

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

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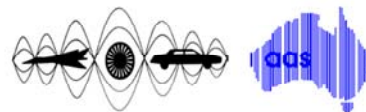
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ICSV14

Cairns • Australia
9-12 July, 2007



The “Casa del Suono”



COMUNE DI PARMA

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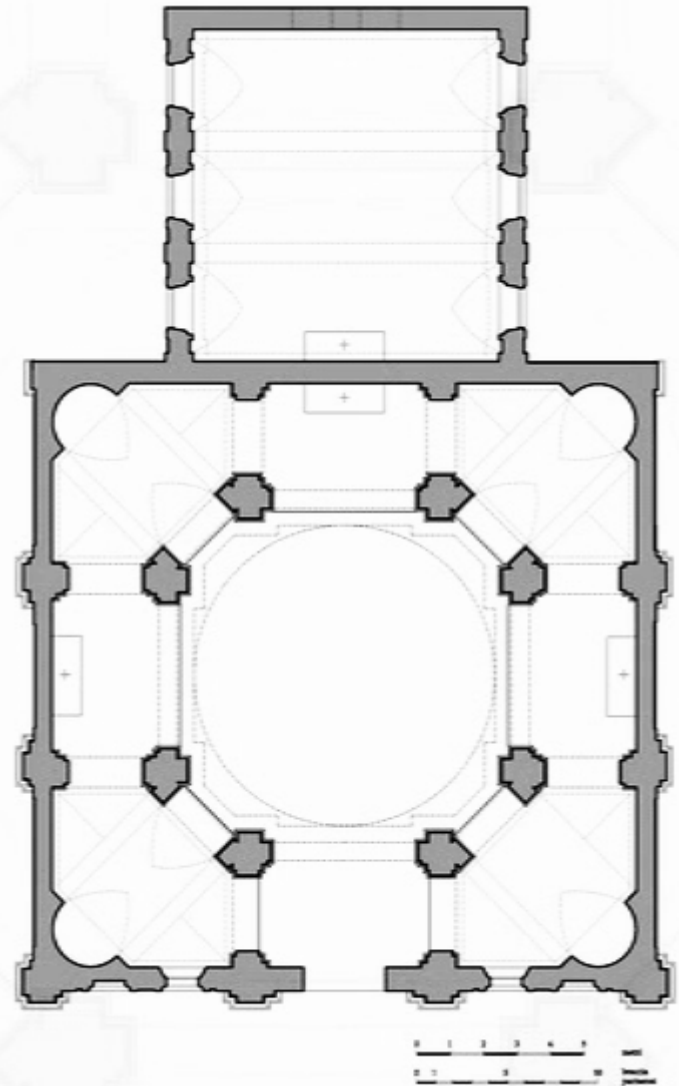
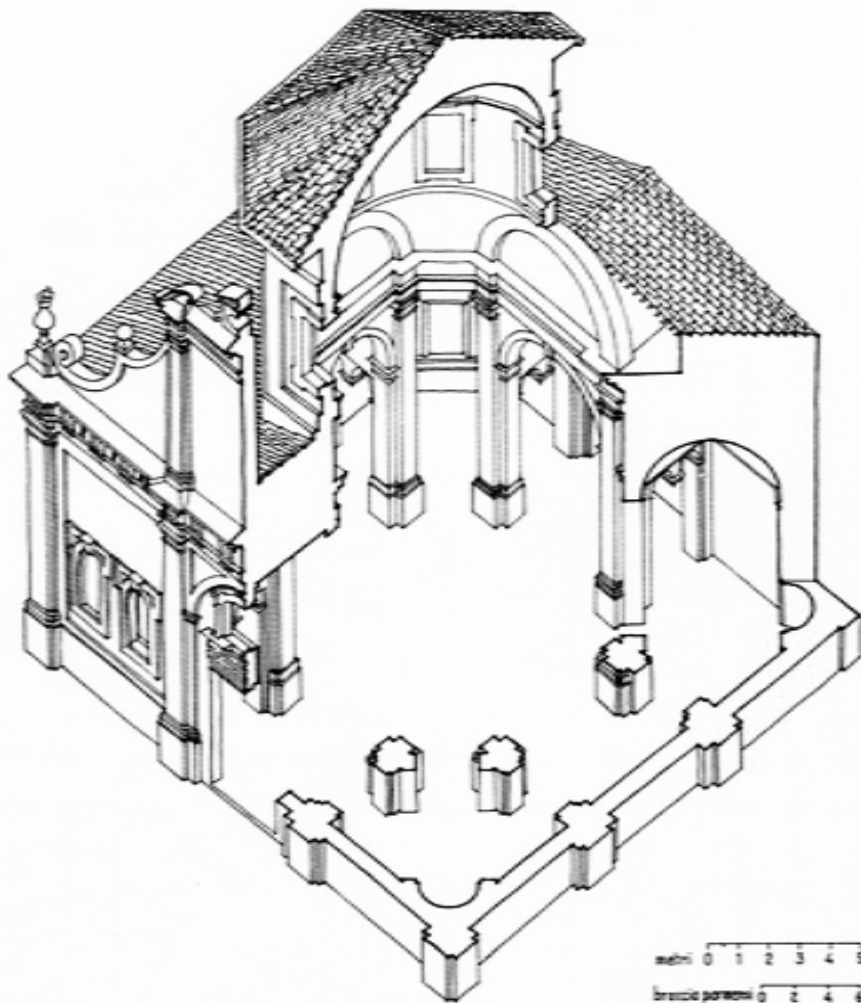


- It was born thanks to the cooperation of University of Parma, Comune of Parma, and with funds (approximately 2 million Euros) provided by Casa della Musica, Italian Government and Cariparma Foundation
- The institutional goal is to display the famous Patanè's Collection of vintage grammophones and 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)

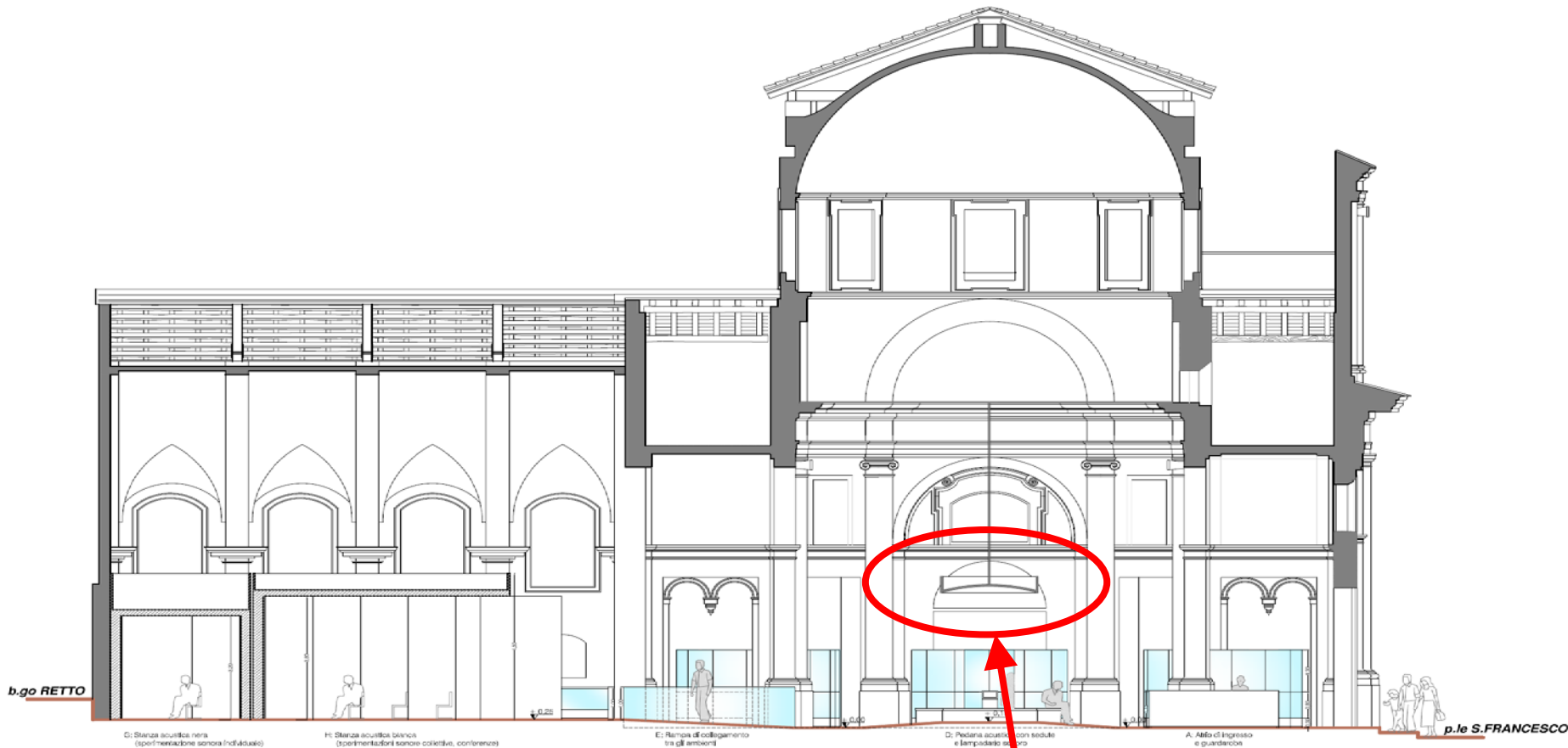
The S. Elisabetta Church



A Baroque square church, with annexed rectangular chapel

The S. Elisabetta Church

Scala 1:100



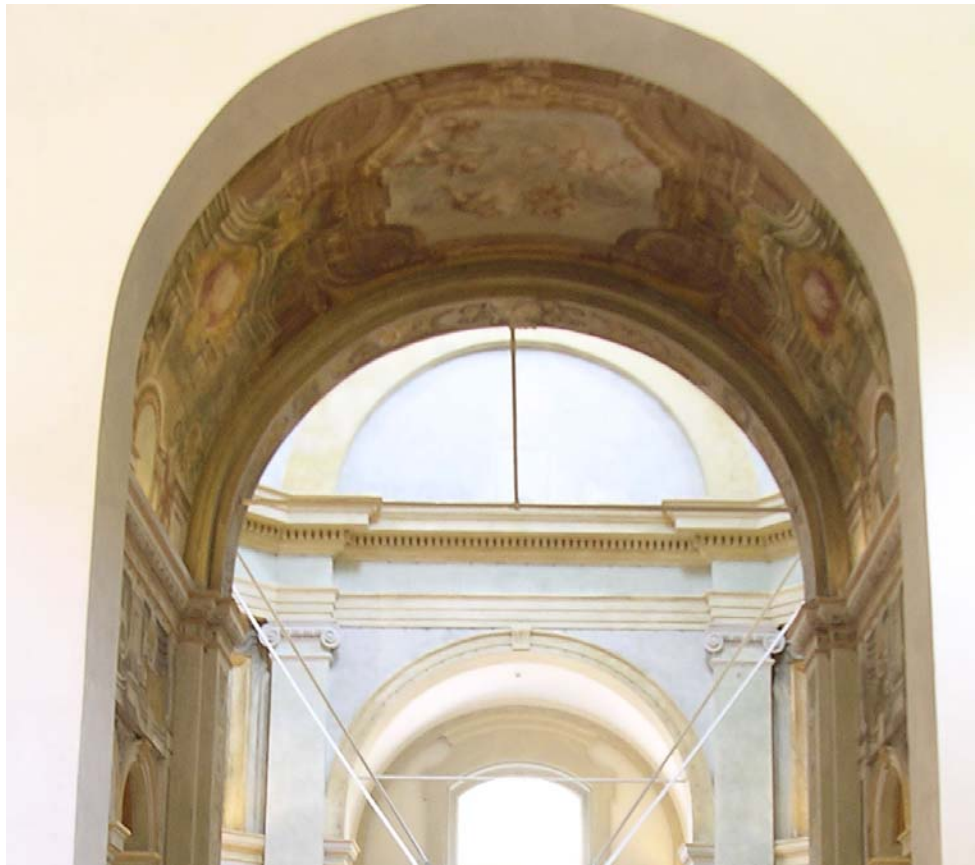
The main room is characterized by a very tall dome, with a lot of light thanks to many windows; in the center of the dome the SONIC CHANDELLIER was installed

The S. Elisabetta church



Before the restoration the building was in miserable conditions

The S. Elisabetta church



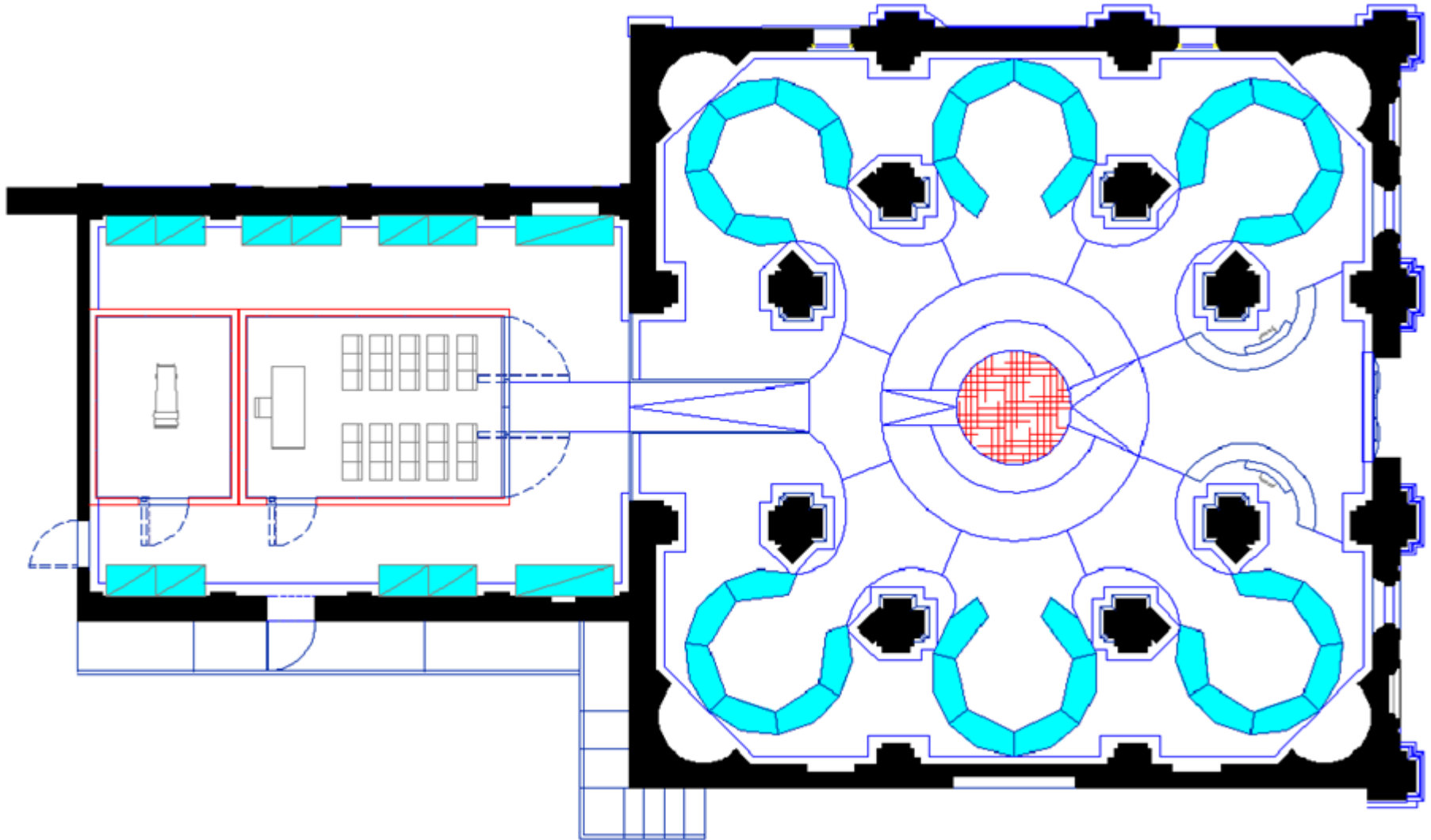
Advanced restoration techniques revamped the original beauty

The S. Elisabetta church



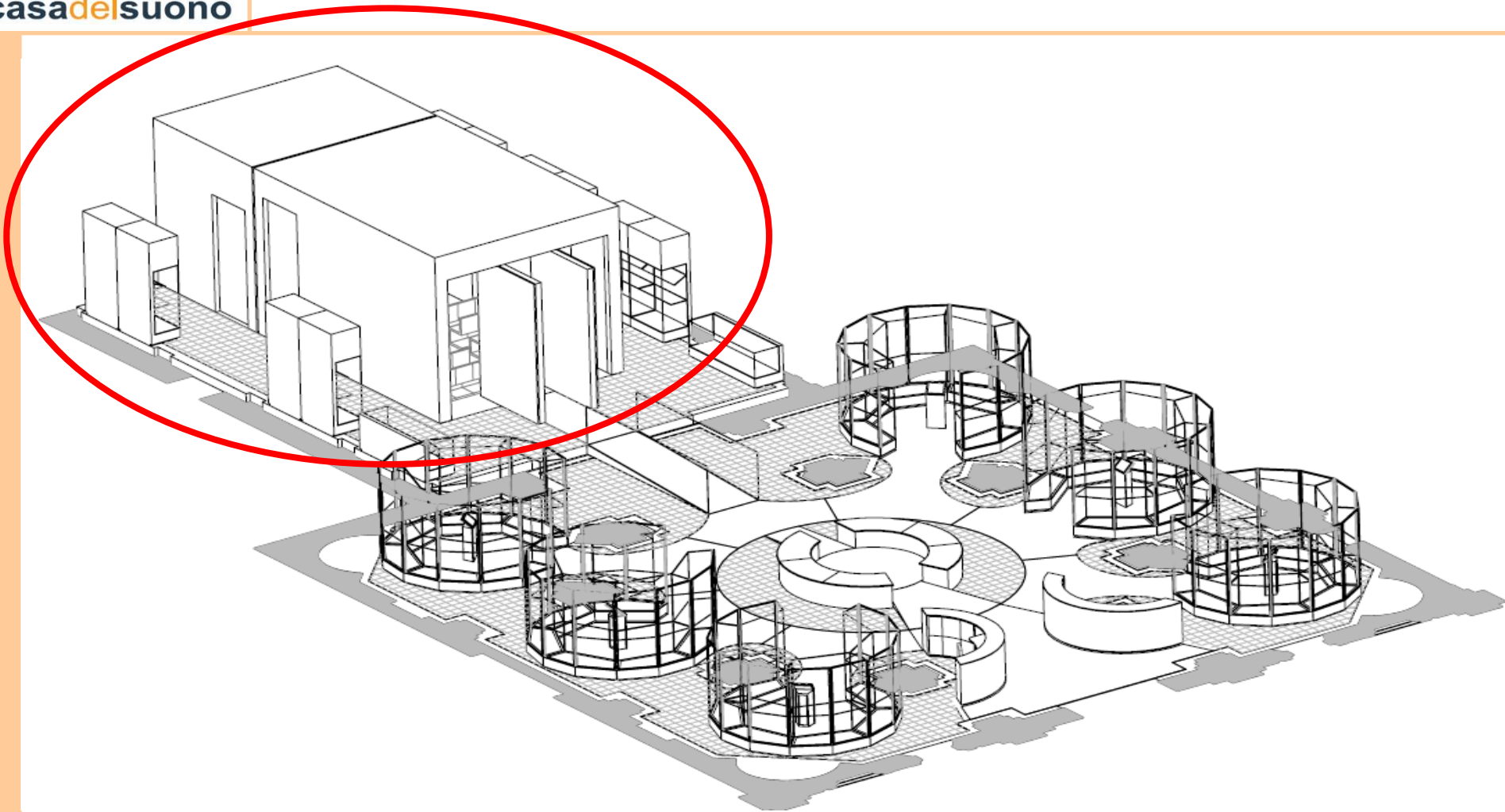
However, these restoration and consolidation techniques caused the acoustical behaviour of the church to worsen significantly, raising the reverberation time of the empty room from 2.3 s to more than 4.0 s

