

Large-Scale Loudspeaker Arrays – Past, Present & Future

Part One : Control Systems, Interfaces and Networks Part Two: Electroacoustic Considerations

David Scheirman AES Vice President, Western Region, US/Canada Retrospective view through lenses of two prior AES conferences



- 1988 : AES 6th Conference, Sound Reinforcement (Nashville, TN, USA)
 - "Sound Reinforcement in the Year 2000" how to leverage the computer?

- 1994: AES 13th Conference, Computer Controlled Sound Systems (Dallas, TX, USA)
 - Networking technologies, standards efforts, DSP, and "smart arrays"

• In 30 years: Large-scale loudspeaker arrays have changed radically

- A focus on portable live sound reinforcement for concerts & special events
- Will be referring to multiple, modular boxes in arrays (not individual columns)







Introduction & Overview, continued



• General overview of technical trends shaping system evolution over time: computer control, onboard amplification, line arrays

 Most recent advances: higher onboard amplifier channel count, which enables higher-resolution steerable array technology Part One : computer control, user interface & networked audio considerations



 1988, AES 6th Conference, Sound Reinforcement – how to leverage computers for loudspeaker array control?

• New serial interface (RS-422), developed by IED, was highlighted

• Sound Reinforcement in the Year 2000 (C. Henricksen) : computers would soon *"…run, monitor and control large systems; speakers would be more clever…"* etc.



• Digital control initiatives were primarily focused at the mixing console, focusing on mix-cue and programmable equalization challenges



1987 - Amiga 500 system (Richmond Sound Design, Command/Cue)



1987 - Solid State Logic 6000E Total Recall System (Grammy Awards)

Programmable DSP, digital integration

- Electronic crossovers, program equalizers, delay lines, limiters were mostly separate hardware devices
- The integration of EQ functions, signal delays, limiters, room-mode compensation and more using digitally-based signal processors was hypothesized
- "...The future may bring equalizers that combine several different user interfaces but are combined by the computer to control one set of hardware..." (R. Cabot, 1988)



Clair/TC Electronics remote controlled EQ system



Computer control



- Altec, IED and 20 other manufacturers of programmable audio devices had all supported a joint initiative
- Bob Rodgers, Altec-Lansing: developer of the device control language (1989-90 AES papers)
- AES-15-1991 (PA-422) was ratified



(Control) Networks

 Amplifier control networks justified development costs due to economic scale

- Commercial opportunities for power amplifiers in large fixed-venue systems led to rapid technology advances
- Crest, Crown and QSC had been developing systems for networking hundreds of amplifiers, ca. 1988-91



RS232/RS42



Large-scale venue control application

- 7,000 seat performing arts hall (Kremlin Palace, Moscow) – commissioned 1991
- Equalizers, delay lines and power amp networks each required a separate PC

 Lack of a comprehensive, mature standard for interoperability of devices in various product classes, from different vendors



3 IBM PC's: AKG Delta Stereophony delays, I.R.P. equalizers, Crest NexSys for amplifier control



Typical live-system application

 Integration attempts for large-scale live performance systems

 Seven separate computers: RF mics, MIDI cue commands, EQ, power amplifiers with Crown IQ, measurement, etc.

• This was an unsustainable trend





Multi-vendor networking initiative

- MediaLink: multi-media networking with a common GUI, fiber-optic links and a planned migration path to lowlatency digital audio transport
- One computer, (either PC or Mac), linked with multiple audio product categories from dissimilar vendors (RF microphones, programmable EQ's, networked power amplifiers, etc.)
- Increasing industry expectations for integration of control & digital audio

VNOS (Visual Network Operating System) GUI for QSControl in audio booth, University of Nebraska Memorial Stadium, 1994





 Rapid advances in digital control and networking technology for audio devices

Impending shift to Ethernet-based technology

 Increasing expectations placed upon AES standards efforts (WG-10 Working Group for Computer Control of Sound Systems)







Computer-Controlled Sound Systems



 "...as computer technology is integrated into more and more sound systems, the industry requires hardware and protocol standards to control and monitor audio equipment...today there are many different computer control systems, most of which are proprietary and incompatible."

