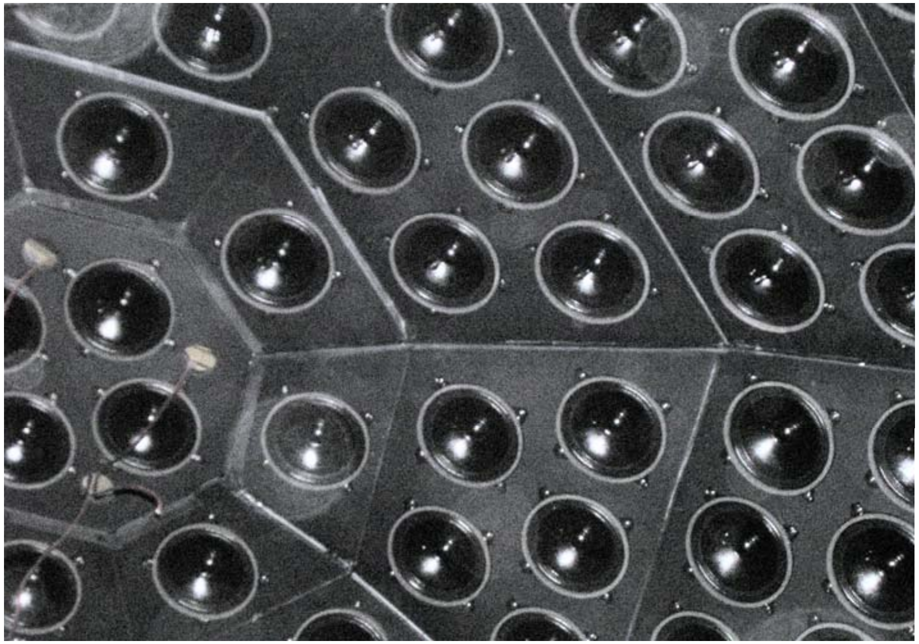




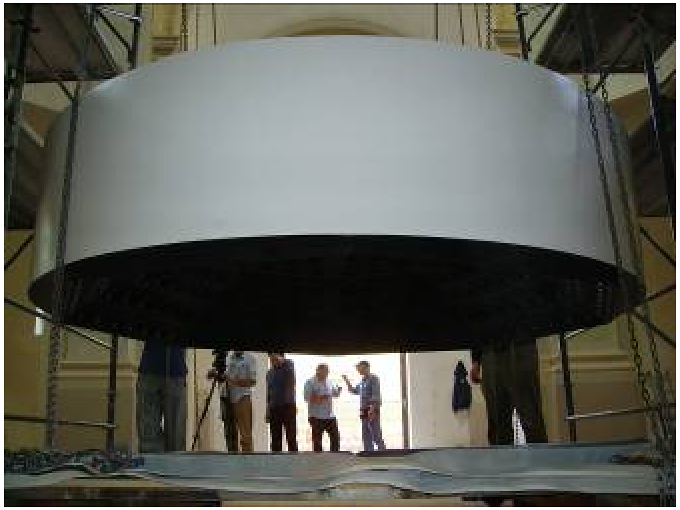
Design and Construction



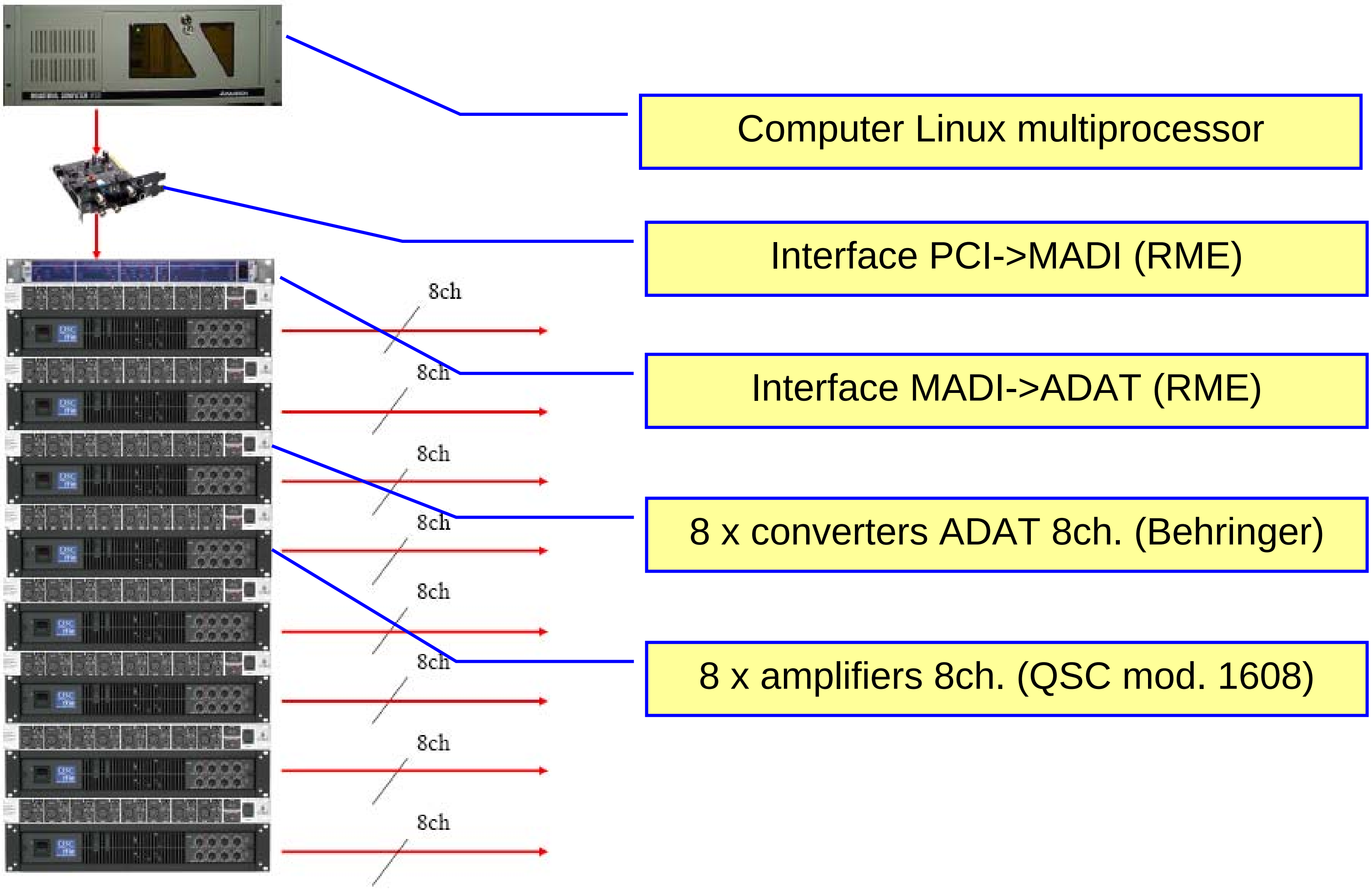
Special 32 Ohm model by Ciare



Installation



Hardware (computer, converters, amplifiers)



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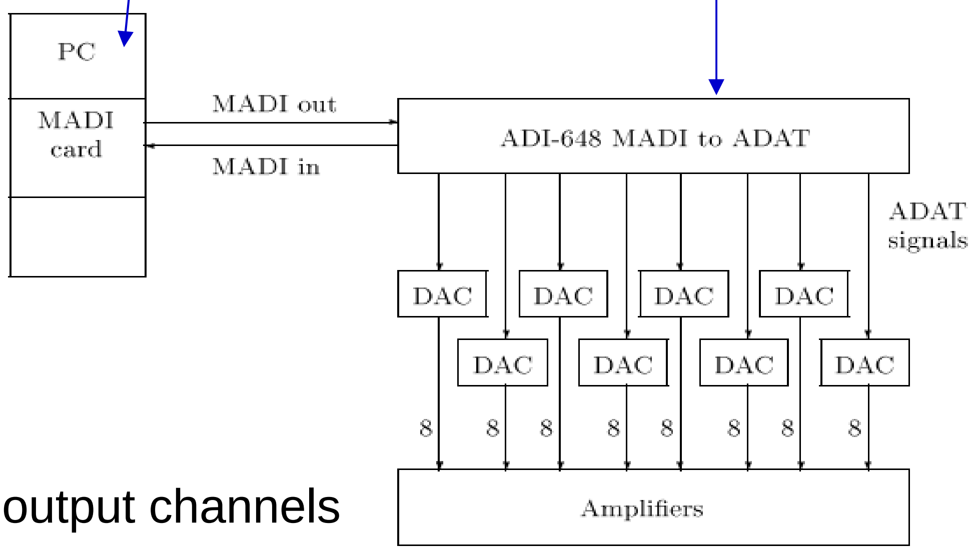
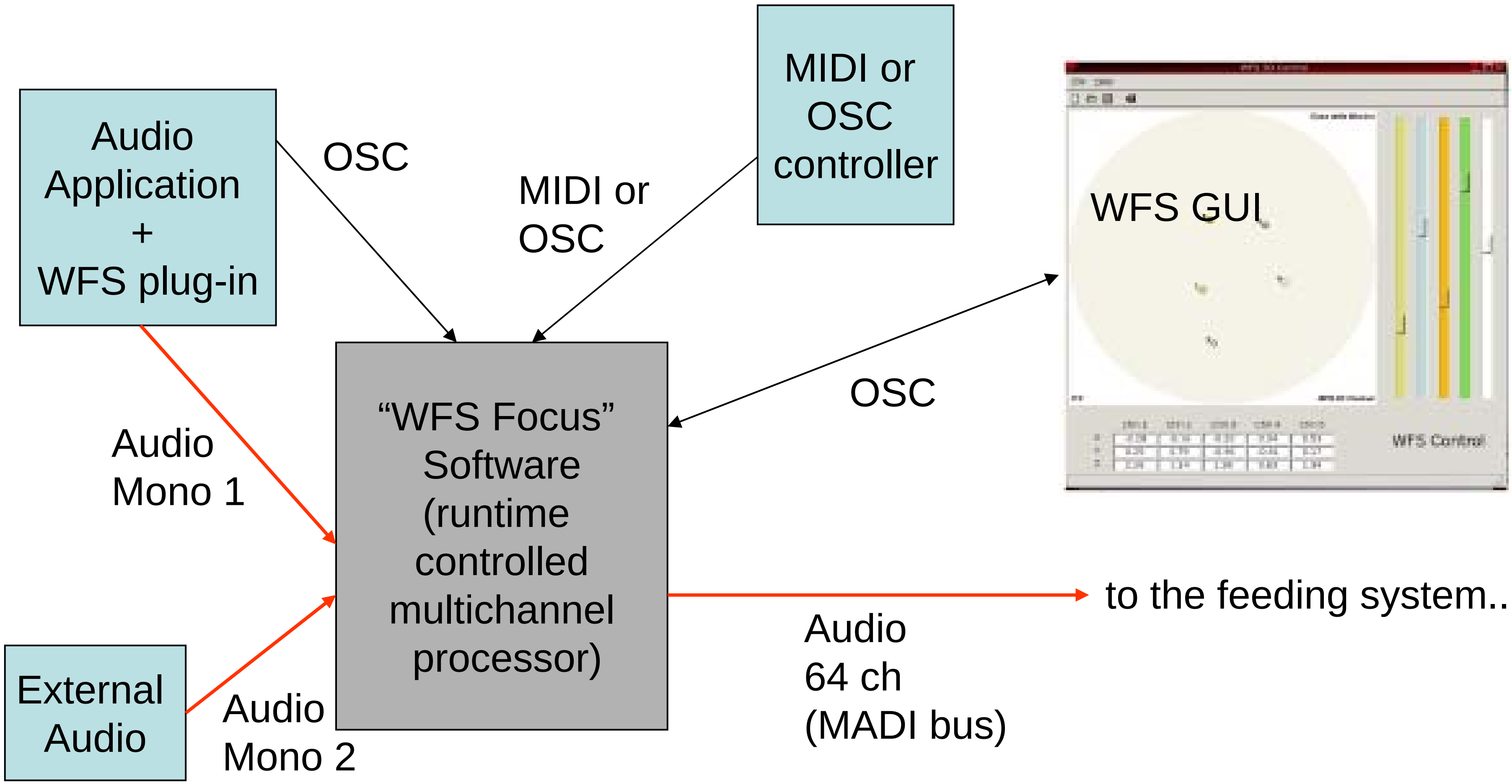


