



AALTO UNIVERSITY - DEPARTMENT OF MEDIA

TIME TURNED INTO SPACE - 2019

# A BRIEF INTRODUCTION TO SPATIAL SOUND

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# A BRIEF HISTORY OF PURELY MUSICAL ATTEMPTS

- ▶ Contrarily to what many believe, spatial sound is born long before VR and is possibly as ancient as music.
- ▶ Cori spezzati - Willaert, Gabrieli, Venice 16th century. Monteverdi, Vespro della Beata Vergine, 1610. <https://www.youtube.com/watch?v=JiyjQzPsy3I>
- ▶ Tallis, *Spem in alium* Queen Elizabeth's 40th birthday, 1573: 40 separate vocal parts eight 5-voice choirs. <https://www.youtube.com/watch?v=Z3FJxDsa-5k>
- ▶ *Tuba Mirum* section of Hector Berlioz's *Requiem*, 1837. Four separate brass ensembles in the four points of the compass introduce the choir.
- ▶ Off-stage brass section in Giuseppe Verdi's *Requiem* 1874. <https://www.youtube.com/watch?v=DY0P3UKFXC8>
- ▶ Ives the unanswered question, 2 instrumental groups: offstage strings vs on-stage trumpet soloist and woodwind ensemble, 1908 - 1930/35. <https://www.youtube.com/watch?v=vXD4tIp59L0>
- ▶ Brant Antiphony I, 1953, five spatially-separated orchestras. Windjammer, 1969 stationary horn soloist and several wind players who moved along prescribed routes while playing. *Orbits*, 1979, a *Spatial Symphonic Ritual for 80 Trombones, Organ and Soprano Voice* <https://www.youtube.com/watch?v=onAYYOObbWc> + Video interview on spatial music <https://www.youtube.com/watch?v=fmi3uEHH8oM>
- ▶ Stockhausen Gruppen, 1958, Three independent orchestras to play at the same time but at different tempos, creating a conflict of time and space. [stockhausenspace.blogspot.fi/2014/12/opus-6-gruppen.html](http://stockhausenspace.blogspot.fi/2014/12/opus-6-gruppen.html)
- ▶ A pretty good historical account of spatial music: [https://econtact.ca/7\\_4/zvonar\\_spatialmusic.html](https://econtact.ca/7_4/zvonar_spatialmusic.html)



# 1877 THE FIRST PHONOGRAPH

- ▶ 1877, Thomas A. Edison: The earliest recording systems were pioneered in the 1800's.
- ▶ Thomas Alva Edison succeeds in recording and playing back the song *Mary's Little Lamb* from a strip of tinfoil wrapped around a spinning cylinder in 1877.
- ▶ The "recording" was monophonic and the transduction was only mechanical (no electricity involved).



