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Active Control of Room Acoustics, and Public Address in Large Volumes

*Acoustique active et
sonorisation des grands volumes*

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B-2 Geometrical and Electronic line arrays

B-3 The DGRC technology

A-1 What should be achieved

Active Acoustics differs from PA :

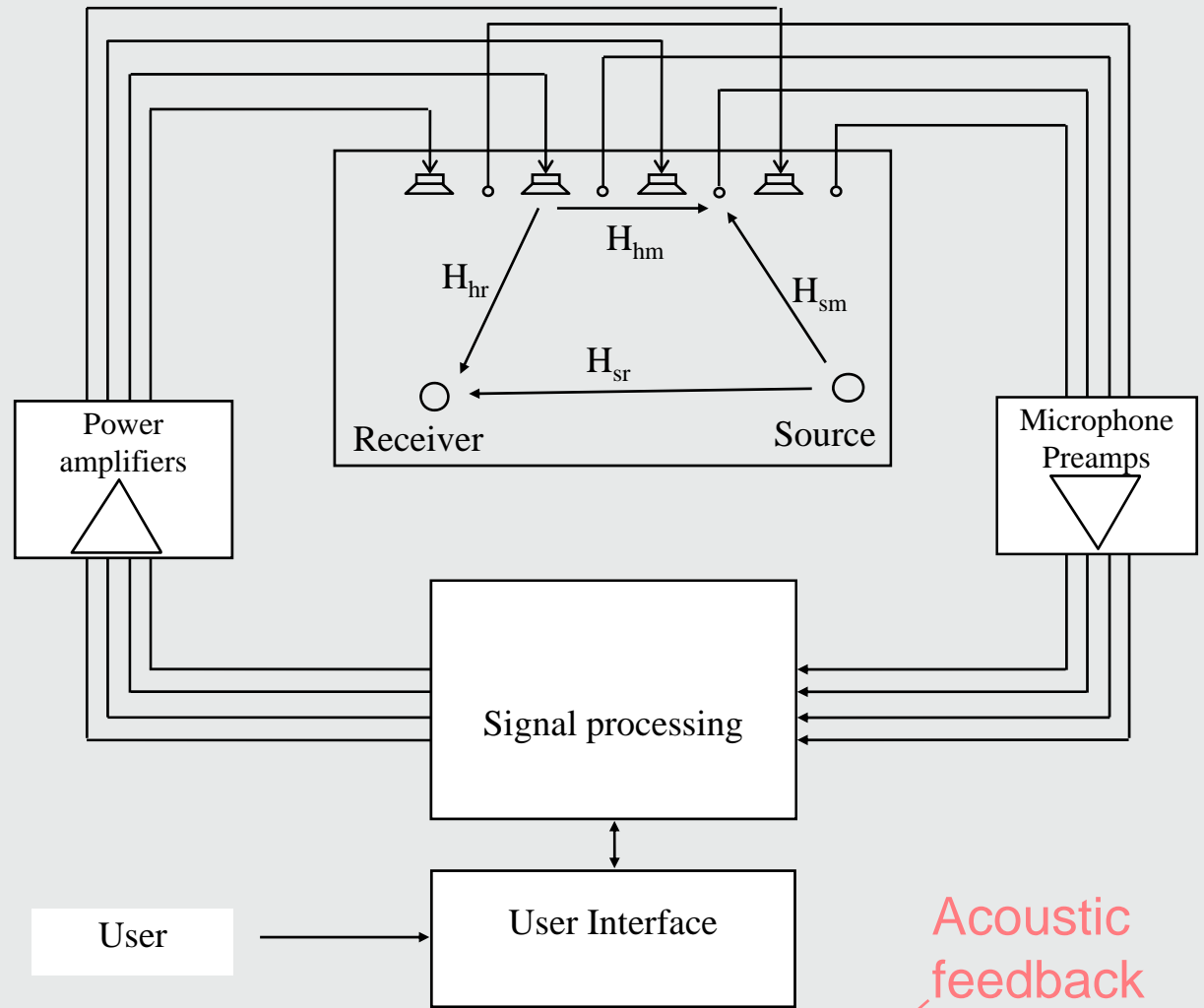
- listeners and performers must have **impression of natural acoustics**

Active Acoustics should provide **acoustic variability** :

- reinforce direct sound (theatre, conference)
- extend time and/or level of reverberation (concert, opera)
- control of early reflections
- enhance acoustics on stage

It should be easy to use, reliable, **robust to acoustic changes**

A-2 Basics

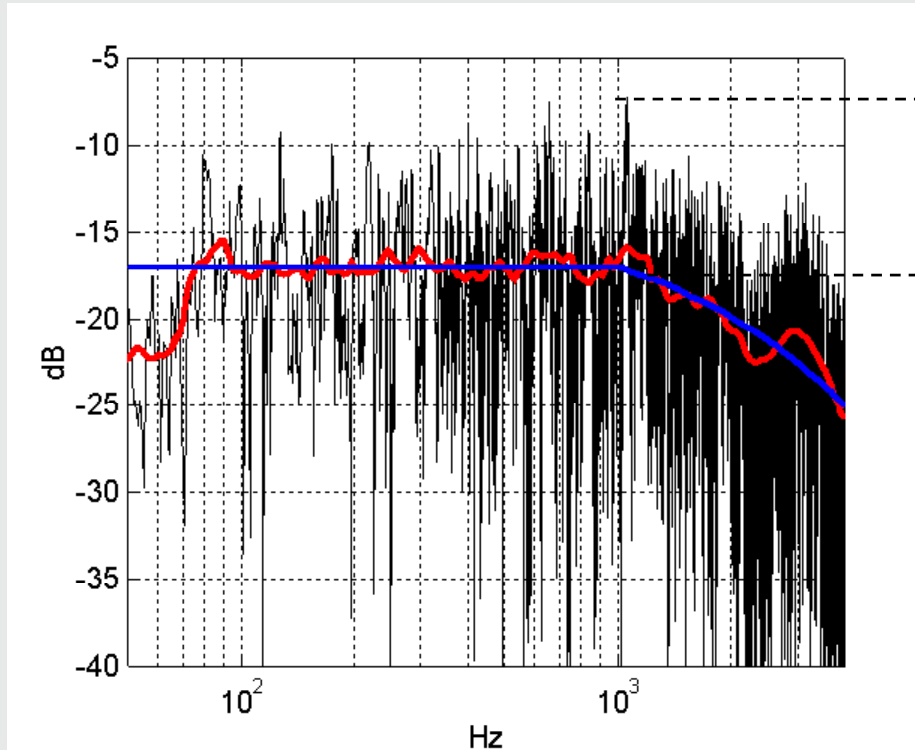


Transfer Source \rightarrow Receiver : $H_{tot} = H_{sm} + H_{ea}$

Contribution of system : $H_{ea} = H_{hr} \cdot (I - G_{mh} \cdot H_{hm})^{-1} \cdot G_{mh} \cdot H_{sm}$