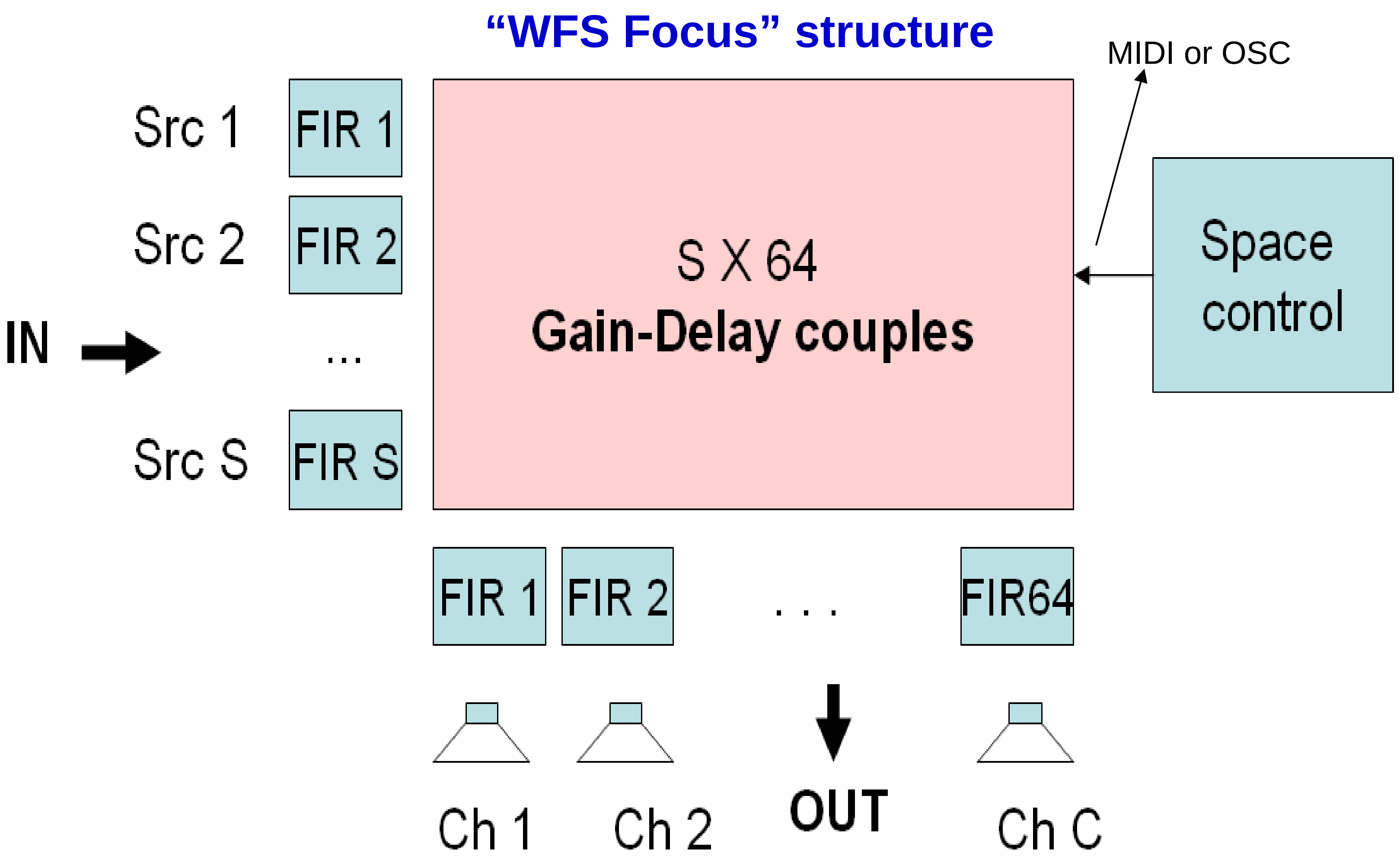
64 output channels

Software

Software structure on Linux PC

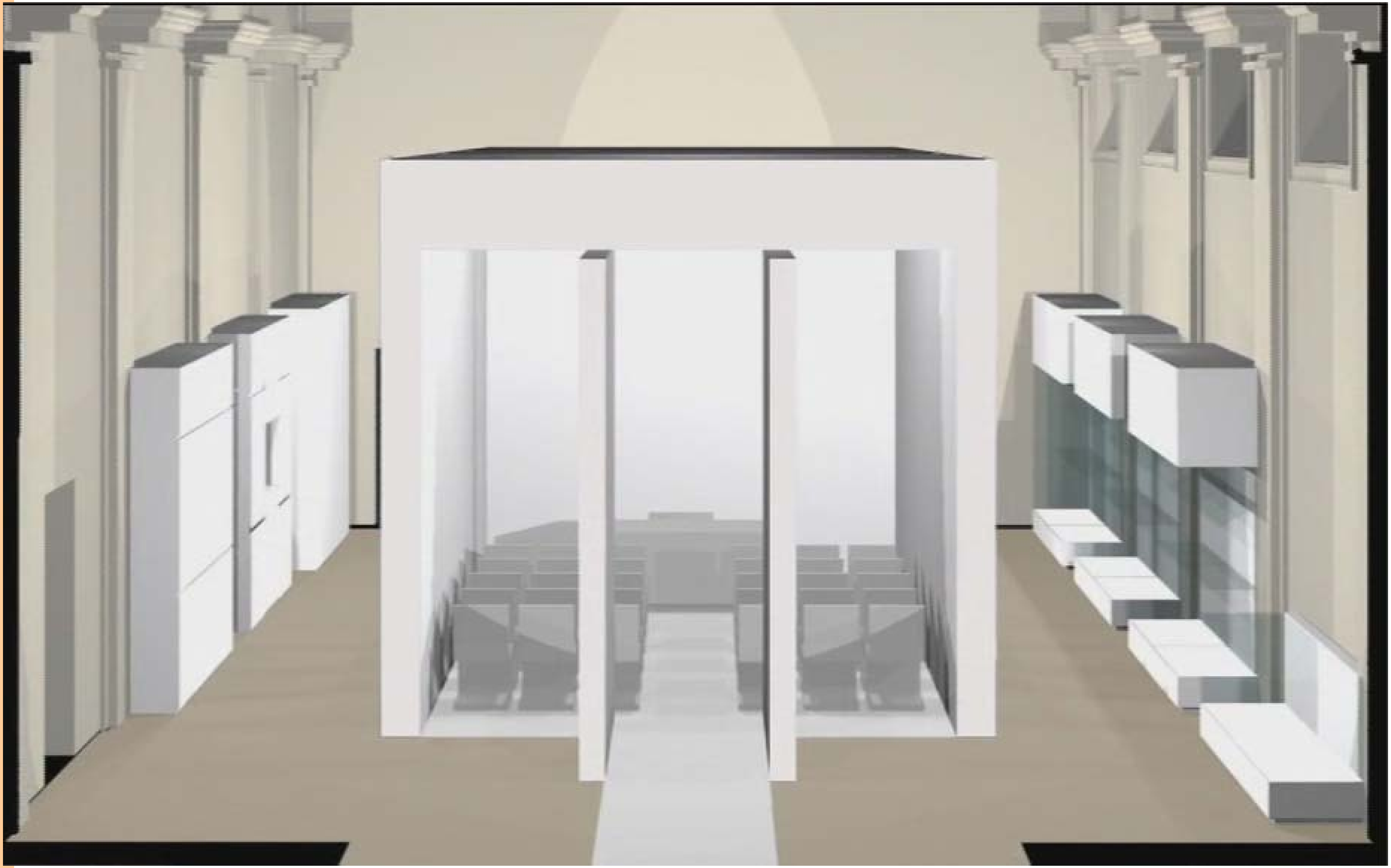


Software

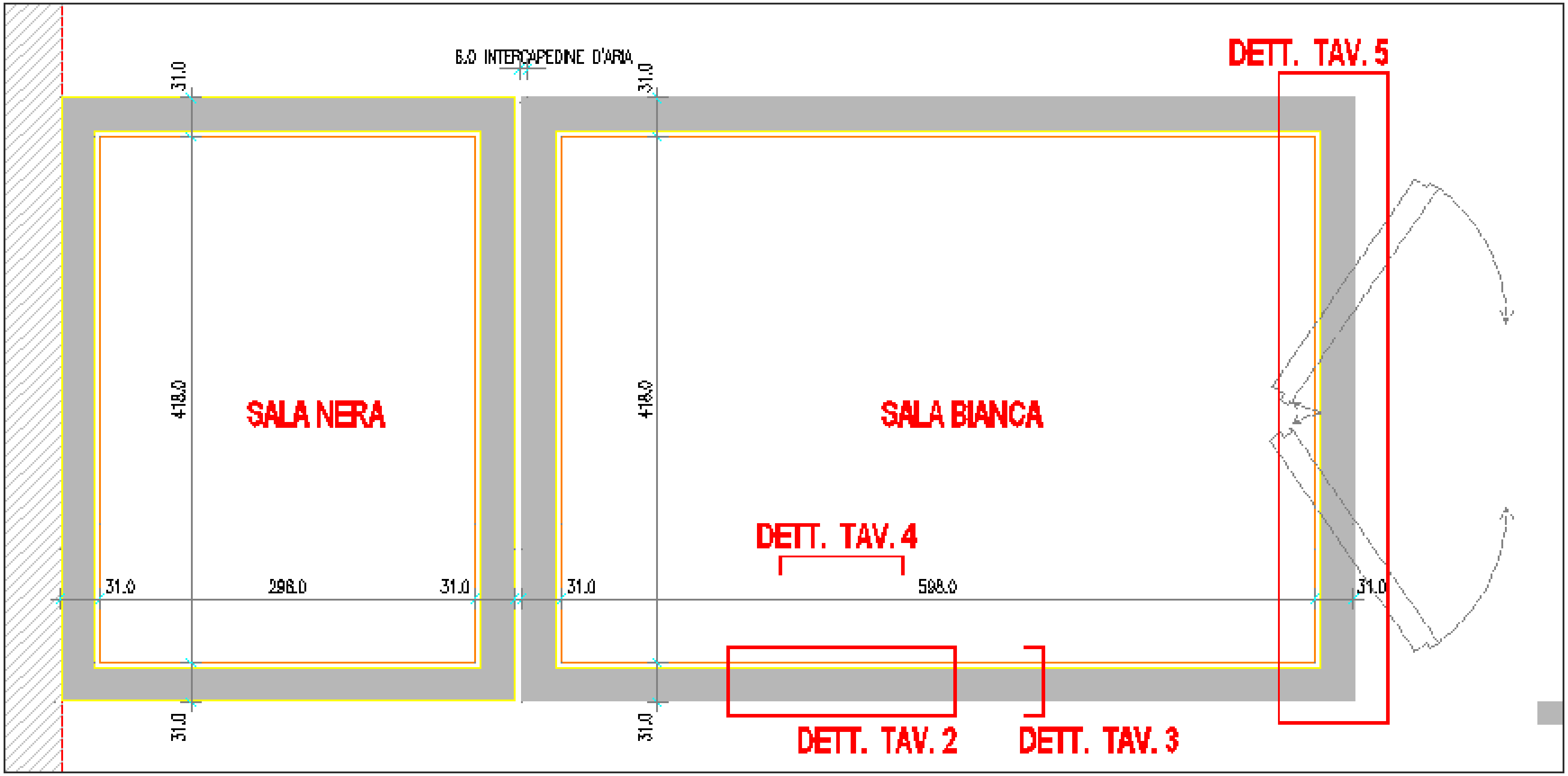


"WFS Focus" structure
MIDI or OSC
Src 1
FIR 1
Src 2
FIR 2
IN
...
Src S
FIR S
S X 64
Gain-Delay couples
Space control
FIR 1
FIR 2
. . .
FIR64
OUT
Ch 1
Ch 2
Ch C

Listening rooms



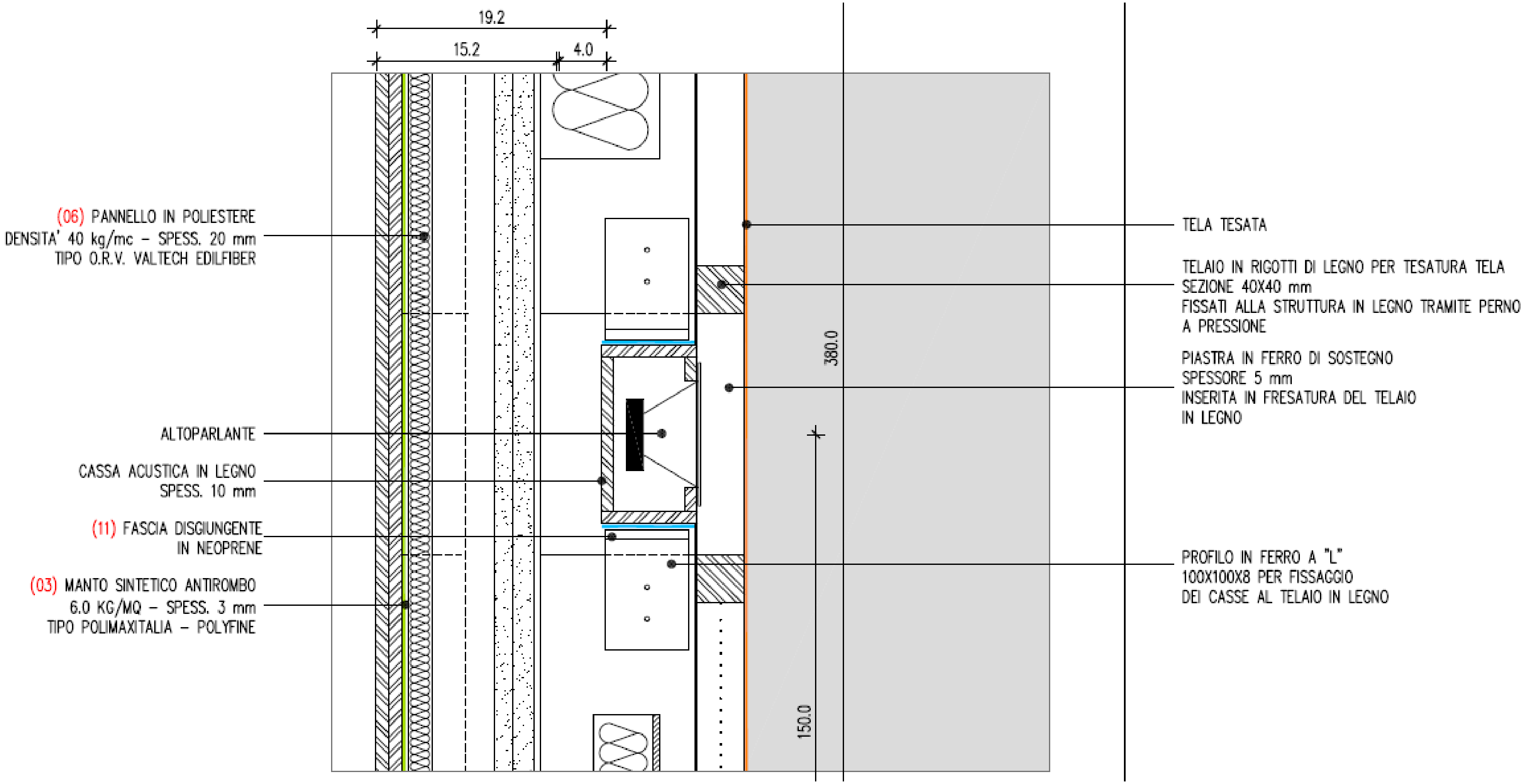
Listening rooms



PLANIMETRIA
SCALA 1:50

- La sala bianca ospita sino a 30 ascoltatori, ed è dotata di un sistema surround planare tipo WFS (192 altoparlanti)