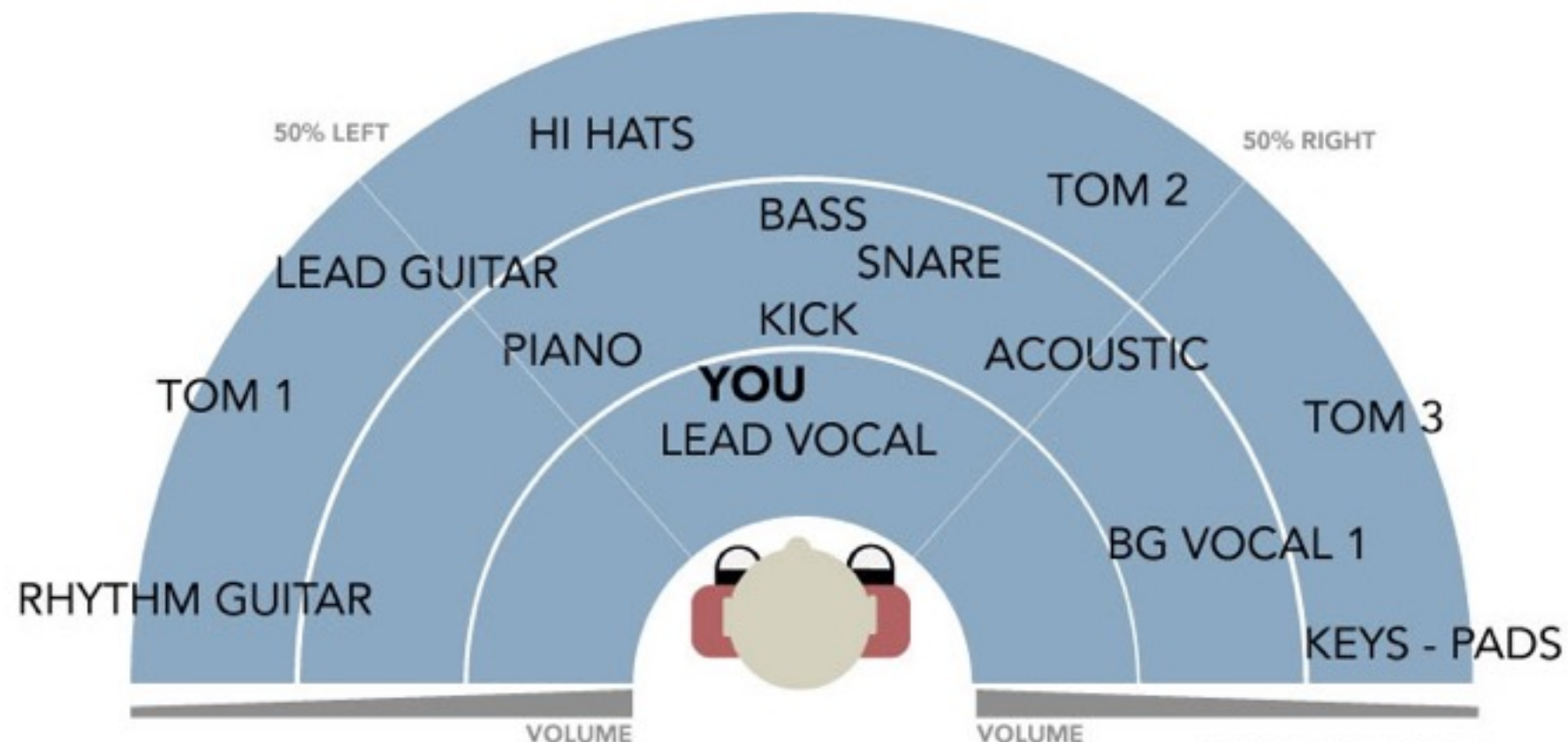
# 1881, THÉÂTROPHONE: FIRST SPATIAL PLAYBACK

- ▶ Clement Ader, using carbon microphones and armature headphones, accidentally produces a stereo effect when listeners outside the hall listened to two adjacent telephone lines linked to two different stage mikes at the Paris Opera.
- ▶ He places 10 microphones (telephone transmitters) in front of the stage uses these to transmit and reproduce 5 individual pairs of receivers at the Palace of Industry; two miles away from the Paris Exhibition.
- ▶ Listeners at the Place of Industry could perceive some degree of spatial realism. In 1890 the invention was commercialised by Compagnie du Théâtrophone and operated till 1932.



# 1931 – STEREOPHONIC SOUND

- ▶ Alan Blumlein experiments with two microphones, two channels and two loudspeakers for recording/reproduction.
- ▶ His patent “Improvements In and Relating to Sound Transmission, Sound Recording and Sound Reproducing Systems” forms the base of what we call *stereophonic sound* today.
- ▶ His most important realisation was that stable “phantom” images could be perceived by a central placed listener between two correctly positioned loudspeakers (on the left and right) using level differences between the loudspeakers, that would be interpreted as time and level differences by the auditory system.
- ▶ The theory was suggested in 1931, the first stereophonic recording was produced in 1958.