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



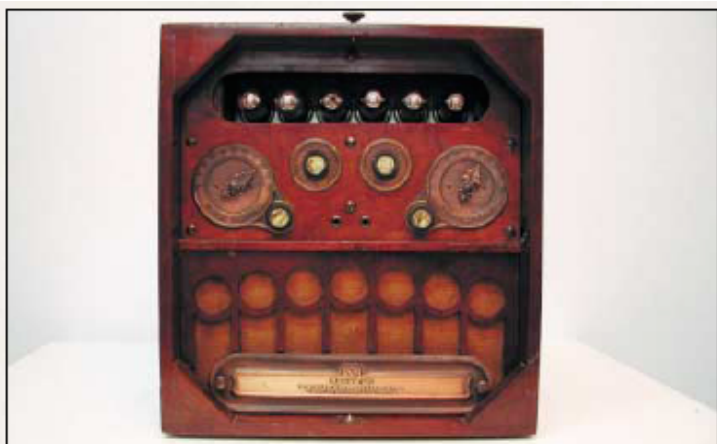
RADIO FRANCESE
4 valvole esterne



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



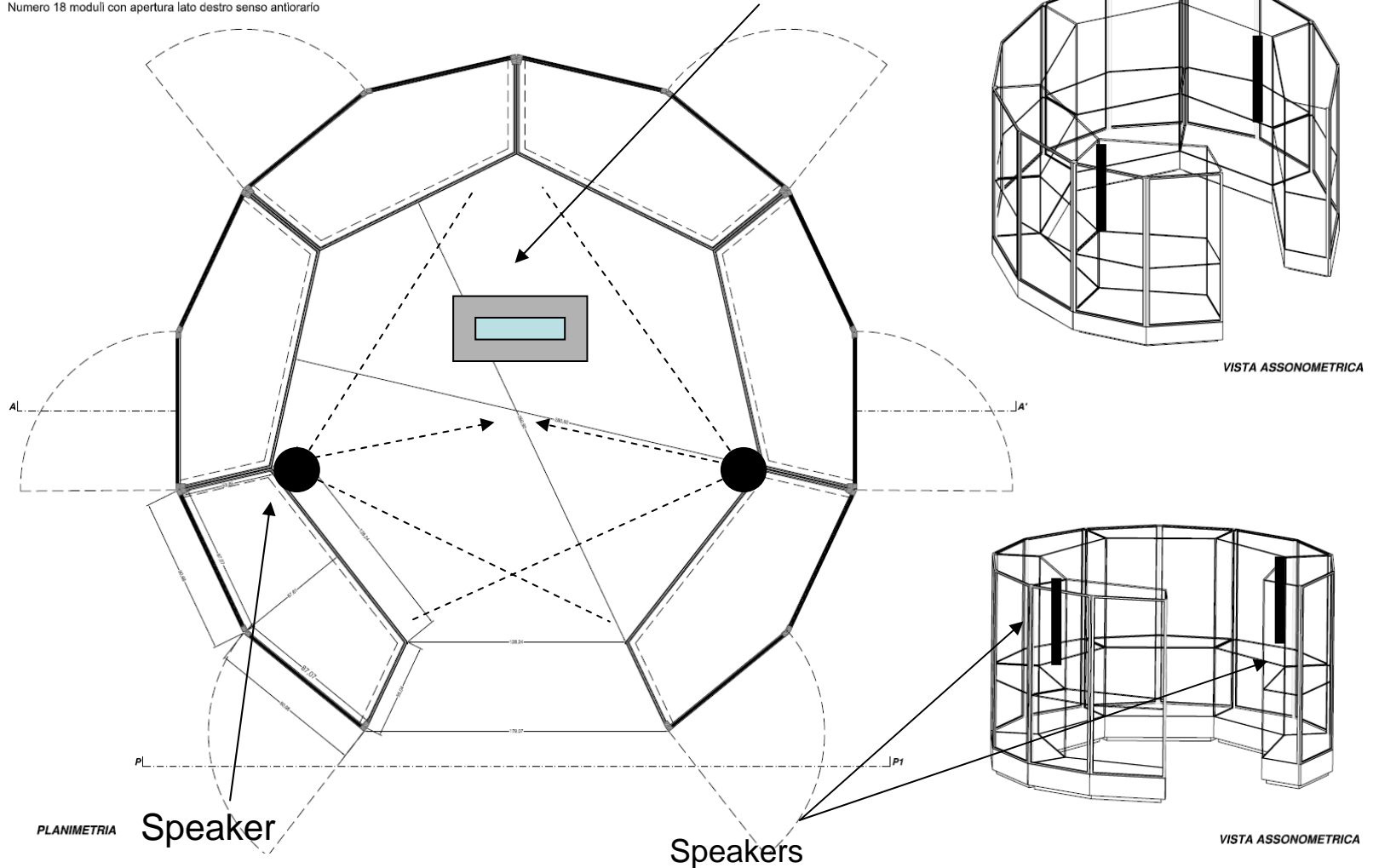
SAFAR mod. 846
1939

Exhibit's sound system

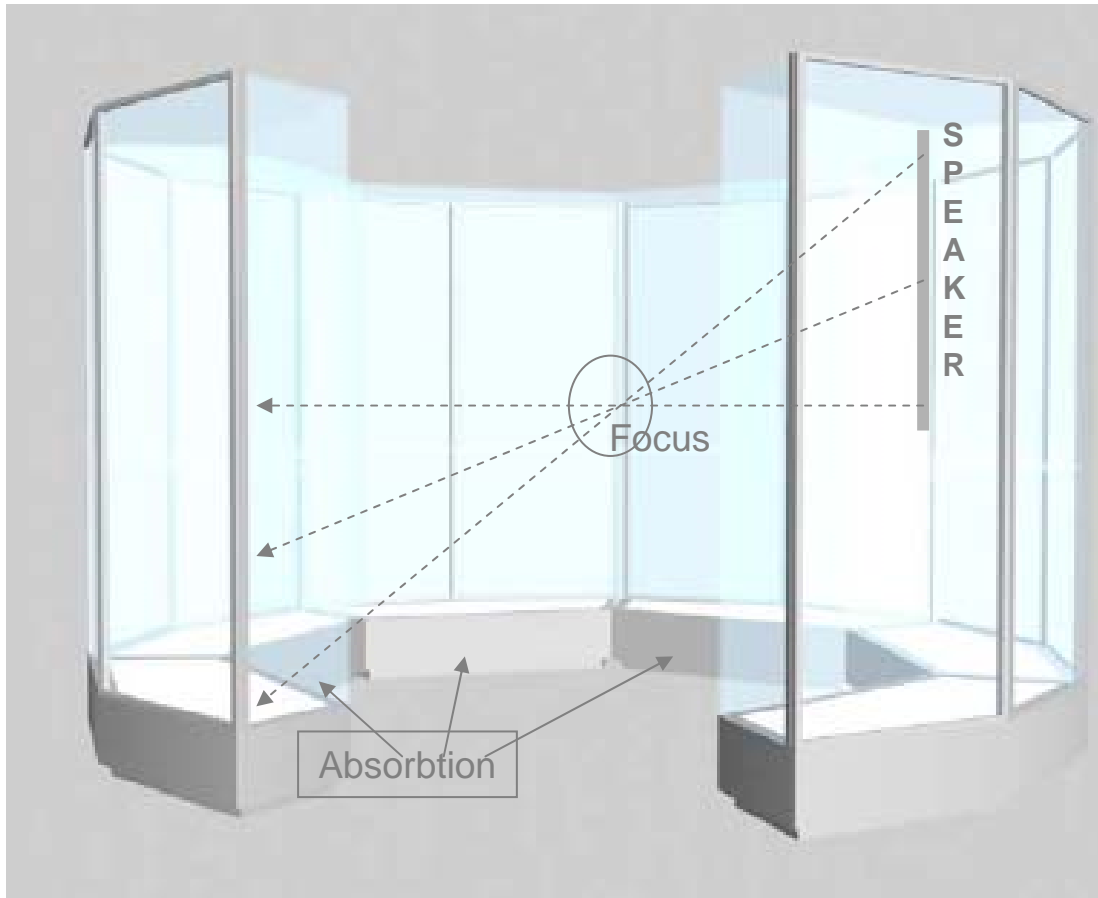
- Numero 6 moduli per nicchia
- Numero 36 moduli complessivi
- Numero 18 moduli con apertura lato sinistro senso orario
- Numero 18 moduli con apertura lato destro senso antiorario

Touch screen

B_ NICCHIA ESPOSITIVA
scala 1:20

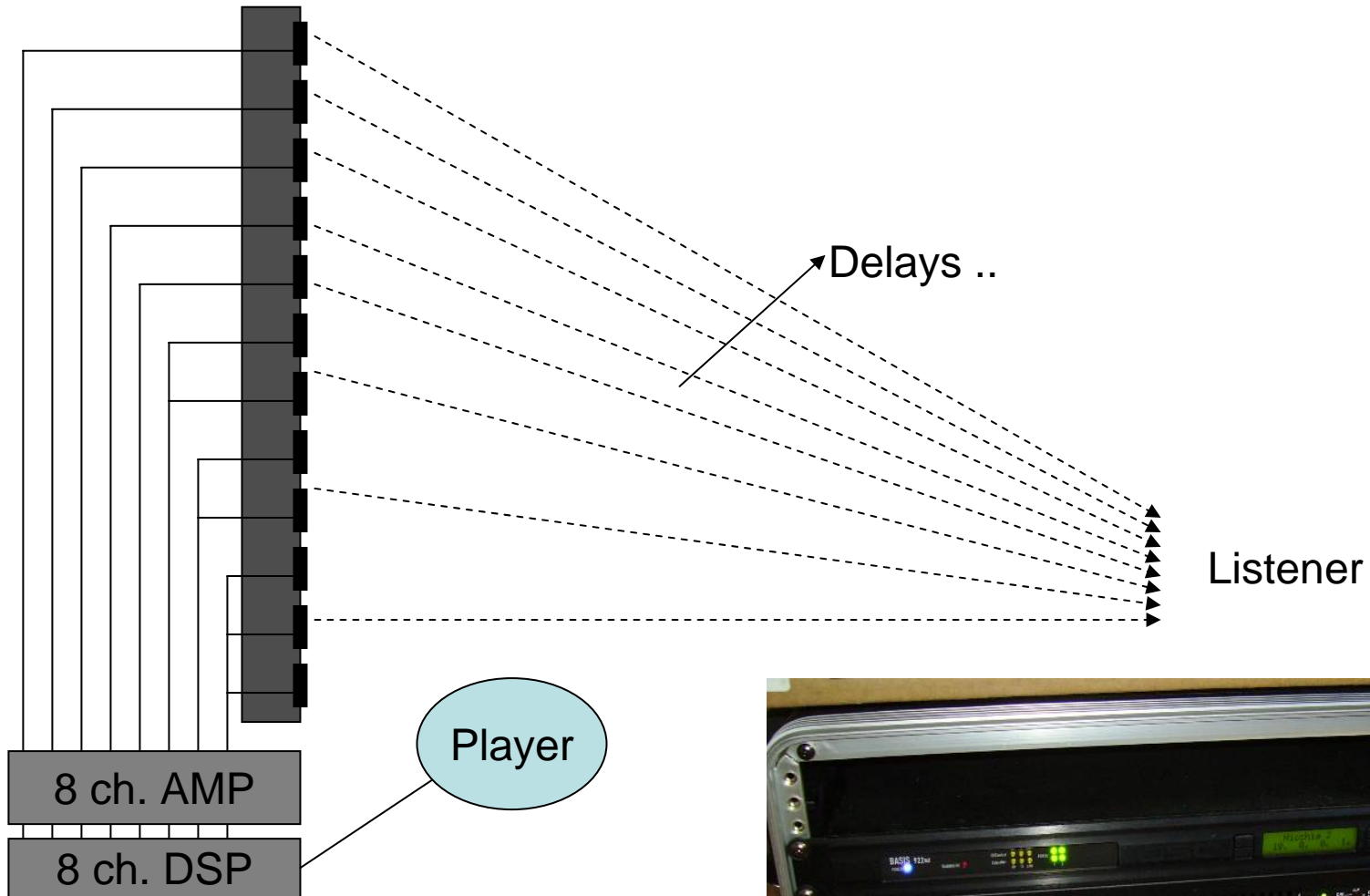


Exhibit's sound system



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



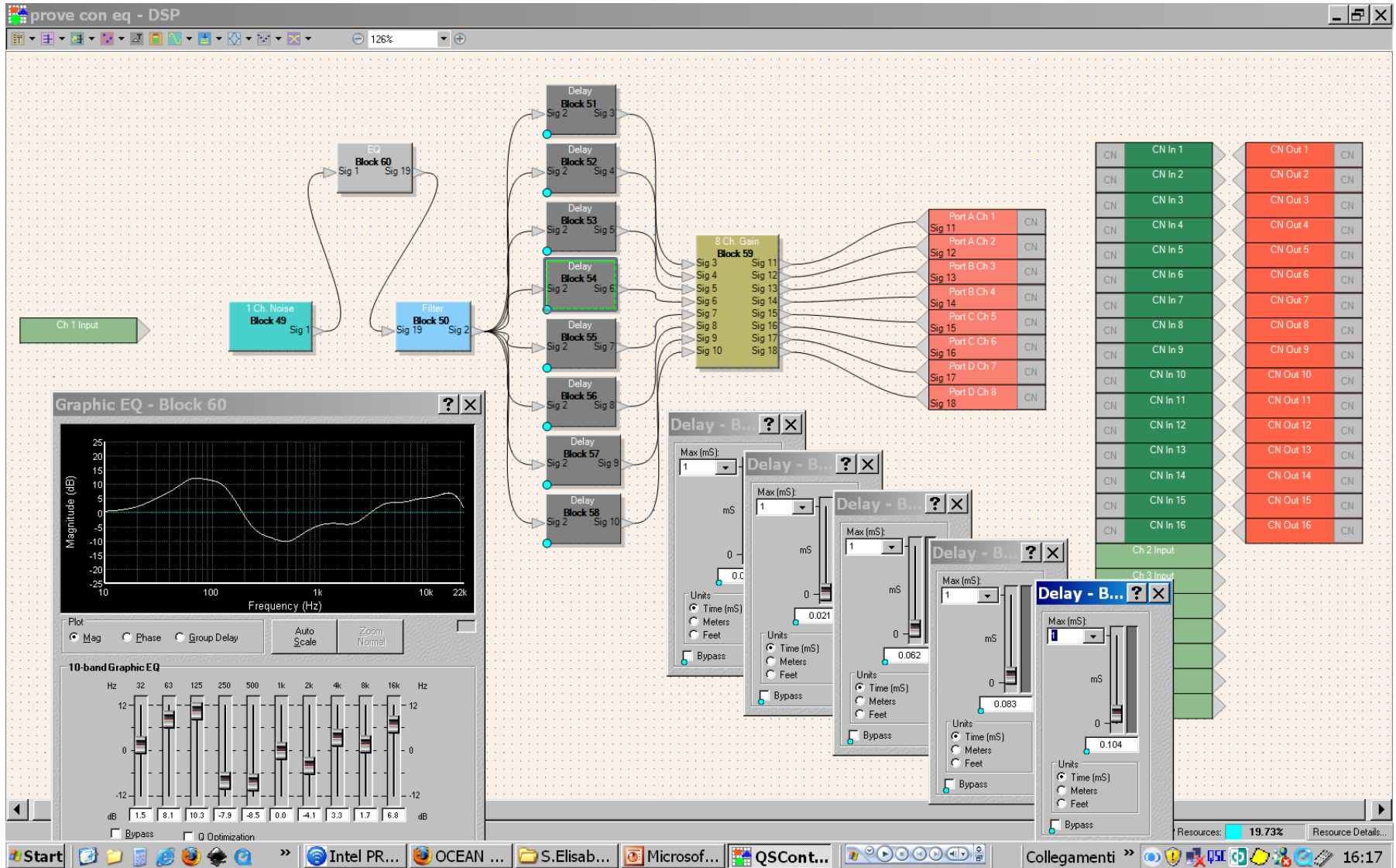
QSC 8-channels amplifier + BASIS
DSP controller / Cobranet interface



DSP control of line arrays

prove con eq - DSP

126%



The screenshot displays a DSP software interface with a signal flow diagram. The main diagram shows a signal path starting from a 'Ch 1 Input' block, passing through a '1 Ch. Noise Block 49', then an 'EQ Block 60', and a 'Filter Block 50'. The signal then branches into eight parallel paths, each containing a 'Delay' block (Block 51 to Block 58). These paths converge into an '8 Ch. Gain Block 59', which is connected to a multi-channel output array. The array consists of 16 channels, with the first 8 channels (CN Out 1-8) highlighted in red and the last 8 channels (CN Out 9-16) in green. The output array is labeled with 'Port A Ch 1-4', 'Port B Ch 5-8', 'Port C Ch 9-12', and 'Port D Ch 13-16'. The interface also features a 'Graphic EQ - Block 60' window showing a magnitude response graph and a '10-band Graphic EQ' window with frequency sliders. The bottom of the screen shows a Windows taskbar with various open applications and a system tray displaying the time as 16:17.

