Proceedings

of the

20th

International Planetarium Society Conference

Hosted by the

Bibliotheca Alexandrina

26-30 June 2010

Hoda S. Elmikaty & Omar Fikry, Conference Hosts

Dale W. Smith, Proceedings Editor

THE SOUND OF SPACE: A LOOK AT THE HISTORY AND FUTURE OF AUDIO IN PLANETARIUMS

René Rodigast
Fraunhofer IDMT
Ehrenbergstrasse 31
98693 Ilmenau
Thüringen, Germany
rdt@idmt.fraunhofer.de

Leslie M. Gaston
University of Colorado Denver
Campus Box 162
PO Box 173364
Denver, Colorado 80217 USA

Abstract: Exciting innovations in audio for planetariums are happening alongside more traditional sound presentation formats. This paper provides a look at past practices and productions, examines unique workflows in the present, and recommends future audio standards for planetariums to follow in order to exhibit the best sounding shows. The research in this paper is based on a look at previous recommendations, current work with the latest audio technology, and a survey of over 100 planetariums worldwide.[1]

Introduction

What makes a good sounding show, and from whose perspective? Sound engineers are concerned with reverb times and intelligibility. Show producers and their sound designers want to have a well-mixed balance of music, sound effects, and dialog. But in the end, audience members might be subconsciously impressed with a good soundtrack, and may only complain if it's too loud – or not loud enough.

A need for standards

The ideal solution is to rely on the expertise of engineers and show producers to resolve any deficiencies in the sound system. Further, the planetarium community should take advantage of their collective decades of experience: although each planetarium has its own "personality", establishing a few standards for sound will raise awareness of the importance that audio plays in each production or show, and enrich the audience's experience.

Acoustics

History

Planetarium designers recognized as early as the 1920s that acoustic treatment was necessary to help with intelligibility, and very soon thereafter recognized the need for perforated domes to achieve acoustic transparency.

The Zeiss Planetarium in Jena, Germany was founded in 1926 and was the world's first planetarium. Many experiments were done in those first years to improve room acoustics. In front of the white concrete dome, steel sheets with 20 percent holes were mounted, which were later replaced with aluminum. They also performed tests with cork absorbers.

At the Hamburg Planetarium in Germany, a perforated metal sheet was used, behind which absorbing material like glass wool was used. In the zenith of the dome was a hole for the "zenith loudspeaker", which normally reproduced the narrator's voice. On some areas, the dome material was cut away for the speakers.

In 1986, Phil Groce (contributing author for *The Planetarian)* noted that smaller loudspeakers could be placed very close to the perforated dome surface, while low frequencies (below 100 Hz) could be redirected to subwoofers on the floor. According to this author, "For the first time in the history of planetariums, Phase Technology Corporation designed and built speaker drivers to respond to the unusual acoustical problems presented by a perforated planetarium dome". [2]

Present and future technology

Although reverberant domes pose a unique challenge acoustically, optimization for them is possible. First of all, the first reflections of the sound must be reduced by using high absorptive walls and floors. Furthermore, a concrete speaker direction (raked, directly) is important to reduce sound reflections and other well known acoustical effects (echo, "whisper gallery", "acoustical lens"). Reducing the bandwidth of the sound signal also results in an improvement for reducing sound reflections in the dome—especially for low frequencies. As we know, in planetariums the low frequencies are very important: they are needed for sound reproduction but cause major problems. Simulations and auralisations with EASE [3] (simulation software) shows that good results can be achieved with a high-pass filter at 250 kHz (24dB/oct) [4]. In practice a high pass filter at 150Hz should used because of the compatibility with conventional subwoofers. One separate subwoofer channel (or ideally, more than one) provides a better way to control the sound energy. Furthermore, high volume levels are critical in every reverberant dome but the reverberation time is a static, frequency-dependent parameter. For this reason, we have to control the sound energy.

Production

History

In Jena, no sound reinforcement was used in the early days due to the prevalence of acoustic problems. Later, music from a shellac disk was used, and sent to a speaker as the lights were dimmed.

As early as 1947, Mueller Planetarium in Nebraska used a separate sound console for productions, allowing for more room and flexibility. Another contributor to early writings on sound was Jack Dunn, who guided the planetarium community through his articles on the use of music albums (on vinyl, of course!) such as Mannheim Steamroller's "Fresh Aire". [5]

Starting in the 1960s, stereo was the prevalent format, and planetariums began to experiment with adding more loudspeakers for more coverage.

