A digitally controlled two dimensional loudspeaker array

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The full staff: LAE and..

- **Paolo Martignon**
  - Project management, geometry and filter design

- **Daniele Torelli**
  - SW development on Linux PC

- **Fons Adriaensen**
  - Consultance on SW, HW and algorithms
  - Wiring design and realization

- **Roberto Zana**

- **Audiolink srl and AIDA srl, Parma**
  - Place, instrumentation, hardware help and consultance

- **Aldo Piazza**
  - Chandelier iron structure realization

10/09/2008
The project: a “sonic chandelier”

- S. Elisabetta church (reverb time 5 sec)
- Sonic chandelier:
  - Moving virtual sources (WFS)
  - Active insulation
Presentation outline

- Wave Field Synthesis concepts, spatial aliasing
- Speakers choice and line array prototype
- 2D array design and realization
- HW description and signal processing scheme
- Filters structure, design and implementation
- Validation test and measurement
Sound focalization by WFS
(Delft University of Technology, 90’s)

Sensible parameters:

\[ \frac{A}{\lambda} \]
Set the beam width.

\[ \frac{\Delta x}{\lambda} \]
Spatial aliasing, secondary lobes.

The front curvature is obtained by means of a gain-delay set..
The spatial aliasing problem

**The spatial Nyquist theorem:**

**Sampling condition:**

\[ \lambda_x = \frac{\lambda}{\sin \varphi} > 2 \cdot \Delta x \]

antialiasing sampling filter

\[ \Rightarrow f_{\text{max}} \leq \frac{c}{2 \Delta x \sin \varphi} \]

**Reconstruction condition:**

\[ \sin \theta_{em} (f) \leq \frac{c}{2 \Delta x f} \]

Omnidirectional  Rigid pistons

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Our choice: single transducer, extended range
A simplified prototype

- 24 channel line array
  - Plays the role of a scale model of the disc, though it is not
  - Diametral section of the disc

- The 3D effect of the disc is projected on a plane
- Algorithm production and testing, speaker testing
Chandellier: design, manufacturing and assembling
Lifting up..
Speakers to channel connection

Frounhofer distance for a group of speaker at 10 kHz is about 4 meters

228 loudspeakers
64 channels

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More on the sound field.

Absorption

1 kHz

500 Hz

1 kHz

2 kHz
The feeding system

64 output channels
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From WFS to filter structure

Common WFS EQ and speaker EQ (mag and phase)

Antialiasing sampling filter

Gains and delays

Antialiasing reconstruction filter

Single speaker relative EQ

Input FIR

Array shape

Dynamic delays-gains matrix, Output FIRs

Speaker directivity

Output FIRs

Gain-Delay couples

S x 64

FIR 1
FIR 2
... 
FIR S

Space control

256 taps

Ch 1
Ch 2
Ch C

Inverse filtering...
concave
main focus
convex

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4096 taps
Output FIR design

Inverse filtering (Ole Kirkeby)
Input FIR design
From filter to SW structure

Input FIR

Array shape

Dynamic delays+gains

Speaker directivity

Output FIRs

“WFS focus” SW

WFS focus SW

Brutefir

input FIR dynamic gains and delays

“WFS focus”
By Daniele Torelli and Fons Adriaensen

S1
S2
... S5

64 Ch
64 Ch
64 Ch
64 Ch

BRUTEFIR
By Anders Torger

MADI OUT

64 Ch

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Moving the focus: “WFS focus” concept

- **Input FIR convolution, SR = 48 kHz**
- **Sample rate doubling, 96 kHz**
- **DYNAMIC FRACTIONAL DELAY and GAINS**

**Output FIRs**

64 Ch

**Spatial information**

Effect of a fractional delay with linear interpolation.

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User interfaces

MADI inputs (external sources)

MIDI controller

OSC

“WFS focus”

“WFS focus”

“WFS focus”

Mono signals

Audio application, I.E. “ARDOUR”

ARDOUR “WFS focus” plugin

Spherical coordinates centered on main focus → fractional delay and gains

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Results

• Precise and smooth, “click” free sound moving
• Appreciable Doppler effect
• “Objective” sound scene
• Good distance perception
• 22 dB decay at medium frequencies between the center and a peripheral point 5 m distant (center of one shell). Tested with filtered pink noise.
• Very sensible increasing of the active insulation with people beneath the array

10/09/2008
Thank you!