

# The Why and How of With-Height Surround Sound

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# Your next 45 minutes on ~~the graveyard shift~~ this lovely Saturday morning:

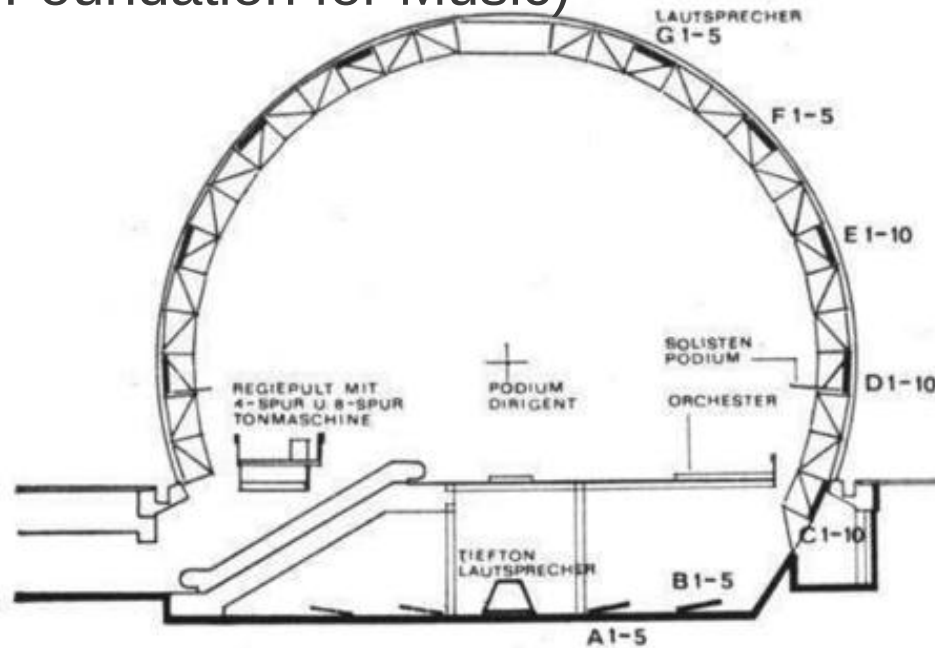
- A bit of history
- How do we perceive elevated sound?
- Why include height at all?
- How do different methods (re-)produce height?
  - A closer look at multichannel stereo techniques
  - VBAP
  - Ambisonics



# A bit of History

German Pavillon World Expo 1970:  
50 speakers in a sphere,  
acoustically transparent grid floor.

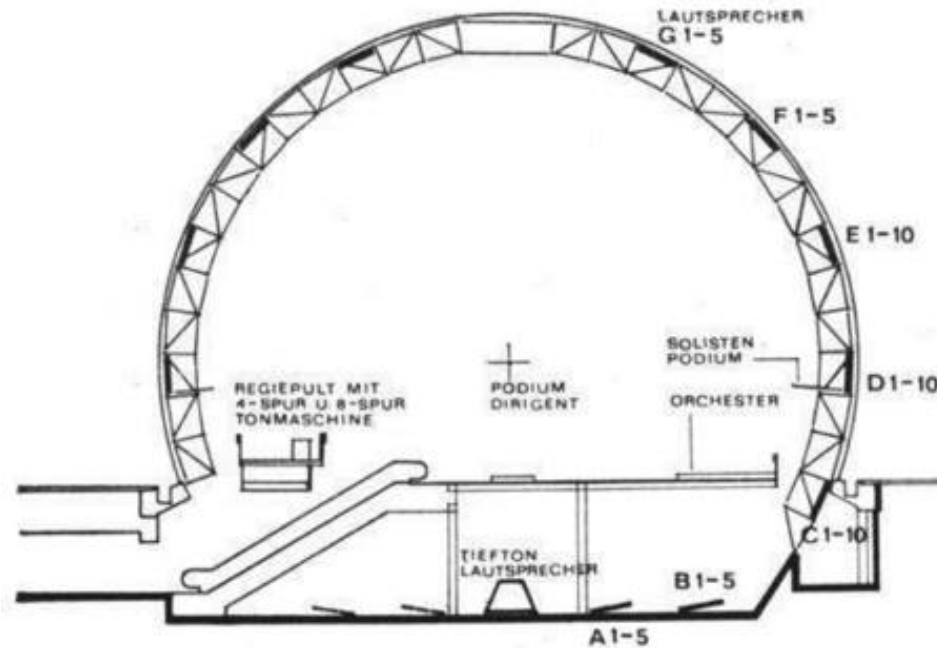
(both images © Stockhausen  
Foundation for Music)



