

Mapping the Invisible Landscape

An Exercise in Spatially Choreographed Sound

Paul Bavister of Audialsense describes how a series of auditory research installations in the Turbine Hall of the Tate Modern presented the opportunity to play with the relationship between sound and the built, inverting the usual relationship in which architecture accommodates the acoustic.

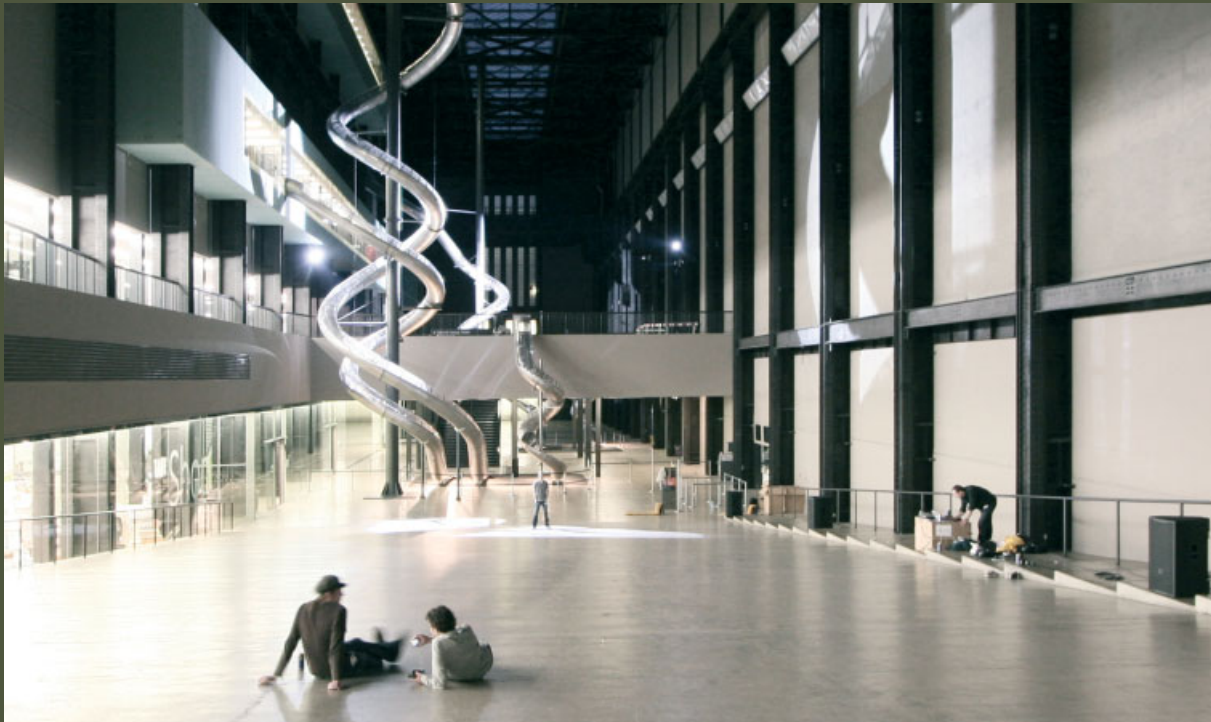
audialsense

The Unilever Series:
Carsten Höller

Audialsense, '100hertz', Tate Modern,
Bankside, London, April 2007
The Turbine Hall interior.



Beginning the walk down the ramp of the Turbine Hall to get a feel for where the standing waves occurred.



The site of the installation showing speakers located on the steps along the side of the Turbine Hall.



Recording the pulse of the standing waves on a digital sound recorder from a fixed position.

When sound is reflected off a room boundary, the reflected wave interacts with the incident wave causing constructive and destructive interference patterns.

The physical relationship between architecture and sound has been practised throughout history. The built-in 'resonant chambers' in the walls of ancient theatres and temples, and the Denge sound mirrors near Dungeness in Kent are but two examples of how the physics of sound influences the shape of the built environment. However, this relationship can be turned on its head, and an acoustic environment that has been shaped by the built can emerge as 'unseen architecture', never previously considered or imagined by its original designers.

