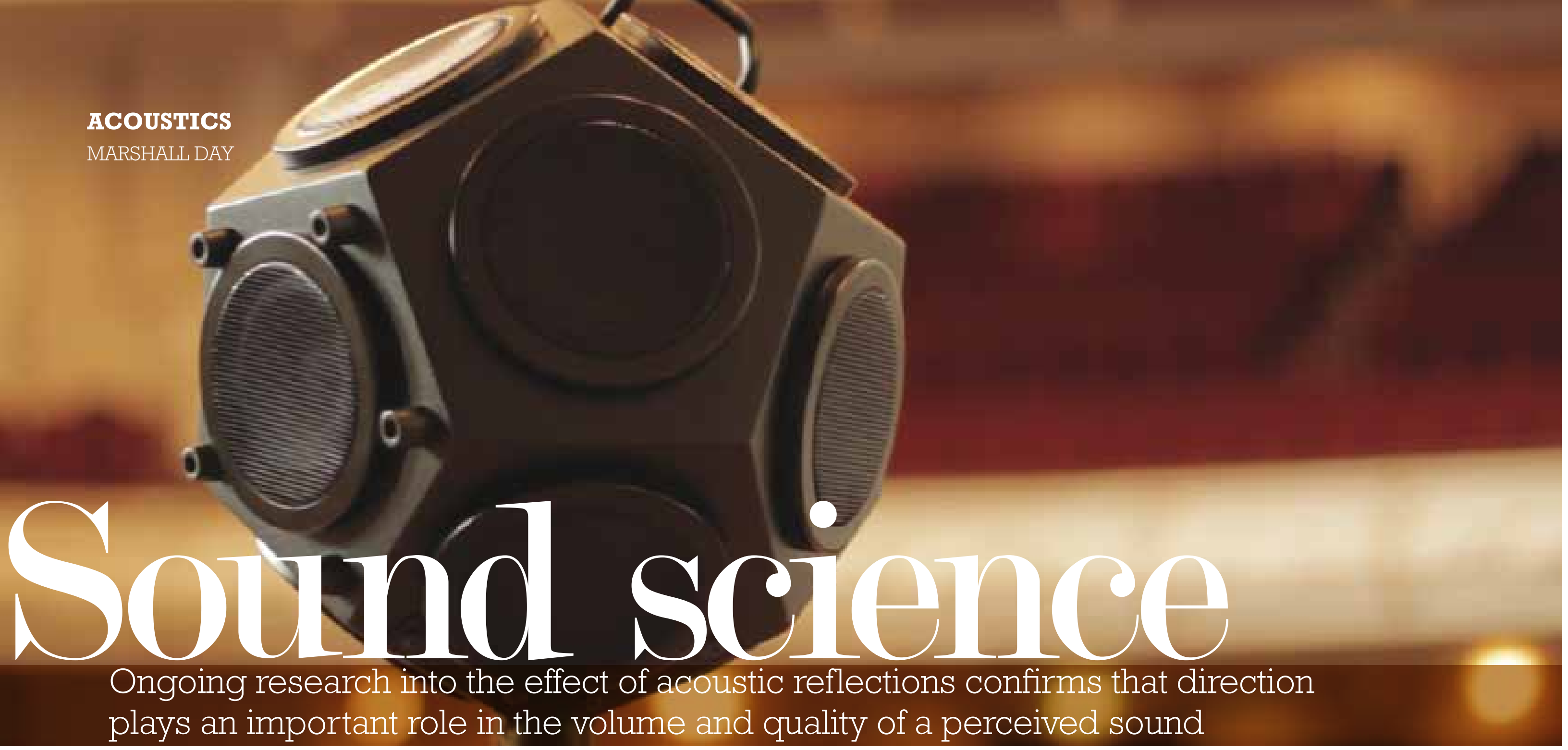


Sound science

Ongoing research into the effect of acoustic reflections confirms that direction plays an important role in the volume and quality of a perceived sound

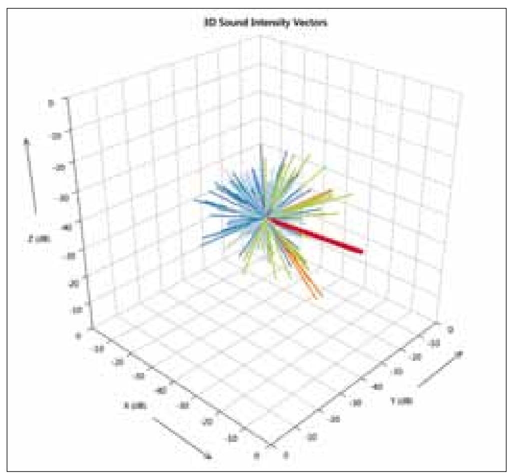
Although many great concert halls were built prior to 1900, by the middle of the 20th century auditorium design had not progressed much beyond the estimation of reverberation time. However, the craft of understanding and analysing the acoustics of performing spaces has greatly developed in more recent times.