# 1951, PIERRE SCHAEFFER: POTENTIOMETRE D'ESPACE

- ▶ System designed for the premiere of Pierre Schaeffer's *Symphonie pour un homme seul* in 1951. Intended to control the dynamic level of music played from multiple turntable.
- ▶ Loudspeakers' placement in the hall: two loudspeakers at the front, right and left of the audience, one placed at the rear, and one in the centre above the audience.
- ▶ It created a stereophonic effect by controlling the positioning of a monophonic sound source over multiple speakers. One of five tracks, provided by a purpose-built tape machine, was controlled by the performer and the other four tracks each supplied a single loudspeaker. Mixture of live and preset sound positions.
- ▶ On stage, the control system allowed a performer to position a sound simply by moving a small, hand held transmitter coil towards or away from four larger receiver coils arranged reflecting the loudspeaker positions.
- ▶ The central concept underlying this method was the notion that music should be controlled during public presentation in order to create a performance situation.
- ▶ "One finds one's self sitting in a small studio which was equipped with four loudspeakers—two in front of one—right and left; one behind one and a fourth suspended above. In the front center were four large loops and an "executant" moving a small magnetic unit through the air. The four loops controlled the four speakers, and while all four were giving off sounds all the time, the distance of the unit from the loops determined the volume of sound sent out from each. The music thus came to one at varying intensity from various parts of the room, and this "spatial projection" gave new sense to the rather abstract sequence of sound originally recorded. ([Gradenwitz 1953](#))"



# 1973, MICHAEL GERZON: AMBISONICS

- ▶ Traditional surround technologies are more immersive than simple two-channel stereo, but the principle behind them is the same: they all create an audio image by panning audio in a specific, pre-determined array of speakers. Stereo sends audio to two speakers; 5.1 surround to six; 7.1 to eight; and so on.
- ▶ Ambisonics is “speaker-agnostic.” It can be decoded to *any* speaker array in a sphere of dome setting.
- ▶ Ambisonic audio represents a full, uninterrupted sphere of sound.
- ▶ A more accurately, each of the four channels represents, in mathematical language, a different **spherical harmonic component** – or a **different microphone polar pattern pointing in a specific direction**, with the four being coincident (at the centre point of the sphere):
- ▶ **W** is an omni-directional polar pattern, containing all sounds in the sphere, coming from all directions at equal gain and phase.
- ▶ **X** is a figure-8 bi-directional polar pattern pointing forward.
- ▶ **Y** is a figure-8 bi-directional polar pattern pointing to the left.
- ▶ **Z** is a figure-8 bi-directional polar pattern pointing up
- ▶ <https://www.youtube.com/watch?v=gnXzPIRdQBg> ambisonics microphone
- ▶ <http://www.blueripplesound.com/products/o3a-core> free ambisonics plug-in