Acoustic feedback

A-2 ...Basics

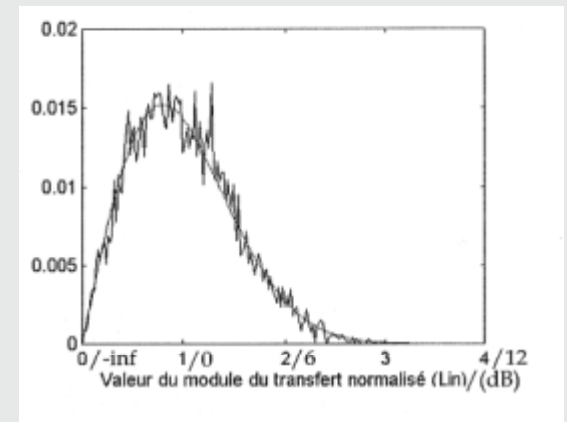


≈ 11 dB

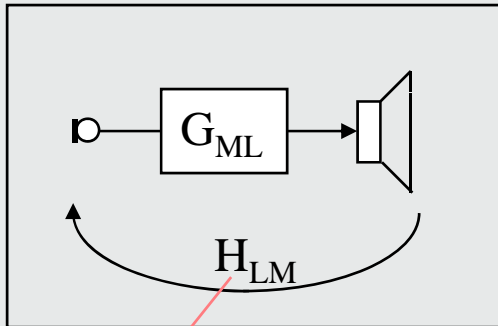
$$\sigma_n = \frac{\text{std}}{\text{mean}} = 0.523$$

Open loop Transfer function (equalized)

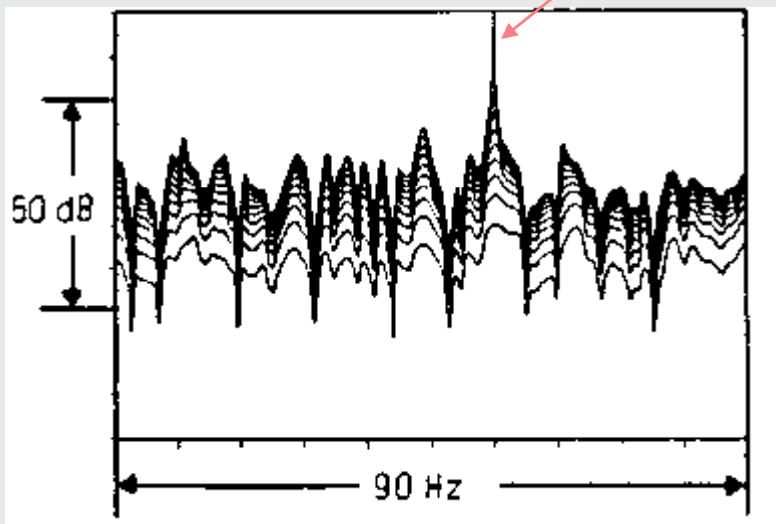
→ Rayleigh distribution



A-2 ...Basics



Feedback → coloration



$|G_{ML} \cdot H_{LM}|$ versus gain

→ 6 dB margin → $\Delta RT = 1\%$ / channel

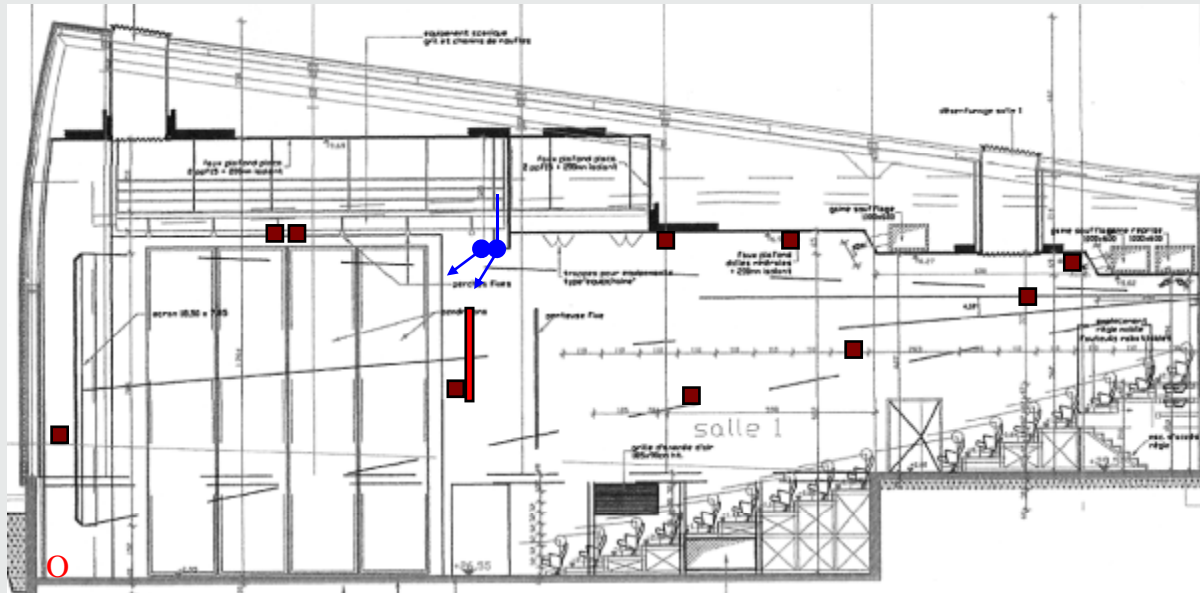
Regenerative systems need large number of channels (30 to 100)

A-2 ...Basics

Non-regenerative (In-line) systems :

- Use of directional microphone close to stage
- Use of electronic reverberation and time-variant filters
- Limited number of channels

Nota : **Acoustic feedback is never negligible in practice**



SSA - Lausanne, 30-10-08

A-3 Brief history

1965 : Assisted Resonance

1983 : MCR Philips

ACS, SIAP, LARES, RODS, Carmen...

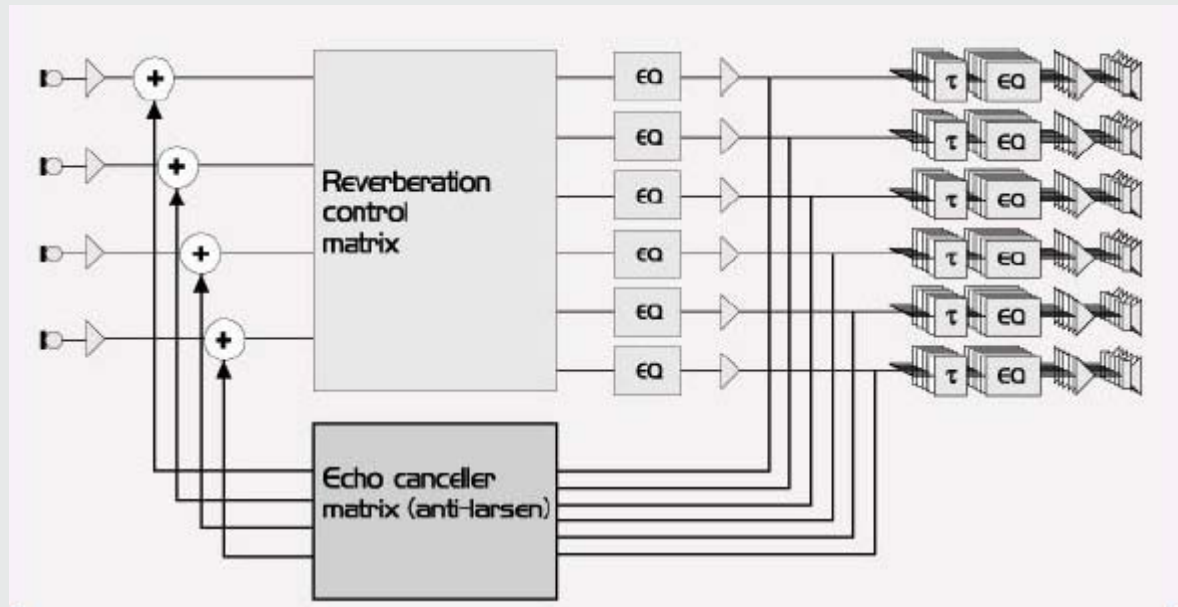
Still **very few systems installed and used** :

- too much coloration, pb with reliability and robustness
- sometimes difficult for musicians to accept « electronic »
- sound technicians are confused with PA.