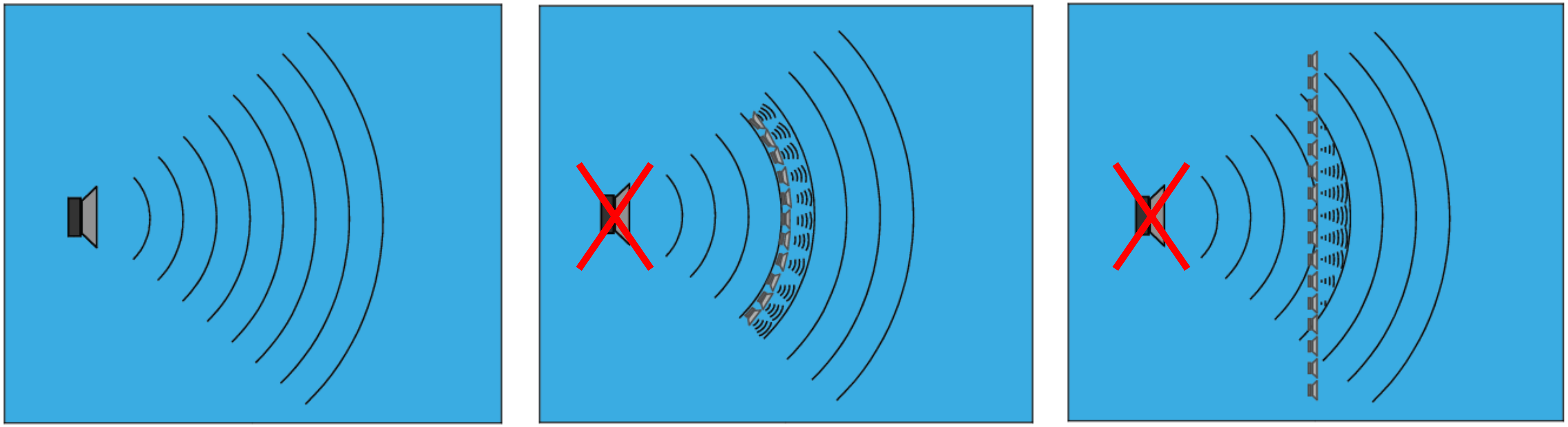
30-seats room ("sala Bianca")



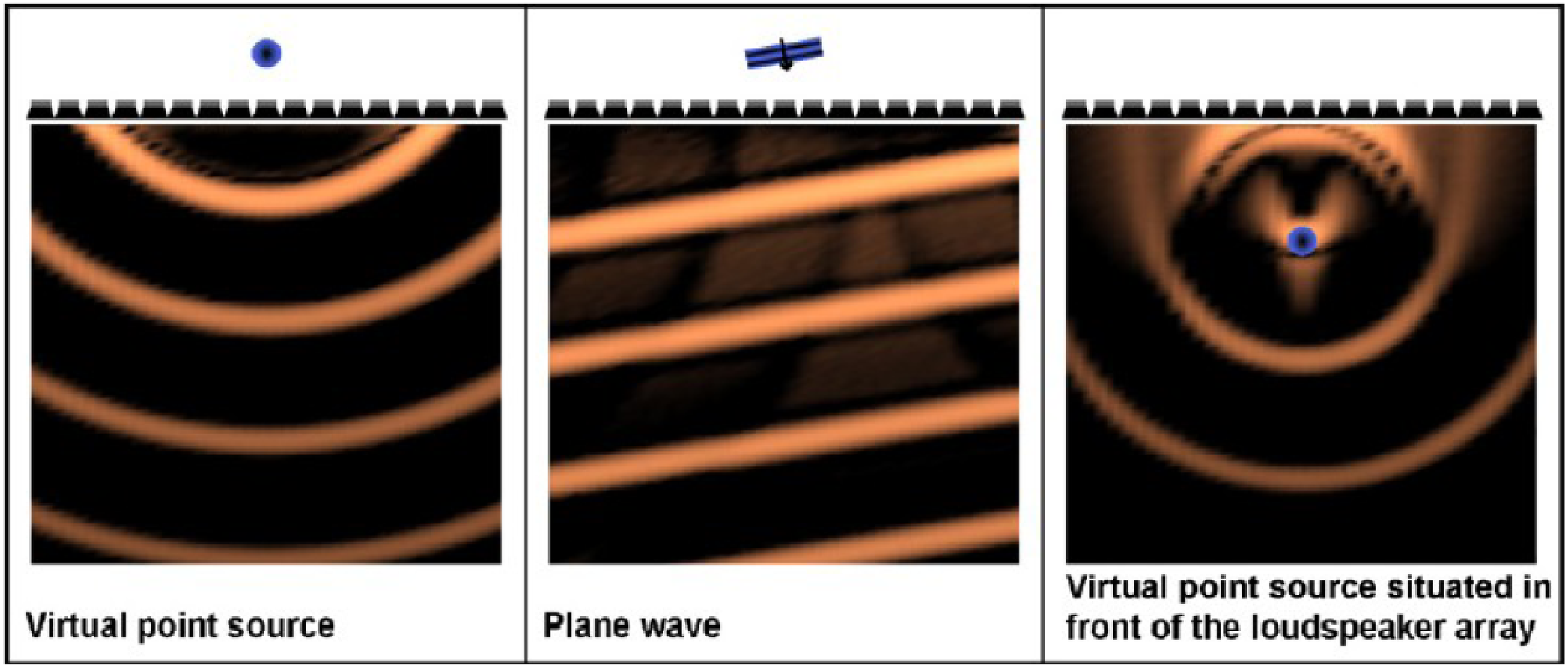
- 176 loudspeakers are incorporated in the perimetral walls, completely surrounding the audience at ear-height

The WFS technology

- Wave Field Synthesis is a playback technique which makes use of linear loudspeaker arrays which are used for creating wavefronts appearing to be radiated by a virtual source
- Concept: spatially sampling a wavefront

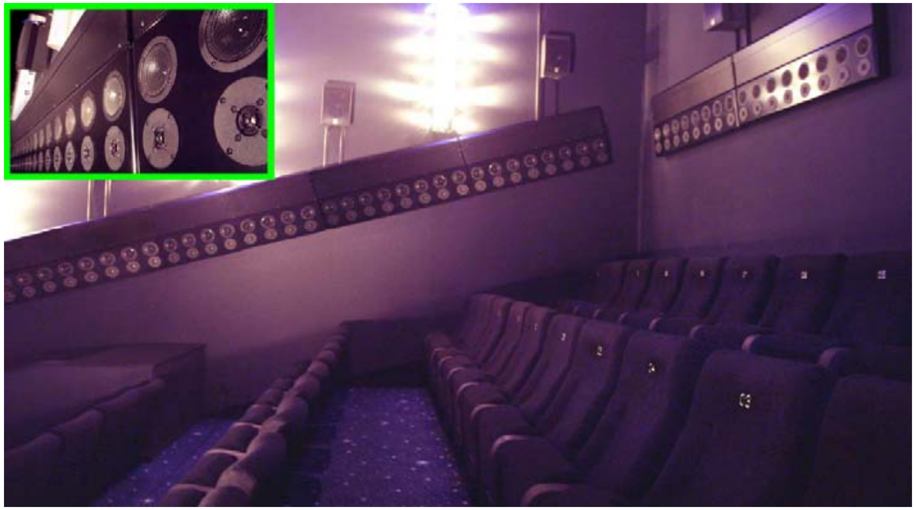


WFS applications

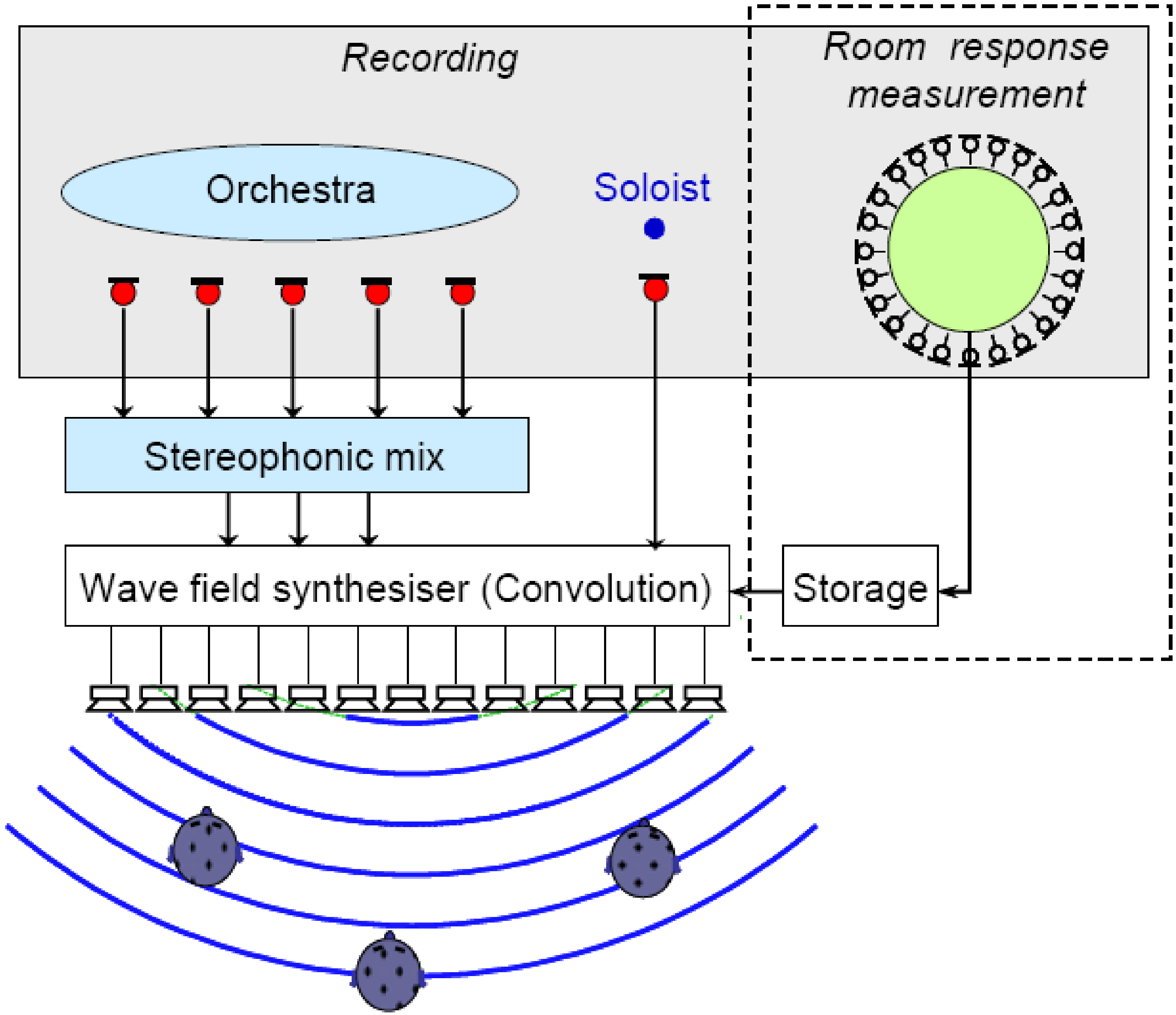


- WFS can generate point sources or planar sources, and even point sources which appear to be inside the room, in the middle of the audience area