# 1970'S, MURRAY SCHAFER: SOUNDWALKS

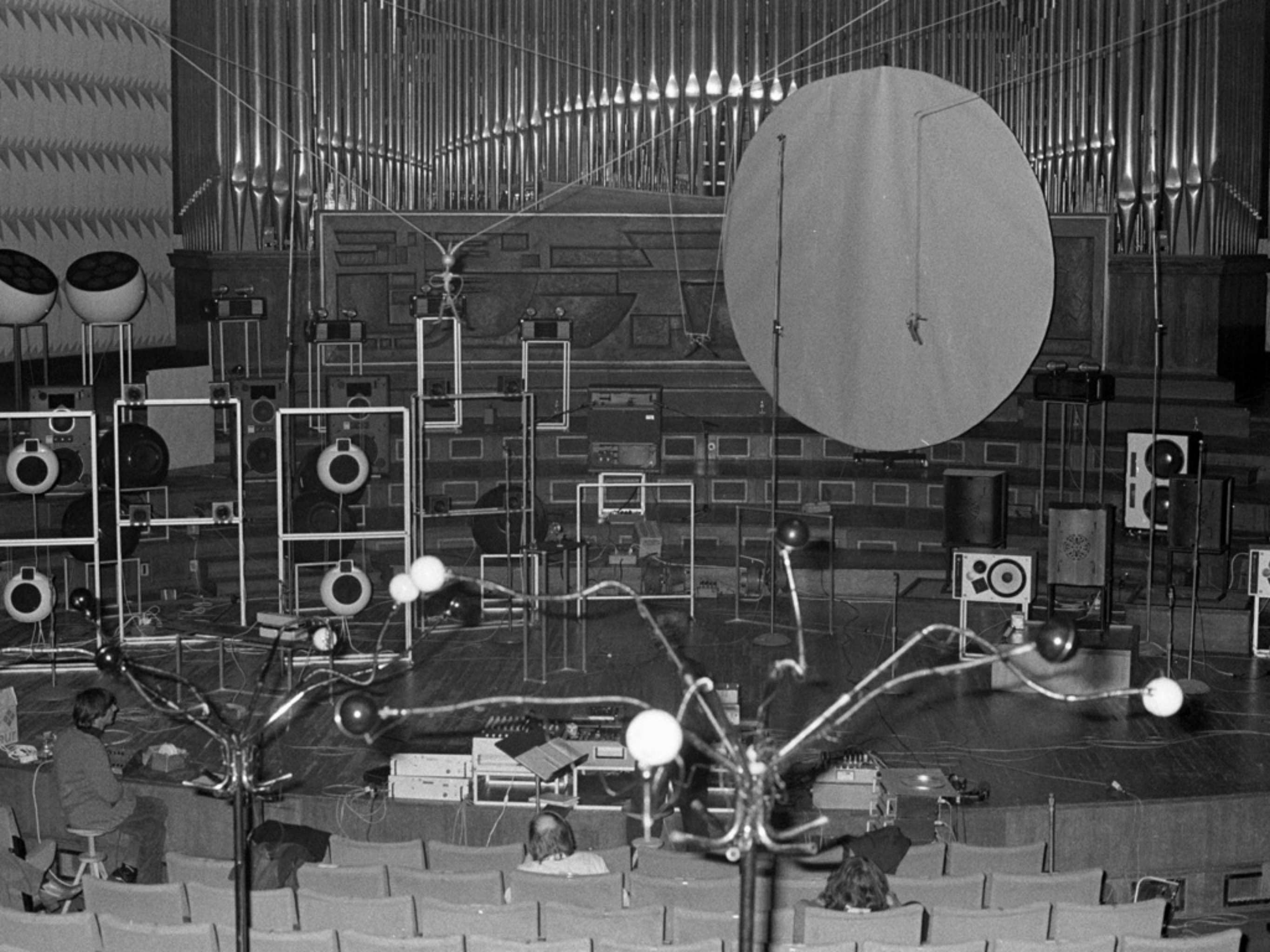


- ▶ A soundwalk is a walk with a focus on listening to the environment. The term was first used by members of the World Soundscape Project, an international research project of the late 1960s at Simon Fraser University in Vancouver.
- ▶ The project initiated the modern study of acoustic ecology. It was under the leadership of composer R. Murray Schafer in the 1970s.
- ▶ Hildegard Westerkamp, from the same group of artists, defines soundwalking as "*... any excursion whose main purpose is listening to the environment. It is exposing our ears to every sound around us no matter where we are.*"
- ▶ <https://www.sfu.ca/~westerka/writings%20page/articles%20pages/soundwalking.html>
- ▶ <https://musicampto.com/2013/06/17/what-are-soundwalks-soundscapes/>