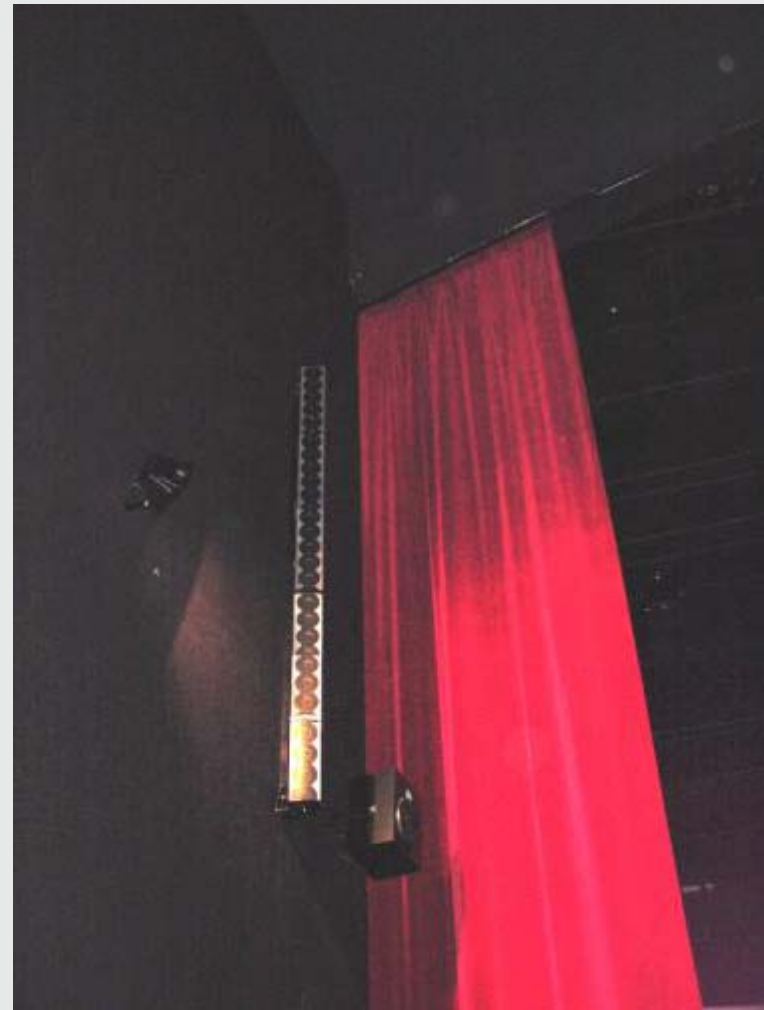
2006, new technologies : ASR, Constellation (VRAS)

A-4 The ASR system

- In-Line system
- **Echo cancellers** → reduce feedback → increase gain per channel → less channels → reduced cost
- Directional loudspeakers for **direct sound reinforcement**

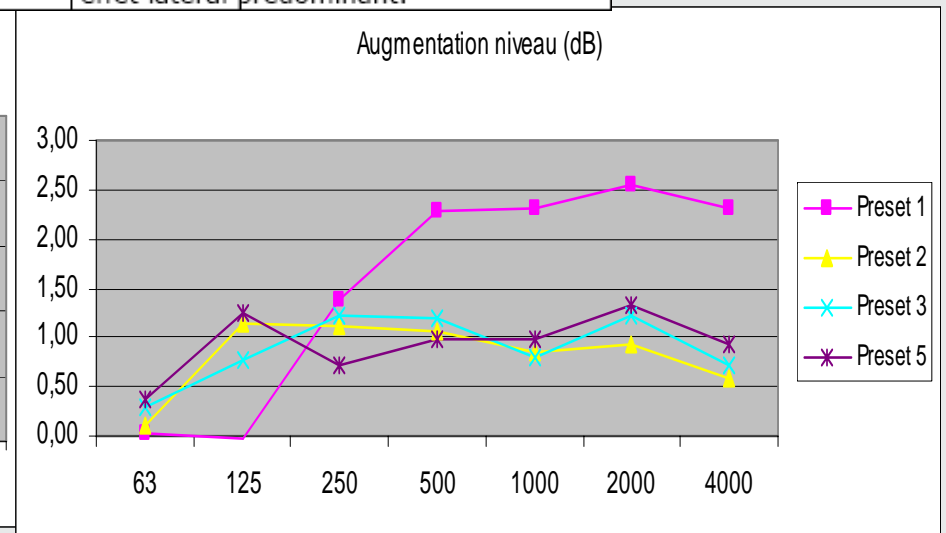
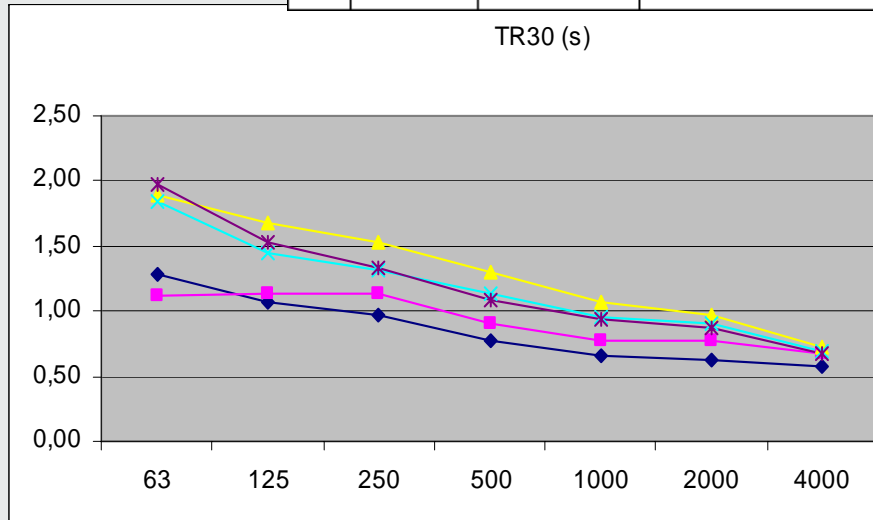


A-4 ...The ASR system



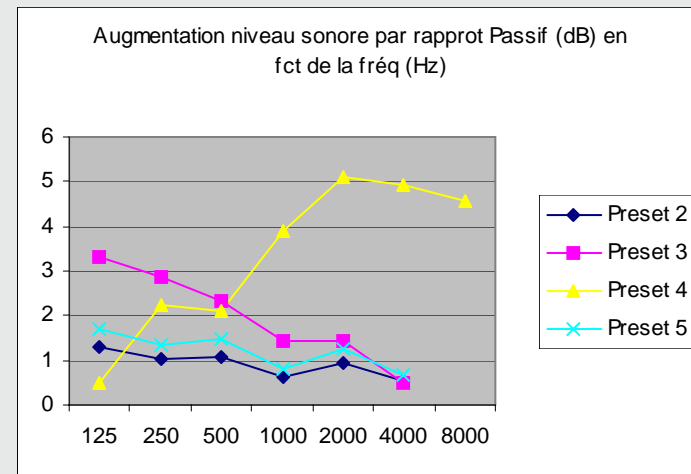
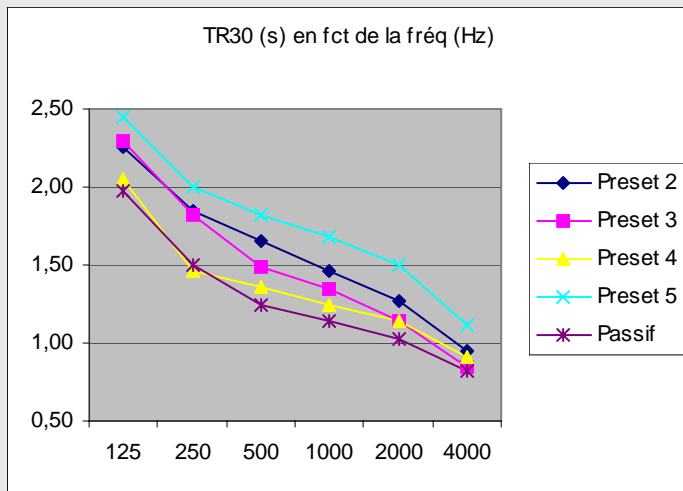
A-4 ...The ASR system

