Electronic Architecture

Bjorn van Munster
SIAP Acoustic Systems

Variable acoustics

- Adapting the acoustic environment in order to accommodate different types of performance

Variable acoustics Approaches

- Two technical approaches:
  - Mechanically
    - Architecturally adjusting the physical dimensions and surfaces in a space to suit performance requirements
  - Electronically
    - Electro-acoustically introducing reflections and reverberation to suit the performance requirements

Variable Acoustics

Mechanically

- Possibilities:
  - Moveable reflectors
  - Retractable / sliding curtains
  - Orchestra shells
- Drawbacks
  - Expensive
    - Elaborate installation
    - Large building volume
  - Sometimes Impractical

Variable Acoustics

Electronically

- Acoustic enhancement system
  - No effect on aesthetics
  - Less building volume
  - High flexibility
  - High sound quality
  - Extra features

Expectations

- In recent years, both performance spaces and audio systems have increased in complexity, due to improved materials and electronics, especially DSP
- Audiences and performers are now expecting
  - Clear intelligible speech
  - Tonally balanced music
  - Uniform coverage in the seating area
  - Envelopment

Natural vs Enhanced Sound?

- Natural sound is created by a multitude (hundreds of thousands) of early decorrelated reflections and reverberation
- The goal of an enhancement system is to mimic these natural reflections with hundreds of virtual reflections
- Early enhancement systems have attempted to simulate natural sound, using resonant systems, very small number of time-variant recirculated filters, a mix of early reflections and recirculated energy from the reverberant field
- Much progress has been made using these simulations, however, natural sound does not involve feedback or regeneration and the DPS has come to the rescue
- Today, the continuously evolving power of DSP processing allows the digital generation of hundreds of FIR filters, containing time-constant, decorrelated, frequency dependent, early reflections and reverberation, which can be convolved with the direct sound picked up from the stage

Sound Reinforcement

- Sound Reinforcement:
  - Takes a blended sum of all microphone and direct instrument inputs and provides amplification and uniform coverage to all areas of a venue
  - This approach in effect overwhelms the natural acoustics of the space

Sound Enhancement

- Electronic enhancement systems are designed to electro-acoustically alter the acoustics of a space
- This enhancement occurs by providing virtual reflections and/or reverberation
- This enhancement is intended to improve the natural acoustic condition of the space to improve intelligibility or music quality
- They do not generate sound, but pick up sounds in the space, process them and feed the processed sound back into the space to enhance the performer’s and/or audience’s experience
- They cannot reduce reverberation
- They are best used in spaces where acoustical problems are first corrected
- Once the natural acoustics are corrected, electronic architecture can be used to provide a level of acoustical flexibility in the nature of the acoustical environment that is not practical or possible with architectural solutions

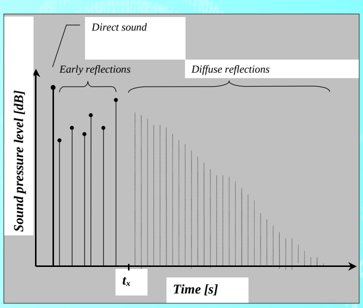
What is Enhancement?

- The basic concept of all electronic architecture systems is that a series of strategically placed microphones pick up sound generated within a space. This sound is then processed (convolved with FIR filters as in an auralization) and fed back into the space as additional reflections and reverberation
- Time variance has traditionally been used to minimize feedback by decorrelating the path between microphone and speaker in real time and stabilize the system, but today time-constant decorrelation, with a large number of decorrelated signal paths, can also be used
- The processing of the signal and the room locations at which the signal is picked up are what differentiate the various design approaches, all attempting to provide flexibility, while remaining stable and free of coloration
- The predominant sound is the acoustic signal from the stage with a system gain of up to 3 dB, depending on the application
- High quality hardware is vital and the system must be free of resonances, because there is a continual real time acoustic/enhancement comparison being made by the performers and audience