# 1974, FRANCOIS BAYLE GRM: ACOUSMONIUM

- ▶ In 1966 composer and technician François Bayle is in charge of the Groupe de Recherches Musicales.
- ▶ In 1974 Bayle and the engineer Jean-Claude Lallemand created an orchestra of loudspeakers (*un orchestre de haut-parleurs*) known as the Acousmonium. (Anon. & [2010]). An inaugural concert took place on 14 February 1974 at the Espace Pierre Cardin in Paris with a presentation of Bayle's *Expérience acoustique* (Gayou 2007, 209).
- ▶ The Acousmonium is a specialised sound reinforcement system consisting of between 50 and 100 loudspeakers, depending on the character of the concert, of varying shape and size. The system was designed specifically for the concert presentation of musique-concrète-based works but with the added enhancement of sound spatialisation. Loudspeakers are placed both on stage and at positions throughout the performance space (Gayou 2007, 209) and a mixing console is used to manipulate the placement of acousmatic material across the speaker array, using a performative technique known as *sound diffusion* (Austin 2000, 10-21).
- ▶ Bayle has commented that the purpose of the Acousmonium is to "*substitute a momentary classical disposition of sound making, which diffuses the sound from the circumference towards the centre of the hall, by a group of sound projectors which form an 'orchestration' of the acoustic image*" (Bayle 1993, 44).
- ▶ As of 2010, the Acousmonium was still performing, with 64 speakers, 35 amplifiers, and 2 consoles (Anon. & [2010]).







# 1980'S BINAURAL SOUND

- ▶ Binaural recording requires a dummy head technique where two cardioid microphones are placed inside the ear canals of a mannequin (or real) head to record the stereo track with the effect of the dummy head HRTF.
- ▶ It is possible to emulate this effect by simply apply the HRTF filtering to any recorded mono-source, which is the base of current VR sound systems.
- ▶ It only works via headphones!
- ▶ In 1979, first commercially produced binaural pop record was Loe Reed's *Street Hassle*. In 1983 Pink Floyd used *holophonics* (a similar sistem developed by Hugo Zuccarelli) for *The Final Cut*.
- ▶ Many AMSR recordings are done with commercially available binaural microphone to use in one's ears.
- ▶ Listening examples
- ▶ <https://www.head-fi.org/threads/legally-downloadable-binaural-recordings-links.223165/>  
Disclaimer: extremely sexist!!!
- ▶ <https://www.youtube.com/watch?v=Yd5i7TlpzCk> Disclaimer: just a bit silly...
- ▶ <https://en-de.sennheiser.com/ambeo-blueprints-downloads> a free plug-in for binaural sound.



# 1982 BIRMINGHAM ELECTROACOUSTIC SOUND THEATRE (BEAST)

- ▶ A sound diffusion system specifically designed for the performance of [electroacoustic music](#). It is a long-running project of the Electroacoustic Music Studios at the [University of Birmingham](#), founded in 1982 under the directorship of [Jonty Harrison](#). Since 2014 BEAST has been directed by [Scott Wilson](#), along with Annie Mahtani and James Carpenter as technical director. Simply put, it consists of a set of loudspeakers connected to a computer, usually controlled by a diffusion console.
- ▶ BEAST can consist of up to over 100 channels of [loudspeakers](#), often arranged largely in pairs or rings,, and includes ultra-low frequency loudspeakers (*bins*) and custom-built trees of high frequency speakers (*tweeter trees*) which can be suspended above an audience.
- ▶ The minimum set-up that BEAST would ordinarily use for stereo diffusion comprises a set of 8 loudspeakers known as the *Main Eight*. These four pairs of loudspeakers, using BEAST nomenclature, are termed *Main*, *Wide*, *Distant* and *Rear*. The *Main* and the *Wide* speakers together form the main, frontal sound image, the *Main* speakers being placed to act somewhat like the loudspeakers in a typical studio, and the *Wide* speakers acting to stretch that sound image out across the audience's sound stage. The *Rear* speakers, which are behind the audience, provide immersion and the possibility of movement around the audience. Finally, the *Distant* speakers, which are positioned to hold their image behind the *Main* speakers, create a sound whose perspective is distant to that of the *Main* pair.
- ▶ Other speakers are added to this *Main Eight* to allow additional possibilities for sound movement and differing sound perspectives.