- T. Roseberry, IED, Conference Co-Chair



- 1988: Beam-steerable arrays using Stage Accompany's SA 4525 with SAnet described at AES 84th Convention, Paris (B. Kok, G. Rosenboom, E. Wijnker)...
 - devices. Existing computer interfaces and protocols are unsuited for pro audio applications or suffer from high complexity and price. This paper describes a newly developed remote control network for professional sound, light and
- As speaker system designers awaited suitable robust control networks, software interfaces and standards, a decade of R&D time was afforded to electroacoustic development

Standards efforts, competing platforms

• 1994: Echelon Corporation (LonWorks, control, licensed)

-Meyer Sound's RMS

-Apogee Sound's AmpNet

-Renkus-Heinz' R-Control

- 1995: Fast Ethernet introduced, 100 Mbit/s IEEE 802.3u-1995)
- October 1995: AES 99th, NYC Harman Pro announced plans for proprietary HCA (Harman Communications Architecture)
- December 1995: MediaLink Technologies (control network with digital audio planned) – announced withdrawal from Pro Audio industry
- 1996: QSC became Peak Audio's first licensee of CobraNet





AES' SC-10 standards committee for computer control of sound systems (ca. 1992-98)

Proliferating Protocols



Networked audio product developments

- 2001: Ethersound introduced (Digigram's Ethernet-based protocol)
 - 64 channels of 48 kHz, 24-bit PCM audio
 - 125-microsecond latency
 - Licensees including Allen & Heath, Biamp, Camco, DigiCo, Nexo, Yamaha, more

- 2005: industry's first self-powered, arrayable line array speaker with digital audio connectivity, able to connect with other product classes
 - JBL VT4888DP-CN
 - DrivePack electronics, CobraNet digital audio
 - Harman HiQnet protocol, evolution of Crown's IQ-2000
 - AKG RF mics, Soundcraft mixers, Crown amplifiers, dbx processors







User-interface challenge: more complex

• A single large manufacturer could possibly integrate control & configuration across different audio product classes

• But a GUI having multi-device compatibility with many different manufacturers would require a new, common control interface language



control & configuration of different product classes, from RF mic receivers to powered loudspeakers

Let's move back to digital audio transport & networking issues and how it relates to the user-interface challenge

- 2006: Audinate develops Dante, a licensed set of software, hardware and network protocols delivering uncompressed multi-channel low-latency digital audio over Ethernet using Layer 3 IP packets.
 - Large licensee group including Aviom, Bosch, Bose, EAW,

IED, Lake, Lab.gruppen, Peavey, QSC, Shure, TOA & more

Audinate's Dante Controller Software interface for digital audio transport system configuration

Leveraging Ethernet: advanced protocols





Leveraging Ethernet: advanced protocols

- 2009: AVB (Audio Video Bridging) promoted by AvNu Alliance
 - IEEE Standard 802.1, Audio Video Bridging
 - Founding promoters: Broadcom, Cisco, Intel, Harman, Xylinx
 - Promoters include Avid, Audinate, Bosch, Dolby, Meyer Sound, Sennheiser, many more.
- May 2015: new President & Chair appointed (senior technologists from Cisco, Intel)



AvNu Alliance logo, with mark for compatible device certification



- Proprietary standards evolve from specific product or vendor (IBM PC, UNIX, Microsoft Windows, etc.)
- Single vendor has total control over functionality, usefulness, cost of its technology to users.
- Open standards tend to stimulate innovation over time; may meet the needs of some users but not others.
- Open, non-proprietary standards tend to have longer development times, may require a leading champion in commercial marketplace to keep from languishing or failing.



- 2010: AES-X192 study for achieving interoperability of networked audio
- 2012: AES & EBU (European Broadcasting Union) announced joint, active collaboration for AES-X192
- 2012: AES & OCA (Open Control Architecture) Alliance jointly established AES-X210 project (control and monitoring standard)
- 2013: AES67-2013 standard released @135th Convention, NYC (audio applications of networks: high-performance streaming audio-over-IP interoperability)



- 2104: MNA (Media Networking Alliance) establishment announced @AES 137th Convention, Los Angeles
- 2014: AES-X210 Open Control Architecture progressed towards potential ratification of OCA 1.3 as a public (open) standard
- In summary: complex, interlinked activity; many acronyms & tradenames
- Commercial industry still seeks viable open standards



- 1994 at AES 13th Conference, Computer-Controlled Sound Systems, it was clear significant development was required on several fronts if a hypothetical "smart" loudspeaker array were to be developed
 - Control networks
 - Digital audio transport
 - Customized software user interfaces
- From an electroacoustic perspective, advancements would also be required on several fronts
 - Onboard electronic modules
 - Improved, controllable loudspeaker directivity
 - Active directivity control at an array level (not just individual speaker enclosures)