Live music has long been an added attraction provided by planetariums, with experimental musicians such as the synthesizer duo "Complex" in the 1980s. Live shows add awareness of the planetarium and provide a cultural service to the community. The challenges were dealing with the acoustic space and the existing sound system. In some cases, sound engineers elected to simply rent additional equipment in order to "fill in the holes", providing monitoring for the musicians (so that they could hear themselves clearly), and provide controlled, floor-level coverage for some audience members. [6]

With the advent of Compact Discs and Digital Audio Workstations in the 1990s, planetarium operators began to embark on a "digital audio adventure" that continues to this day. Early computer audio systems could handle 6, 8, or 16 tracks for editing and perhaps 8 channels or more for playback. These systems cost $7,000 and more. Today, an unlimited number of tracks and up to 24 channels can be incorporated for about one-fourth of the same cost. [7]

Present and future technology

Today, Jena, Mueller, and many other planetariums are using 5.1 surround sound. Hard disk players and media servers are used for audio playback. Terms such as "ambisonics", "3D audio" and "wavefield synthesis" (WFS) are beginning to enter our vocabulary, and indeed some planetariums are at the cutting edge of these new sound technologies.

As always, making sure each audience member has a similar experience is important. To realize a realistic and uniform acoustical perspective for all audience seating positions there are different technical possibilities:

- A sound system based on Wave Field Synthesis (IOSONO)
- A wave field synthesis based sound system with reduced speaker numbers (Fraunhofer Spatial Pan)
- Directional mixing based on Deltastereophonie [8],[9] or Virtual Amplitude Panning (VBAP) [10]

Wave Field Synthesis

In this model, the listening area of a dome is surrounded by a closed array of loudspeakers (speaker panels) at the height of the horizontal line. On the basis of the Huygens' Principle of wave propagation, virtual audio objects can be emulated in a realistic way through a closed array of speakers. As various wave fronts reproduced by the loudspeaker arrays combine and cancel each other out, natural sounding virtual audio objects can be synthesized. This means that every loudspeaker is driven by a unique signal that depends on the position of the speaker and the virtual source in the room. [11], [12], [13]

To perform the complex task of controlling such a huge number of loudspeakers, special software is needed. To store and distribute the audio sources and their positions and characteristics, the 3D-Audio profile of the MPEG standard is used.

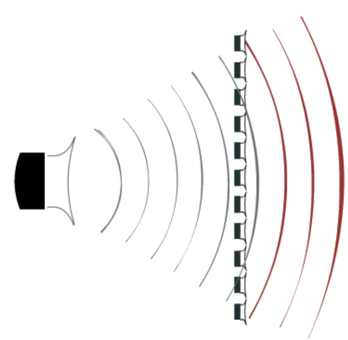

Figure 1. Principle of Wave Field Synthesis

Figure 1 shows the principle of Wave Field Synthesis. The listener at position B hears the sound originating from position A. With Wave Field Synthesis (WFS) technology all listeners in the area of the dome can determine the exact position of sound sources. These audio sources have a unique position and can be animated. This is shown in Figure 2.

Now virtual sound sources can be located within or outside the listening space. The result is an extraordinary spatial stability of an acoustic image. Through the application of WFS, new creative possibilities in the field of mixing sound material are available [11], [12], [13], [14].

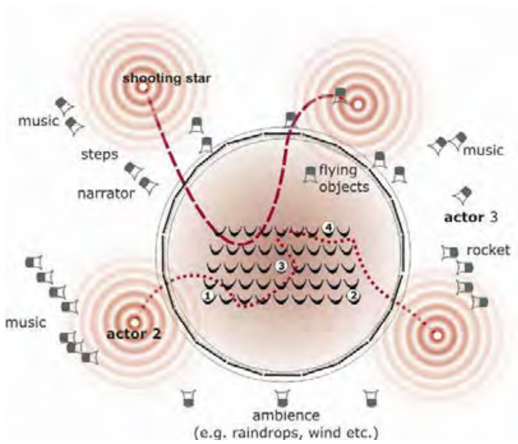

Figure 2. Animation of audio objects

Spatial Pan

Besides using WFS as "high end" solution for sound reinforcement in planetariums, there is also an alternative method for spatial sound in the dome. For the so-called "Spatial Pan" system, fewer loudspeakers are necessary than for WFS. Just as in WFS sound systems, every speaker will be separately controlled with an adapted WFS Algorithm; but in contrast to a WFS system, a completely closed wave field cannot be generated.