Ch 1 Input

1 Ch. Noise Block 49 Sig 1

EQ Block 60 Sig 1 Sig 19

Filter Block 50 Sig 19 Sig 2

Delay Block 51 Sig 2 Sig 3

Delay Block 52 Sig 2 Sig 4

Delay Block 53 Sig 2 Sig 5

Delay Block 54 Sig 2 Sig 6

Delay Block 55 Sig 2 Sig 7

Delay Block 56 Sig 2 Sig 8

Delay Block 57 Sig 2 Sig 9

Delay Block 58 Sig 2 Sig 10

8 Ch. Gain Block 59 Sig 3 Sig 4 Sig 5 Sig 6 Sig 7 Sig 8 Sig 9 Sig 10 Sig 11 Sig 12 Sig 13 Sig 14 Sig 15 Sig 16 Sig 17 Sig 18

Port A Ch 1 CN

Port A Ch 2 CN

Port B Ch 3 CN

Port B Ch 4 CN

Port C Ch 5 CN

Port C Ch 6 CN

Port D Ch 7 CN

Port D Ch 8 CN

CN In 1 CN Out 1 CN

CN In 2 CN Out 2 CN

CN In 3 CN Out 3 CN

CN In 4 CN Out 4 CN

CN In 5 CN Out 5 CN

CN In 6 CN Out 6 CN

CN In 7 CN Out 7 CN

CN In 8 CN Out 8 CN

CN In 9 CN Out 9 CN

CN In 10 CN Out 10 CN

CN In 11 CN Out 11 CN

CN In 12 CN Out 12 CN

CN In 13 CN Out 13 CN

CN In 14 CN Out 14 CN

CN In 15 CN Out 15 CN

CN In 16 CN Out 16 CN

Ch 2 Input

Ch 3 Input

Graphic EQ - Block 60

Magnitude (dB)

Frequency (Hz)

10-band Graphic EQ

Hz

dB

Resources: 19.73% Resource Details...

Start Intel PR... OCEAN ... S.Elisab... Microsof... QSCont... Collegenti 16:17

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



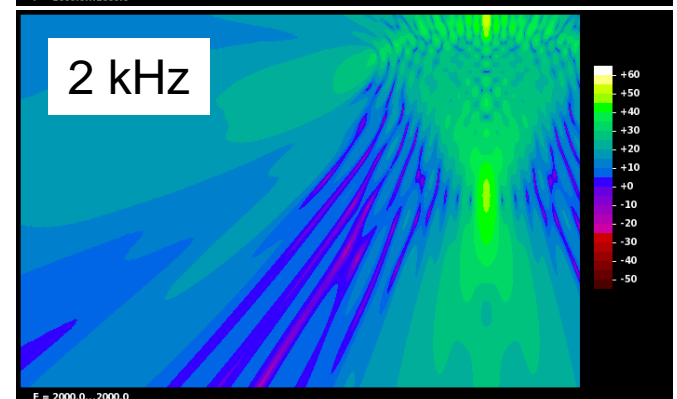
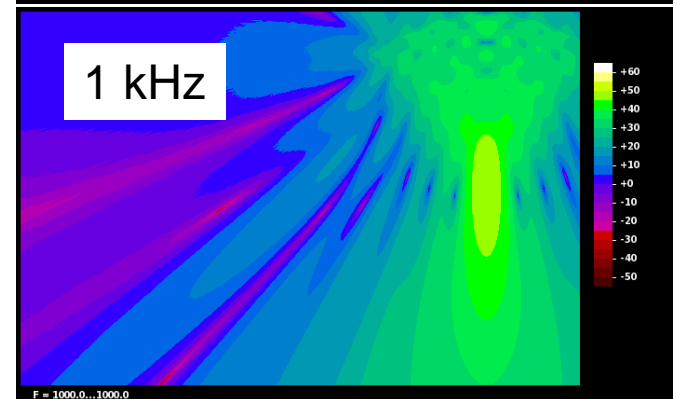
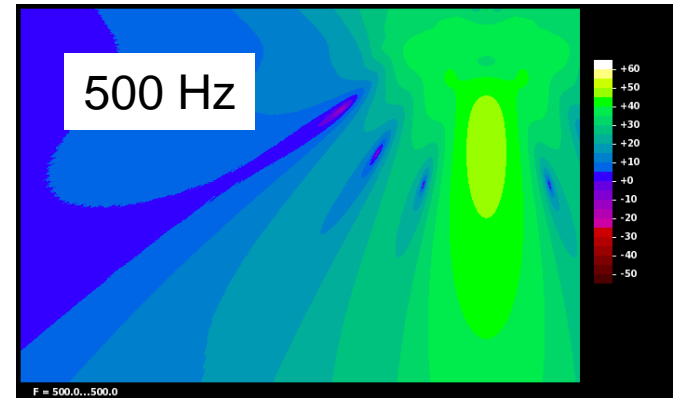
Nicchia n. 5 - RADIO AND RADIOGRAMMOPHONS
1935-1954

The Niches

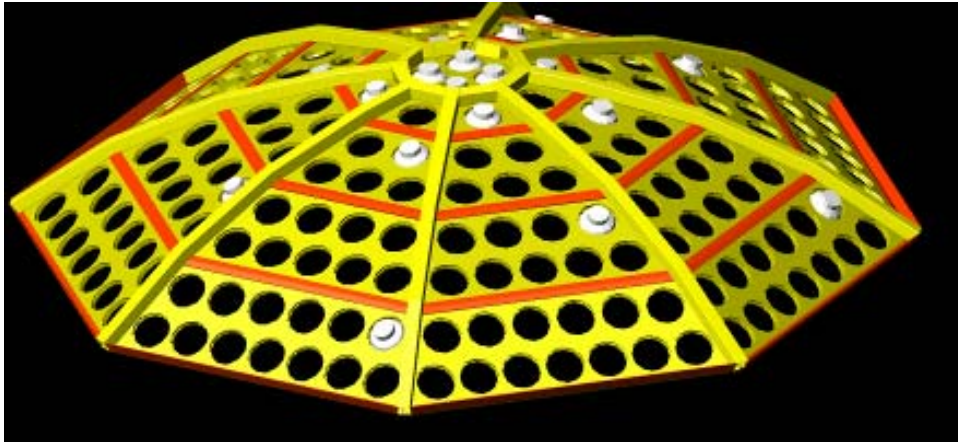


Nicchia n. 6 - RADIO, TURNTABLES, AMPLIFIERS, STEREO
1950 - 2007

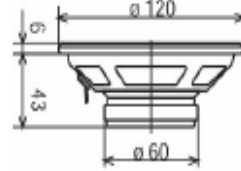
The “Sonic Chandellier”



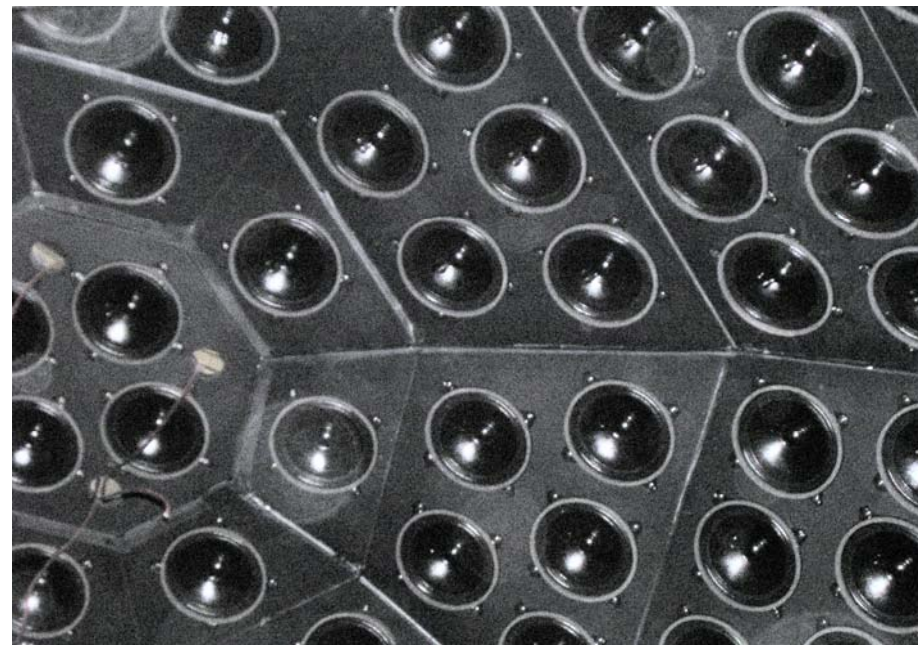
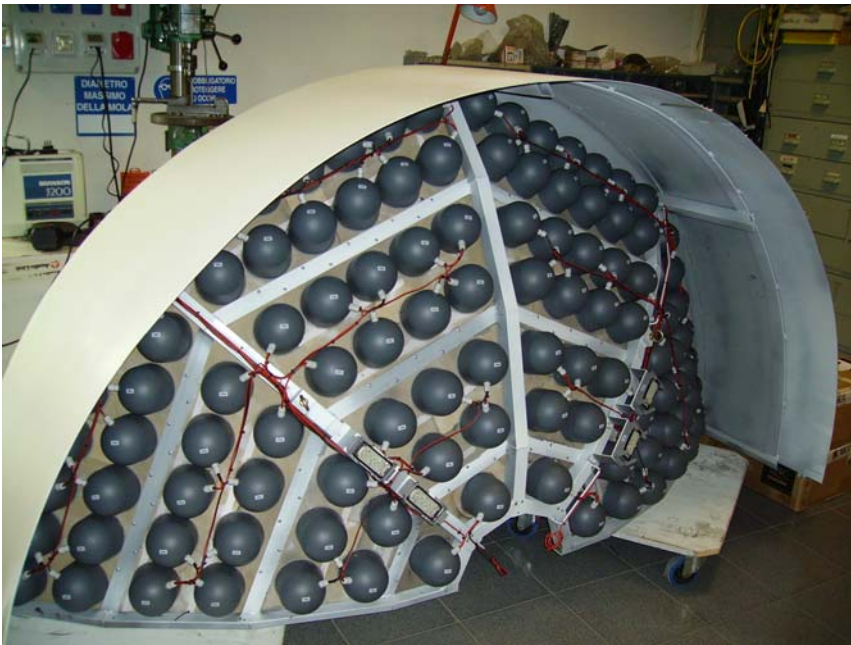
Design and Construction