Since its conversion from a power station in May 2000 by Herzog & de Meuron, the Turbine Hall at Tate Modern on London's Bankside has established itself as one of the world's most important cultural landmarks. Its cavernous interior has hosted some of the largest interior installations ever produced, and as such each Unilever-sponsored project is highly anticipated due to the challenge of this scale. For one evening on 5 April 2007, Audialsense (Paul Bavister, Jason Flanagan and Ian Knowles) were given access to the vast space of the Turbine Hall to conduct a series of auditory research installations looking at the spatial effects of 'pure sound' within such a large volume, effects that could be experienced audibly, and physically due to the large pressure differentials inherent in standing waves.

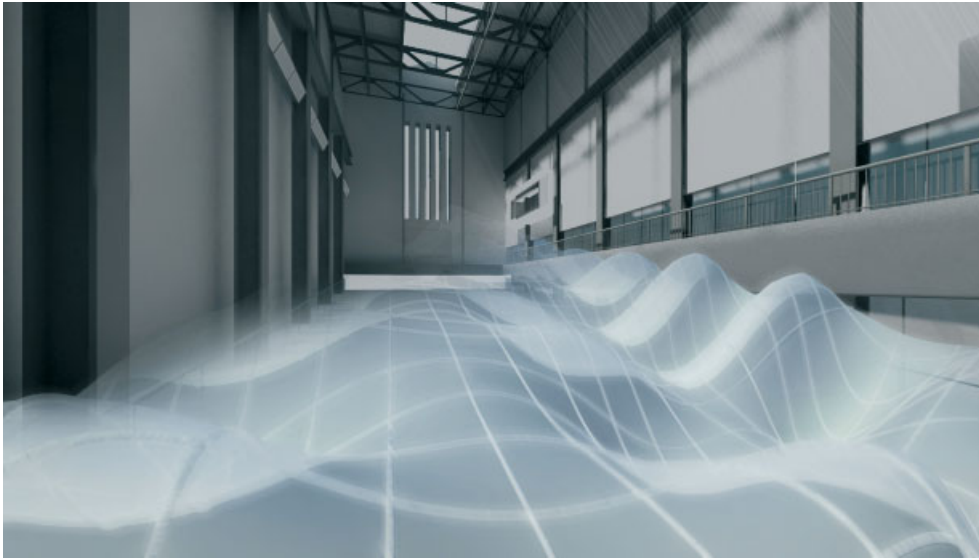
Sound is made up of travelling pressure waves. Externally, sound levels diminish with distance as the energy is dissipated. The interaction of sound with architecture brings about a much more complex situation. When sound is reflected off a room boundary, the reflected wave interacts with the incident wave causing constructive and destructive interference patterns.

Standing waves may be created from the collision of two waves (with equal frequency and wavelength) travelling in opposite directions. The net result alternates between zero and a maximum amplitude, unlike the travelling waves. In a room, the locations of these maxima and minima are stationary and can be both predicted and experienced physically.