By applying the "Spatial Pan" method, a 2D horizontal sound adjustment with relatively fluent object movements and nearly individual spatial sound for every audience seat can be created. This sound system can be considered as a cost effective alternative to WFS. In Figure 3 a simulation for sound distribution in a dome with "spatial pan" sound systems is shown. As we can see, a wide energy distribution is possible with a defined sound radiation. [15]. Wave field synthesis and Spatial Pan Sound systems also available as full 3D system [15]

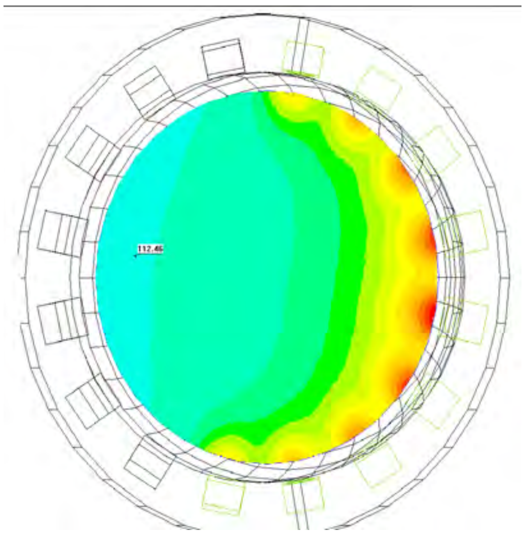

Figure 3. Acoustical simulation for SPL-distribution of a "Spatial Pan" sound system in a dome

Directional Mixing

This sound reinforcement technology is based on the "precedence effect" (or "law of the first arriving wavefront") and provides the basis for directional hearing [16]. The principle is shown in Figure 4.

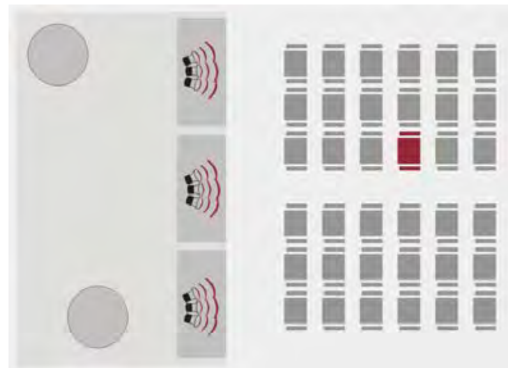

Figure 4. Principle of Directional Mixing

Directional hearing means that the first wave front that reaches the human ear determines the localization of the sound source.

For the definition of specific directional areas in the dome (positions A and B), different groups of loudspeakers must be driven. The signal of the sound source will be reproduced over the amplitude-and time-scaled loudspeaker groups which are permanently adjusted to the position of the sound source. Particular loudspeakers in such a group will be provided with different delay times of the source signal.

As a result, the first wave front reaches the seats of the auditorium with time adjustment, and the audience perceives the sounds from the correct direction.

Sharing with other planetariums

The 2008 IPS paper, "Methods for Sharing Audio Among Planetariums" [1] presents some of the challenges to sharing audio among planetariums. Issues such as loudspeaker orientation, audience orientation, number of channels, and type of playback media were discussed. Perhaps more than any single reason, the need to share audio should be a driving force behind the community's need to seek standards for playback.

A typical way to transfer content to other planetariums is to use single tracks saved on various media. Currently, types of audio media include uncompressed multi channel sound formats shared by Tape (Tascam DAXX, ADAT), disc (CD or DVD), audio files (.aiff, .wav), a session from a Digital Audio Workstation (Nuendo, ProTools, Cubase, Logic, etc) or a coded format like AC3.

For distribution purposes, the sound format has to be free of limitations and flexible enough for collecting individual information, characteristics or requirements. Unfortunately, none of the formats listed above contain metadata (auxiliary data about the program material) in a flexible way. Therefore, it would be useful to go to an object based format. In Figure 5, the difference between an object based approach and a channel based approach is shown.

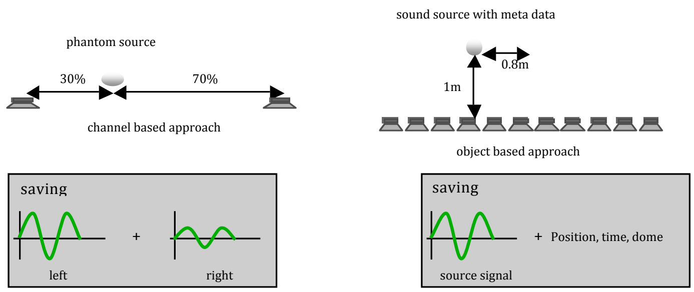

Figure 5. Object-versus channel-based approaches for sharing data

An audio event (track, file) has individual characteristics like:

- a position (sometimes dependent on the visual image)
- a time where the sound is active
- level
- processing information (compressed, EQ, convolved, etc.)
- an environment (small, big, concrete dome, perforated dome, studio, etc.)