Tecnology WFS @ IRCAM, IRT

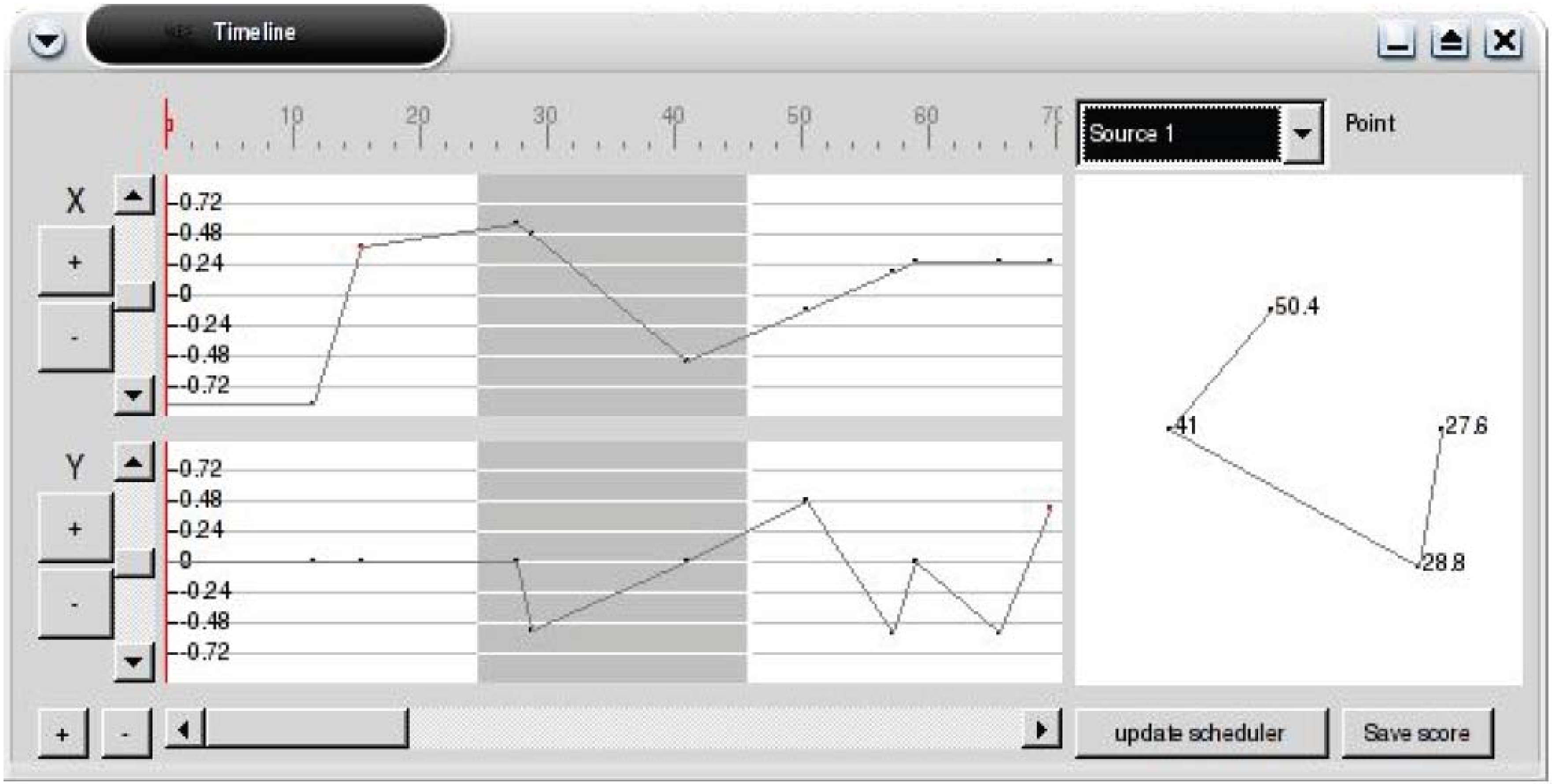


Synthesis of a virtual environment with WFS



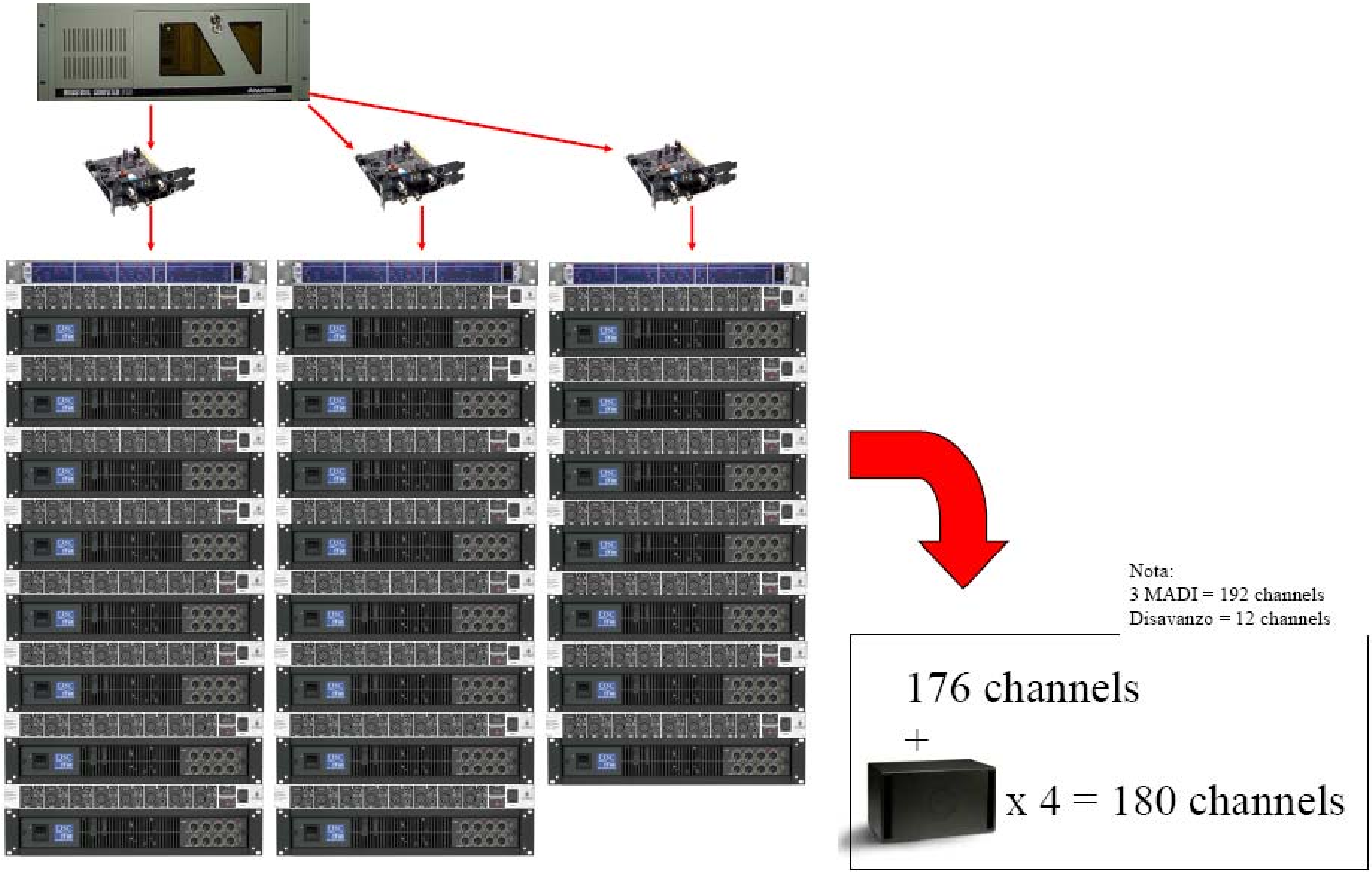
FREE Software for WFS

- The Linux program Wonder makes it possibile to generate WFS signals and to move in realtime the virtual source being synthesized

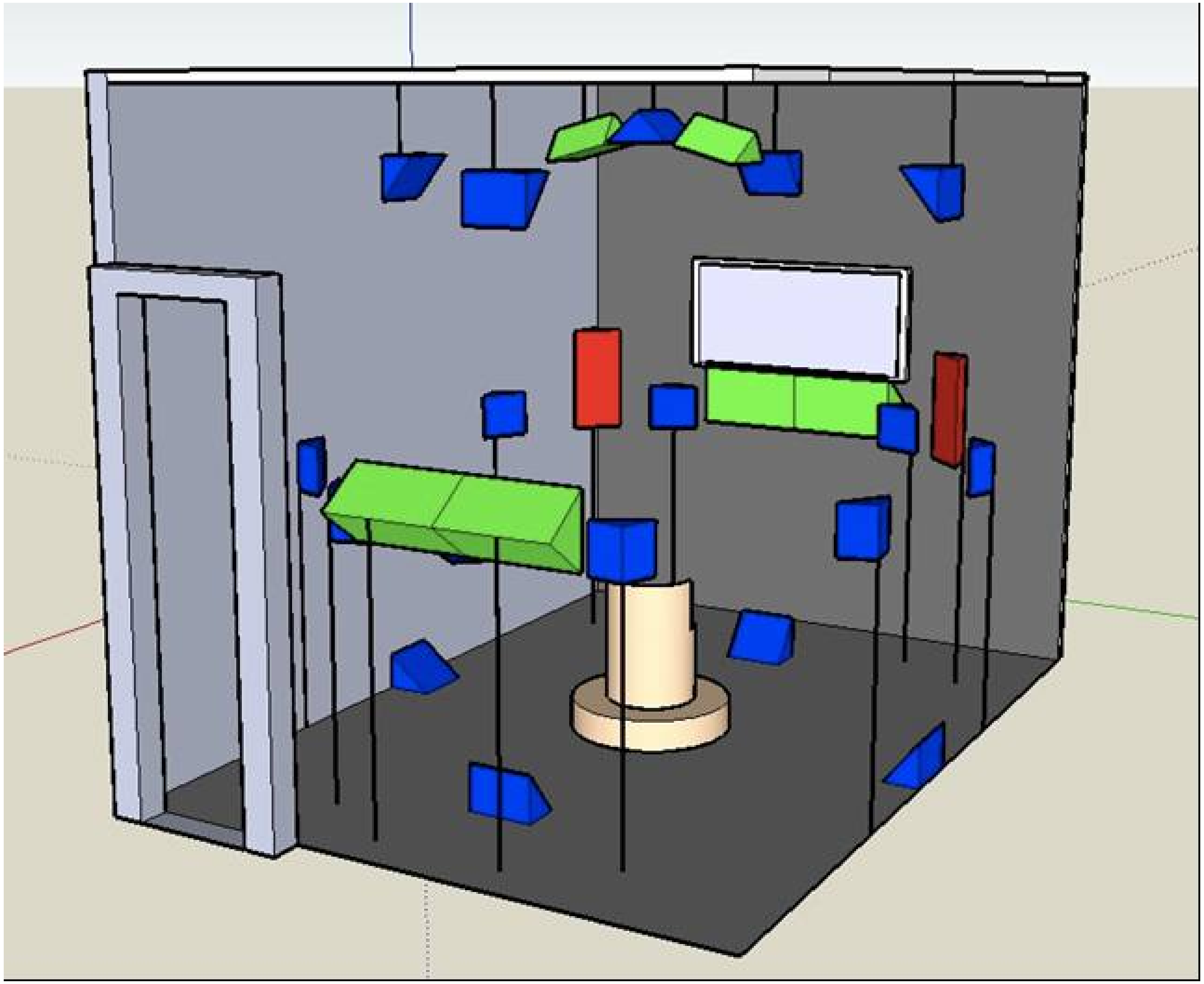


Low-cost hardware for WFS

- The cheaper solution is based on a PC containing three MADI interfaces (64 ch. each), connected with a rack of low-cost converters (Behringer)

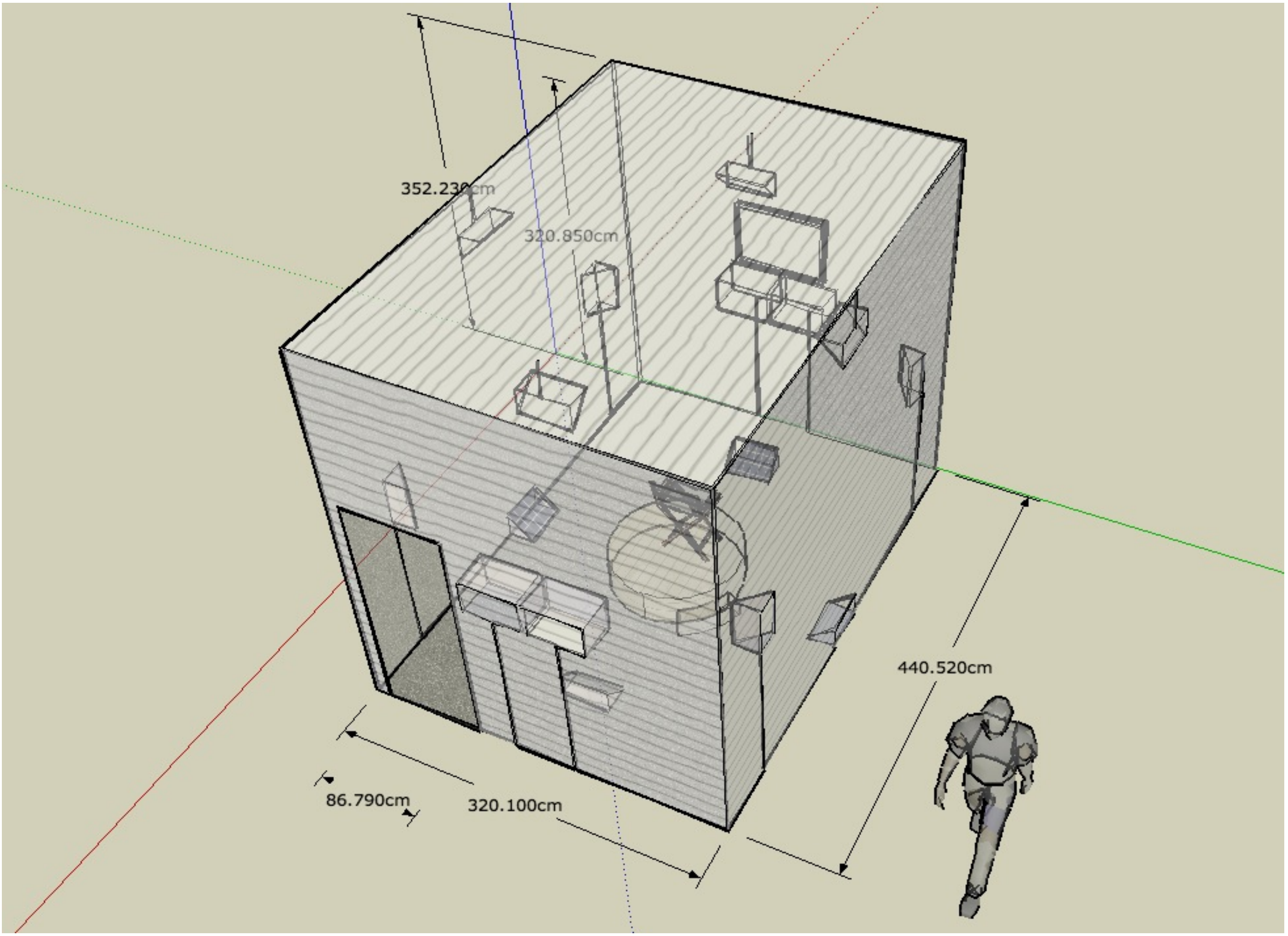


Single-seat room ("sala Nera")