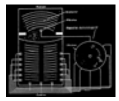
In-line vs Feedback Systems

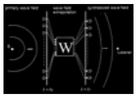
- In-line Systems:
  - These systems only pick up the direct sound energy from the stage and convolve the sound with electronically generated early reflections and reverberation (FIR filters)
  - They are independent of the reverberation of the room
  - Early reflections and reverberation come from the same "softspeaker", i.e. each speaker is inaudible!
- Feedback or Non In-line Systems:
  - These systems use microphones in the room that pick up the reverberant sound energy of the room for recirculation through acoustic feedback
  - Hence, they rely on the sound energy in the acoustical environment to provide enhancement
  - If acoustical problems are present, they can get magnified
- Combination:
  - These systems use a combination of the in-line approach for early reflection generation and the feedback approach to provide reverberation

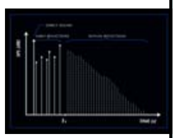
Acoustic Enhancement

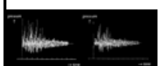


- Early reflections (10-50 ms):
  - Fill in missing reflections
  - Affects e.g. ASW | EDT | Speech intelligibility
- Reverberant (late) reflections (after 50 ms)
  - Affects e.g. Reverberation time/level | Envelopment | Tonal balance







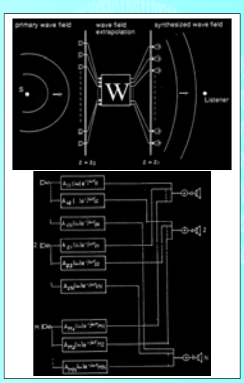


- Ancient Greek / Byzantines
- 1950 — Delay systems on tape
- 1960 — Resonance / Recirculation
- 1970 — Tapped reverberance
- 1980 — DSP based reverbs
- 1990
- 2000 — Complete in-line FIR systems and Combination approaches

History of Enhancement

- Historic Approaches
  - Ambiophony (Vermeulen,1954)
  - **A**ssisted **R**esonance (Parkin, 1960)
  - **M**ultiple **C**hannel **R**everberation (Franssen, 1968)
  - **E**lectronic **R**eflected **E**nergy **S**ystem (Jaffe, 1970)
  - **R**everberation **O**n **D**emand **S**ystem (Barnett, 1985)
- Systems Available Today
  - **A**coustic **C**ontrol **S**ystems (Berkhout, 1988)
  - **L**exicon **A**rtificical **R**everberation **E**nhancement **S**ystem (Griessinger, 1990)
  - **S**ystem for **I**mproved **A**coustic **P**erformance (Prinssen, 1991)
  - **V**ariable **R**oom **A**coustic **S**ystem (Poletti, 1998)
  - CARMEN (Vian, 1998)
  - **A**ctive **F**ield **C**ontrol (Yamaha, Kawakami, 2000)

ACS

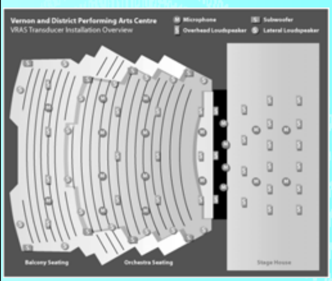


- The ACS system typically has 24 to 36 microphones close to the source (5 - 6 m)
- Reflection simulation units are provided by analog bucket-brigade delays (may have evolved to DSP)
- Each microphone covers a small part of the stage area, such that the array as a unit covers the entire stage area and picks up as little reverberant sound as possible
- The ACS system is inherently time variant

LARES Concept

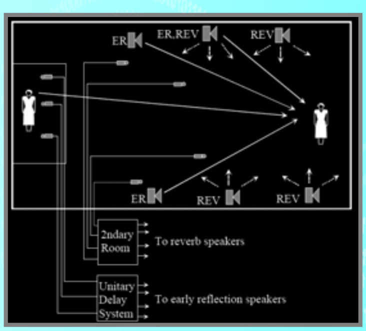
- The LARES system uses a time varying technique and feedback to decorrelate signal paths, providing stability and improve reverberation quality
- The use of this time-varying filter is an ingenious use of DSP, however it does limit the ability of traditional measurement systems such as MLS and Dual channel FFT techniques from directly measuring the resultant impulse response, created by the LARES processor
- For example, if you use 2 mics and 3 (2 in x 4 out) processors, you have 36 uncorrelated signal paths
- Auto-decorrelation of each signal using time variance adds an additional 6 dB extra stability
- This is comparable to 96 decorrelated paths, 3 dB for each doubling of decorrelated signals, i.e. 24 x2= 48; 48x2 = 96