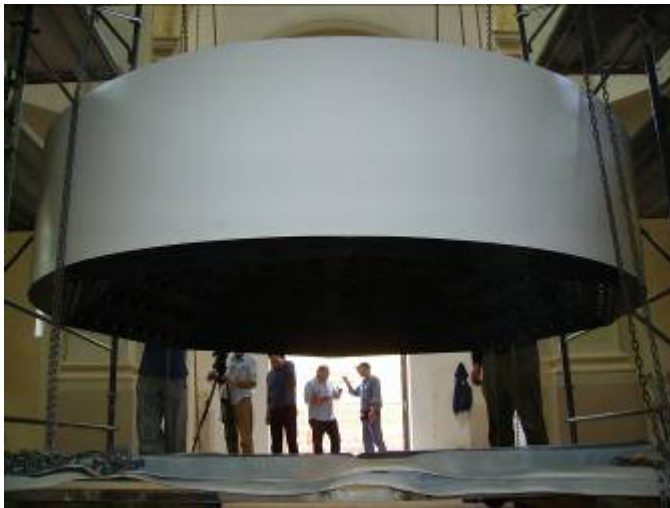
Design and Construction



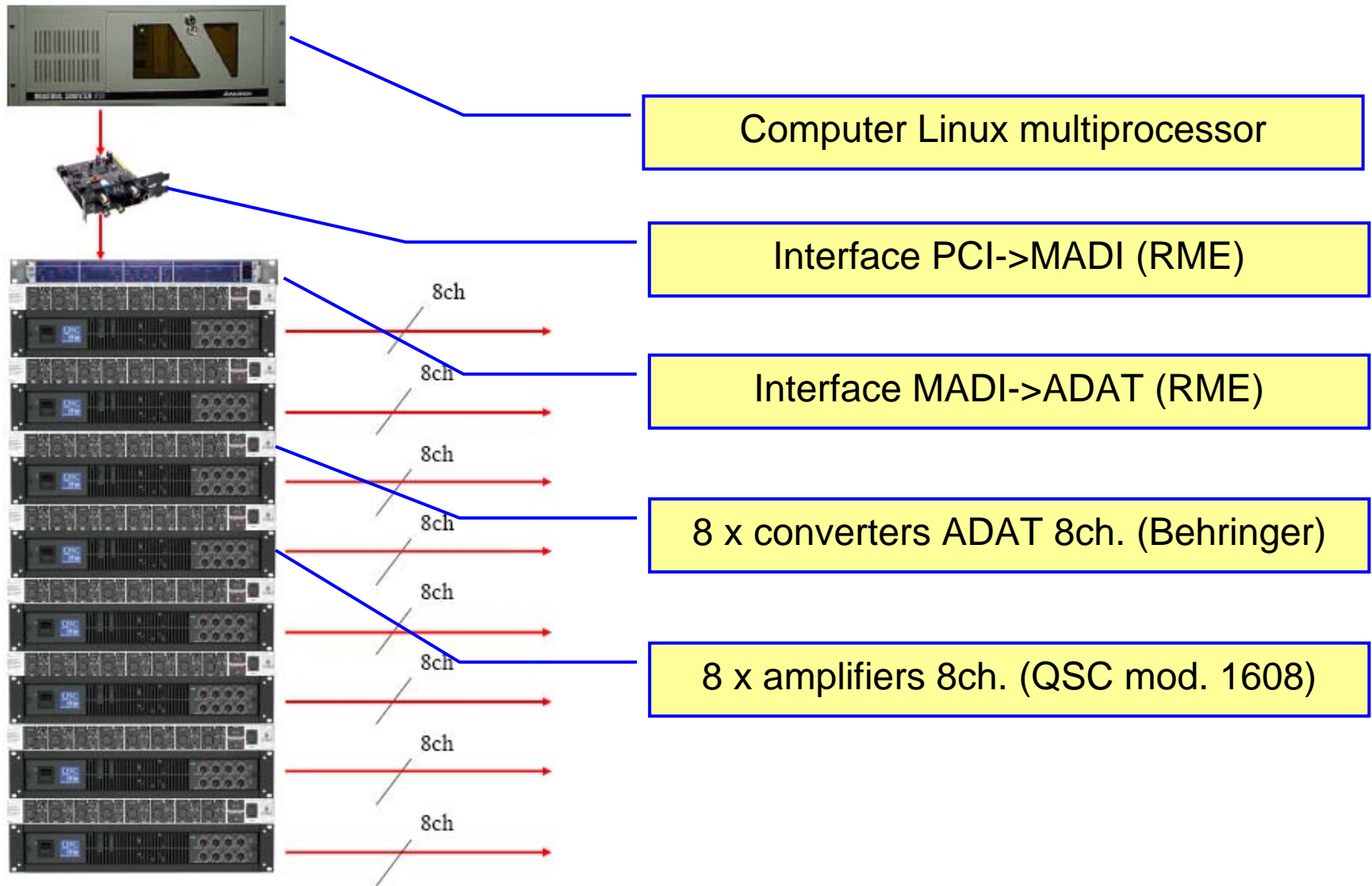
Special 32 Ohm model by Ciare



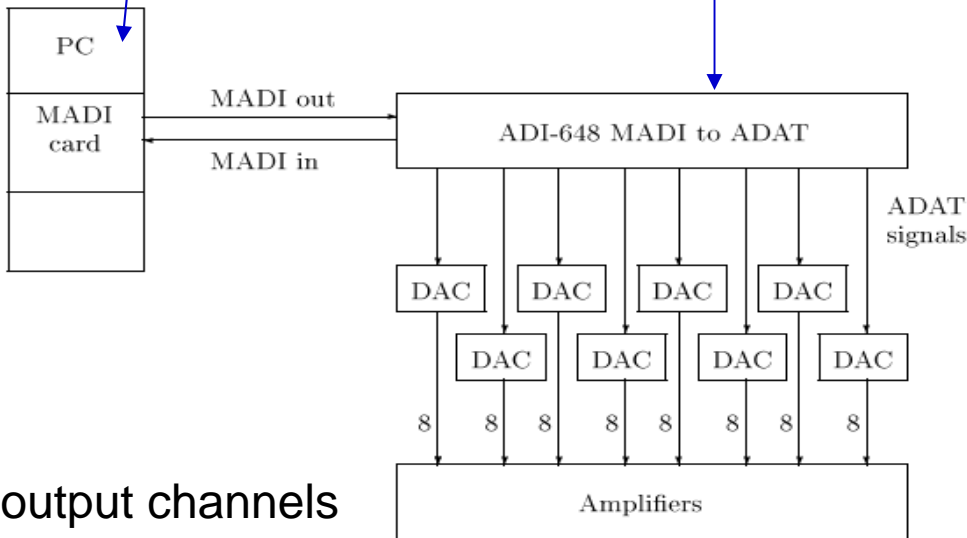
Installation



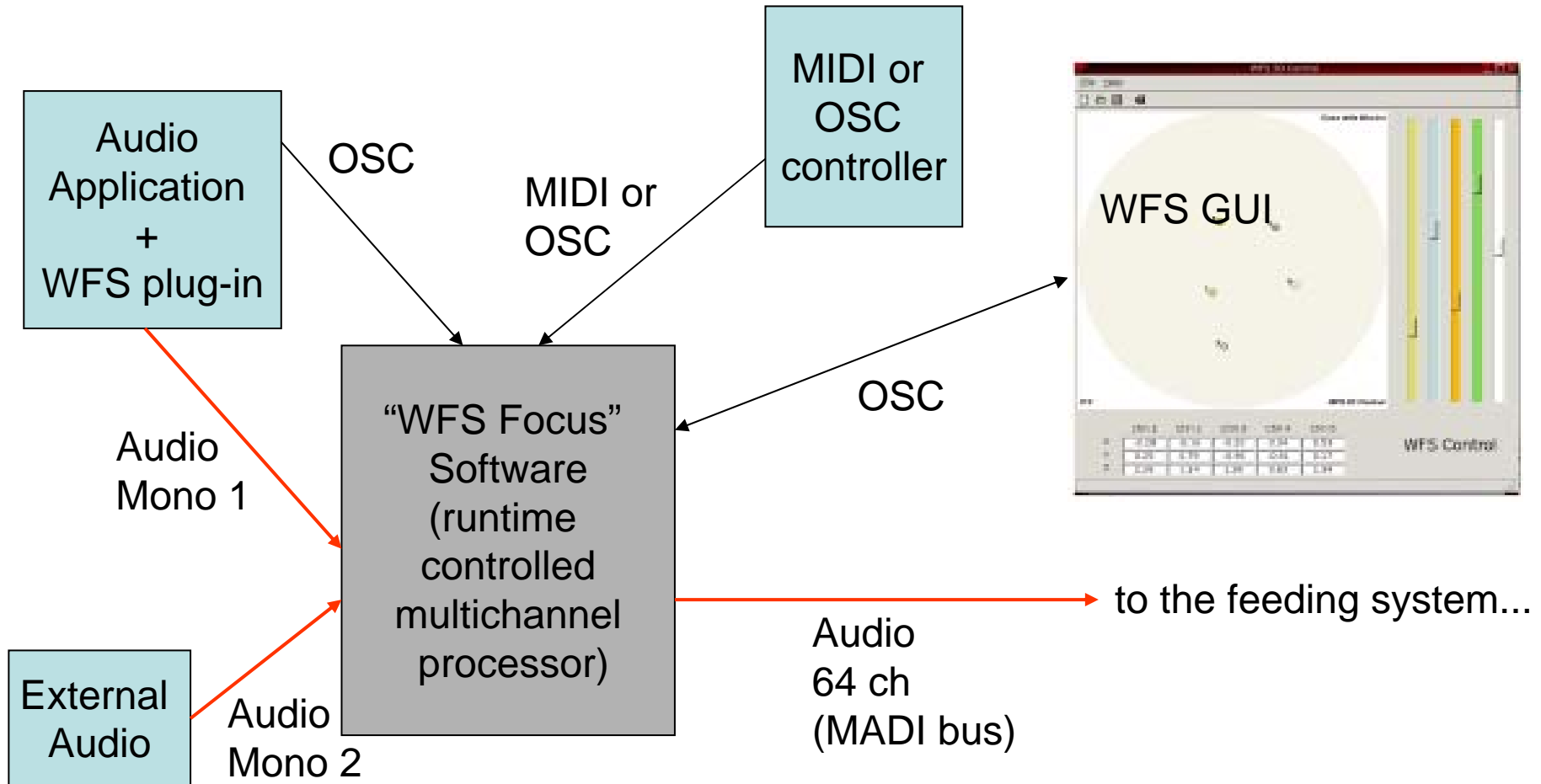
Hardware (computer, converters, amplifiers)



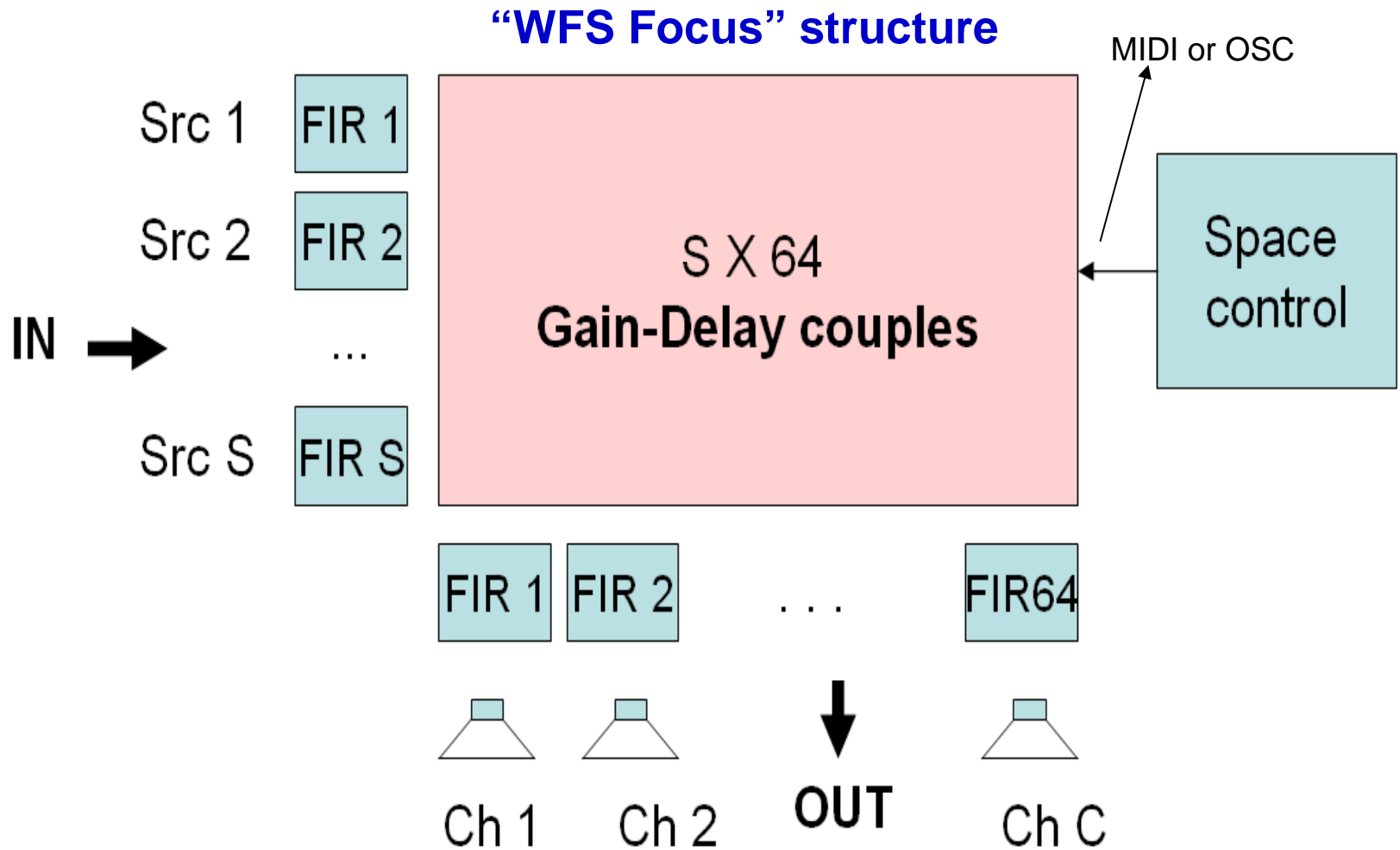
Hardware (computer, converters, amplifiers)



Software structure on Linux PC



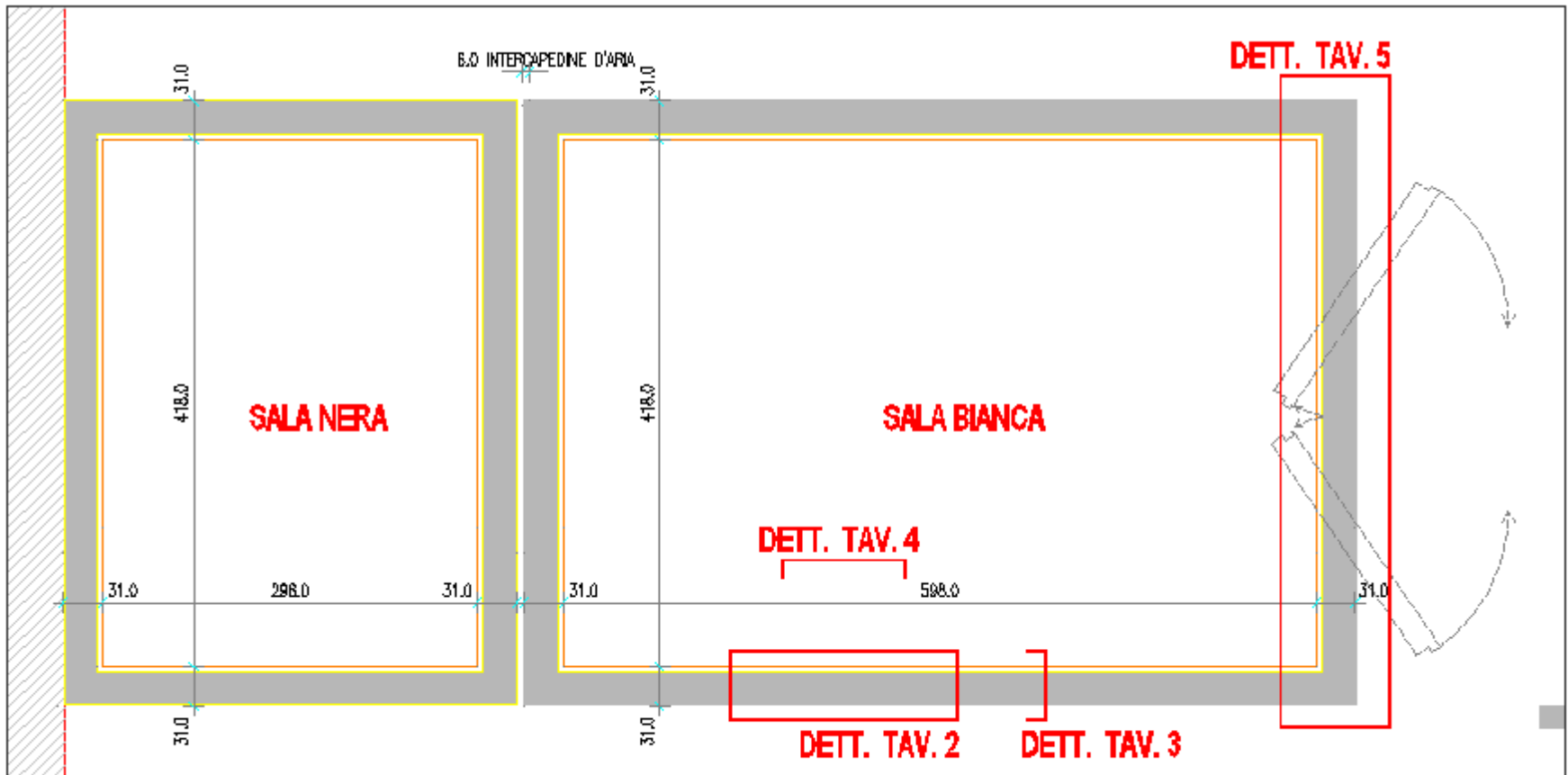
Software



Listening rooms



Listening rooms

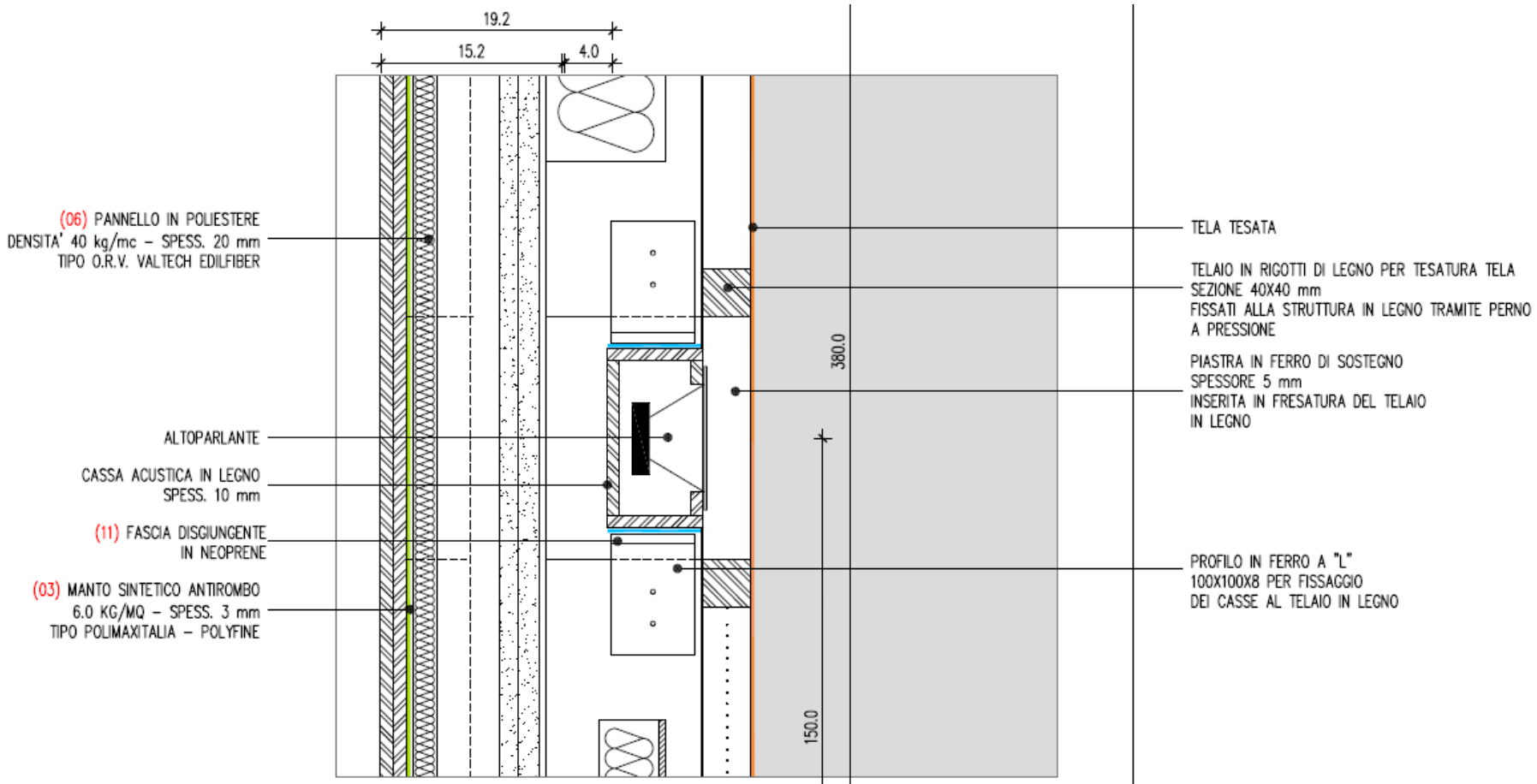


PLANIMETRIA

SCALA 1:50

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

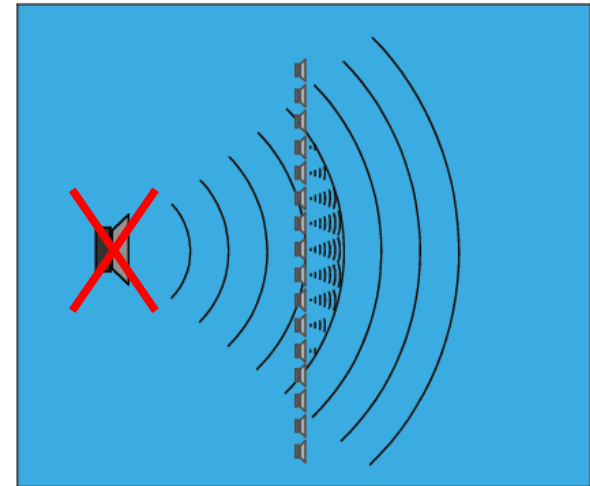
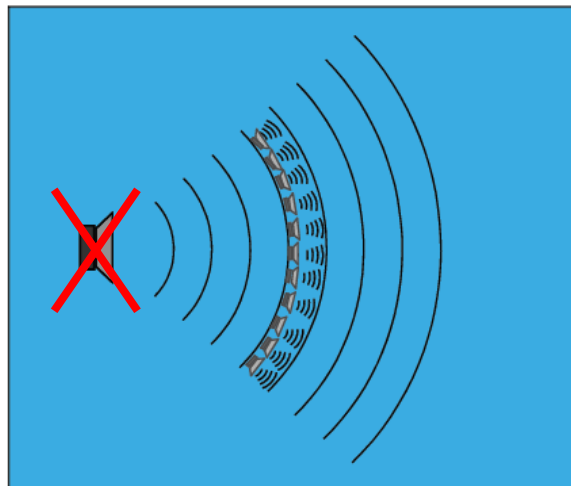
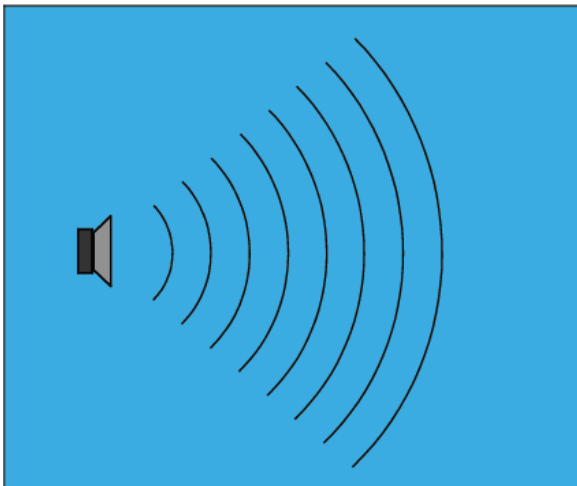
30-seats room (“sala Bianca”)