N°	Jeu Annu-lateurs	Nom	Usage	Caractéristiques
1	0	Théâtre	Théâtre, conférence	Renfort de son direct uniquement. Seules les colonnes fonctionnent.
2	1	Orchestr	Musique orchestrale, chorale	Fort renfort de réverbération. Accentuation du grave. Réverbération spatialement homogène. Accentuation de l'acoustique de scène et du retour salle → scène.
3	1	Recital	Musique de chambre, petits ensembles musicaux	Renfort de réverbération moyen. Effet latéral prédominant en salle. Accentuation de l'acoustique de scène et du retour salle → scène.
4	-	Diffus	Diffusion d'annonces vocales ou de musique de fond	Le signal doit être appliqué sur l'entrée ligne gauche.
5	1	Chanson	Chanson ou petits ensembles	Léger renfort de son direct. Léger renfort de réverbération, avec effet latéral prédominant.



A-4 ...The ASR system

N°	Nom	Caractéristiques principales
4	Théâtre	Renfort d'intelligibilité
3	Latéral	Joue sur la largeur de source, l'enveloppement (effet spatial). Peu d'augmentation de réverb. Pour petits ensembles, jazz, musique de chambre...
2	Sympho_1	Augmentation réverb, balance tonale vers grave. Largeur de source. Pour orchestres.
5	Sympho_2	Encore plus de réverb. Pour musique romantique, chœurs



B- Public Address in large volumes

B-1 What should be achieved

B-2 Geometrical and Electronic line arrays

B-3 The DGRC technology

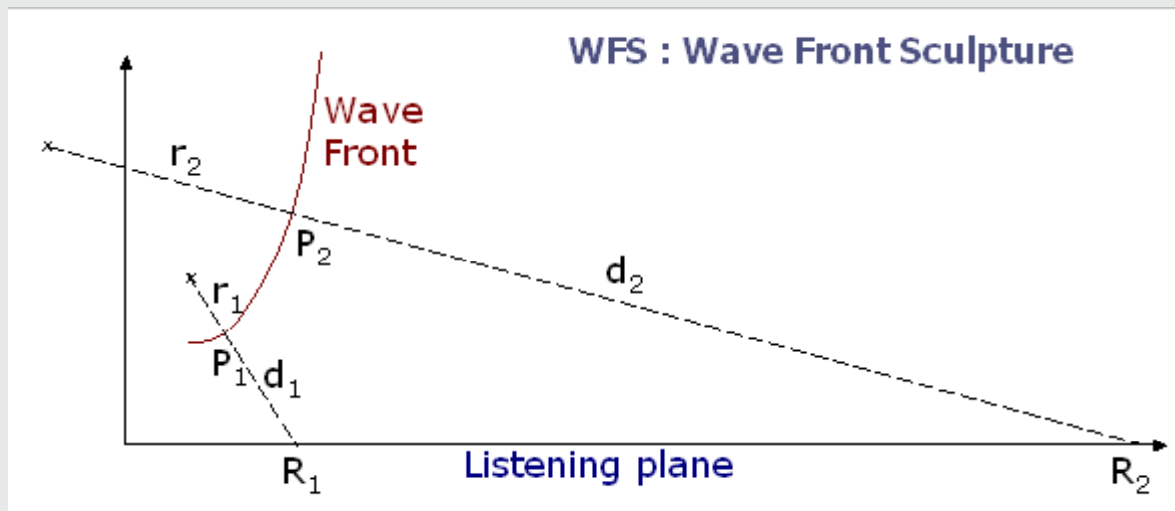
B-1 What should be achieved

- Good **speech intelligibility**
- Acoustical comfort
 - Even coverage of the listening area
 - clear sound, large bandwidth, low THD
 - Adequate SPL
- For Live speech :
 - Good source localization of live speech
 - Low feedback on microphone for reduced risk of Larsen
- Pleasant aesthetics
- Ease of installation and tuning

For railway stations & airports, spaces of worship, amphitheatres, conference rooms, multipurpose rooms, gymnasiums, museums...

B- 2 Geometrical and Electronic line arrays

Loudspeaker arrays → Uniform SPL
 Strong direct sound → intelligibility
 Low visual impact

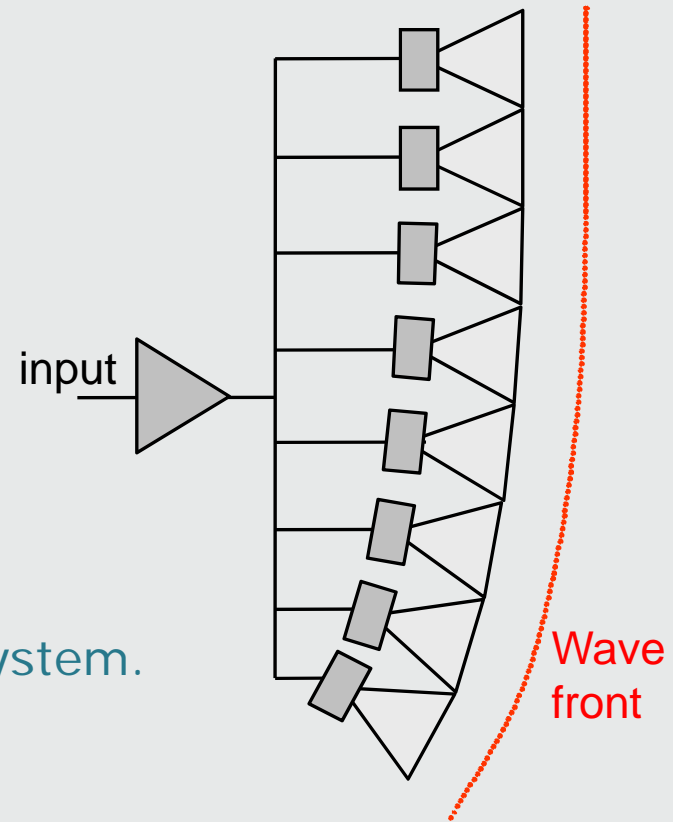


- Geometrical attenuation from P_i to R_i :
 Vertical Plane : $A_v = \sqrt{r / (r+d)}$
 Horizontal Plane : $A_h \approx 1 / \sqrt{d}$
 → $A_{tot} \approx \sqrt{r / (d \cdot (r+d))}$

B- 2 ...Geometrical arrays

Loudspeakers along the desired wave front → J shape.

- ☹️ → Cannot be mounted on a wall
- 😊 Line source when using wave guides
→ almost no secondary lobes at HF.
- 😊 All loudspeakers receive same signal
→ good match and max SPL output.
- ☹️ Need very accurate positioning
of Loudspeakers
→ sophisticated mechanical hanging system.
- ☹️ No flexibility on directivity tuning



B- 2 ...Electronic arrays

Loudspeakers on vertical line (column) + delays + FIRs

☺ → Can be mounted on a wall.