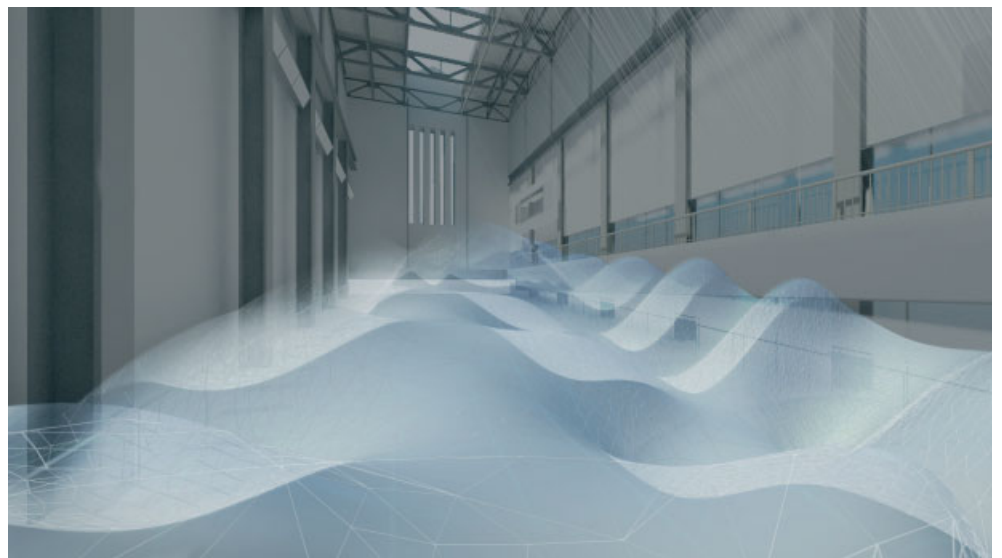
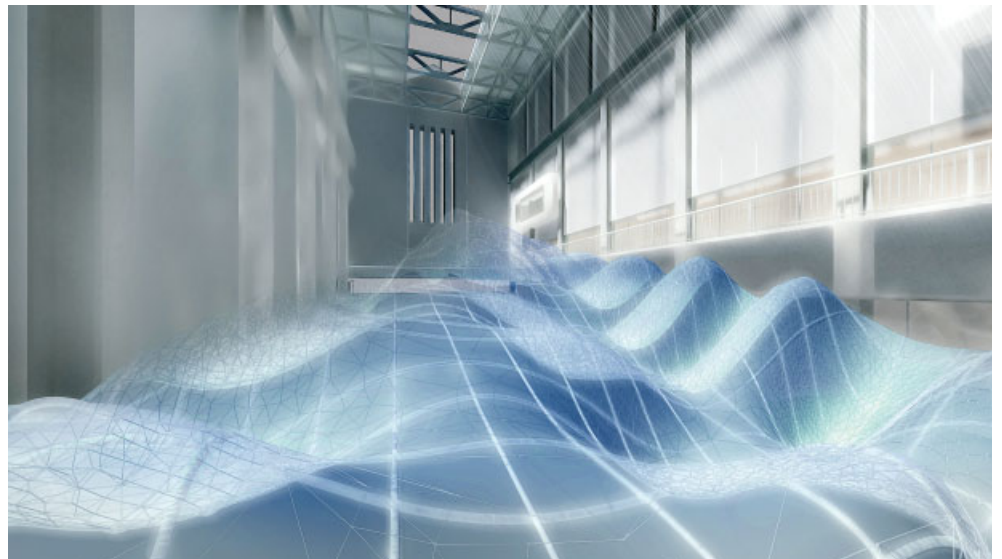
Standing wave phenomena can also occur in a room at specific frequencies, often referred to as resonance frequencies, which are dependent on the dimension and shape of the space. At resonance, the acoustic response of the room will be enhanced. Resonance frequencies are defined as room modes, and depending upon how many of the room boundaries are involved, they are termed axial, tangential or oblique, with axial modes being the strongest.

The fundamental mode is the frequency corresponding to the lowest whole wavelength that can be accommodated in a space, and so there is a fundamental frequency that corresponds to the length, width and height of a room. Multiples of the fundamental are called harmonics.

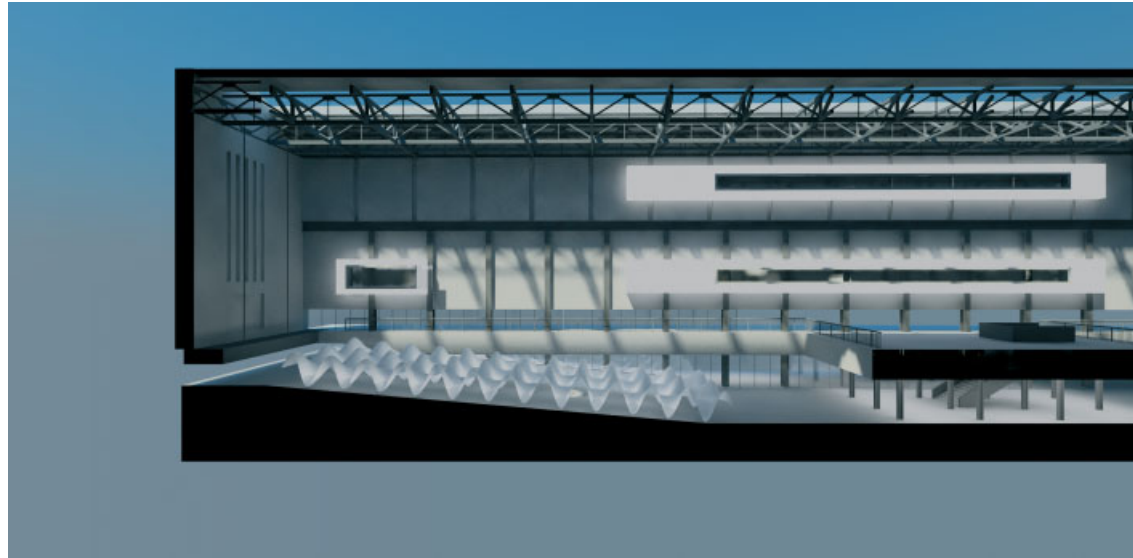
So when standing waves occur at sufficient volume, they become perceivable by physical means, the air densities of the waves being higher than normal air pressure, so that the appearance of walking into, and out of, the sound is apparent. As these waves appear spatially according to the modal characteristics of the room, it is important for designers to understand how these