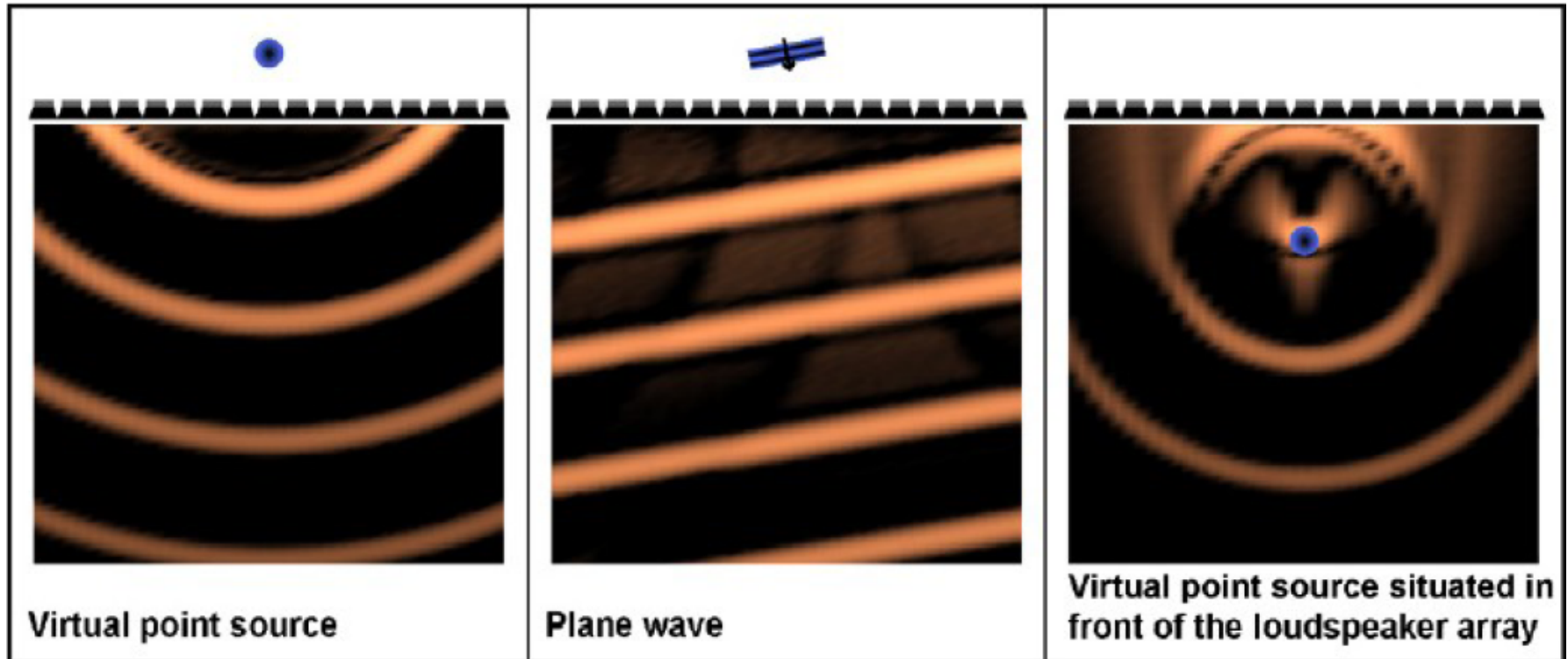
- 176 loudspeakers are incorporated in the perimetral walls, completely surrounding the audience at ear-height

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

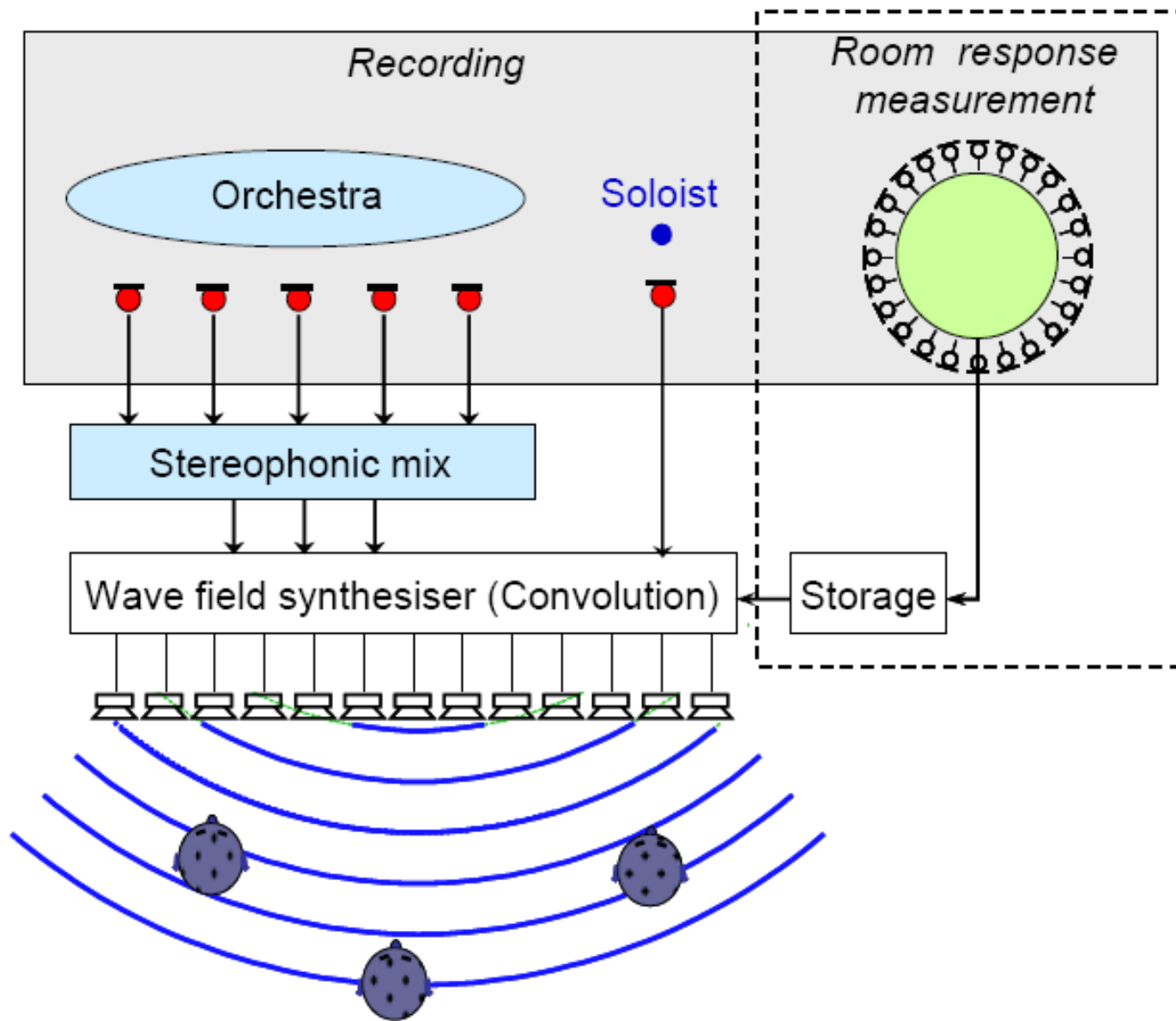


- WFS can generate point sources or planar sources, and even point sources which appear to be inside the room, in the middle of the audience area

Technology WFS @ IRCAM, IRT

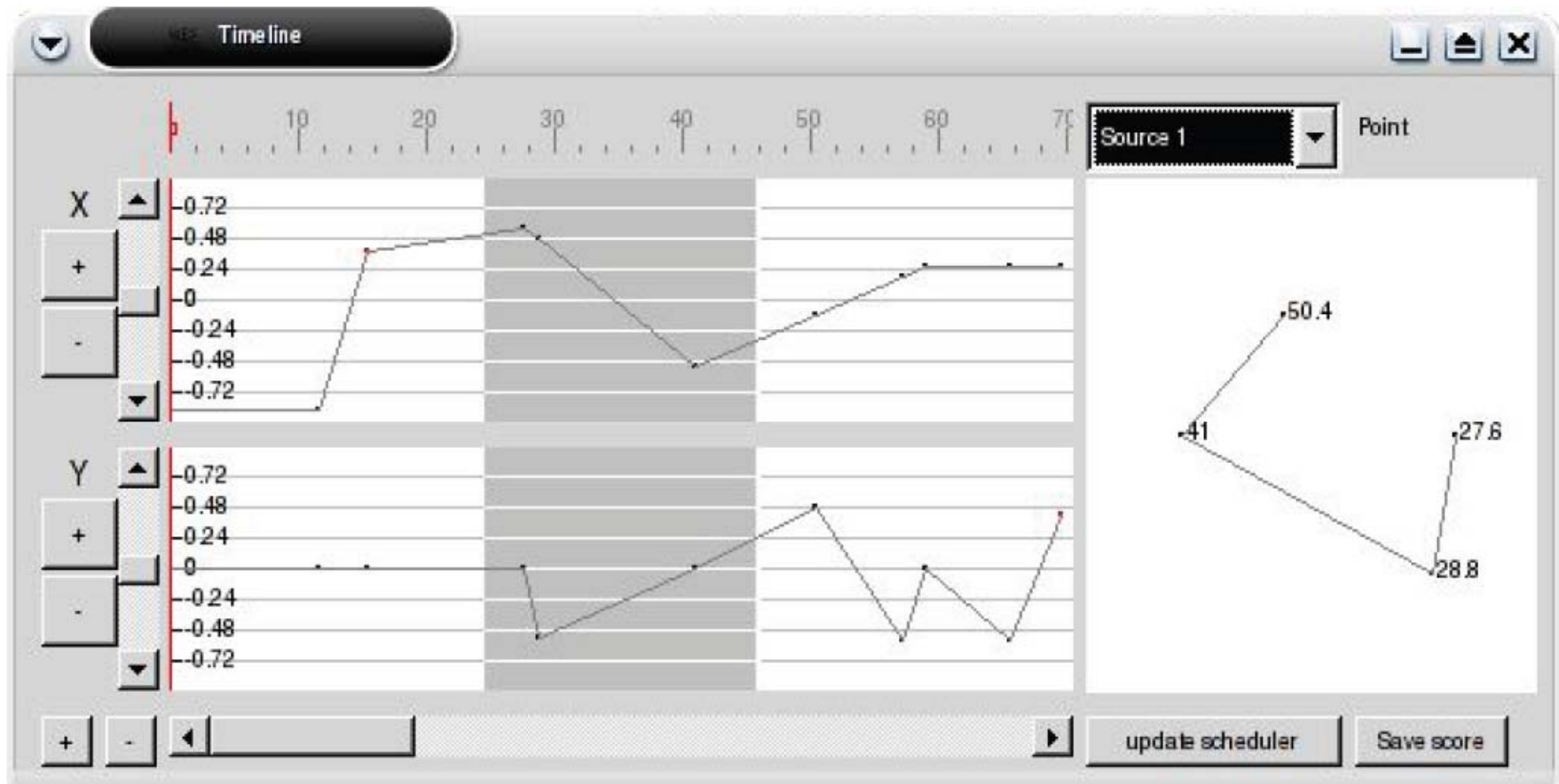


Synthesis of a virtual environment with WFS



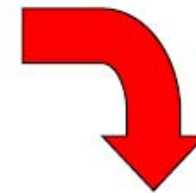
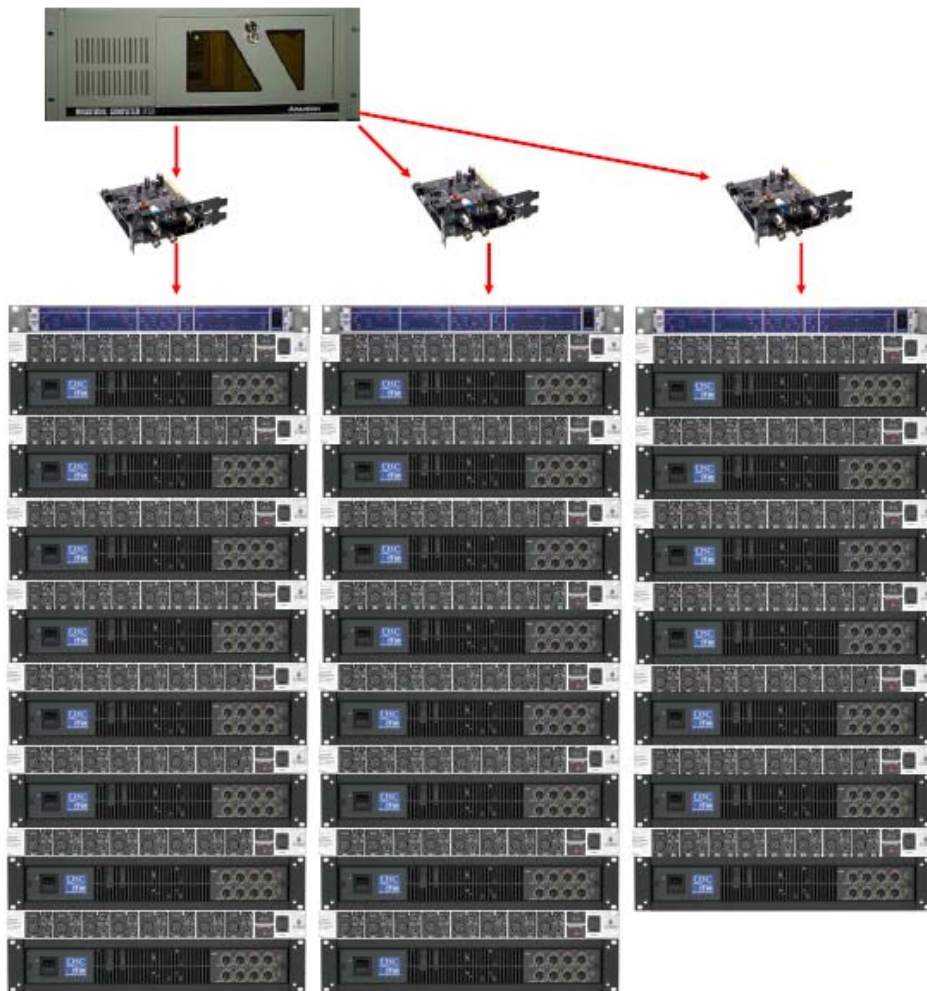
FREE Software for WFS

- The Linux program Wonder makes it possible 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)