System architecture considerations





• 3 system formats: assumptions influence cable logistics & ability to implement beam steering

AES 13th Conference, 1994: Early awareness of array networking requirements



- For controlling arrays of traditional (unpowered) speakers, a network-ready device, a dual-channel digital power amplifier, was revealed (K. Deloria, Apogee Sound)
- EAW proposed to integrate DSP units, network interface, monitoring sensors and power amplification inside each speaker in an array (Forsythe, Burlingame, Rutkin, EAW; Lacas – MediaLink Technologies)

• Array beam steering could be accomplished if two or more identical transducers, separately circuited and amplified, were dedicated to the same passband in boxes



This did not happen overnight

• Alternatives to traditional rack-mounted power amplifiers



JBL D50SMS7 self-powered professional speaker with solid-state "Energizer" (ca. 1967)



Altec Lansing model 1203A powered loudspeaker lwith integral solid-state electronics (ca. 1967)



Evolution of powered speakers for use in portable concert systems



(1972 - presented at AES 42nd Convention, A. Siniscal, Spectra Sonics)



Modular electronics pack with plug-in crossover cards, configurable for tri-amped or quad-amped operation Group of four portable, high-powered, horn-loaded self-powered enclosures (each box 7' high)

Evolution of powered speakers for use in large-scale, portable concert arrays

- 1994: introduction of Meyer Sound's MSL-4
 - Self-powered arrayable box
 - Horn loaded long-throw loudspeaker
 - Attained widespread global acceptance
 - Instilled more confidence in powered systems
 - Company converted entire line to powered systems





Evolution of OEM amplifier modules for use in loudspeaker enclosures

- Within the next decade, Original Equipment Manufacturers began to offer generic amplifier sub-assemblies
 - Bang & Olufsen
 - KSC
 - Pascal
 - Powersoft
 - Power Physics
 - SpeakerPower
 - Etc.



Typical OEM power module with on-board configurable DSP. Model SP3 includes 2 x 1000W and 1 x 500W channels (SpeakerPower, Santa Ana, CA USA).

Early concepts for incorporating beam-steering into portable, modular systems

- 1982: array beam-tilting concepts using DSP, with library of array configuration presets in computer memory, described (D. Meyer, Purdue University)
- 1988: Innovative modular array system with computer controlled, beam-steering capabilities (SA 4525) developed by Stage Accompany; described by Kok, Rosenboom and Wijinker.
- Broader industry still knew little about actual performance of large-scale arrays, and how to optimize setup and operation...







Developing improved measurement tools for large-scale arrays

- As array performance improvements were sought, more objective information was needed on how they were actually performing
- Road (touring) systems were typically set up on a trial and error basis – better measurement tools in the field could help
- Major loudspeaker system manufacturers sought to develop a knowledge base of valid array measurements for their customers; Meyer SIM (Source Independent Measurement) System developed in 1984



Speaker System

with acoustical (room response) measurement



Calibrated microphone

Measuring large-scale arrays under controlled conditions

- Array measurement projects (ground plane format) provided scientific data for assisting setup technicians
- 1989 project at Summit Laboratories (Warner Springs, CA) described by J. Eargle and M. Gander, JBL Professional
- Results aided in the development of more directive array configurations with better inter-box combination characteristics





Line-source arrays: a disruptive technology

- 1992: : Arrayability criteria mathematically defined (C. Heil, Heil Acoustics, and M. Urban); described how array soundfield radiation could be predicted and consistently achieved
- 1994: V-DOSC system, based upon a 2x15" line array element, introduced by L-Acoustics to limited group of rental companies
- 1999-present: live-performance line array systems introduced by other vendors (Adamson, Alcons, Apogee, Coda, d&b Audiotechnik, EAW, EV, HK, JBL, Martin, McCauley, Meyer, Nexo, Outline, RCF, SLS, Renkus-Heinz, Turbosound, Vue many more)



L-Acoustics V-DOSC arrays



User interface considerations for line array systems (predictive software & configuration tools)



- Line array system vendors (whether traditional, or self-powered) need both predictive and configuration interface tools for their customers
- Most manufacturers offer a GUI toolset for field-application use; some integrate predictive and configuration features in a common interface



Integrated acoustical & mechanical prediction tool and control/digital-audio transport interface (Harman Pro HiQnet Performance Manager)