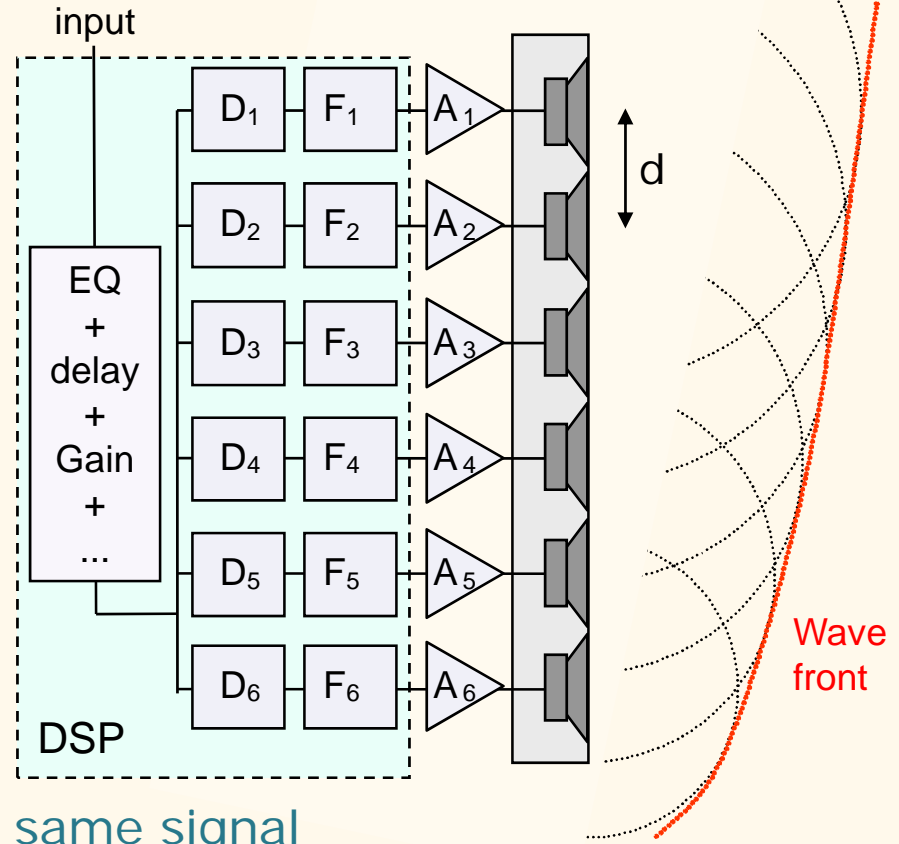
☺ DSP → flexibility of control, EQ, delay, AGC, ...

☺ Directivity tends to be symmetrical about vertical axis → backward lobe points down.

☹ Spatial sampling → Lobes at HF ($f > c/d$)

☹ Needs high nb of channels → cost

☹ Loudspeakers may not all receive same signal → Lp mismatch, lower SPLmax



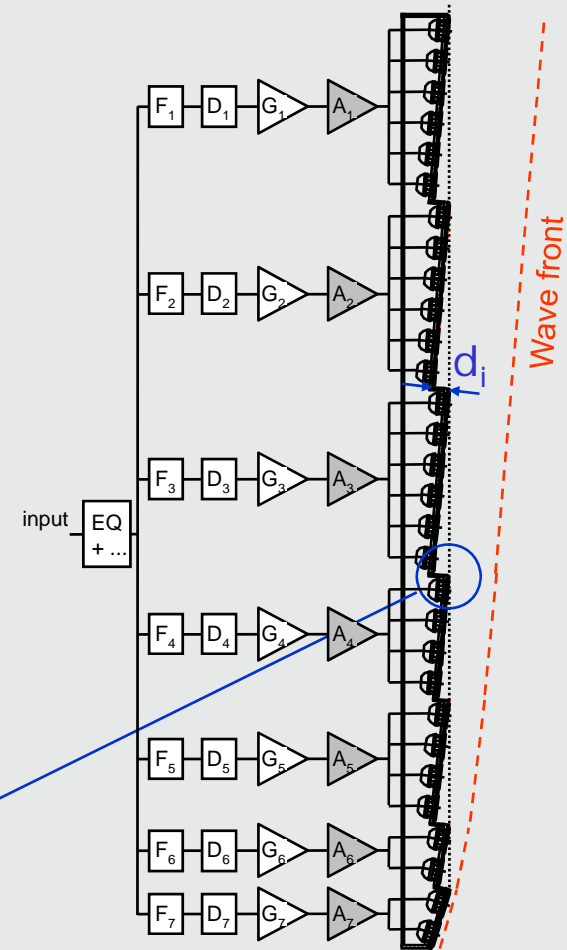
B-3 The DGRC technology

DGRC : Digital and Geometric Radiation Control

- 1- Determine nominal wave front
- 2- Chop it in sections, and align sections on vertical line
- 3- place loudspeakers on sections
- 4- use DSP for Gains, Delays, Filters...

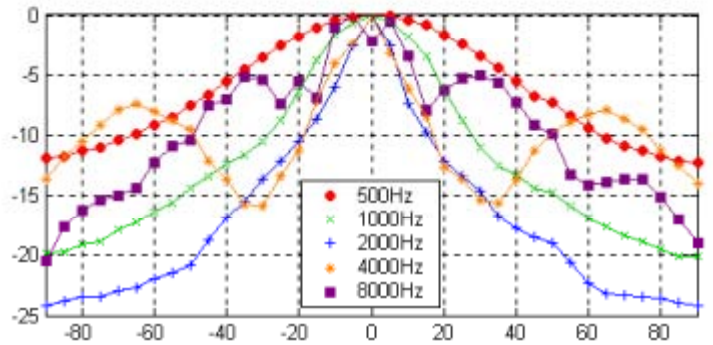
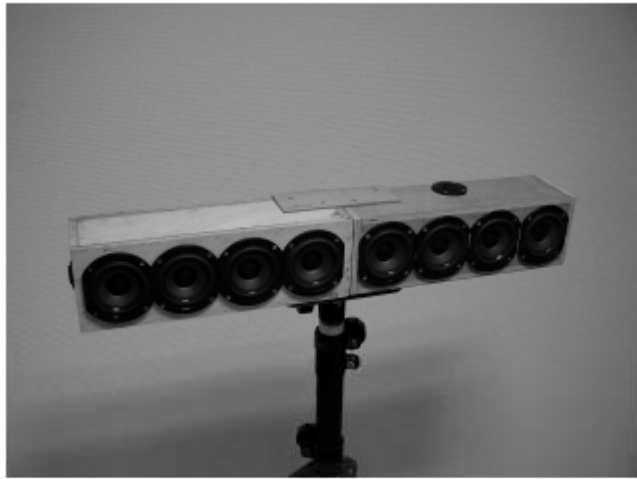
$$D_n = \frac{1}{c} \cdot \sum_{i=1}^{n-1} d_i \quad \text{for } n \geq 2$$

What about diffraction at edges ?