Nota:
 3 MADI = 192 channels
 Disavanzo = 12 channels

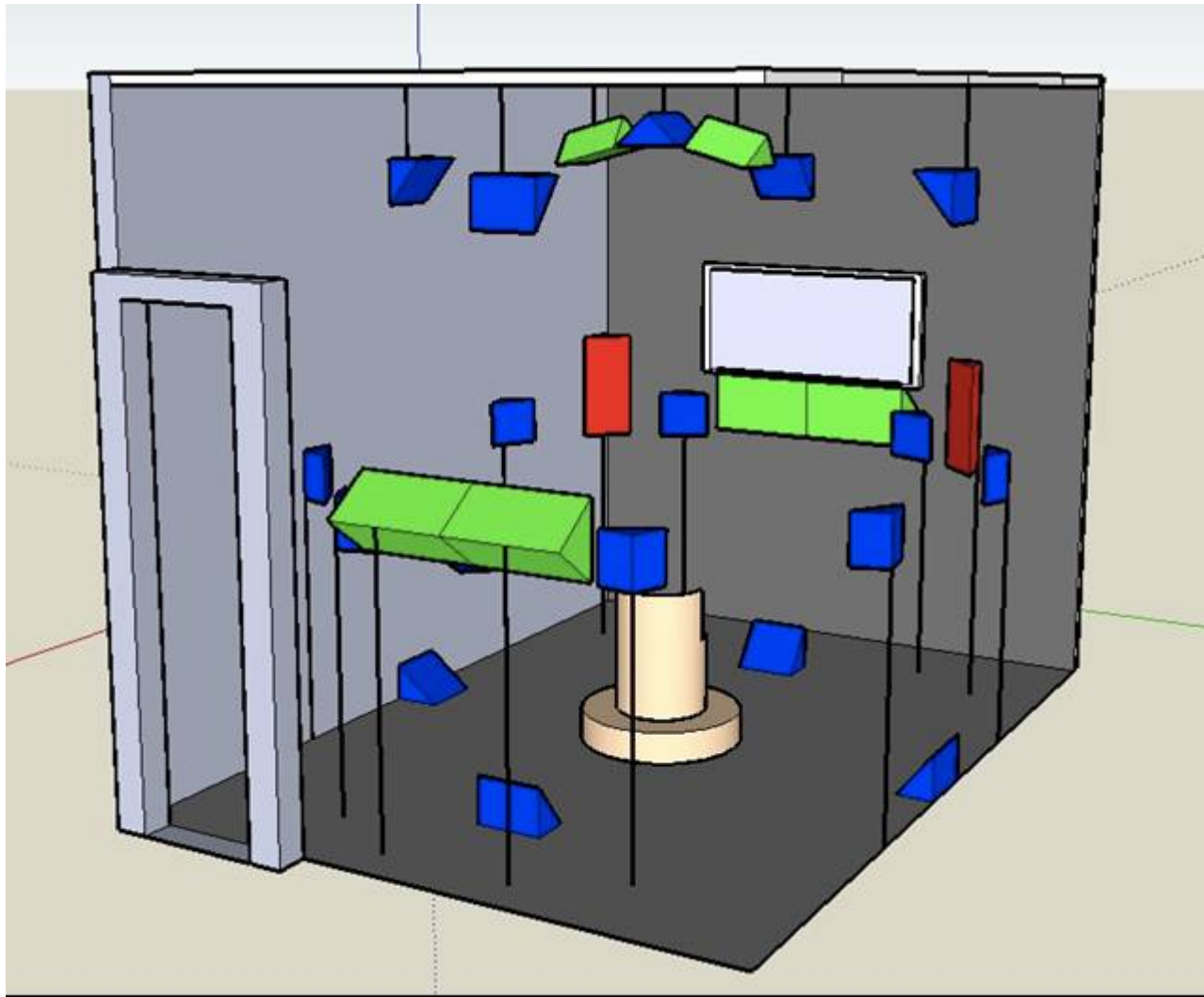
176 channels

+



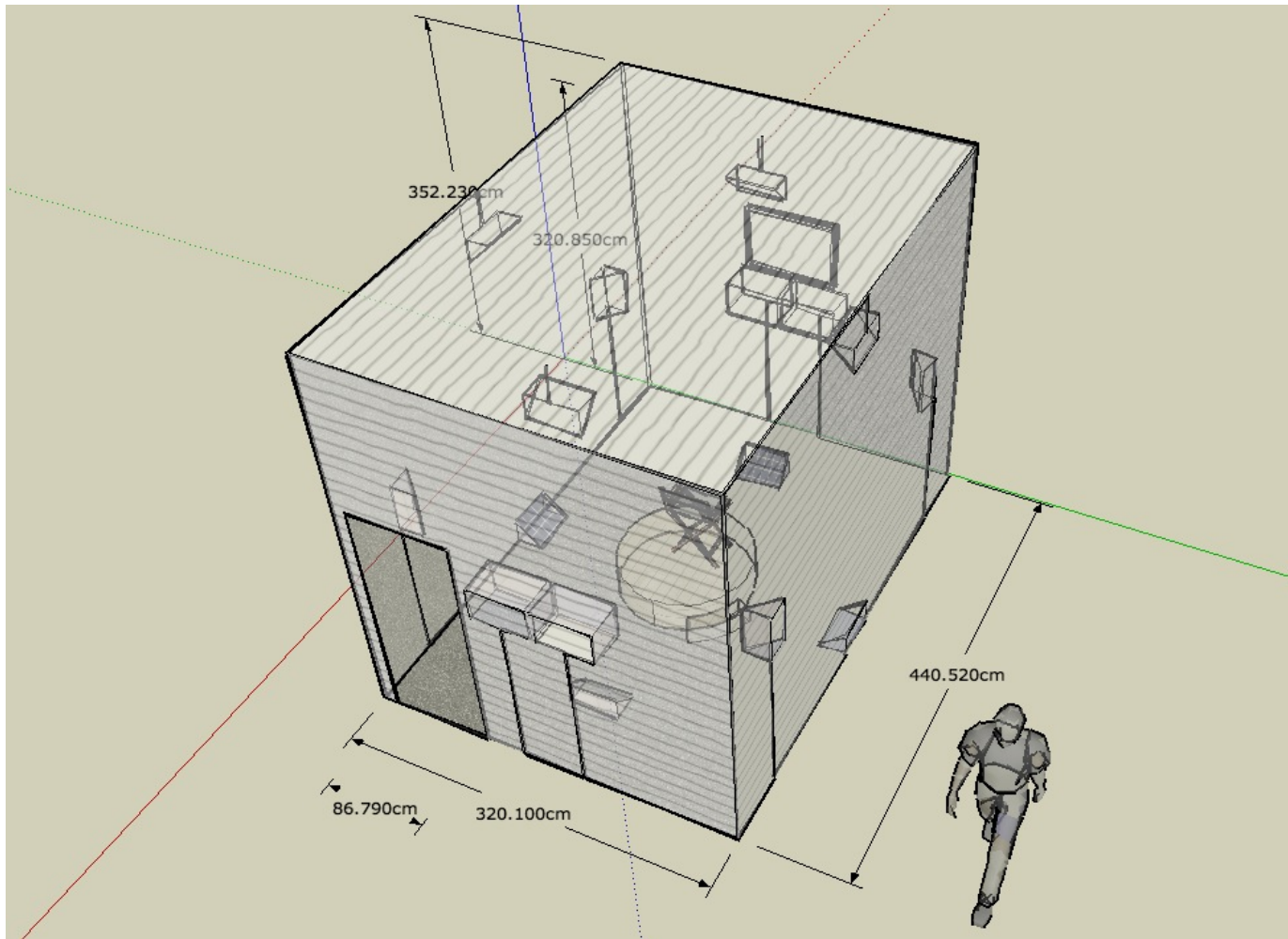
x 4 = 180 channels

Single-seat room (“sala Nera”)



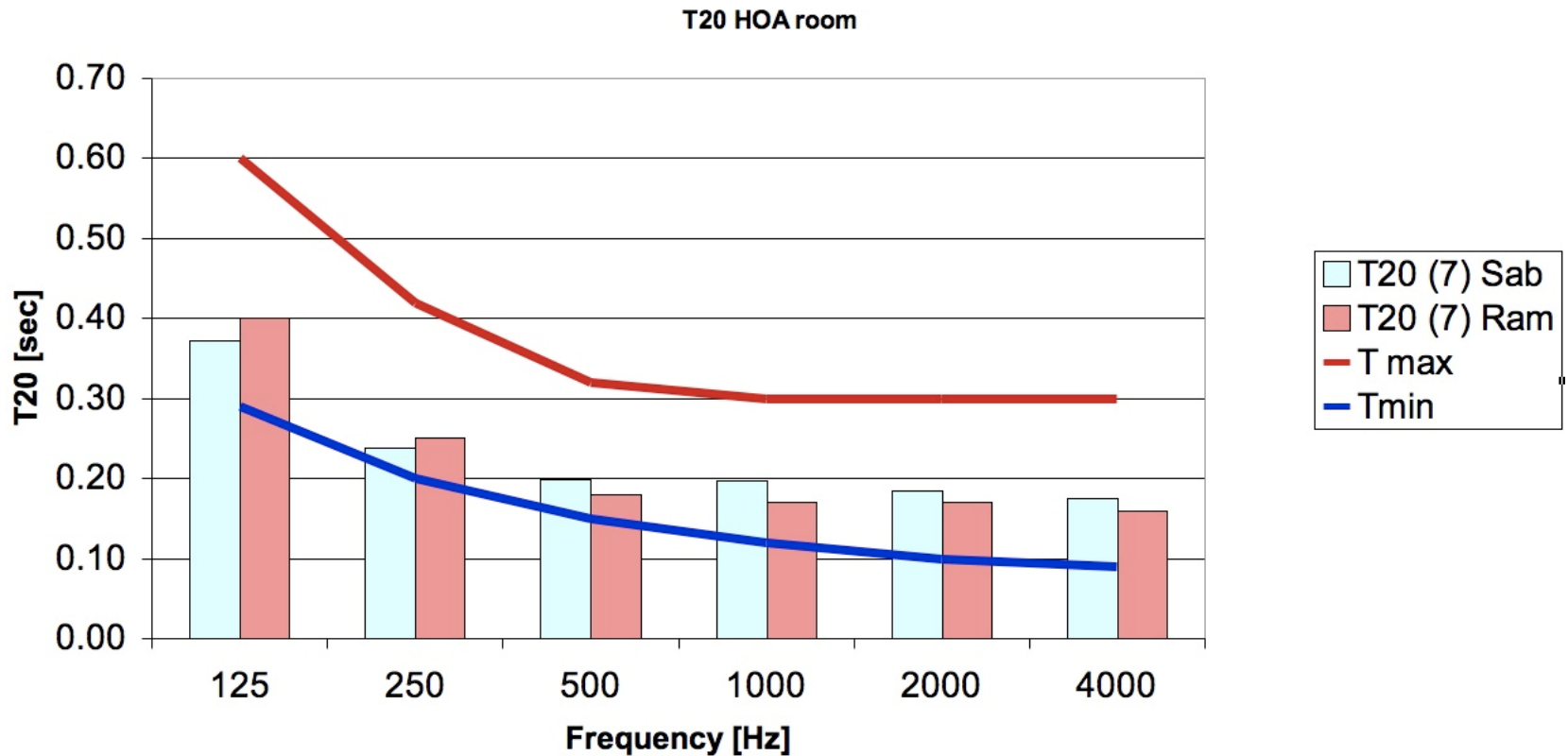
- This room is equipped with 26 loudspeakers

Single-seat room



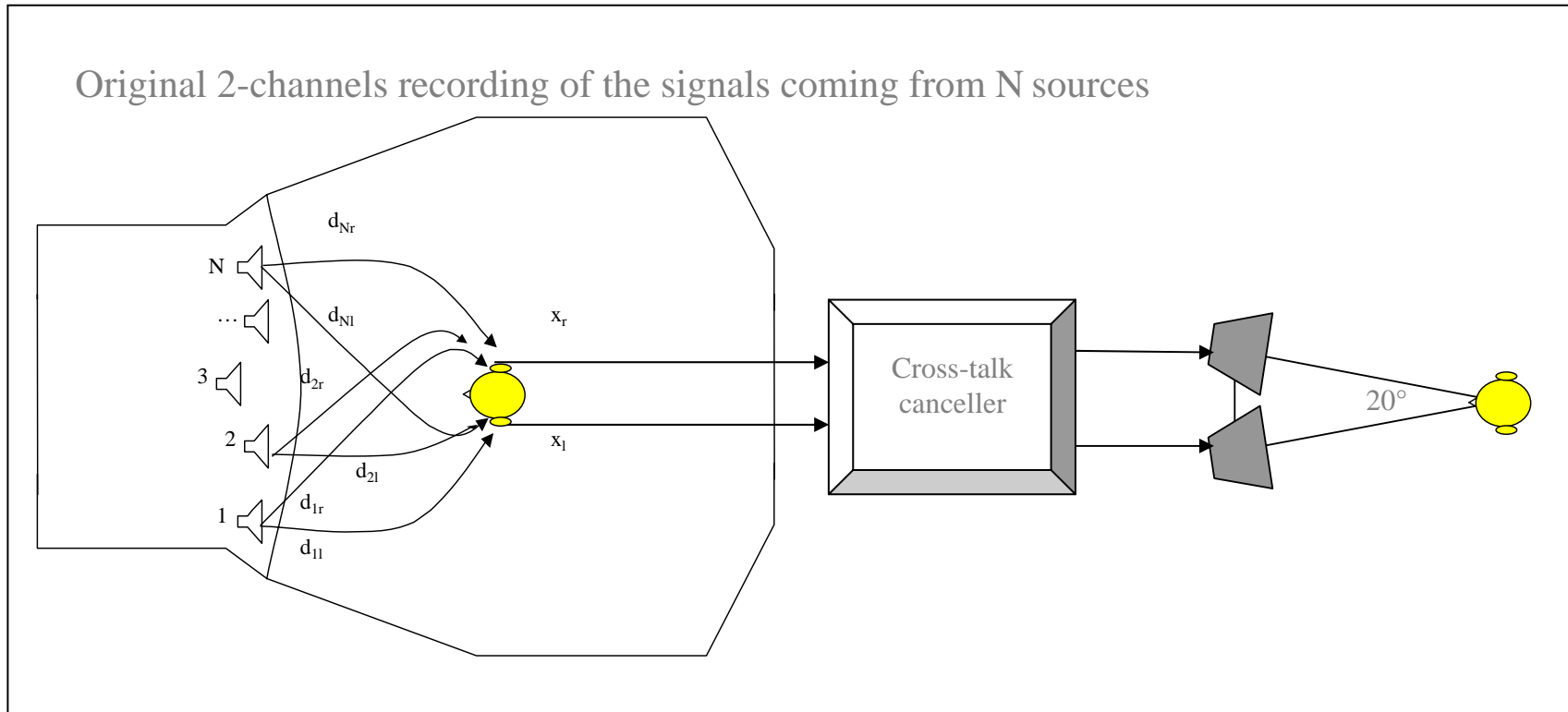
- The walls are made by plywood, gypsum boards and perforated panels with polyester fiber wool, providing good sound insulation and optimal control of reverberation

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 at higher frequencies.

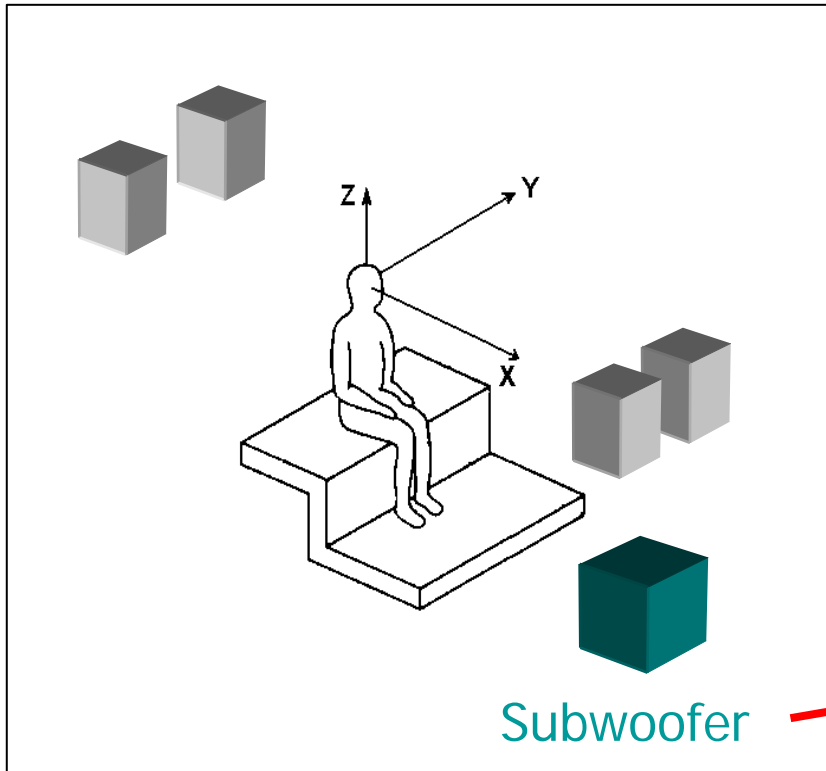
Binaural (Stereo Dipole) method



- Playback is made on 2 loudspeakers located at $\pm 10^\circ$, being fed through a digital cross-talk cancellation system

Binaural (Dual Stereo Dipole)

Schematics



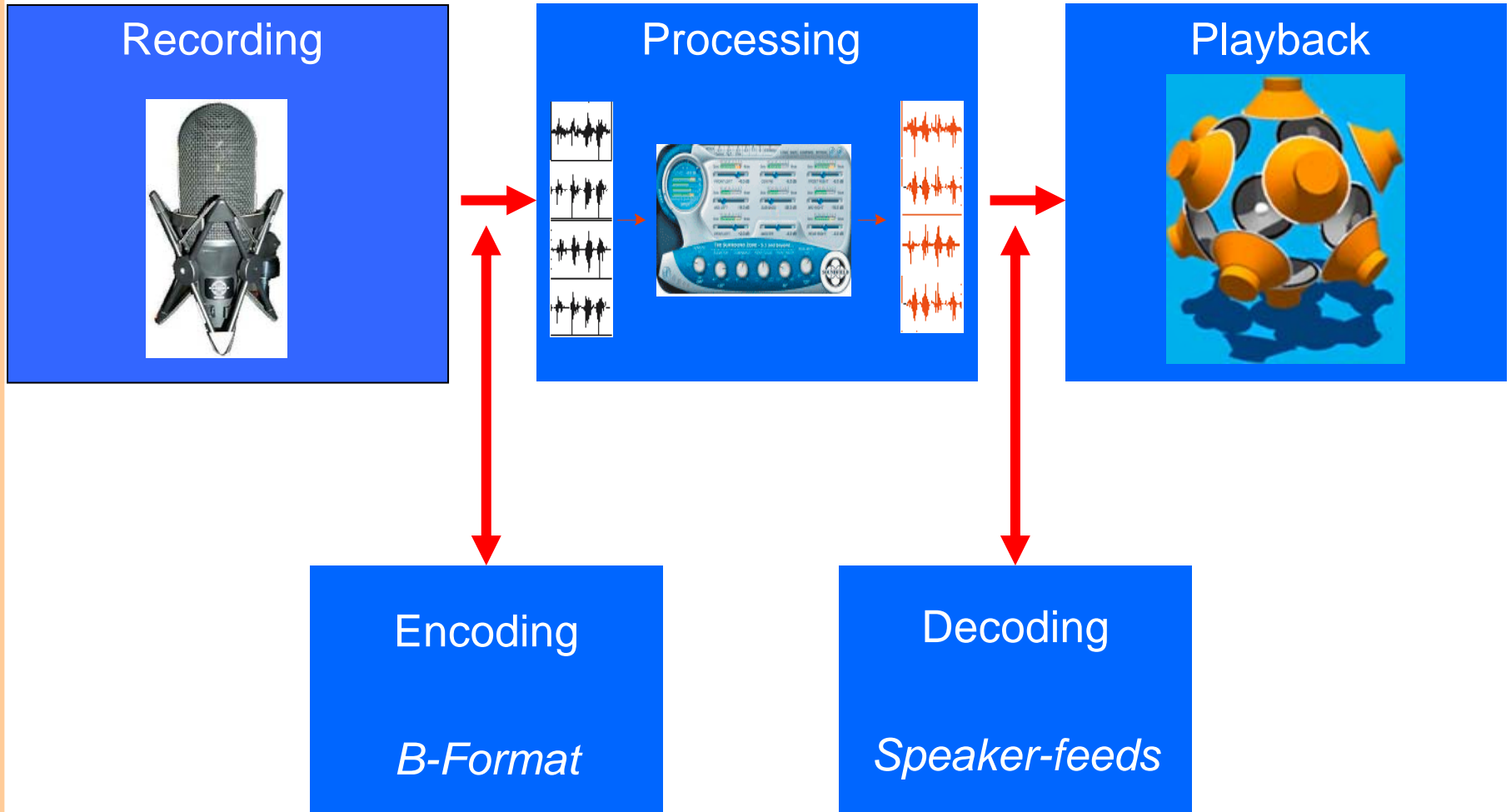
Pro:

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

Contro:

- ~~■ Poor low frequencies~~
- Colouring outside the "sweet spot"