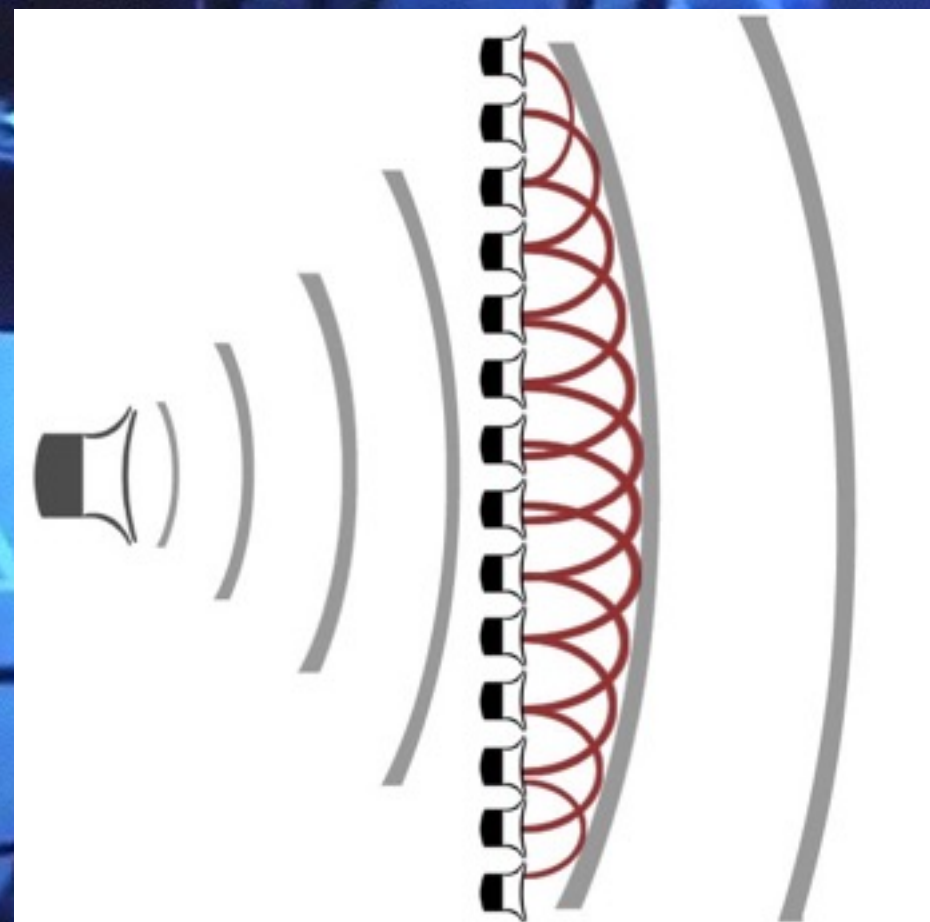
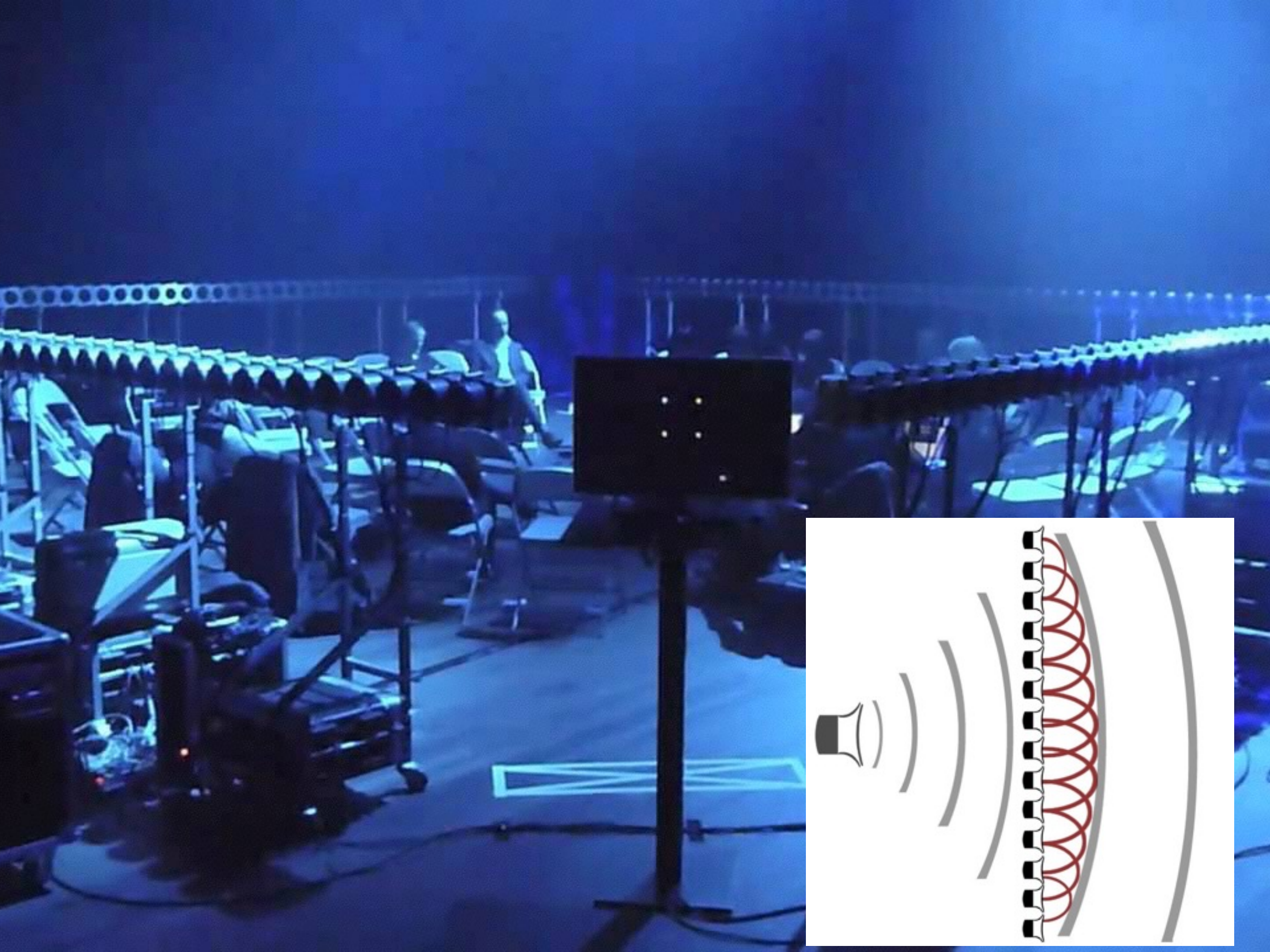