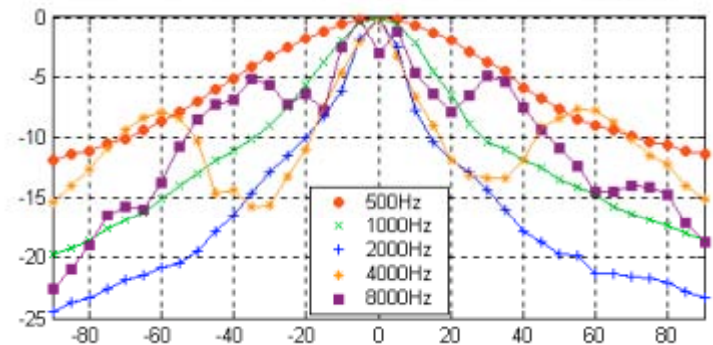
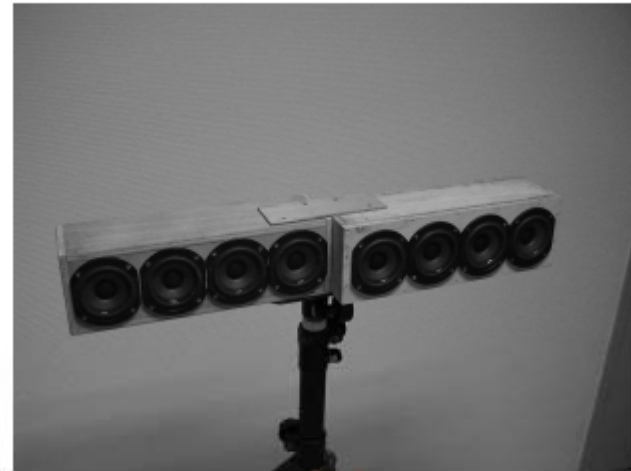


B-3 ...The DGRC technology

Without edges



With edges



Directivity in horizontal plane (°)

→ Diffraction is negligible

B-3 ...The DGRC technology

Advantages

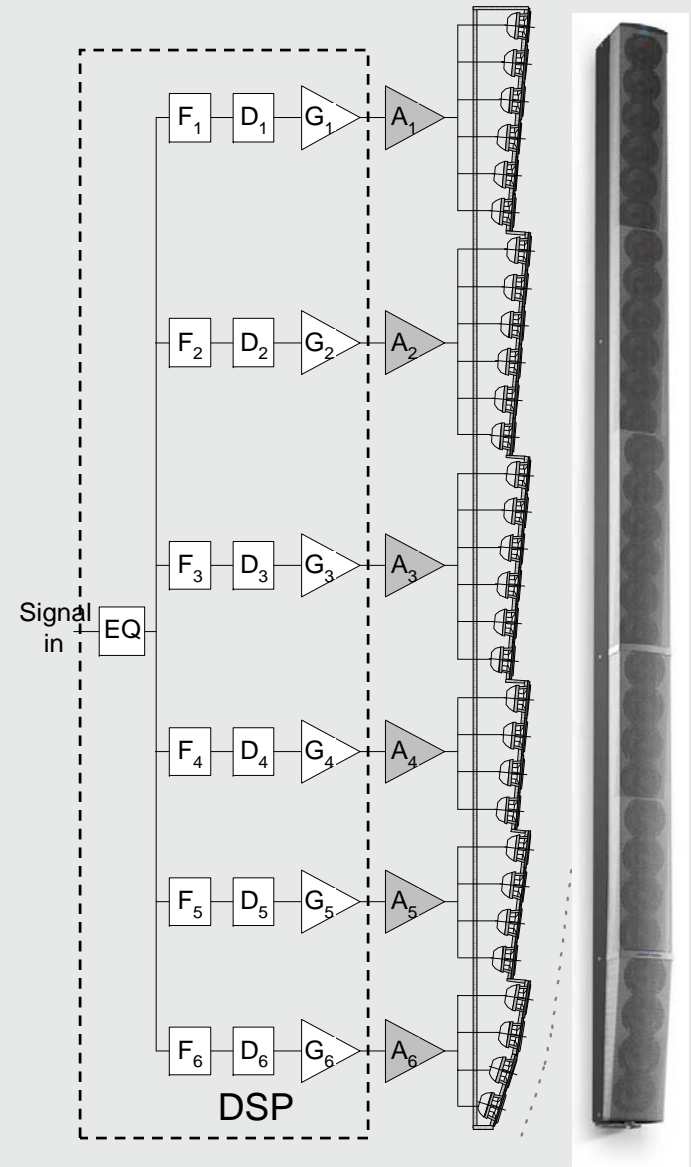
- The number of DSP / amp channels is dramatically reduced
→ low cost.
Example : 2,5m column, section 120x120 mm : 6 channels.
- Nb of channels doesn't depend on nb of loudspeakers
⇒ large nb of loudspeakers
→ clean HF restitution, reduced secondary lobes.
- Orientations of loudspeakers → better HF directivity control.
- Power evenly distributed on loudspeakers
→ good match between loudspeakers, optimised SPL max.
- Principle is applicable to line sources.

B-3 ...The DGRC technology

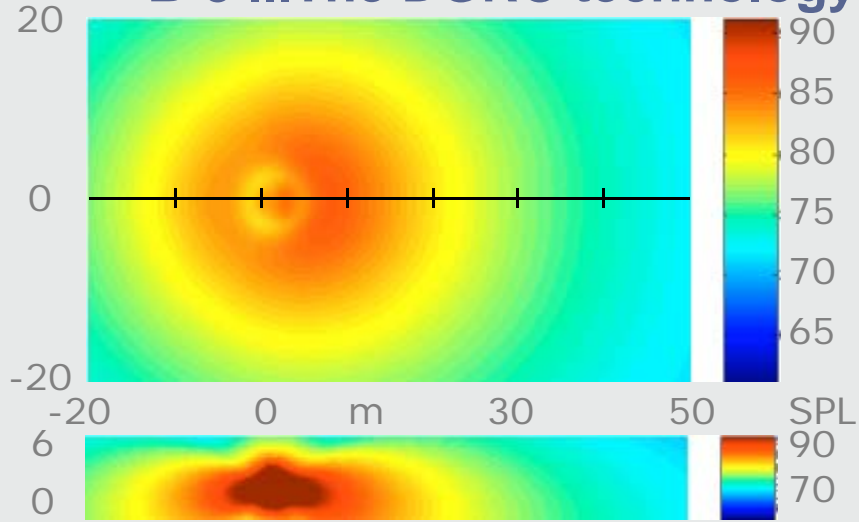
StepArray SA250P : 2,50 m

6 channels, 30 loudspeakers,
3", 2 g moving mass

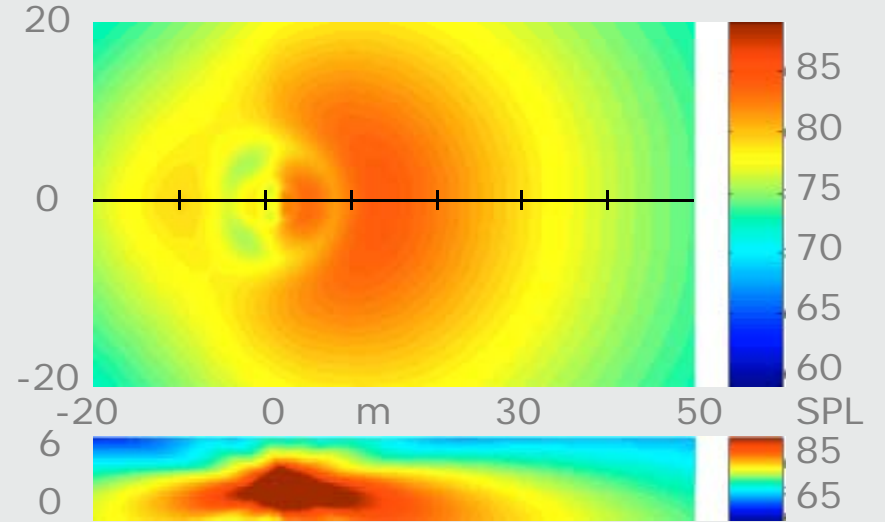
bottom is 1,0m from listening plane
(nominal).