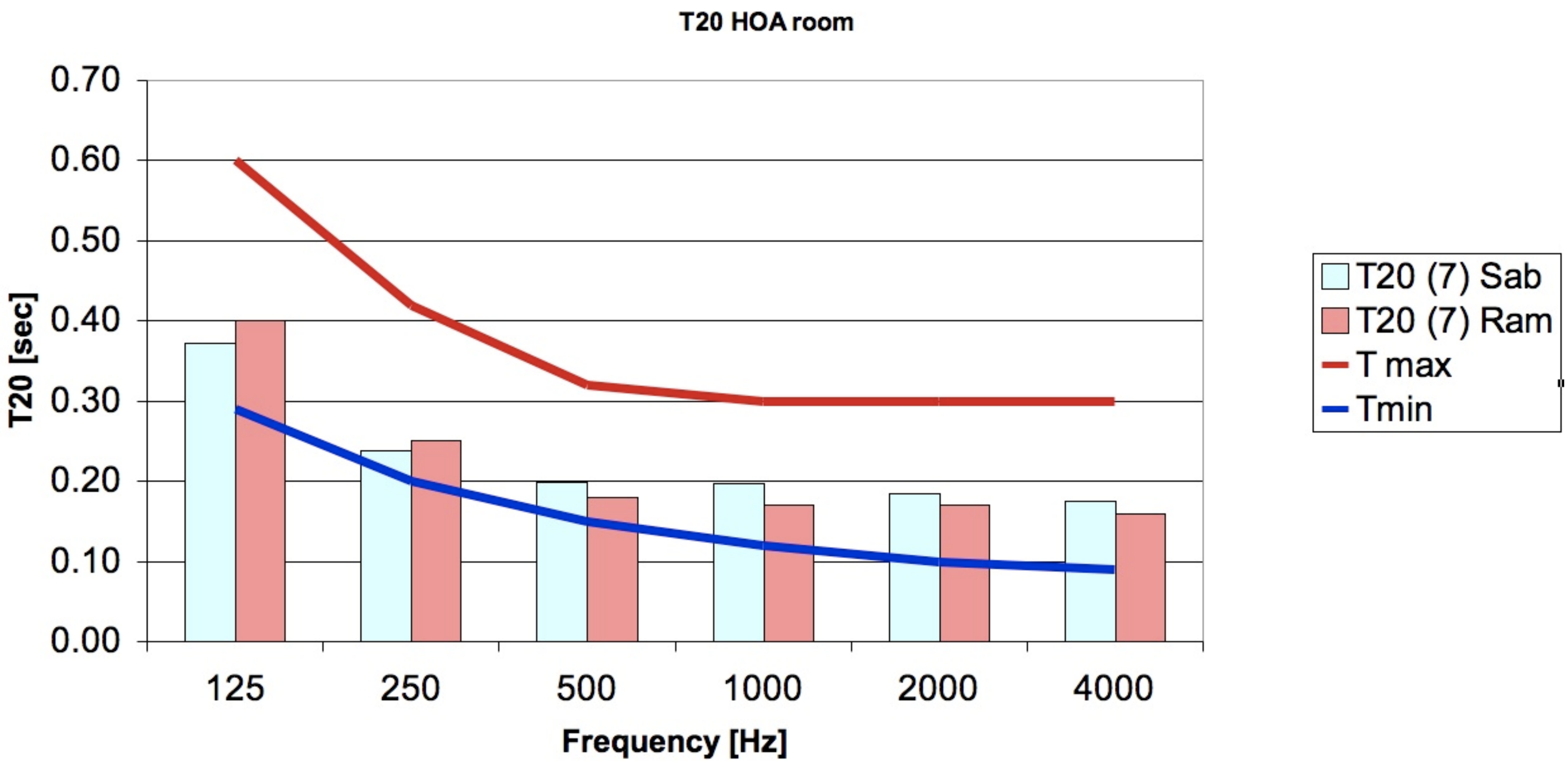
- This room is equipped with 26 loudspeakers

Single-seat room



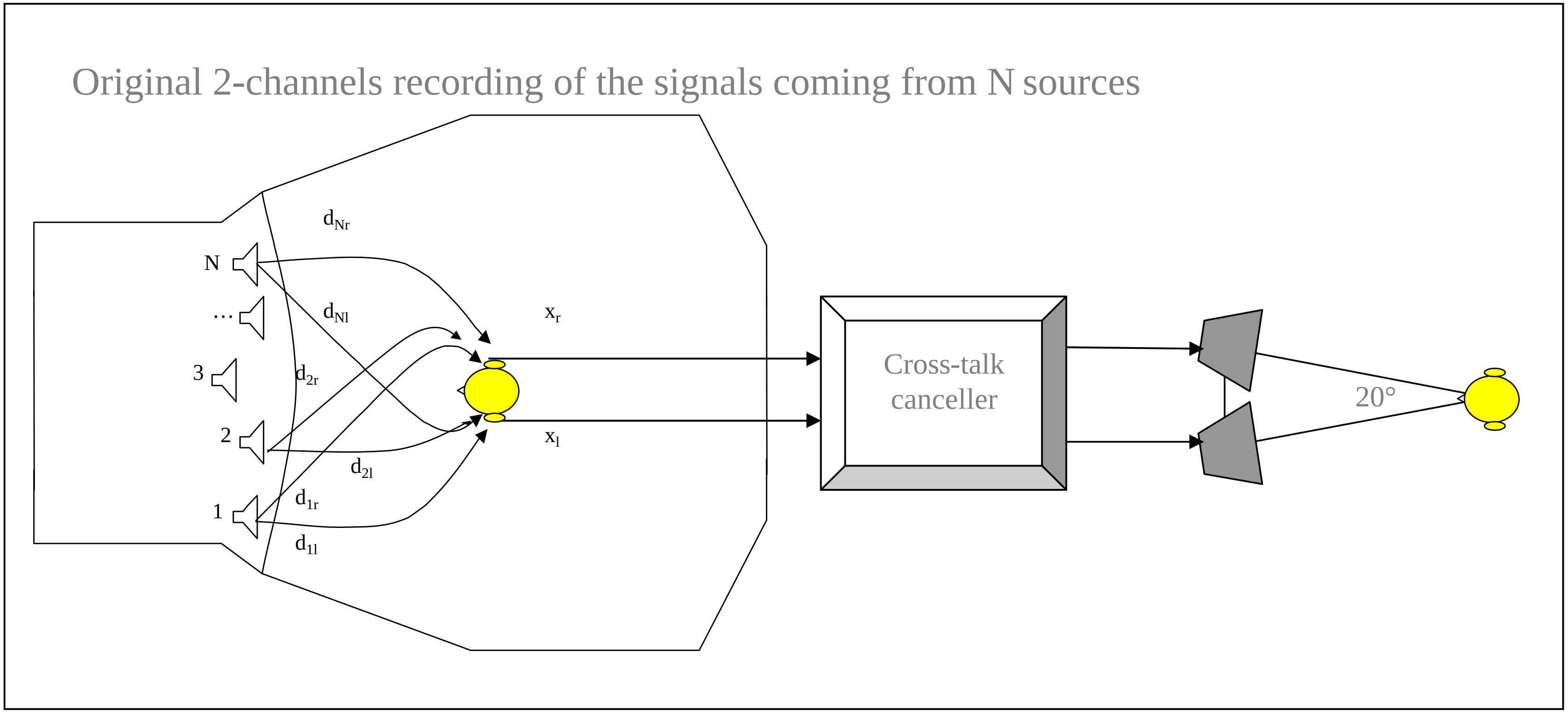
- The walls are made by plywood, gypsum boards and perforated panels with polyesther fiber wool, providing good sound insulation and optimal control of reverberation

Single-seat room



- The sound absorbing treatment, here simulated employing the Ramsete program, provides a value of T20 of 0.40 s at 125 Hz and even lower ar higher frequencies.

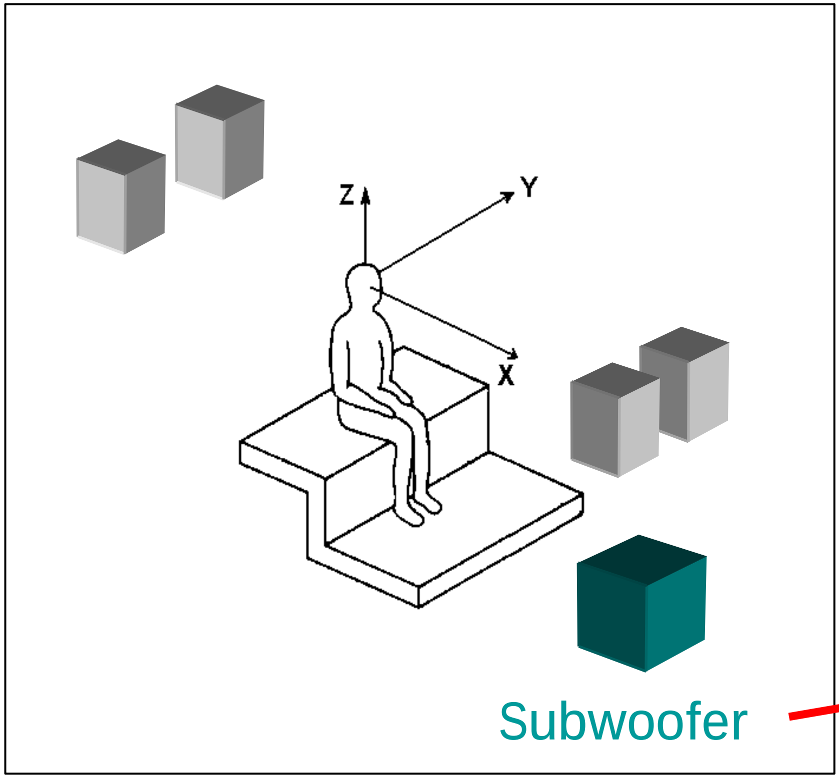
Binaural (Stereo Dipole) method



- Playback is made on 2 loudspeakers located at +/- 10°, being fed through a digital cross-talk cancellation system

Binaural (Dual Stereo Dipole)

Schematics



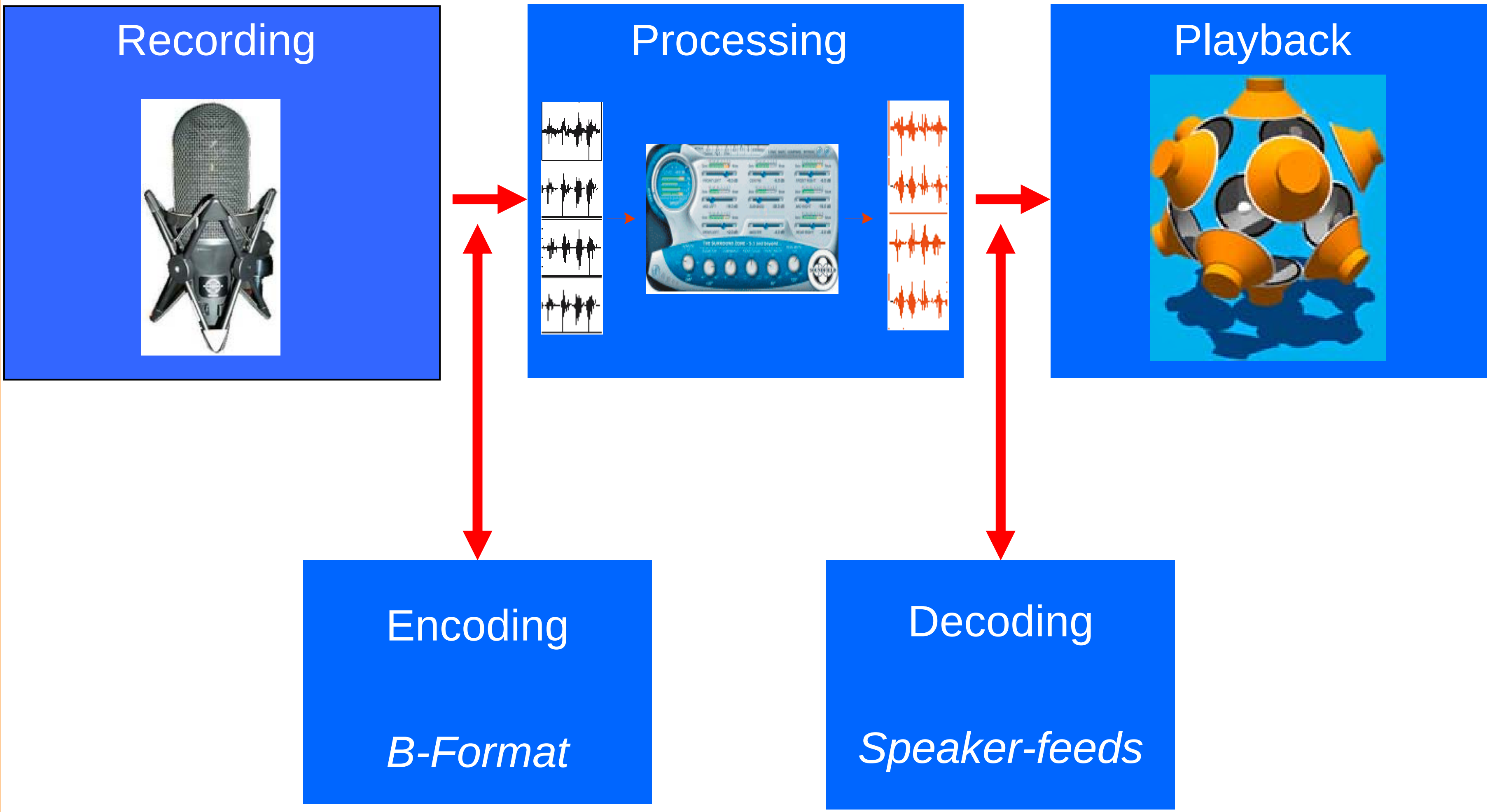
Pro:

- 3D sound reproduction
- Cross-talk cancellation filters also equalize perfectly loudspeaker and microphones

Contro:

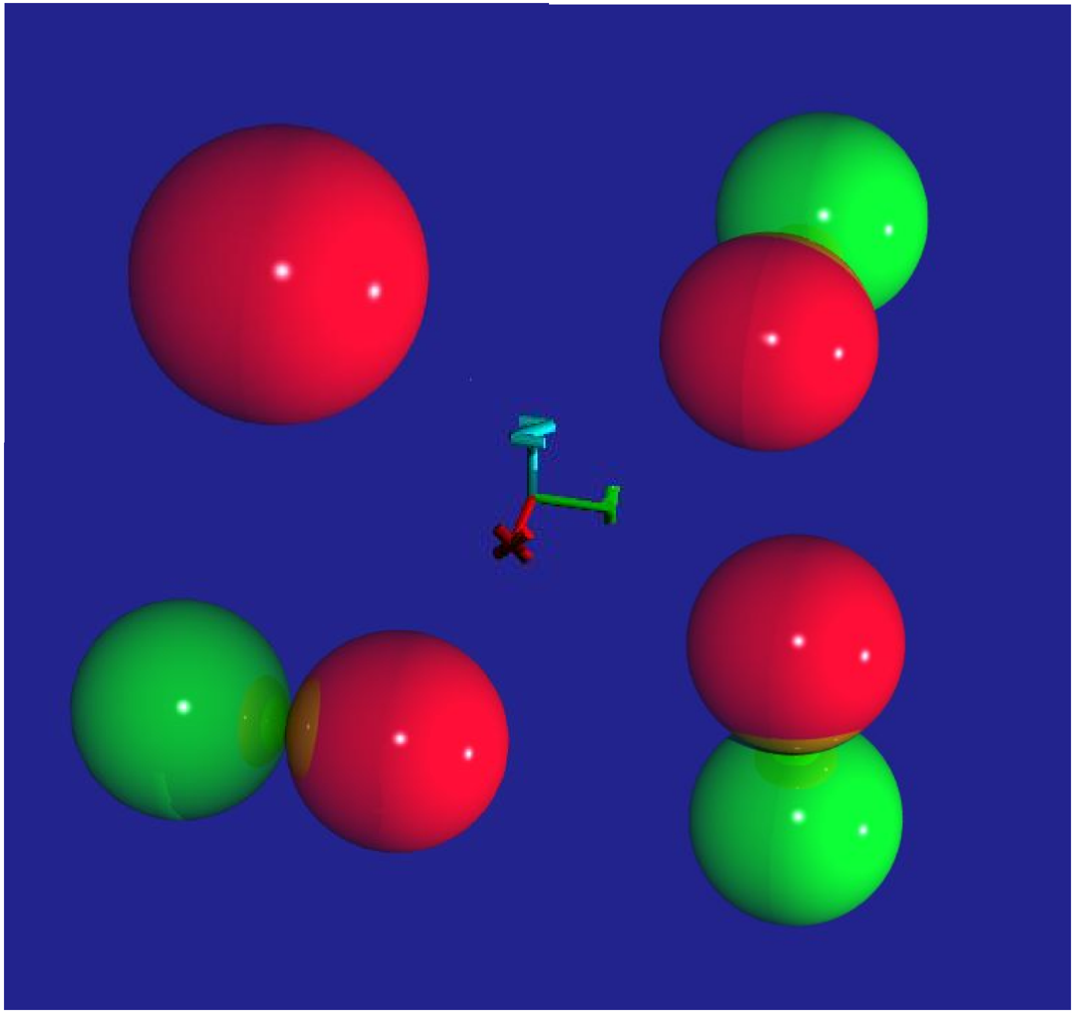
- ~~Poor low frequencies~~
- Colouring outside the “sweet spot”