# A bit of History

Mostly discrete routing, a bit of amplitude panning.

Lots of fun with acoustics.



# A bit of History

François Bayle's Acousmonium (Radio France):  
80 different speakers spread around, for live  
*diffusion* of tape music (usually stereophonic).



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A modern-day successor is the **BEAST** (Birmingham Electro-Acoustic Sound Theatre).





# A bit of History

Systems like these are not aiming at a systematic, portable approach to with-height surround.



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They are part of the artwork, and of the creative process.



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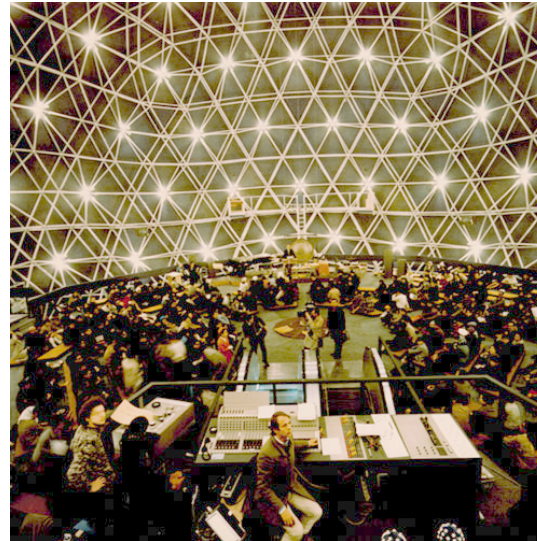
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Their deficiencies mark important artistic constraints, which are either fought against, or put to use.

In any case, they are integral parts of the artwork, too.



# A bit of History



That is of course a brilliant  
excuse :-D



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Let's look instead at systems that

- aim for widespread deployment in a wider potential market



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# A bit of History



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Let's look instead at systems that

- aim for widespread deployment in a wider potential market
- aim to reproduce content by third parties
- define clearly how the system should be implemented



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# A bit of History

- Michael Gerzon 1973, *periphonic* (i.e. with-height) surround sound using 4 channels:  
***B-format***
  - loudspeaker layout agnostic
  - scalable

In 1992, Gerzon proposed this as a candidate format for HDTV. Alas, ...



# A bit of History

- Tomlinson Holman, 1999: eight speakers on the horizontal plane (with heavy frontal bias), two subs left and right, and two elevated frontal speakers: **10.2**
  - speaker feed mixing

(“Twice as good as 5.1”)



# A bit of History

- Werner Dabringhaus, 1999: front left/right, rear left/right, elevated front left/right: **2+2+2**
  - stereo-pairwise mixing using traditional miking techniques

Designed to work on DVD-Audio, with the 5 plus 1 channels available. Some tricks to ensure a meaningful (although compromised) image when played back over an ITU 5.1 rig.



# A bit of History

- Wilfried van Baelen (Galaxy Studios), 2005:  
an ITU 5.1 system with elevated speakers above  
L, R, Ls and Rs: ***Auro-3D***
  - same basic idea, yet more channels

The proposal includes some neat encoding tricks to funnel 10 (or more) signals into 5.1 carriers, or into the 8 PCM streams of a Blu-ray disc.