B-3 ...The DGRC technology

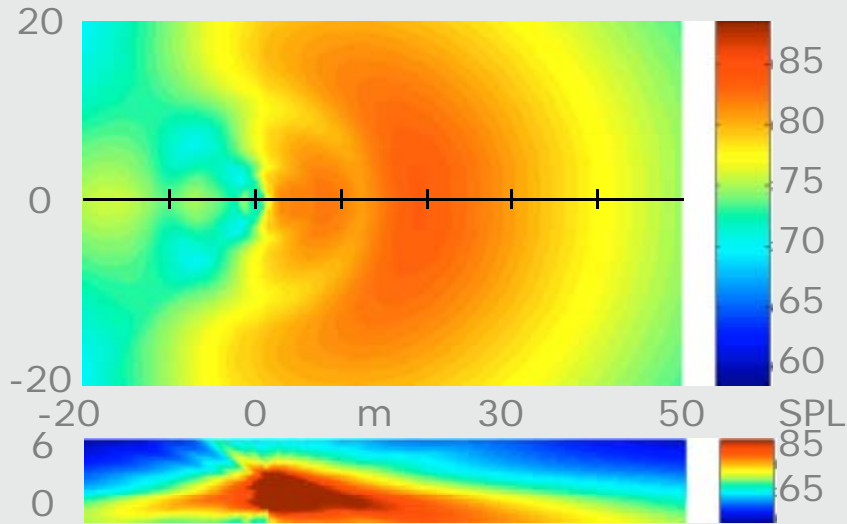


Octave 250Hz

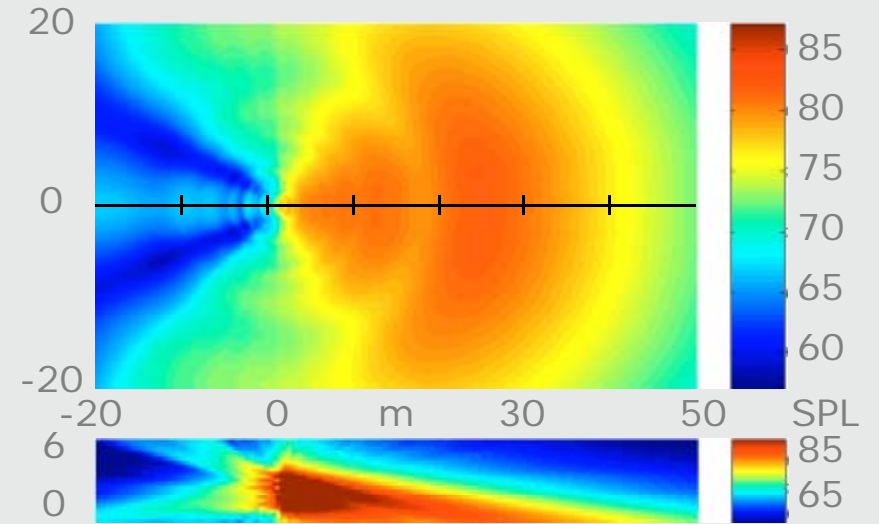


Octave 500Hz

Column SA250P

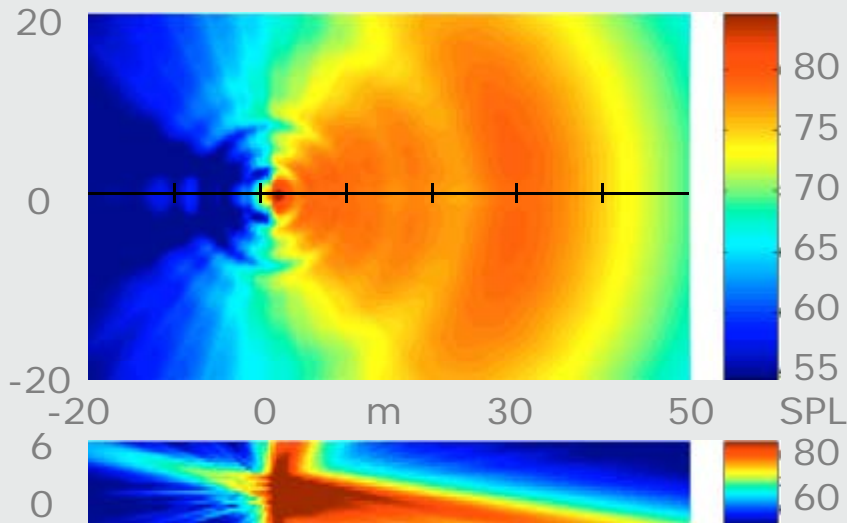


Octave 1000Hz

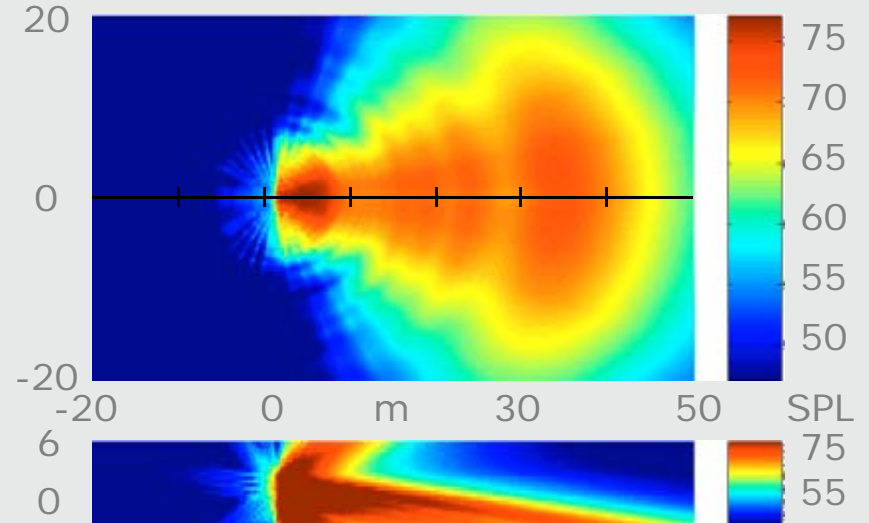


Octave 2000Hz

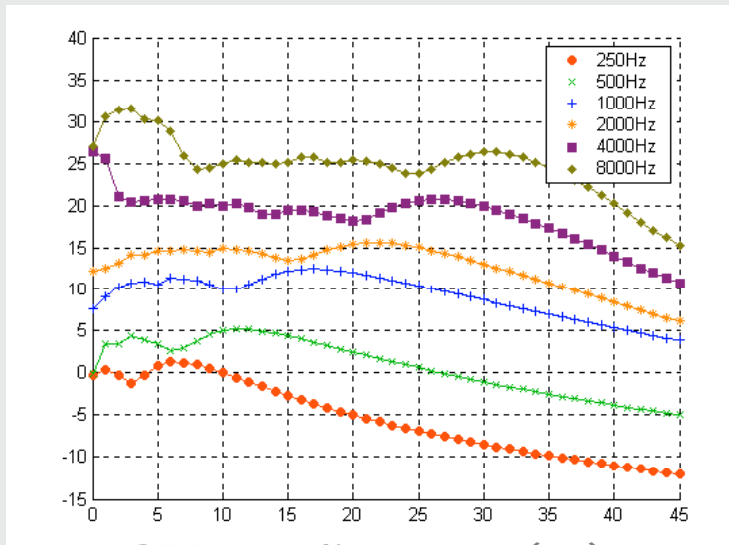
B-3 ...The DGRC technology



Octave 4000Hz



Octave 8000Hz

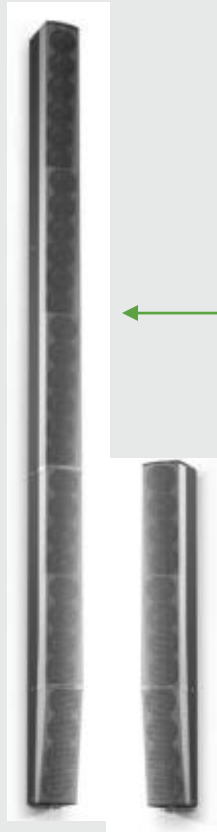


SPL vs distance (m) SSA - Lausanne, 30-10-08

SPL simulations

Range : 37 m
(500Hz-2kHz, +/- 3dB)