Ambisonics Method



Recording

- The Soundfield (TM) microphone provides 4 signals:
  1 omnidirectional (pressure, W) and 3 figure-of-8 (velocity, X, Y, Z)



Recording

Soundfield

microphone

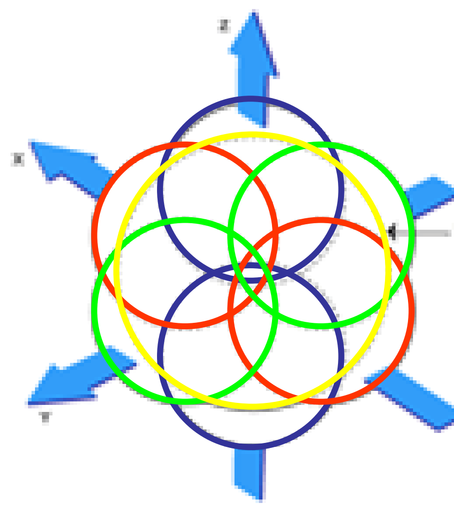
X
Y
Z

Directional components: *velocity*

W

Omnidirectional component : *pressure*

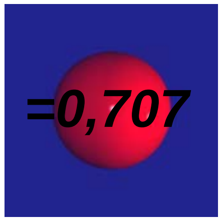
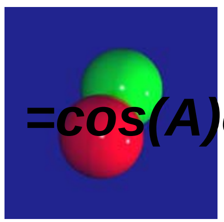
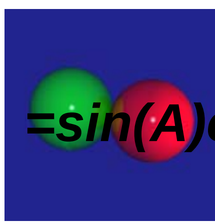
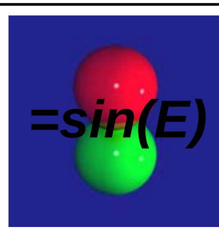
B-FORMAT

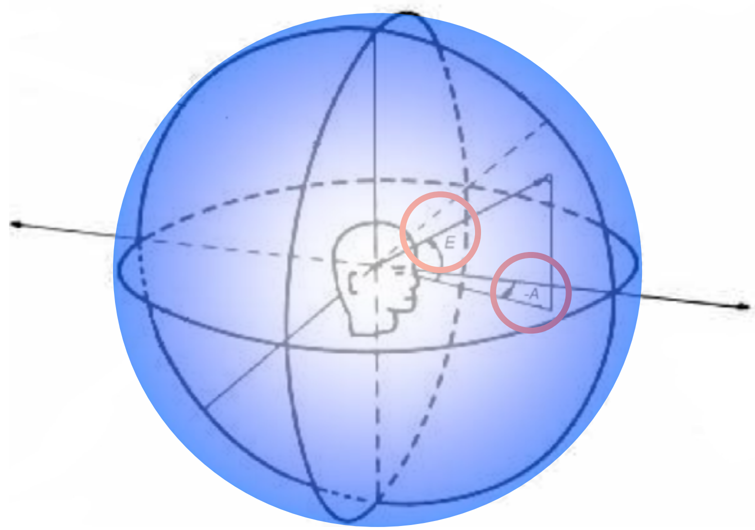


Polar diagrams

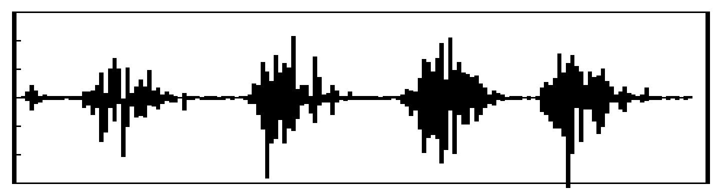
Encoding

Recording | Encoding | Proccessing | Decoding & Playback

0	W		=0,707 *s(t)
1	X		=cos(A)cos(E)*s(t)
	Y		=sin(A)cos(E) *s(t)
	Z		=sin(E) *s(t)

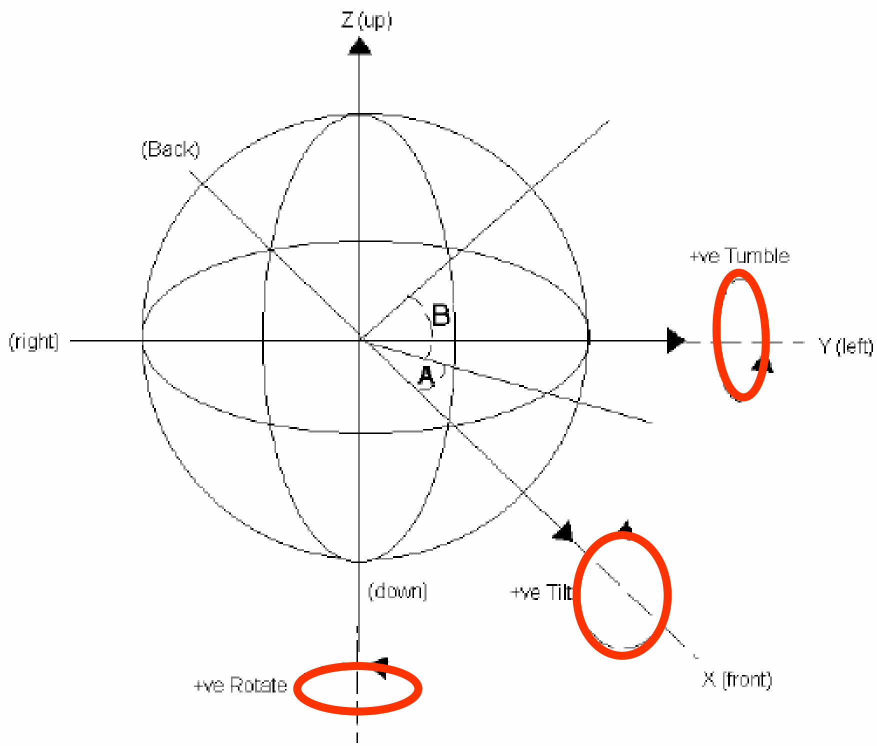


$$\sqrt{X^2 + Y^2 + Z^2} = 1$$

s(t)= 

Processing

Recording | Encoding | **Processing** | Decoding & Playback



$$w' = w$$
$$x' = x \cdot \cos(R) - y \cdot \sin(R)$$
$$y' = x \cdot \sin(R) + y \cdot \cos(R)$$
$$z' = z$$

Rotation

$$w' = w$$
$$x' = x$$
$$y' = y \cdot \cos(T) - z \cdot \sin(T)$$
$$z' = y \cdot \sin(T) + z \cdot \cos(T)$$

Tilt

$$w' = w$$
$$x' = x \cdot \cos(T) - z \cdot \sin(T)$$
$$y' = y$$
$$z' = x \cdot \sin(T) + z \cdot \cos(T)$$

Tumble

Decoding

Recording — Encoding — Processing — **Decoding & Playback**

$$F_i = \frac{1}{2} \cdot [G_1 \cdot W + G_2 \cdot (X \cdot \cos(\alpha) + Y \cdot \cos(\beta) + Z \cdot \cos(\gamma))]$$

ker *i-esim*

Frequenza	G_1	G_2	$\Gamma = \frac{G_2}{G_1}$
>500Hz	$\sqrt{2}$	$\sqrt{2}$	*1*
<500Hz	*1*	$\sqrt{3}$	$\sqrt{3}$

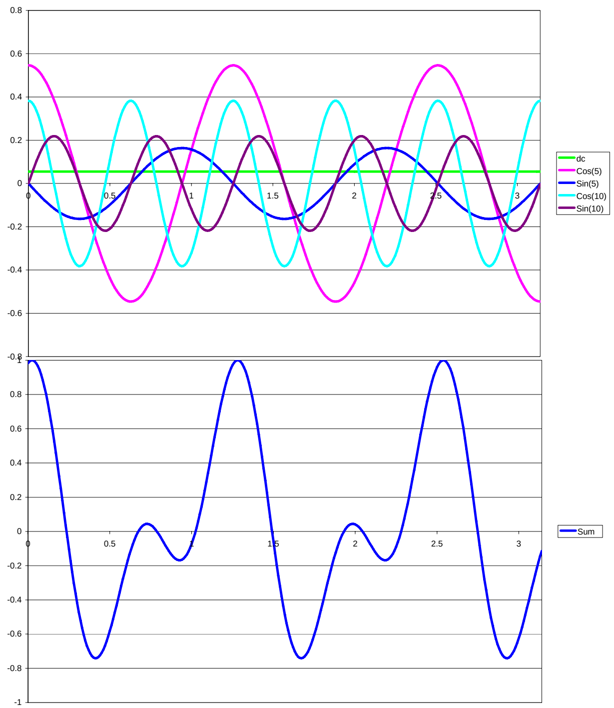
3D decoding

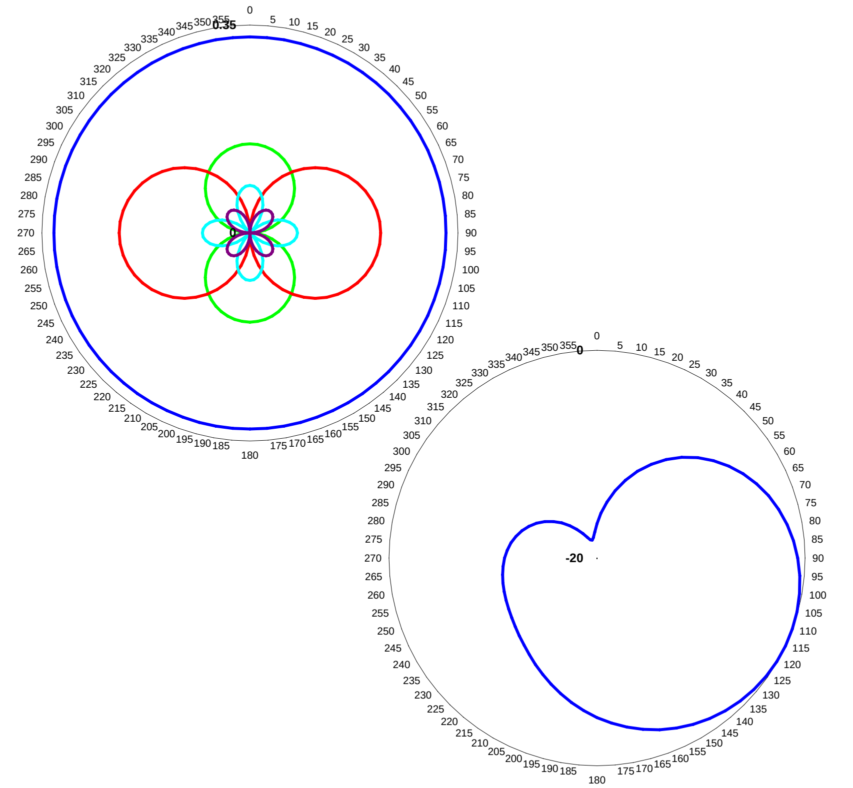
Versione	*Nome*	*Autore*	G_1	G_2	$\Gamma = \frac{G_2}{G_1}$
a)	*Sala da concerto, per tutte le frequenze*	*D.Malham*	$\sqrt{\frac{8}{3N}}$	$\sqrt{\frac{8}{3N}}$	*1*
b)	*Studio, alte frequenze*	*M.Gerzon*	$\sqrt{\frac{8}{4N}}$	$\sqrt{\frac{8}{2N}}$	$\sqrt{2}$
c)	*Studio, basse frequenze*	*M.Gerzon*	$\sqrt{\frac{8}{6N}}$	$\sqrt{\frac{2 \cdot 8}{3N}}$	2
d)	*Studio, frequenze molto basse*	*J.M. Jot*	$\sqrt{\frac{8}{2N^2}}$	$\sqrt{\frac{2 \cdot 8}{N^2}}$	2

2D decoding

High Order Ambisonics (HOA)

- As a complex time-domain waveform can be though as the sum of a number of sinusoidal and cosinusoidal functions, so a complex spatial distribution around a given notional point can be expressed as the sum of a number of spherical harmonic functions
- When the signals corresponding to spherical harmonics up to 3° order are summed with proper gains, one obtains a “virtual microphone” having a directivity pattern which can be very complex and highly directive