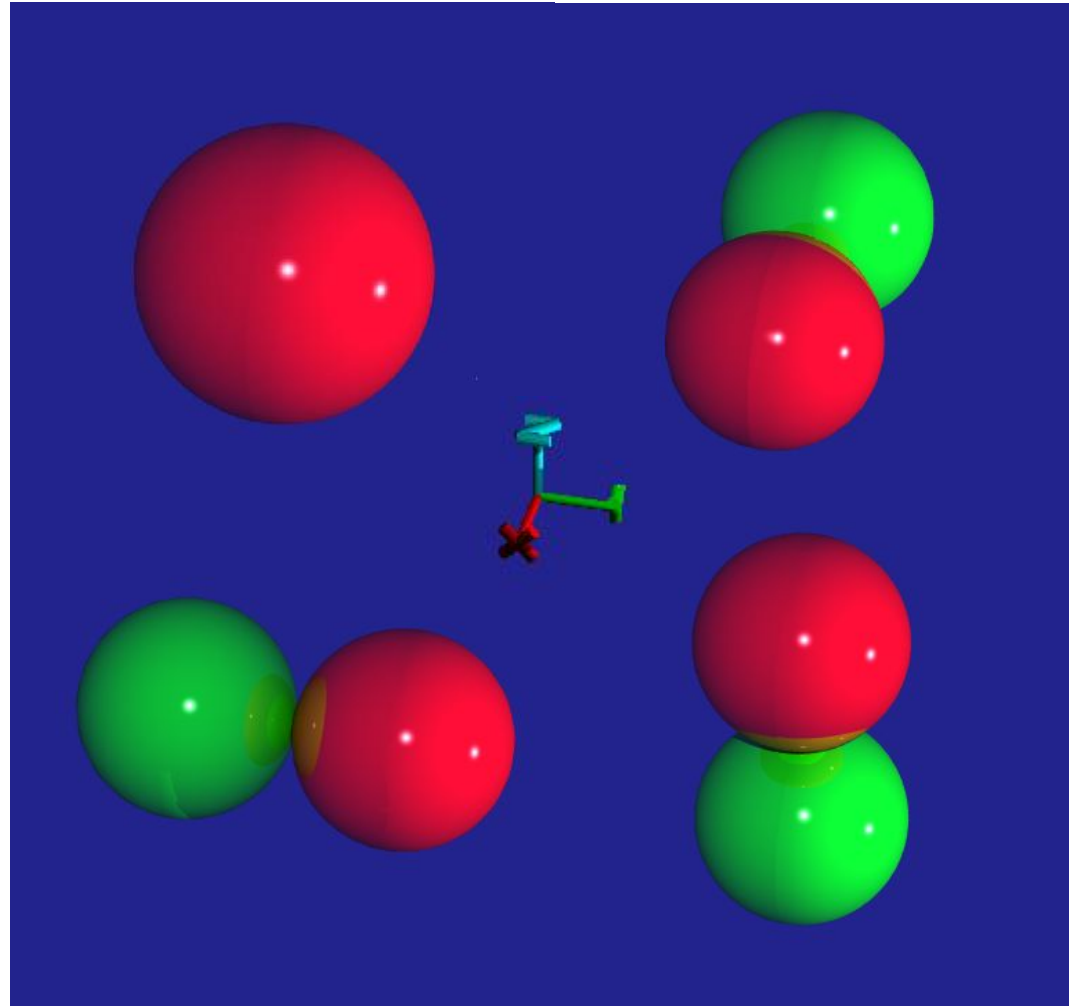
Ambisonics Method



Recording



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





Recording

Encoding

Processing

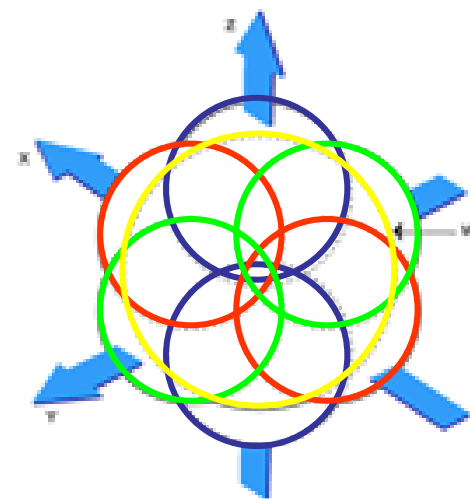
Decoding & Playback



Soundfield
microphone

X }
Y } Directional
Z } components:
W } Omnidirectional
pressure

B-FORMAT



Polar diagrams

Encoding

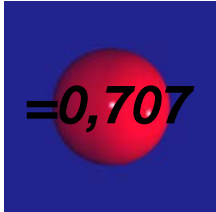
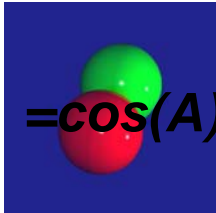
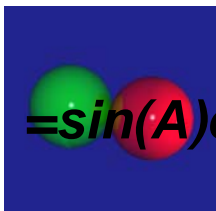
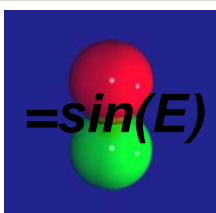


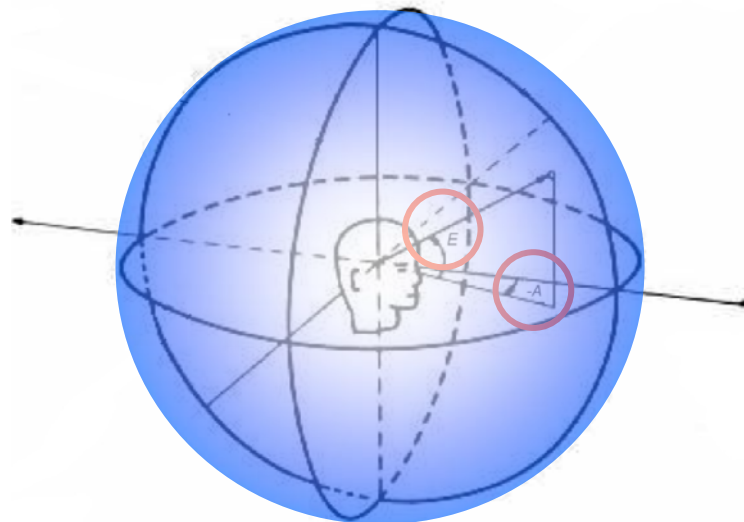
Recording

Encoding

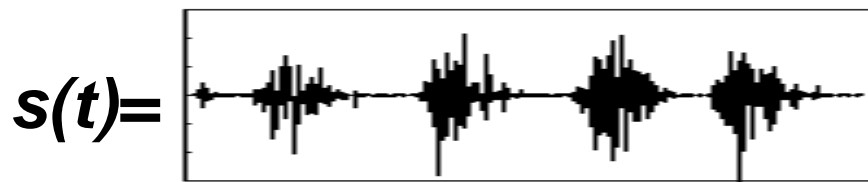
Processing

Decoding & Playback

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



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



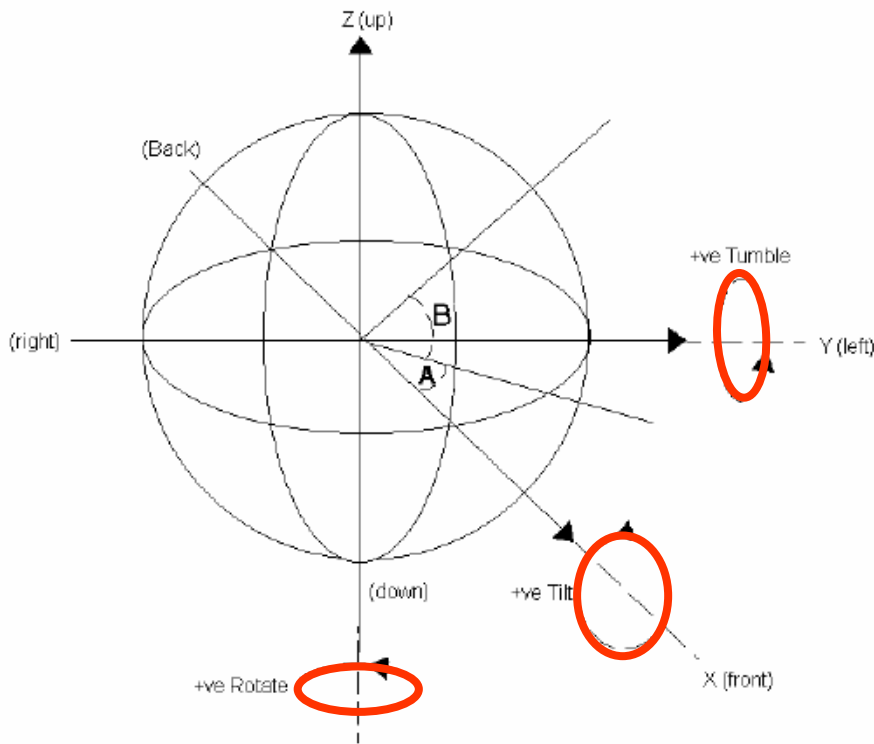


Recording

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



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

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

3D decoding

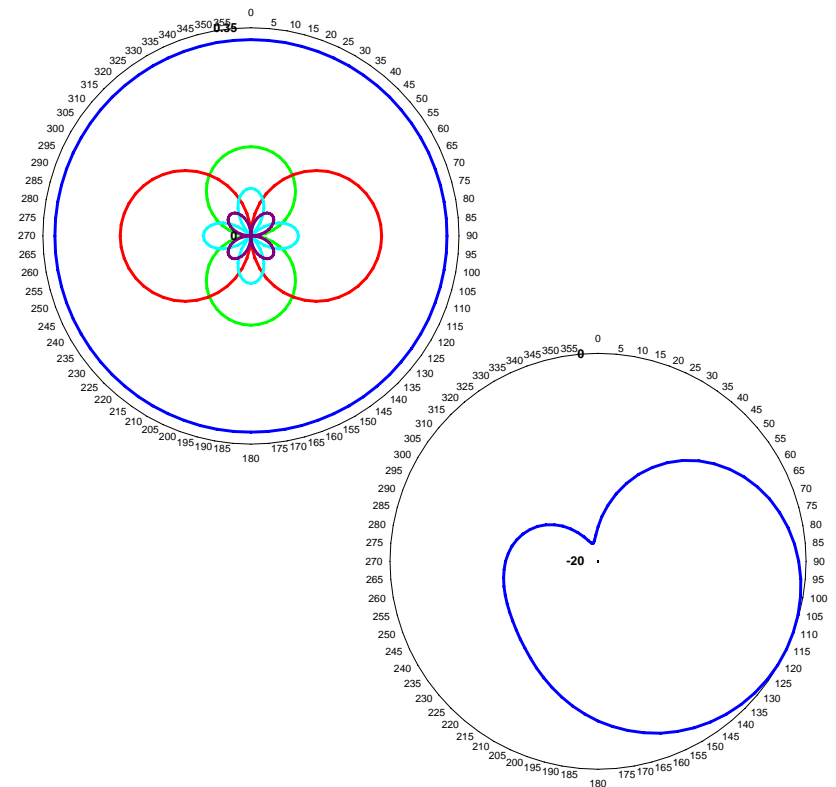
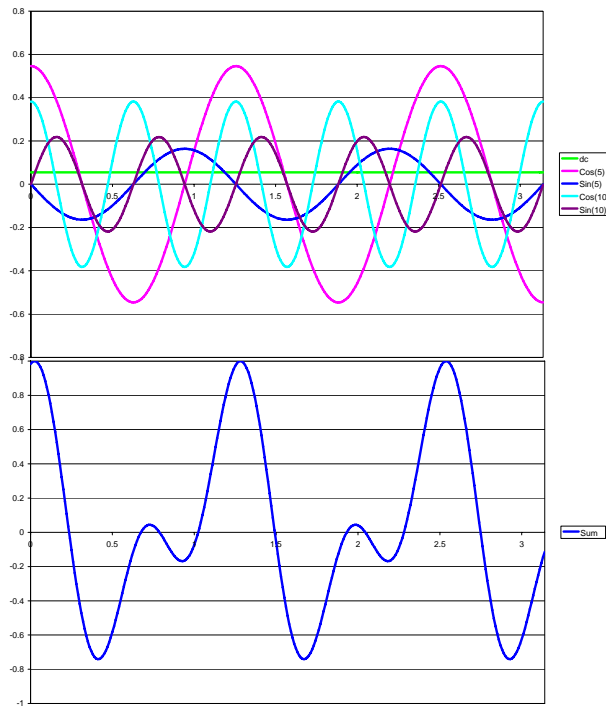
ker *i-esim*

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

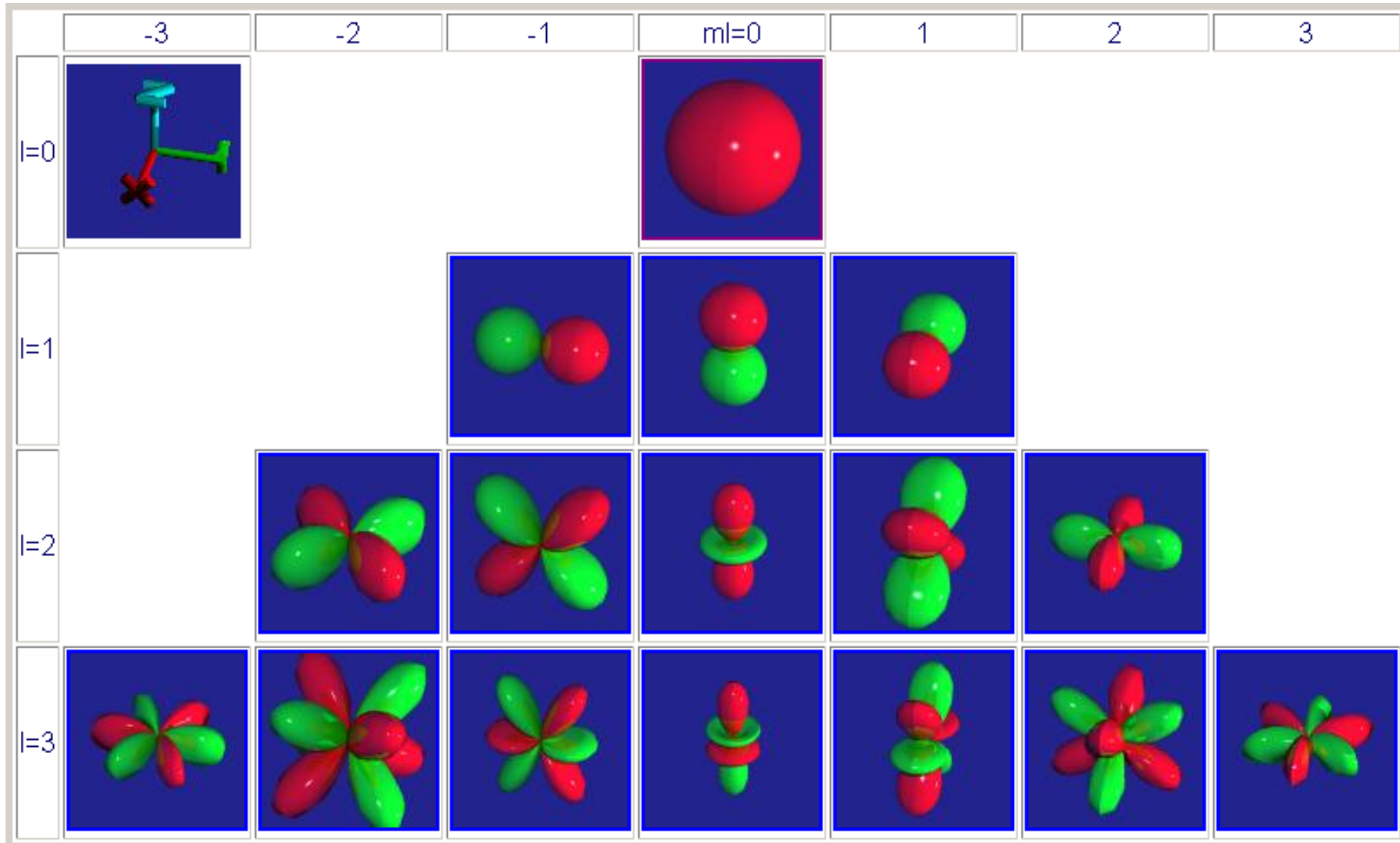
2D decoding

High Order Ambisonics (HOA)

- As a complex time-domain waveform can be thought 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 3rd order are summed with proper gains, one obtains a “virtual microphone” having a directivity pattern which can be very complex and highly directive