VRAS Concept



- Local properties:
  - Mics close to stage
    - Clarity, ASW, Early Decay time
  - In-line systems:
    - affect communication between artist and listener
    - minimise feedback
- Global properties:
  - Mics in reverberant field
    - Loudness, Envelopment
    - Diffuse field
  - Non in-line system:
    - affect the ambience in the room
    - regenerate reverberant sound

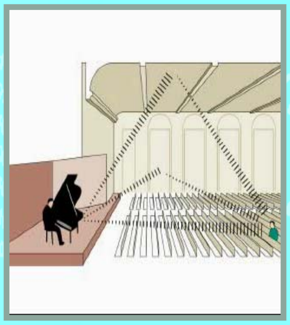
VRAS Concept



- High gain
- Time constant
- Good coverage
- Theatre effects
- Possible recirculation of audience noise, HVAC, problem acoustics

Carmen Concept

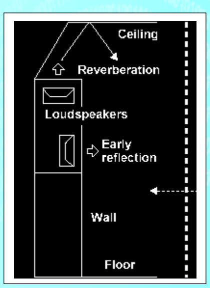
- The concept is active virtual walls, whose absorption coefficient can be altered electronically
- Modern MCR system
- Room contains "cells" consisting of a microphone/loudspeaker combination
- Amplifies reverberation response of room

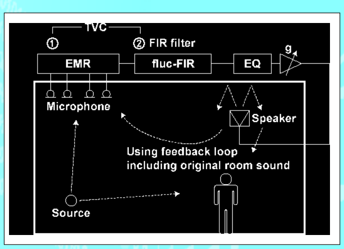


AFC Concept

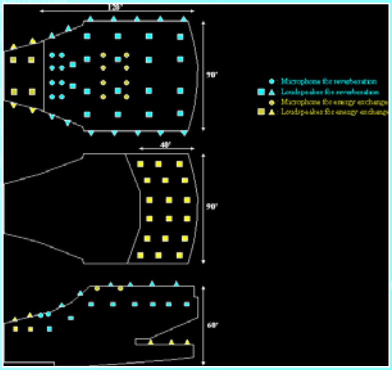
- Increasing the energy density of the diffuse sound by using the acoustical feedback of a system
- Two time-varying techniques
  - Electronic Microphone Rotation (EMR), i.e. variable mic routing to speakers
  - Fluctuating FIR
- Early and diffuse reflections separated
- Indirect radiating loudspeakers
- Results depend on acoustical wall treatment

AFC concept





AFC layout



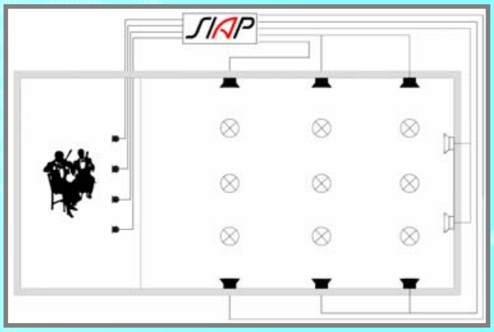
Processor vs Room T60

- In-line systems generate reverberation in the processor and are only marginally influenced by the natural RT of the auditorium. For example, if a processor creates a 2 second RT, this means the processed RT is 2 seconds, whether the natural RT is 0,8 or 1,4 seconds or even whether it is indoors or outdoors.
- If you are a proponent of in-line systems, this is a significant step forward as the potential coloration caused by acoustic feedback is no longer a drawback of acoustic enhancement systems.