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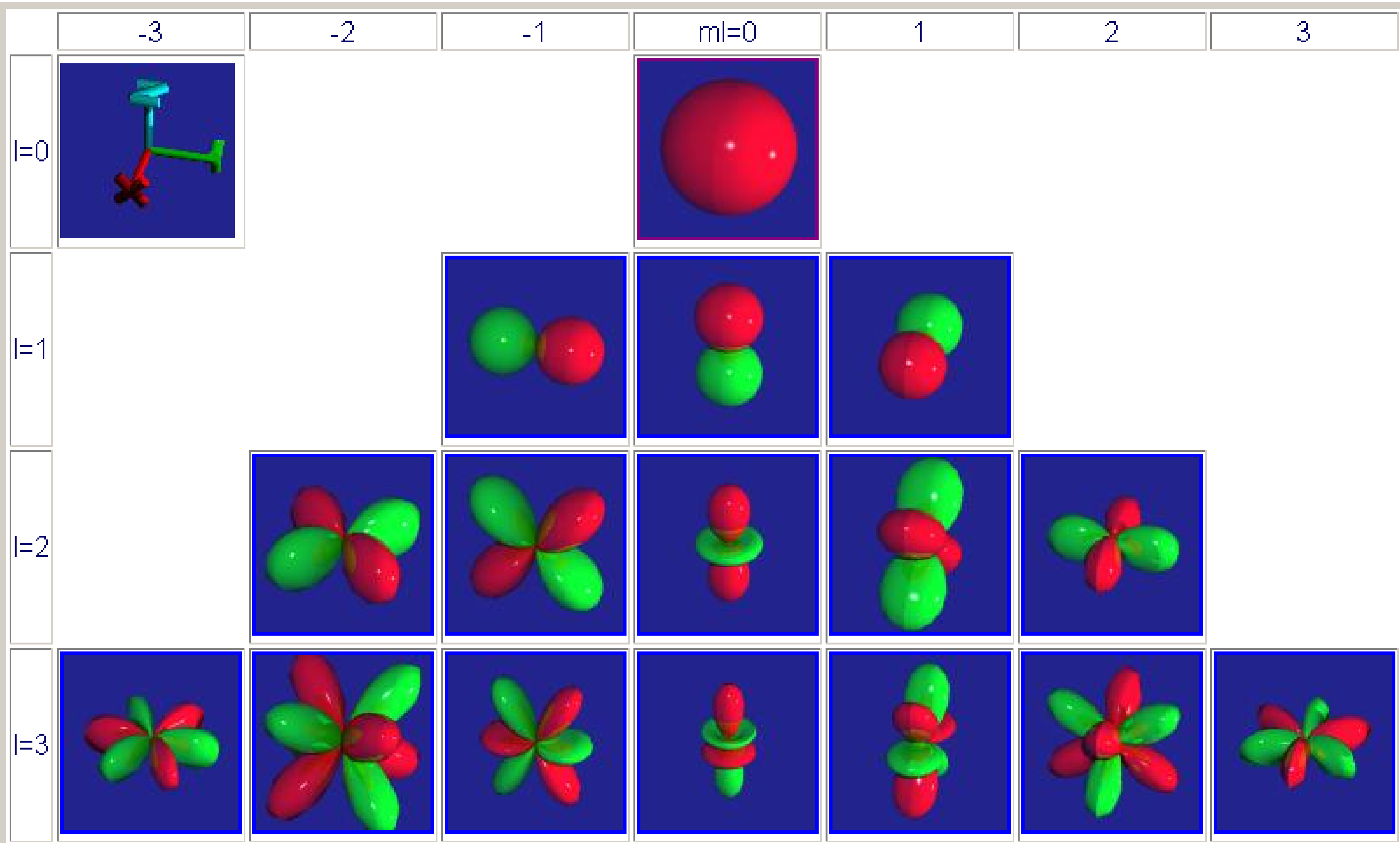
Spherical Harmonics

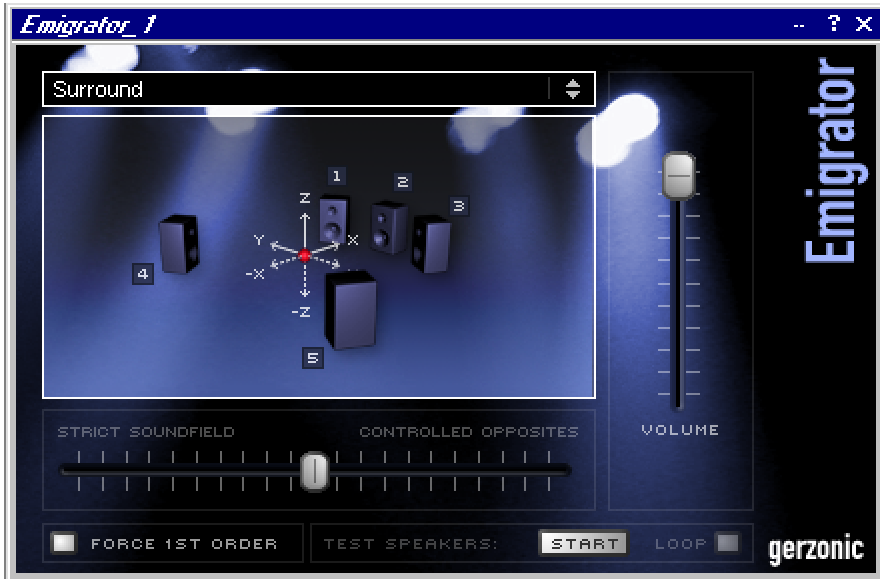


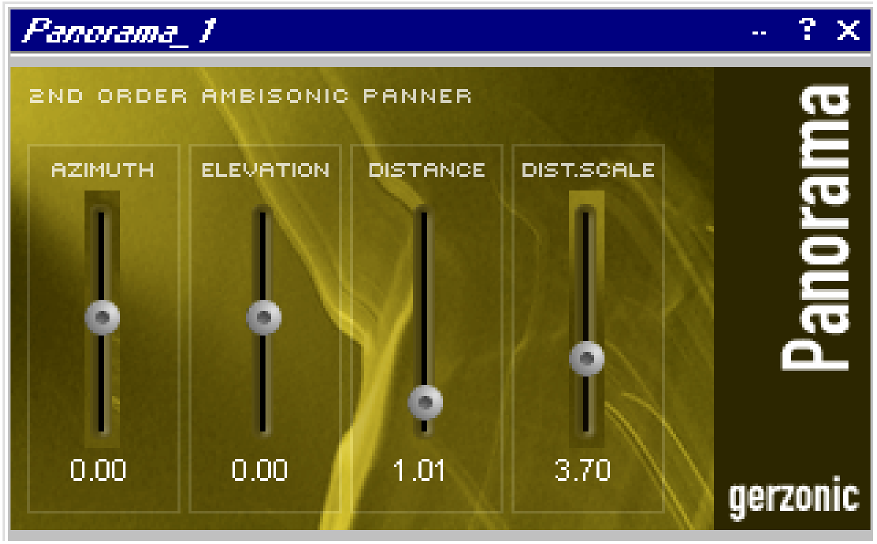
3rd-order spherical microphone

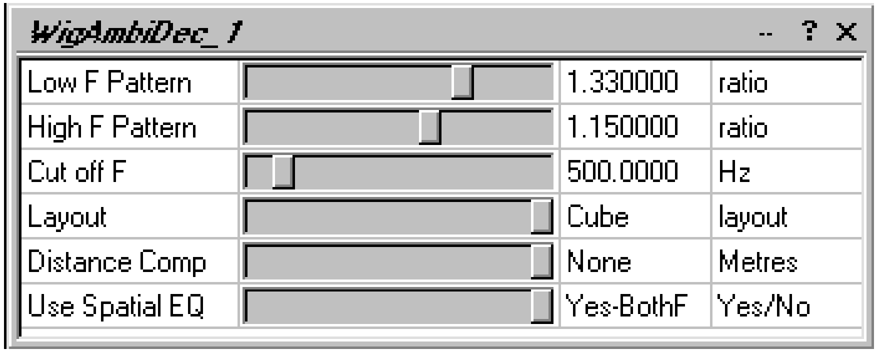
Software for Ambisonics processing

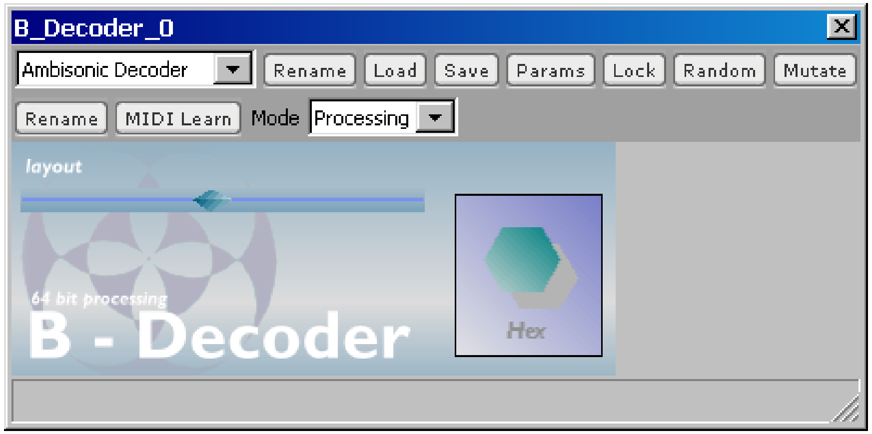
Linux - Jack: AmbiDeco decoder by Fons Adriansen (open source, free)

Software for Ambisonics processing



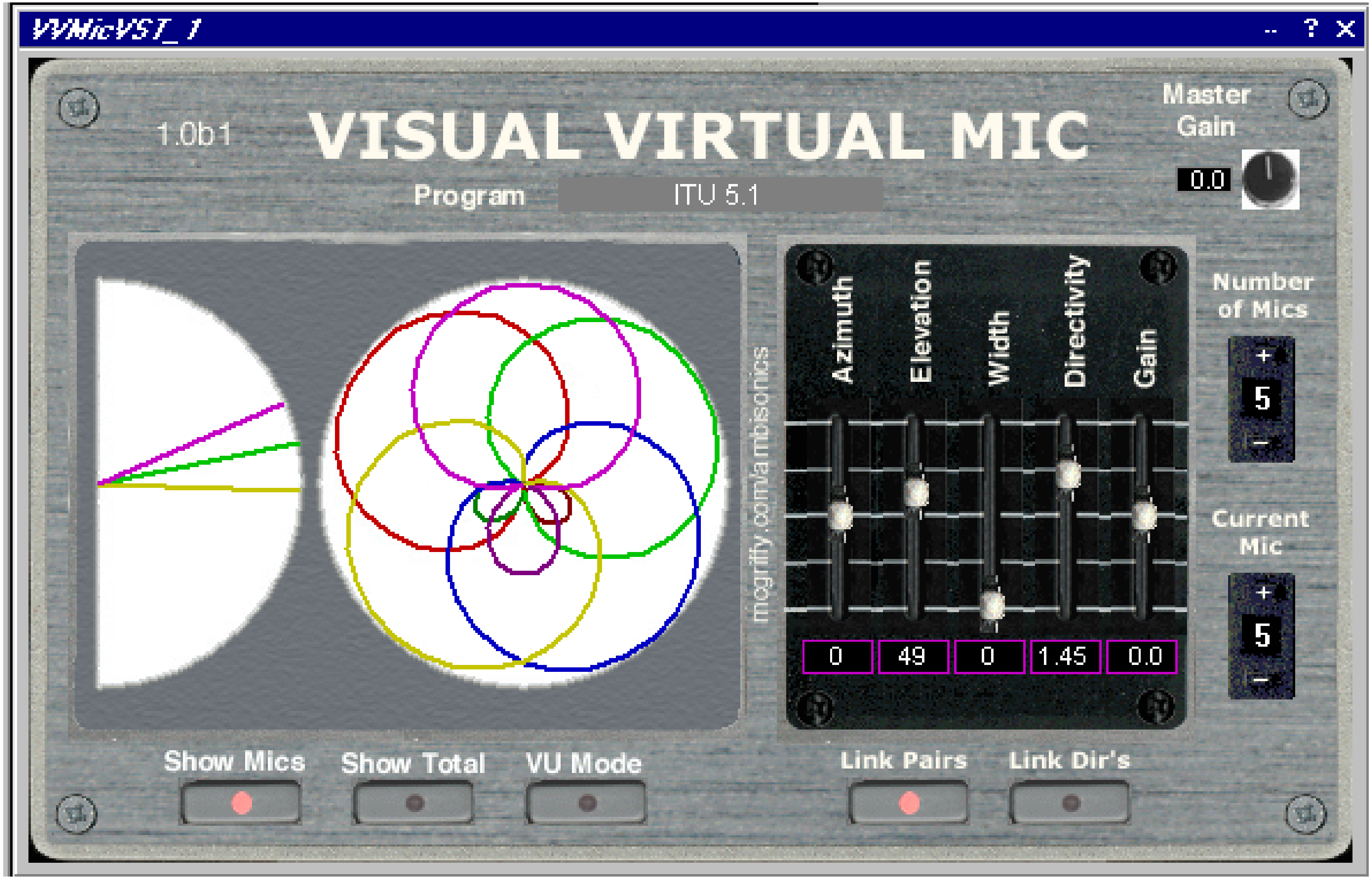






Windows: VST plugins by Gerzonic, Dave Malham, Bruce Wiggins (freeware)