# 1988, A.J. BERKHOUT: WAVEFIELD SYNTHESIS

- ▶ Wave field synthesis (WFS) is a **spatial audio** rendering technique, characterized by creation of virtual **acoustic environments**.
- ▶ It produces *artificial wavefronts* synthesized by a large number of individually driven **loudspeakers**. Such wavefronts seem to originate from a virtual starting point, the *virtual source* or *notional source*.
- ▶ Contrary to traditional spatialization techniques such as stereo or surround sound, the localization of virtual sources in WFS does not depend on or change with the listener's position.
- ▶ It was first developed by Professor A.J. Berkhout at the Delft University of Technology. Wavefield synthesis involves the reconstruction of a single acoustic source from many individual sources (loudspeakers). It is actively under research by many audio research labs.
- ▶ It is based on the Huyghens' principle. Simple example: A rock (or primary source) thrown in the middle of a pond generates a wave front that propagates along the surface. Huyghens' principle indicates that an identical wave front can be generated by simultaneously dropping an infinite number of rocks (secondary sources) along any position defined by the passage of the primary wave front







# ANATOMY OF A SPATIALISER

- ▶ Source(s) position (xyz OR aed), orientation (optional), spread (optional).
- ▶ Speakers position / listener position for headphone based systems
- ▶ Spatialisation / panning strategies (stereo, surround, binaural, ambi, Vbap, Dbap...)
- ▶ Spatial simulation strategies: doppler fx, absorption, reflection, diffusion and reverb.
- ▶ Movements and trajectories (or envelopes). Usually under automations (sequencers) or messages from scripting language (game engines or interactive media softwares).