# A bit of History

- Kimio Hamasaki et. al, 2005 (NHK): ten horizontal channels, eight elevated channels, one “voice of God”, three front low channels, two subs:

**22.2**

Designed as a complement to the proposed Ultra-HDTV standard for total immersion.  
Again, more channels...



# And back in the present...

It seems there are many variations on the theme.

Now let's all go pick an arbitrary pair {N.M} and stick our names on it.



My own humble claim to  
fame is:



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My own humble claim to fame is:

**44.4**



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My own humble claim to fame is:

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*Eat my dust, Kimio :-D*



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*That is of course just a  
joke.*

*The system was used  
for IOSONO playback,  
and higher-order  
Ambisonics.*



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# Learning from History

- Except for Ambisonics, all proposals share the same paradigms/problems
  - more and more channels without real up- and downwards compatibility
  - frontal bias
  - speaker-feed mixing
  - underspecified signal relationships (correlation etc.)



# Perception



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# How do we perceive direction?

Left/right (horizontal) cues are

- interaural time difference ***ITD*** (at LF)
  - no head shading (perfect diffraction)
  - unambiguous phase (wavelength  $>$  2x ear dist.)



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Left/right (horizontal) cues are

- interaural time difference **ITD** (at LF)
  - no head shading (perfect diffraction)
  - unambiguous phase (wavelength > 2x ear dist.)
- interaural level difference **ILD** (at HF)
  - head shading
  - ambiguous phase!





# How do we perceive height?

How about a source that moves up on the *median plane* (i.e. right in front of us)?

- constant ITD, no cue
- constant ILD, no cue

-> All we have is a slight change of tone colour, due to ear flaps (*pinnae*) and head/torso effects.



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If it's just tone colour, how do we perceive height when we don't know the uncoloured sound?

Short answer: we don't.

Long answer: we do not. But some narrowband signals suggest height regardless of the actual source elevation (Blauert, 1983).



# How do we perceive height?

Humans don't perceive height very well. Signal semantics dominate:

- Airplane? must be up. Birds, likewise.
- Footsteps? flowing water? down.

And if you see a source, that's where you hear it, usually (*multi-modal perception*).



# How do we perceive height?

But:

- We can move our head to direct the more acute horizontal localisation mechanisms at any source.
- We can “explore” a sound field at leisure.



# Then why bother?



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- height localisation



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• height localisation

**Nobody cares!**



# Uses for height *localisation*

- better audibility of complex structures due to vertical separation: e.g. organ music
- more precise reproduction of room acoustics: characteristic ceiling reflections
- use of location as a precisely audible musical parameter, like pitch and duration
- discrete sources at height: elevated choirs or solo instruments, opera scenes





# Height reproduction in Stereo

- Stereo := using stereophonic techniques
  - level differences in speaker pairs (=artificial ILD)
  - time differences in speaker pairs (=artificial ITD)

But: not used on the median plane.

Tone colour for any given height is ***not*** the sum of upper speaker tone colour plus lower speaker tone colour weighted by relative amplitude.



# Height reproduction in Stereo

Hence: ILD/ITD not much use for height, steep localisation curve.

Bottomline: it's either on the bottom speaker, or on the upper speaker.

No stable auditory events in between (however, suggesting quick vertical movement is possible).



# Height reproduction in Stereo

Artificially delivered ITD/ILD fall apart when the listener's head is rotated away from the frontal upright orientation.

Don't move!



# Height reproduction in Ambisonics

Ambi attempts to get the soundfield correct, to some degree.

In a correct soundfield, you can move any way you like and collect useful cues.

Once your brain has locked onto a cue, localisation remains stable even if you move.



# Bottom line:

- Only Higher-order Ambisonics and VBAP can create meaningful and stable auditory events at continuously variable elevation.



# Is with-height surround really worth the trouble?



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# Depends.



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**Thanks for your attention.  
I'm looking forward to your remarks and  
questions.**