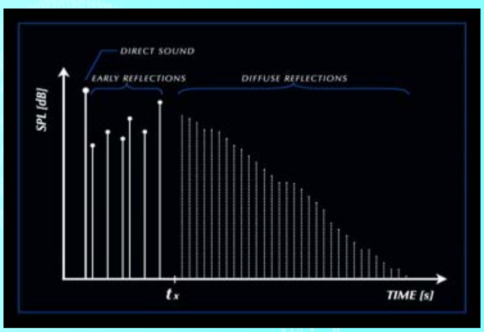
SIAP Concept

- SIAP is an in-line system with (4-8) supercardiod microphones typically located about 8 to 10m above the front edge of the stage
- Each microphones is positioned and aimed to cover the entire stage area and preserve the directional information of the sound
- The SIAP system is (usually) not time variant, so MLS and dual channel FFT measurement techniques can be used to evaluate impulse responses and objective measures
- Time variance is available, if needed
- Retains the acoustical character of the room, but fills in the missing reflections to correct deficiencies
- Achieves natural sound by utilizing hundreds of decorrelated signal paths. i.e. 4 mics into 64 output processor = 256 decorrelated signal paths
- Processors can be ganged for even more decorrelated signal paths
- High speaker density provides uniform coverage

SIAP Concept



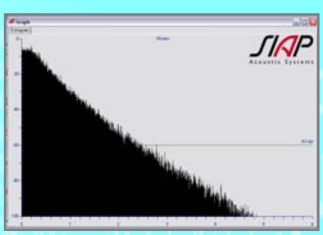
SIAP concept



Entire Finite Impulse Response (FIR) is generated digitally, simulating how real rooms generate sound fields

FIR Generation

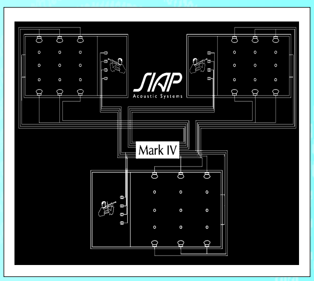
- FIR techniques allow full electronic acoustic architecture:
  - Level
  - Density
  - Time
  - Frequency dependency
- Up to 64 Channels
- 4 seconds



FIR Organization

- Project
  - Zones (Auditorium, Under Balcony)
    - Areas (Sidewalls Ceiling
      - Outputs

Extra Features



- Enhancement of the weakest soloist
- Theatre effects
- Dolby surround
- Acoustic Server™
  - Different acoustic environments in one room, eg. Worship Space
    - Platform
    - Organ
    - Choir
    - Congregation
    - Under Balcony
  - Different acoustic environments in different rooms

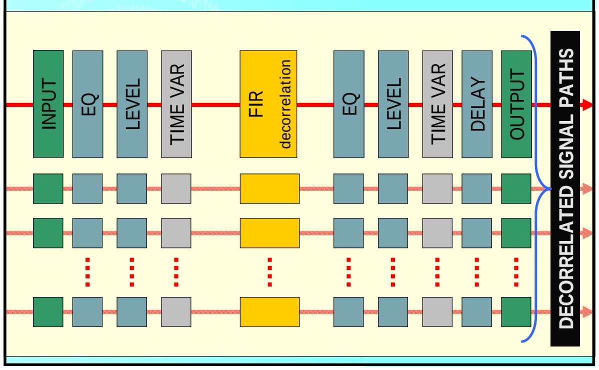
Outdoor Applications

- The topic of an outdoor application, helps to separate the enhancement approaches
- Outdoor applications can only use an in-line system, since there is no reverberant field to recirculate
- In-Line Approaches:
  - SIAP
  - LARES
  - ACS
- Feedback Approaches:
  - VRAS (actually combination)
  - AFC
  - CARMEN

TUNING

- Long, Quiet Nights
- Measurement of the loudspeaker – room transfer function:
  - With the enhancement system off and the microphones muted, the transfer function between the loudspeakers and the room is measured and optimized. This optimization often includes setting equalizers and gain levels
- Measure the microphone-room-loudspeaker transfer function:
  - Un-mute the microphones and set the gain levels for the microphones
  - Next, with the enhancement system bypassed and the microphones in-line, the loudspeaker-room-microphone transfer function is measured (typically this is done at low level to avoid feedback)
  - Once again filters are used to damp any resonance's found
- Stabilize Enhancement System:
  - Put the enhancement system inline
  - With source at typically operating levels, the gain structure of the system is optimized for maximum performance and stability
- Repeat for all Zones:
  - Side walls, ceiling, under balcony, performance areas, etc.

SCHEMATIC TUNING OVERVIEW



This is only the beginning.....