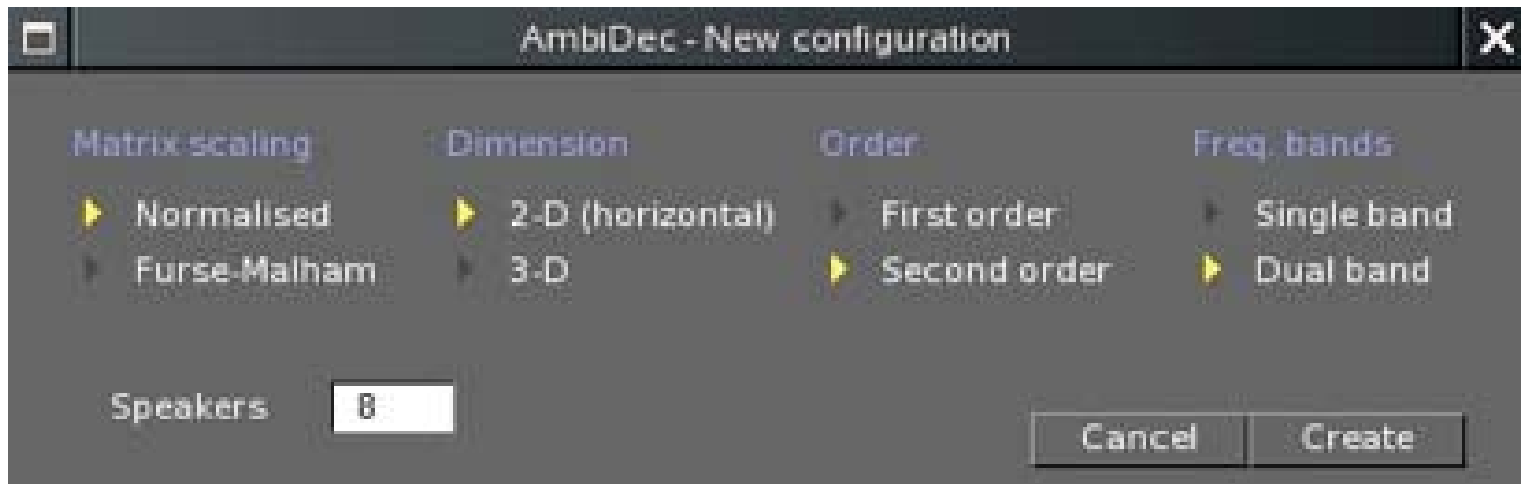
Spherical Harmonics



3rd-order spherical microphone

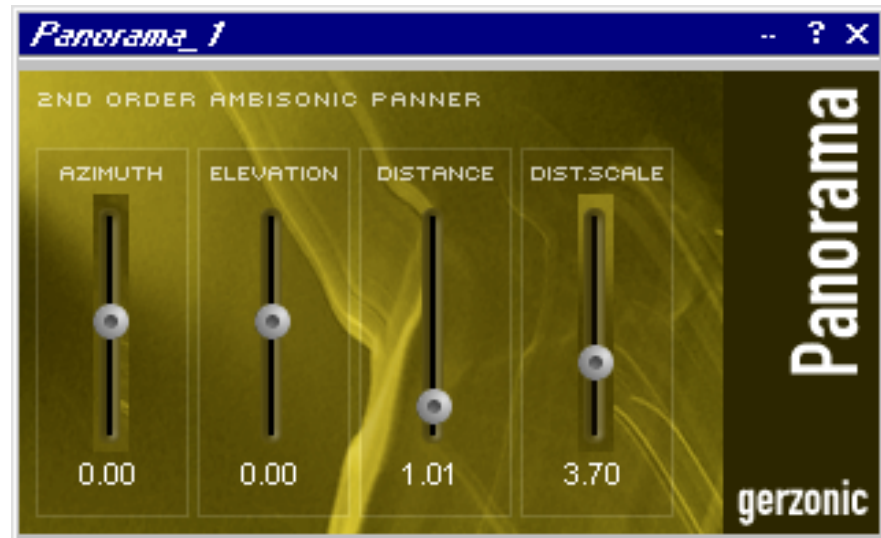
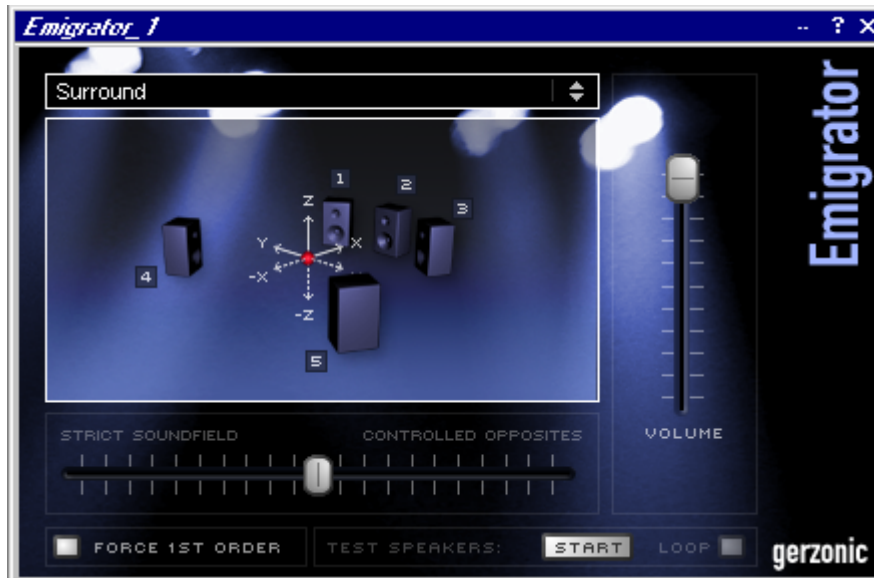


Software for Ambisonics processing



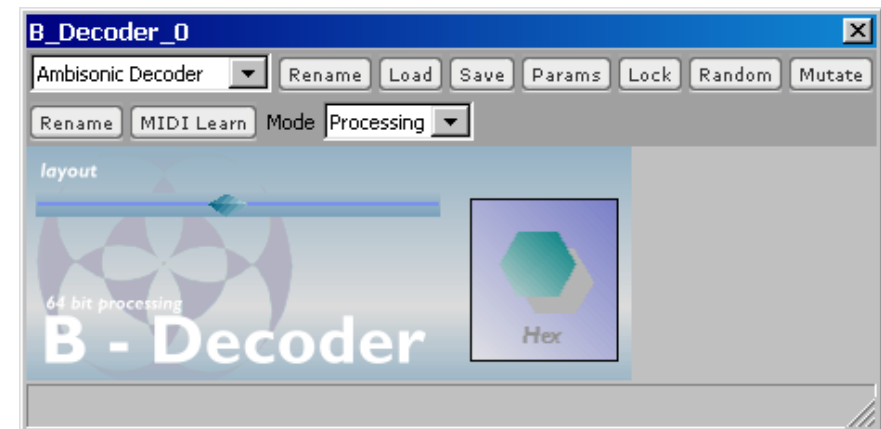
Linux - Jack: AmbiDeco decoder by Fons Adriansen (open source, free)

Software for Ambisonics processing



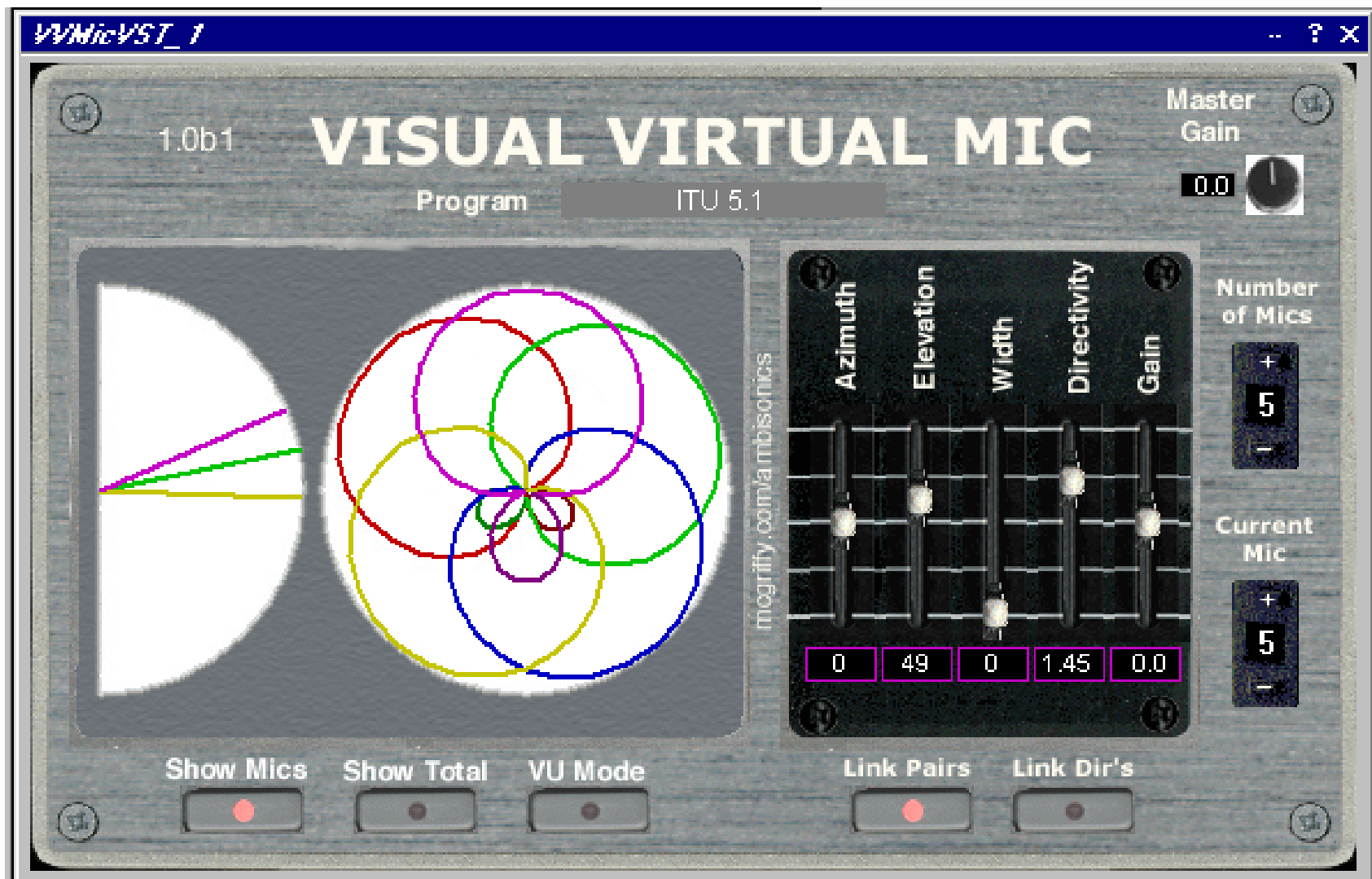
WigAmbiDec_1 -- ? X

Low F Pattern	<input type="text"/>	1.330000	ratio
High F Pattern	<input type="text"/>	1.150000	ratio
Cut off F	<input type="text"/>	500.0000	Hz
Layout	<input type="text"/>	Cube	layout
Distance Comp	<input type="text"/>	None	Metres
Use Spatial EQ	<input type="text"/>	Yes-BothF	Yes/No



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

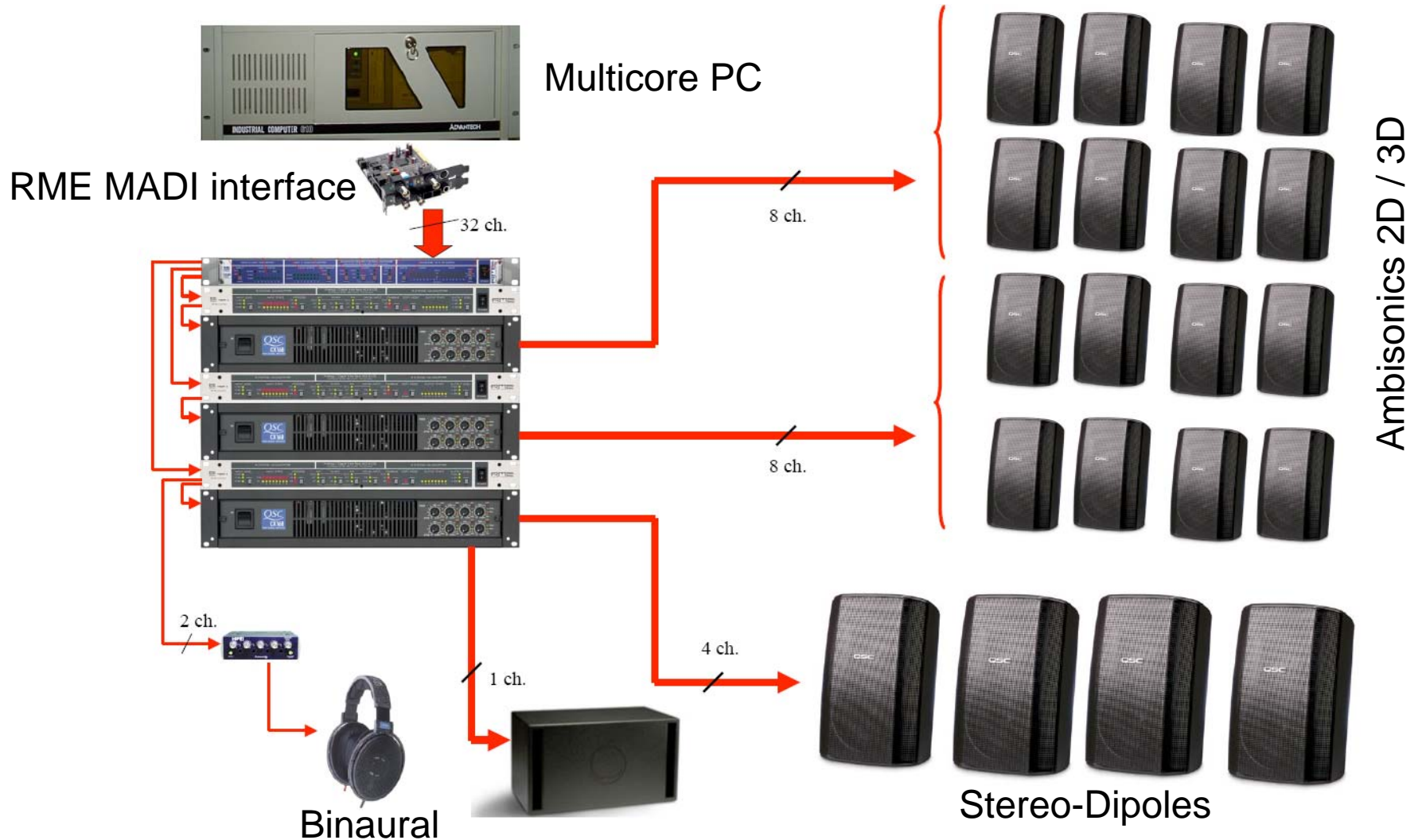
Software for Ambisonics processing



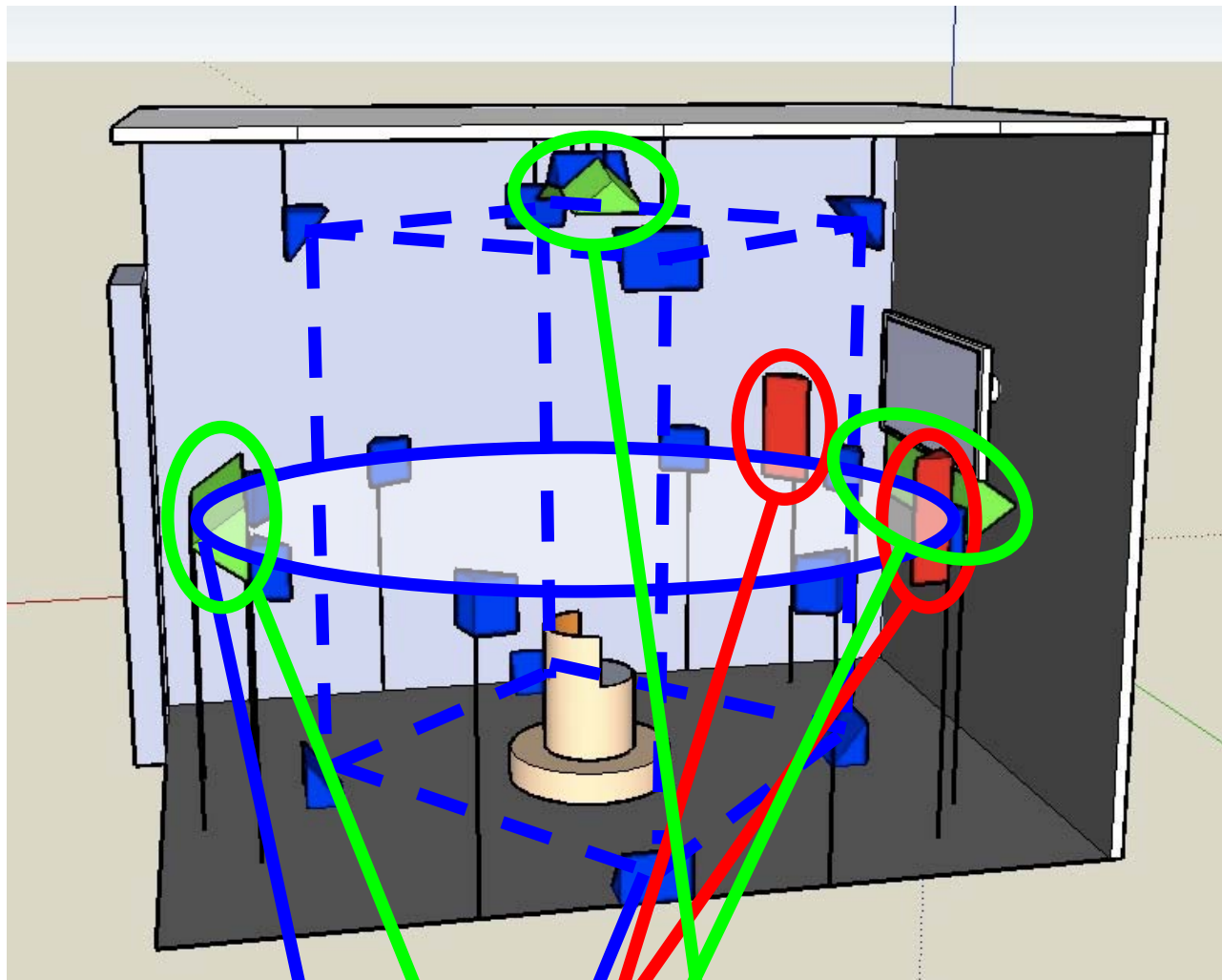
Windows: Visual Virtual Microphone by David McGriffy (freeware)

Low-cost hardware for HOA

- Again, a PC with MADI interface is employed



Locations of loudspeakers



Frontal Stereo-Dipole

Rear

Upper Stereo Dipole

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



Questionario

Soggetto

1 / 8 Nome Angelo Impiego ing.
Cognome Farina Età 48

Prodotto 1 / 6 **1** 2 3 4 5 6 Nome prodotto Fette Biscottate

Sogg. N.	1	2	3	4	5	6	7	8
Prod. N. 1	X							
Prod. N. 2								
Prod. N. 3								
Prod. N. 4								
Prod. N. 5								

Domanda N° 1
Duro Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 2
Friabile Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 3
Crispy Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 4
Crunchy Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 5
Fondente Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 6
Crumbly Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 7
Sticky Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 8
Asciutto Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 9
Pastoso Lineare Per niente Abbastanza Molto Moltissimo

Domanda N° 10
Tempo masticaz. Lineare Per niente Abbastanza Molto Moltissimo

Precedente Successivo Istruzioni Termina

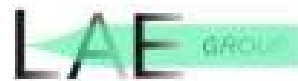
Thanks to:

- Definizione contenuti espositivi e coordinamento:
Alessandro Rigolli (per l'Istituzione Casa della Musica)
- Progettazione allestimento espositivo:
Dario Costi e Simona Melli architetti
- Realizzazione allestimento espositivo:
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 - Gruppo Fallani S.r.l. via Pialoi, 100 Marcon (Ve)
 - Tecno-fer S.r.l. v.le Basetti, 14 Parma
- Progettazione e realizzazione componente acustica (LAE):
 - AIDA srl via G. Sicuri, 60/a Parma
 - Genesis via Benedetta, 83 Parma
 - Audiolink via Monte Prinzera, 17 Parma
- Sistemi informatici: IT City S.p.A. via Traversetolo, 36/a Parma
- Cablaggio:
 - Albacom.Amps Telecomunicazioni S.p.A.
 - Guglielmo srl via Livatino 9 Reggio Emilia
 - Act Parma Srl via Lelio Guidetti 15/A Parma

Thanks to:

- The design and construction of these sound systems have been possible thanks to:

Laboratory of Acoustics and Elettroacoustics (LAE)



www.laegroup.org

Parma