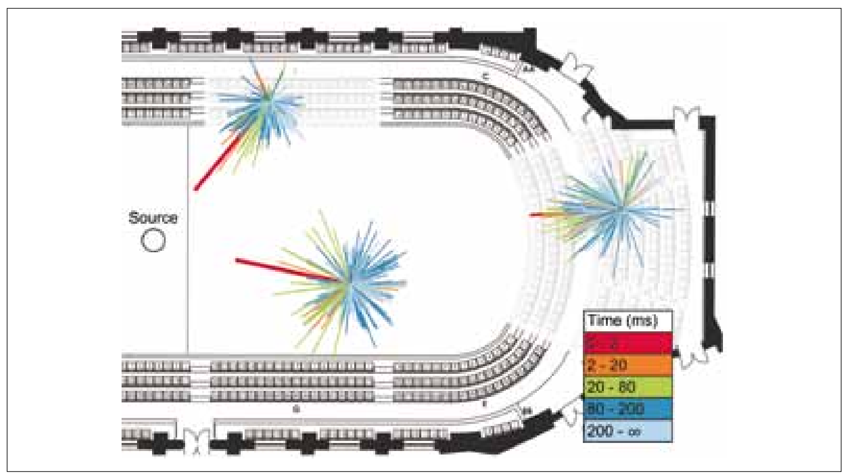
The sound in any concert hall comprises the direct sound generated by the performers and reflections of this sound as it travels throughout the interior of the auditorium. It is now widely accepted that it is not just the timing and the strength of the reflections, but also the direction, that influence the extent a listener is immersed in the sound of a performance.

In 1952, Rolf Thiele, a researcher in Germany, realised that reverberation time did not explain everything in terms of how a room sounds. He proposed a technique for measuring and visualising the directional distribution of reflections as 'hedgehog patterns'. The length and angle of each line corresponds to the strength and direction of each reflection compared to the direct sound.

In the late 1960s, while reviewing various designs for the Christchurch Town Hall, Harold Marshall investigated the effect of room shape on acoustical quality. He discovered that early lateral reflections, associated with narrow, rectangular halls, were important in providing a sense of space. This effect was further investigated and quantified by Marshall in collaboration with Michael Barron in 1981. Spatial impression is now recognised as an important characteristic of good sounding concert halls, and is a key consideration in room design and analysis.

Multidirectional loudspeaker (above) **and tetrahedral microphone array** (opposite) **used for 3D measurements; IRIS plot showing strength, direction and arrival time of a reflected sound** (below left)**; plots measured in the Auckland Town Hall showing variation of reflections at different locations** (below right)





Advanced measurement

The acoustical characteristics of a room are traditionally determined using single channel impulse response measurements. These yield information about sound reflections in terms of time and strength, but not direction. Researchers have developed 3D impulse response measurement systems in the past, but these use custom, expensive or impractical equipment. The IRIS measurement system, developed by Marshall Day Acoustics, enables 3D impulse responses to be captured and analysed through a commercially available tetrahedral microphone array and a calibrated USB audio interface.

The IRIS plot is at the heart of the system. Sound reflections arriving at the microphone array are represented as a series of coloured spikes. The length and direction of each 'spike' of the 'hedgehog' correspond to the reflection strength and direction. Spikes are coloured according to when the reflections arrive. The plot can be used to relate sound rays to physical features of the room, observe the directional distribution of early and late sound energy and identify surfaces causing problematic reflections. The graphical nature of the IRIS plot enables easy comparison between different seats in a room.

Numerical magnitude, time and direction information may be obtained for a comprehensive analysis of individual reflections. A standard impulse response waveform is provided to allow calculation of standard room acoustic parameters according to ISO 3382.

IRIS is considered to be a breakthrough in real-world acoustics. It puts spatial analysis into the hands of acousticians around the world. ■

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