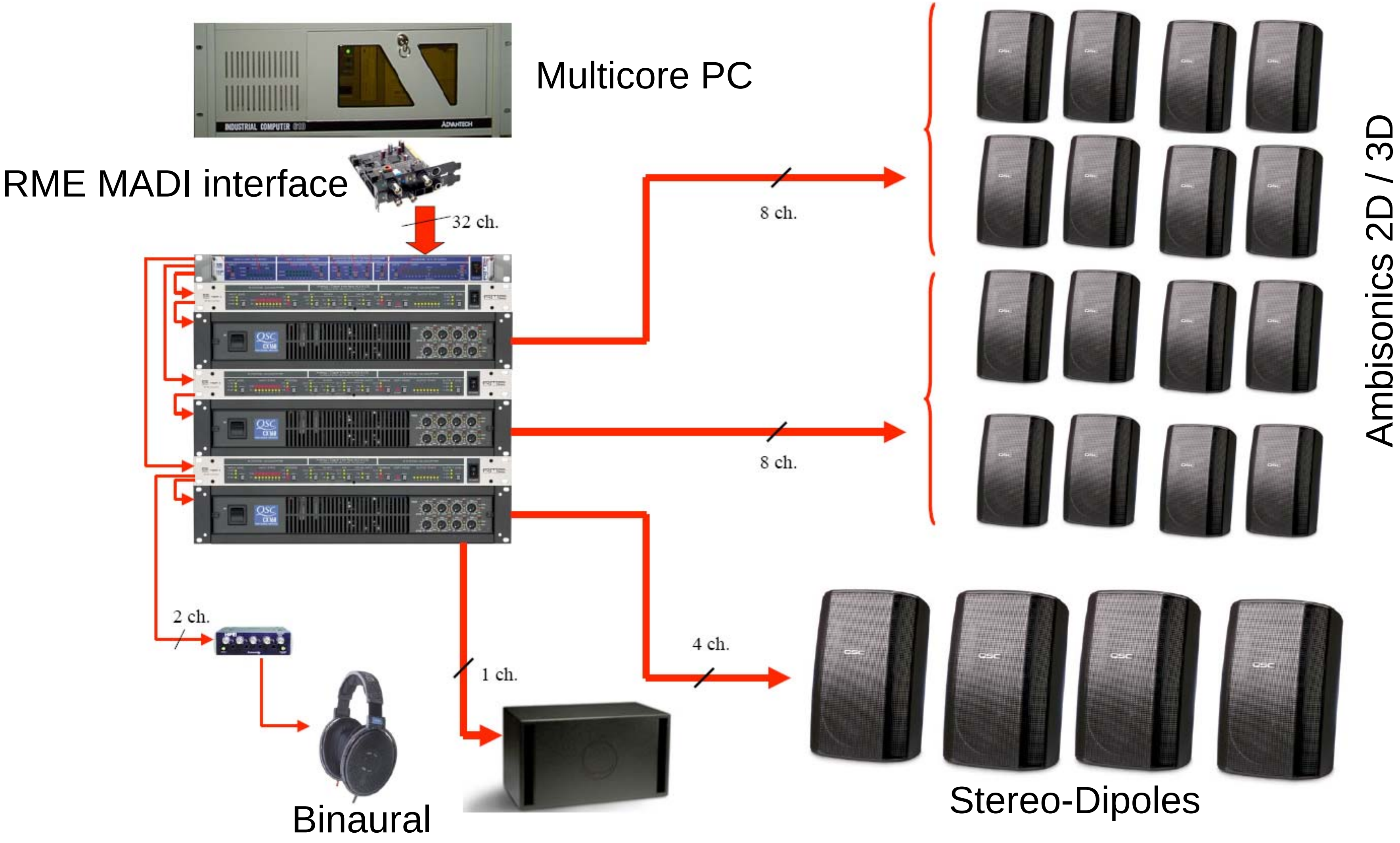
Software for Ambisonics processing



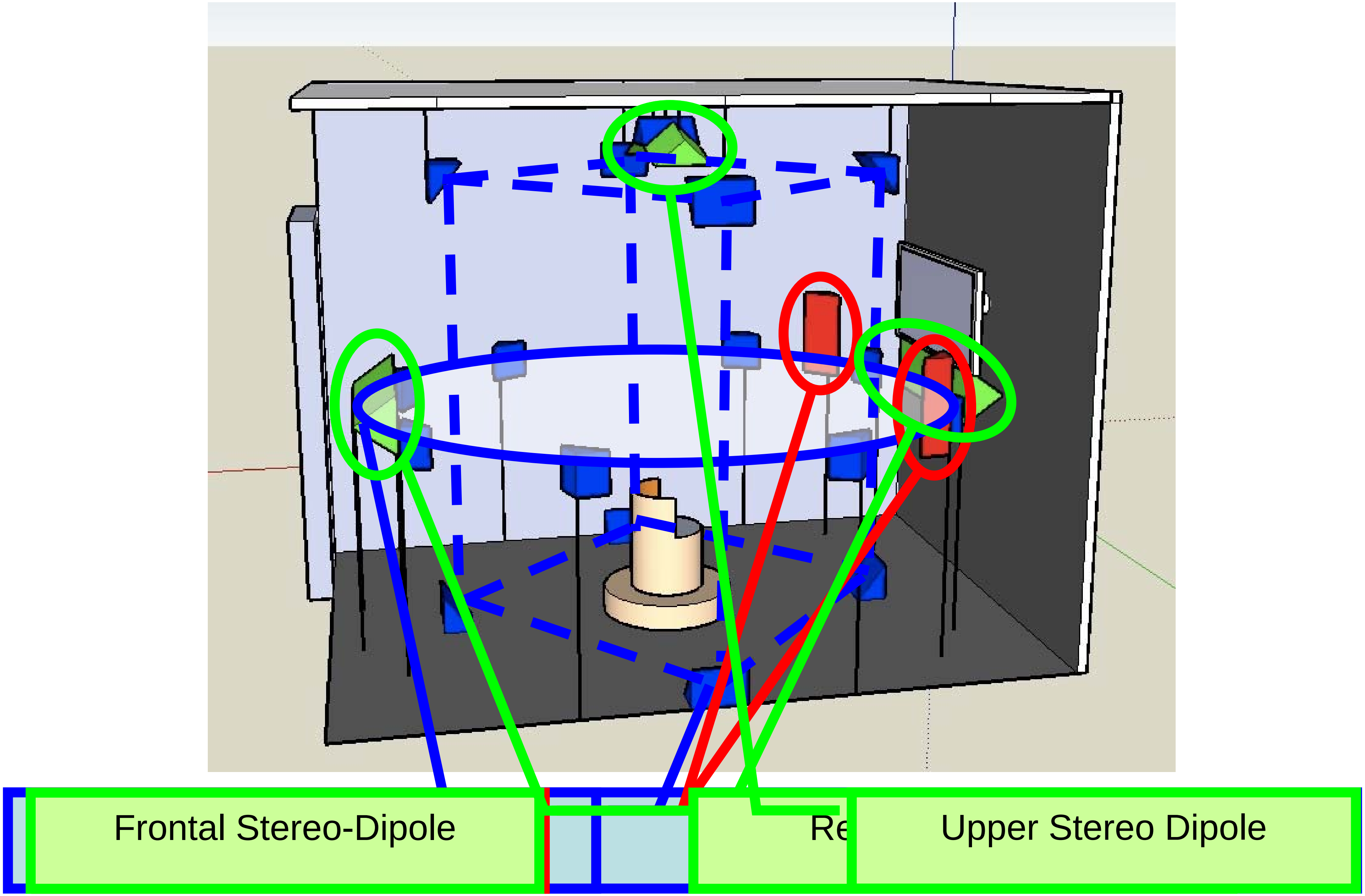
Windows: Visual Virtual Microphone by David McGriffy (freeware)

Low-cost hardware for HOA

- Again, a PC with MADI interface is employed



Locations of loudspeakers



Psychoacoustics research

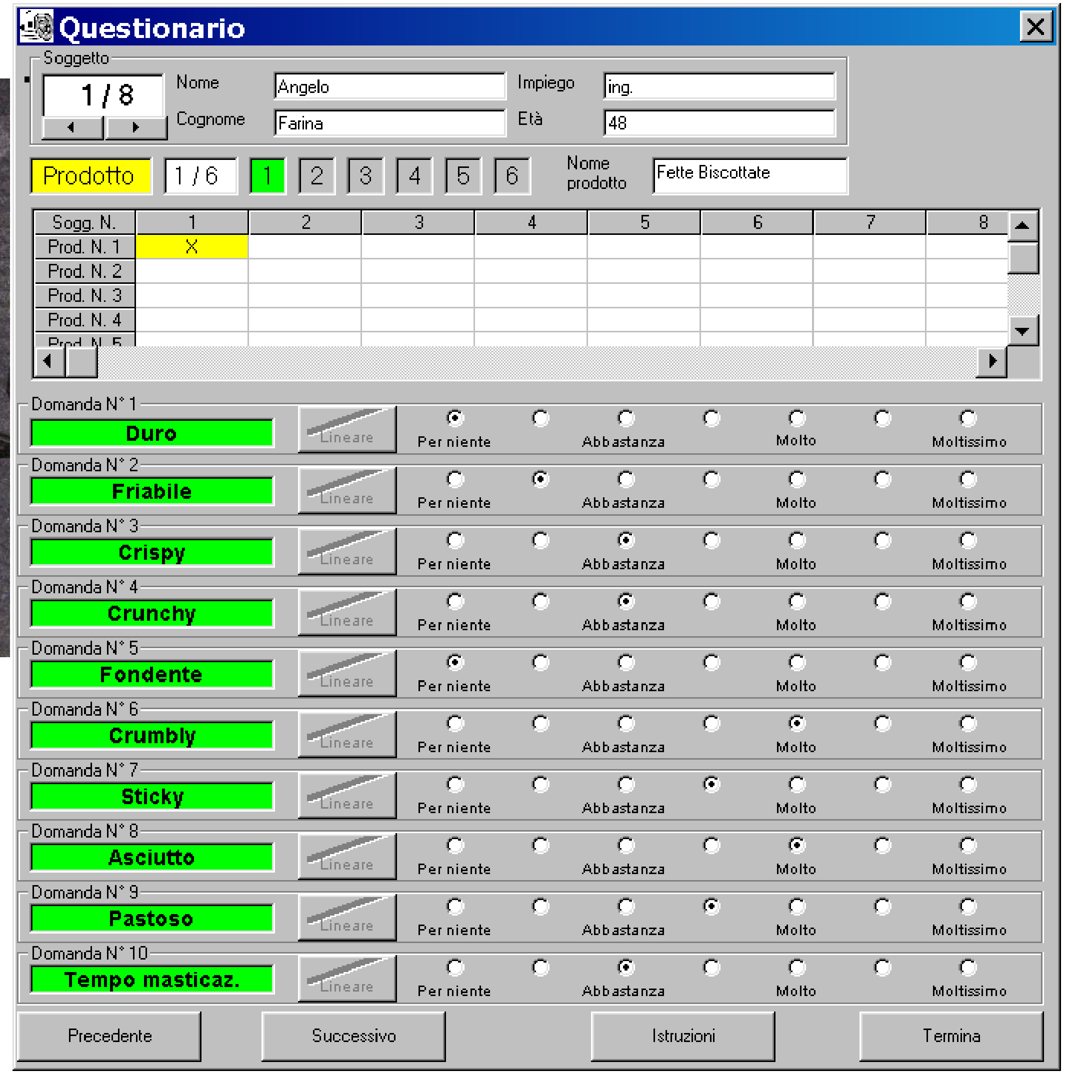
- Musical Food: sound quality analysis of Barilla - Mulino Bianco crackers and bread substitutes

Fette Biscottate Classiche

Spianelle

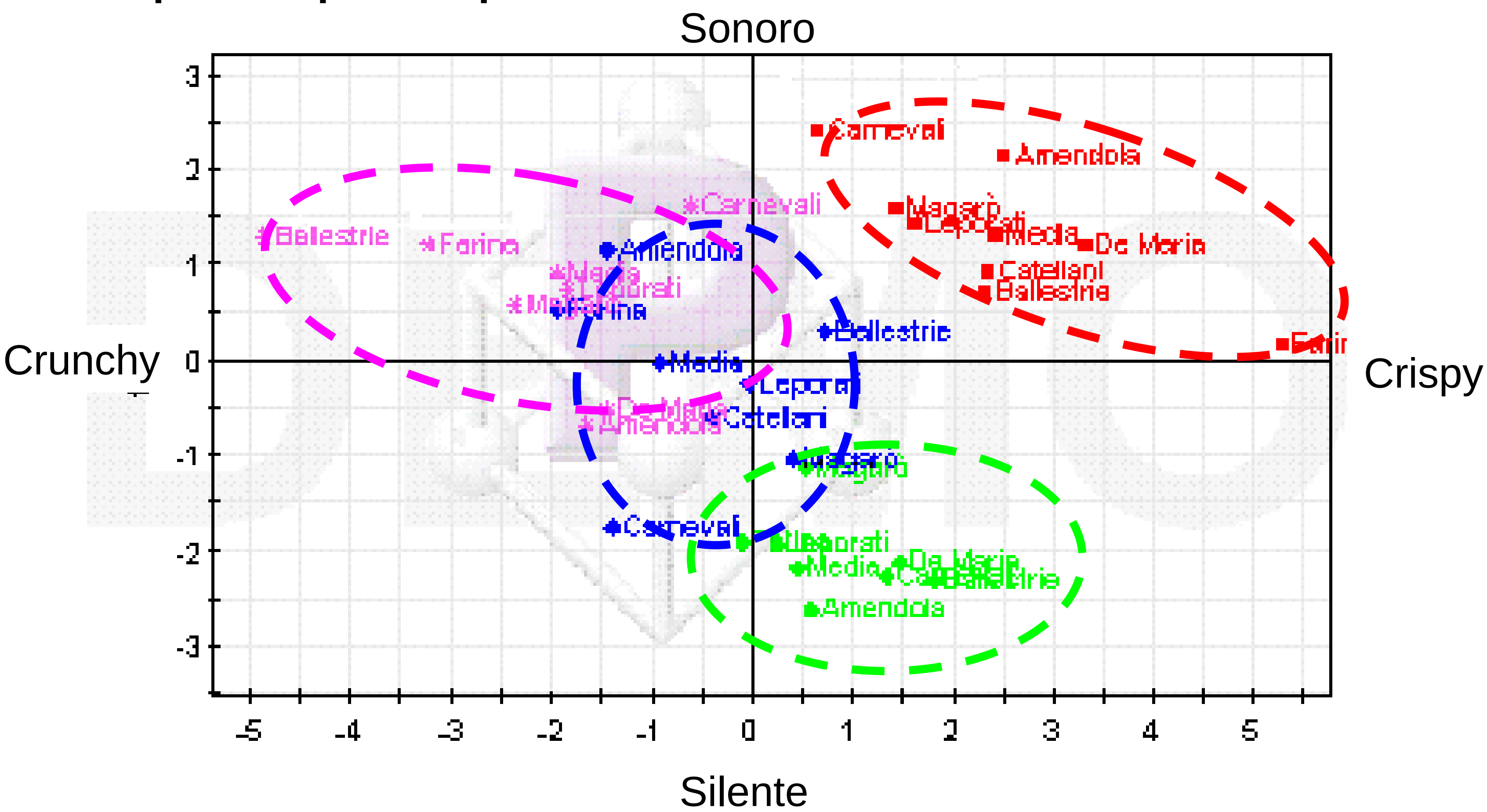
Psychoacoustics research

- Listening tests with compilation of sound quality questionnaires



Psychoacoustics research

- Principal Component Analysis and correlation among physical and perceptual paramaters



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  - Audiolink via Monte Prinzera, 17 Parma
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Laboratory of Acoustics and Elettroacoustics (LAE)

www.laegroup.org

Parma