Most of these parameters are normally changed during playback along with the image (for example, a sound effect panned along with an image of a shooting star.) In this context, an object based sound format should be applicable for production as well as distribution or sharing of the audio program material. An object-based sound can be integrated in the video production on the timeline or coupled with the video objects.

Also, channel-based sound systems use sound positions between the speaker positions (sometimes referred to as "phantom images"). But often it's impossible to place (localize) the sound on its respective position due physical and psychoacoustical limitations of the "traditional" formats.

If an object-based standard is used, all possible content can be produced, exchanged, and played back, individually adapted to the respective dome. Therefore, a fast coding and encoding algorithm is required, and a universal standard for this would have to be accepted by every planetarium.

Conclusion: Audio standards group needed in IPS

The major reasons to create audio standards are as follows:

- a myriad of choices and production styles exist,
- the desire to share shows among planetariums,
- the need for standards is recognized and desired by 92% of surveyed planetariums [1],
- the need to improve audio quality in many planetariums.

With these driving forces in mind, we make this preliminary proposal of the following standards:

- Narration and other dialog elements should come from center (if a loudspeaker exists there) and not be spatialized.
- Audible elements (like rocket dust, cars, etc.) should originate from this visual image. This position should be stable for all audience members.
- Room acoustics in planetariums has to be in a standard range (to be defined) Important parameters in this context are:
    - Reverberation time (RT60)
    - Early reflections
    - Low frequency response
    - Speech transmission index (STI)
    - Distinctness C50, Clarity C80,
- An object-based format that includes an unlimited number of channels should be provided.
- A downmix from higher channel numbers to mono, stereo, and 5.1 should be accommodated.
- An upmix from lower channel numbers to higher number and 3D sound should be accommodated.

References

[1.] Gaston Leslie, "Methods for Sharing Audio Among Planetariums", IPS Conference 2008, Chicago.

[2.] Philip Groce, "Bigger is not always better: New Speaker Systems for Planetariums" Vol. 15, No. 1, pp. 8-9, 1986.

[3.] Ahnert, Wolfgang; Feistel, Rainer, "Binaural Auralization from a Sound System Simulation Program", AES Convention:91 (October 1991) Paper Number:3127.

[4.] Rodigast, Rene, "Spatial Sound in Critical Environment – Full Dome: Optics versus Acoustics", IPS conference 2008, Chicago.

[5.] Jack Dunn, Sky Notes, The Planetarian Vol. 9, No. 3, p. 21, 1980.

[6.] Bill Kinsella, "Cosmic Vibrations: Live Musical Programming in the Planetarium", The Planetarian Vol. 13, No. 1, pp 12-14, 1984.

[7.] Jeff Bowen: "Sound Advice: Comparisons of Popular Computer Based Digital Audio Workstations", The Planetarian, Vo.l 24, No. 3, pp 42-43, 1995.

[8.] W. Ahnert, "The complex simulation of acoustical sound fields by the Delta Stereophony System", 81st AES Convention, November1986, preprint No. 2418.

[9.] W. Ahnert, "Problems of near-field sound reinforcement and of mobile sources in the operation of the Delta Stereophony System (DSS) and computer processing of the same", 82st AES Convention, February 1987, preprint No. 2426.

[10.] Pulkki, Ville, "Virtual Sound Source Positioning Using Vector Based Amplitude Panning", JAES Volume 45 Issue 6 pp. 456-466; June 1997

[11.] A.J. Berkhout, "A Holographic Approach to Acoustic Control", J. Audio Eng. Soc. vol. 36, No. 12, p. 977.

[12.] A.J. Berkhout, D. de Vries, P. Vogel, "Wave Front Synthesis: A new Concept in Electro-Acoustics", 93rd AES Convention, October 1992, preprint No. 3379.

[13.] D. de Vries, E.W. Start, V.G. Valstar, "The Wave Field Synthesis Concept applied to Sound Reinforcement: Restrictions and Solutions", 96th AES Convention, February 1994, preprint No. 3812.

[14.] "Innovative Sound in Dome Theaters", Rene Rodigast, IPS conference 2006, Melbourne

[15.] "A New Method for Sound Production and Reinforcement in Planetarium", Rene Rodigast, IPS conference 2008, Chicago
[16.] J. Blauert, "Localization and the law of the first wave front in the median plane", J. Acoust. Soc. Am. 50, 466–470.
[17.] W. Ahnert, "Comb-filter distortions and their perception in sound reinforcement systems", 84th AES Convention, March 1988, preprint No. 2565.
[18.] "Mueller Planetarium Celebrates 50 Years of Discovering the Universe " <http://www.spacelaser.com/50years.html>. Accessed 13 May, 2010.