The sonic landscape formed by the standing waves in the occupied zone of the hall.



Longitudinal section through the Turbine Hall showing the distribution pattern of the standing waves.



invisible patterns manifest themselves. How do we interact with an invisible landscape of differing air densities, and can such a landscape be visualised?

From transformers in an adjacent (working) power station, sited at either end of the Turbine Hall, a 100-hertz hum is emitted. This hum is omnipresent, and varies only by a few hertz over time, a fluctuation that is modulated by the activities of the people living and working around the gallery who draw on the electricity supply.

In the first installation, Audialsense first played back a pure 100-hertz tone into the gallery to counter the existing tone. The effect was twofold. Initially there was silence. Even though 100 hertz at considerable volume was being played into the hall, there was none of the familiar auditory evidence of this. However, on mapping the locations of standing waves, the volume became apparent: one only had to move slightly to find oneself in a deafening ball of volume. The effect was quite unsettling, a very loud and physical experience, even encouraging clothes to flap! Most spectacular was the incredible interference that occurred when the hall's existing 100-hertz hum dropped a few hertz due to activity in the local area. The hall seemed to slowly groan and shudder, before settling back into its 100-hertz equilibrium.

The Turbine Hall measures approximately 152 metres (498.7 feet) long, 30 metres (98.4 feet) high and 24 metres (78.7 feet) wide, dimensions that correspond to wavelengths of 2.2 hertz, 11.3 hertz and 14.1 hertz. When scaled in a purely mathematical ratio, the pitch of the sine waves enters into the realm of human hearing, and formed a site-specific chord, which was then held for a long time to allow standing waves to be formed

within the space. The standing waves were also site specific, and were physically perceived/experienced. Audialsense then introduced scrolling sine waves into the space. These are waves that rise and fall in pitch between two set parameters, which in this case were defined by the extremes of the human voice, both male and female. As the two 'gender-specific' waves gently oscillated, they passed the static waves as defined by the room, causing interference and beating (rhythmic pulses of sound).

All buildings have an element of 'noise' that exists within their walls. A building's infrastructure acts a conduit/sounding board for all the bumps, squeaks and groans that general occupancy generates, and such sounds can be captured by accelerometers. Using the previously defined site-specific 'chord', Audialsense next added elements of structure-borne noise into the mix, finally hearing the building as defined by both spatial and physical qualities.

In order to establish the locations of the standing waves during each of the installations, a number of walks were taken through the hall along a predetermined route of equal length and time with a digital sound recorder. The recordings were then uploaded to a computer and visualised using basic frequency and spectral analysis software, which revealed the fluctuations in sound pressure during each individual installation. As the walks were identical in time and length, any shift in the analysis data indicated a changed location of standing-wave phenomena. Longitudinal and lateral standing waves at 100 hertz were identified, the acoustic response of the Turbine Hall being a series of pools of constructive and destructive interference revealing a landscape of sound that is dramatically opposed to the regular, linear nature of the architecture. **AD**

The results of these experiments were presented at the Sonic Arts Networks annual conference in Plymouth in 2007. Audialsense would like to thank Tate Modern and JBL speakers for their kind support of this project.

Text © 2008 John Wiley & Sons Ltd. Images © AUDIALSENSE; photos Phillipe Brysee, drawings © KibweTavares