B-4 The StepArray range



SADrive control PC software



Columns SA100P, SA250P, SA250S, SA180P

UT26 processor



SSS option

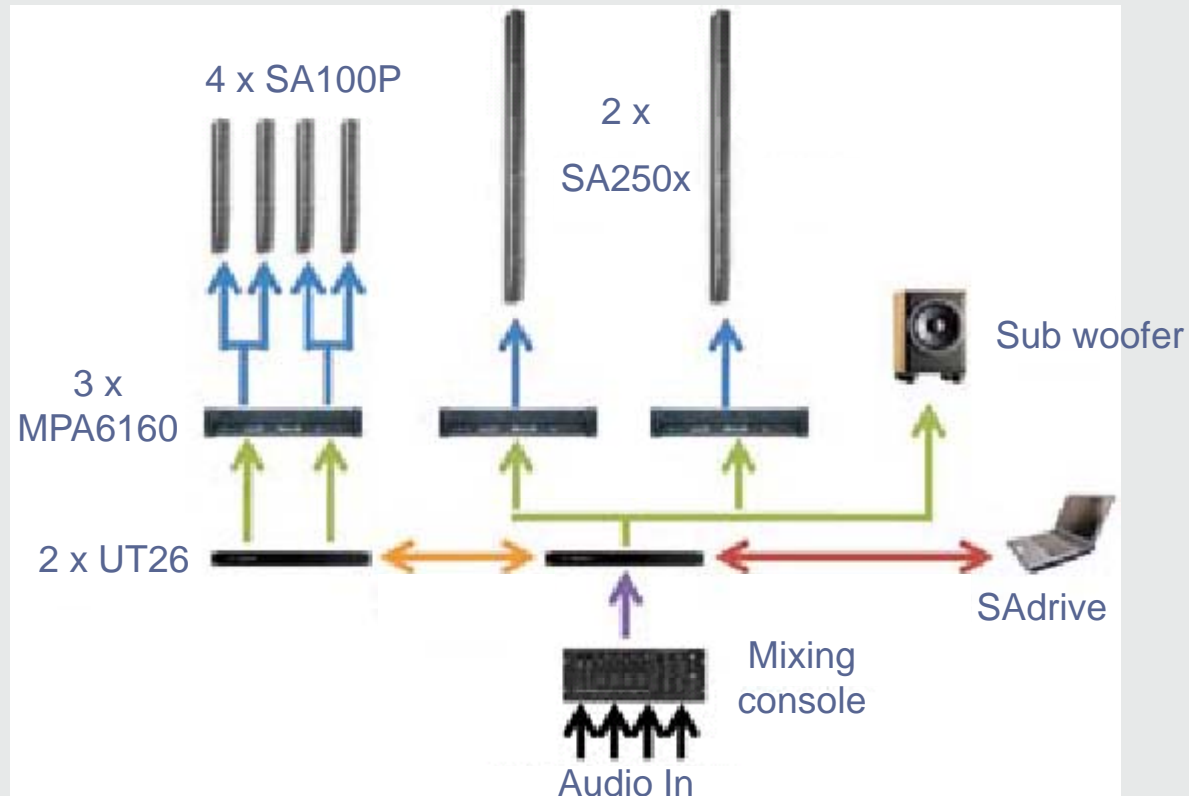


MPA6150 amplifier

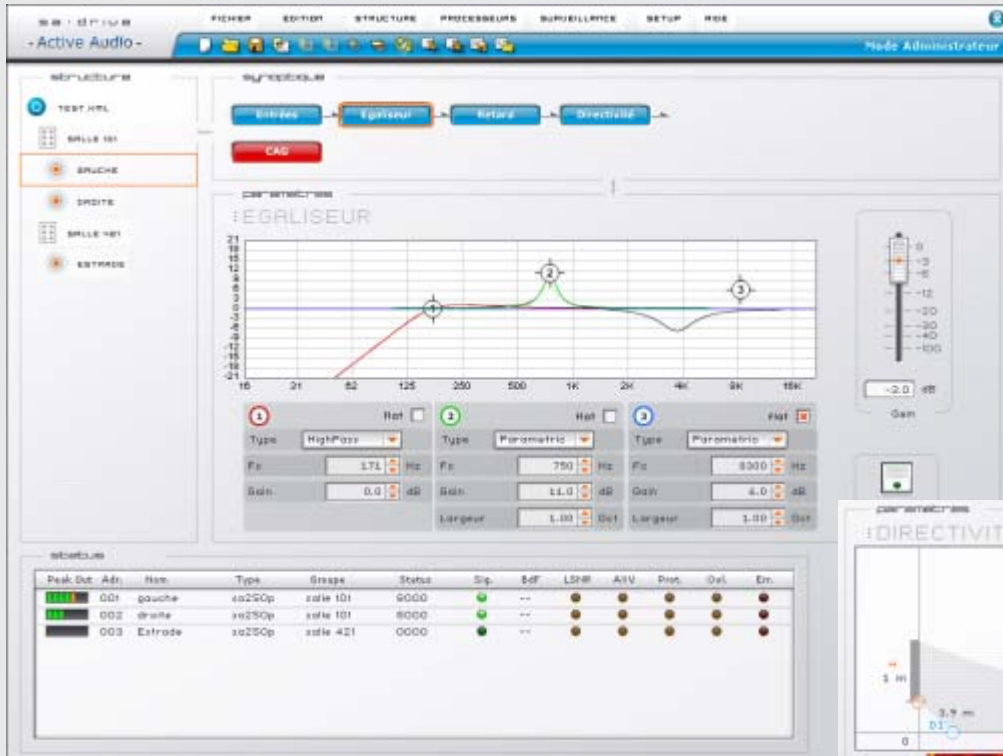


B-4 ...The StepArray range

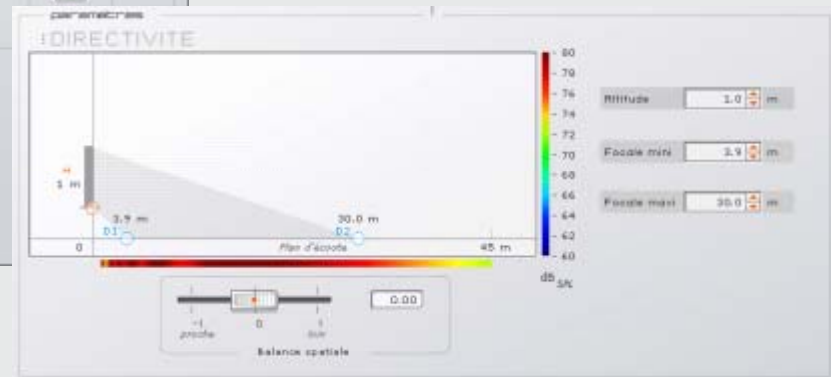
External processing and amplification → cost effectiveness



B-4 ...The StepArray range



SAdrive control software



Directivity control

B-4 ...The StepArray range



SSA - Lausanne, 30-10-08