Evolution of pre-engineered OEM user interface tools

- Just as with OEM-supplied DSP/amplifier modules for loudspeaker system builders, necessary OEM software tools are becoming available
- Speaker system manufacturers have access to user-interface tools that can be customized for their own branded requirements



(EASE Focus software from Ahnert Feistel Media Group, Berlin, Germany)



A new frontier: adaptive algorithms



- High performance, powered line array systems with semi-automatic configuration functions require specialized algorithms to access DSP filter sets, apply array EQ settings, etc.
- As a speaker system manufacturer takes on more responsibility for array and whole-system configuration, its custom algorithm development requirements are dramatically increased



Simplified adaptive filter/algorithm circuit example (Avalos, Sanchez, Velasquez - 2011)



 Systems that integrate the various technical developments that have been discussed

 Self-powered, line-array type systems with computer control, network connectivity, dedicated software user interface(s), and beam-steering capabilities

 Two current high-profile examples, each now fielded for the past few years for demanding professional live-event tours



1. Shift from "point and shoot" boxes to line-source array elements

2. Greater widespread acceptance of self-powered boxes for large arrays

3. Ubiquitous adoption of PC control via Ethernet-based networks

4. Ability to integrate control & digital audio without degrading quality

Example #1: Martin MLA (introduced 2010)

- Mechanically-variable box splay angles with electronically-steerable array characteristics
- Manufacturer's marketing term: *Multi-Cellular* Loudspeaker Array
- U-Net on CAT5, w/VU-Net & Display2 software; 6 amplification channels per box driving 7 total transducers
 - 3 separately circuited HF drivers
 - 2 separately circuited MF drivers
 - 2 jointly circuited LF drivers
- System operator relies upon pre-calculated and insitu array configuration data, compiled using vendor's proprietary processes

Martin MLA Display2 DSP software interface (user has Access to blue-shaded functions like input selection, PEQ, array delay, etc.)





Example #2: EAW Anya (introduced 2013)

- Electronically-variable array elements with fixed (0-degree) box splay angles: straight-hung array
- Manufacturer's marketing term: ADAPTIVE System, Adaptive Performance
- Ethernet/Dante (XLR & USB), and Resolution-2 software; 2 amplification channels per box driving 22 total transducers
 - 14 separately circuited HF drivers
 - 6 separately circuited MF drivers
 - 2 separately circuited LF drivers
- System operator can achieve coverage adjustment and array directivity optimization by purely electronic means

EAW Anya array element : unique, patented shape. Note heatsink for 22-channel amplifier module on back panel





Elusive Vision of Interoperability

- Several digital audio and network communication protocols, standards and commercial offerings have evolved in recent years
- Industry still seeks openly-available standard platform(s) to enable different product classes from dissimilar vendors to be compatible within the same system
- Two current system examples noted, while designed and distributed by divisions of the same company, rely upon different user interfaces, digital audio transports, and non-compatible control networks...



Input vs. output system requirements





(mics, effects, mix consoles)

"B" CHAIN: Output Side



(speaker processing, amps, arrays- traditional, or self-powered)

 Input: many signals with frequent control signals sent to relatively few destinations

• Output: fewer signals with infrequent control changes sent to larger number of destinations





1. Increasing number of specialty OEM vendors will offer pre-engineered sub-assemblies for use by system manufacturers



2. Increased availability of OEM suppliers and technical information will enable smaller, newer, entrepreneurial vendors to compete



3. Ever-more intelligent adaptive algorithms will accelerate product development for 'smart' arrays, adapting to venue coverage requirements...and maybe even the program material they reinforce



System operators will have access to an increasing number of branded (loudspeaker array) options at varying price points



5. AES Standards efforts and industry R&D advances will continue to converge, but openstandard interoperability of digital control and transport will remain elusive



6. Shortening product life cycles and shifting trends in the rental sound industry will complicate speaker system developers' design and manufacturing efforts



7. Broad-based shift to large-scale self-powered speaker arrays with high-resolution beam steering capabilities may not take place unless/until largest global rental firm(s) with custom-built proprietary systems migrate to this format



Over three decades, increasing DSP power has resulted in on-board electronics suitable for creating complex speaker arrays with venue-adaptive characteristics.

It remains to be seen whether such increasingly-complex products will remain as closed, proprietary (control and network) systems unique to individual manufacturers.

In the future, a look back upon this AES 59th Conference should be an interesting exercise for product developers, system specifiers and operators alike.