Shining a laser spotlight on the egg box myth

By Ben Piper

Egg boxes have often been suggested as a cheap acoustic treatment for the home studio. In March 1988 the Riverbank Acoustical Laboratories measured the absorption properties of egg boxes, finding that their noise reduction index was 0.4 [1]. The results showed that at low frequencies egg boxes did very little but from 700 Hz up there were some moderate levels of absorption. This experiment deals with the question of whether they can be used as absorbers but what about their diffusion characteristics? This article will use the example of measuring the spatial distribution of reflections from a panel covered with egg boxes to show how the non-invasive technique of refracto-vibrometry can be used to measure a sound field.

Refracto-vibrometry

A scanning vibrometer is typically employed to measure the vibration of surfaces, particularly in the automotive and loudspeaker industries. Vibrometers work on the principle of laser Doppler vibrometry where a laser beam is focussed on a vibrating target and the Doppler shift of the light caused by the moving surface is measured by the instrument. Mirrors within the instrument are mounted on rotating stages allowing the laser beam to be scanned at a number of angles giving full 2D scans of vibrating surfaces. They are highly sensitive instruments that offer the possibility of measuring a large number of points on a surface in a fast and non-invasive way.

One of the uncertainties associated with this method is the effect of sound on the laser beam as it passes from the instrument to the surface in question. As a sound wave travels through a fluid medium it causes local changes in density that result in small changes in the fluid's refractive index and therefore in the speed of sound and, consequently, the time of flight. To the vibrometer, these are indistinguishable from surface vibrations and it interprets the local perturbations as small velocity components.

Refracto-vibrometry makes uses of this phenomenon to make relative measurements of the spatial distribution of sound within a 2D measurement plane by employing a static reflecting surface behind the measurement plane. Figure 1 shows a typical layout.

There are several options for the static reflecting surface including mirrors, retro-reflective cloth, tape and paint. Each has its own benefits and weaknesses but for a flexible set-up a large retro-reflective cloth curtain is preferred. Its surface is made from many tiny glass hemispheres which reflect a high percentage of incident light back in the direction it came from with a small amount of light scattered.

Refracto-vibrometry could be applied in any indoor environment so long as the background noise is low, the sound field being measured is loud and there are not strong thermal currents. Due to its highly controlled acoustics, an anechoic or hemi-anechoic chamber is ideal for these measurements. The size of the room limits the amount of time available for each measurement point and as a result the lowest frequency that can be measured. If, for example, a measurement was being made where the loudspeaker was placed in the centre of a 3 metre wide room with the reflector and the vibrometer positioned at opposite walls the time the sound would take to hit the reflector would be close to 4.5 milliseconds giving a theoretical low frequency limit of 220 Hz.

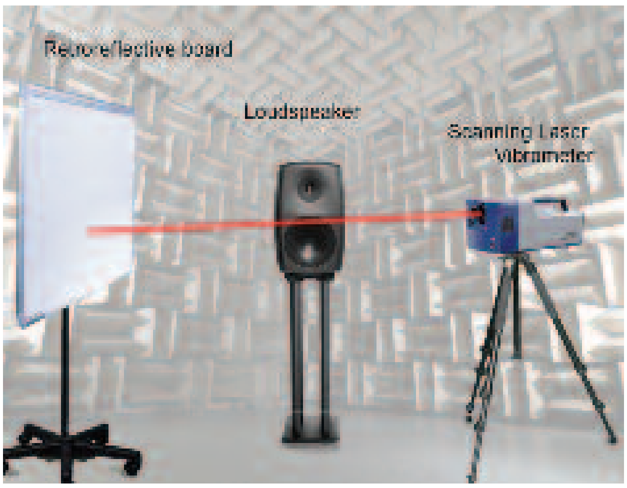

Figure 1 - Typical refracto-vibrometry set-up

The scattering from an egg box panel

For a demonstration of the kind of measurements that are achievable using the refracto-vibrometry technique previously described and to help shine further light on what acoustical properties that egg boxes actually have, a 60 cm x 60 cm wooden panel was covered with evenly spaced egg boxes. The egg boxes were six egg size and with the same shape compartments. The panel was mounted on a screen holder in the centre of a hemi anechoic chamber. A loudspeaker was placed 1.5 metres away and the tweeter was aligned with the centre of the panel using a laser plumb line. A photo of this set-up is shown in Figure 2. The horizontal guide is offset as the plumb line was placed on top of the loudspeaker.

The signal connected to the loudspeaker was a 20 nanosecond impulse from a function generator with a 1.5 V RMS amplitude and 1 kHz high pass Butterworth filter applied. With the speakers output set to maximum this produced a signal at the egg box panel in excess of 90dB. The pulse had an 11 Hz repeat frequency. The signal was also connected to the vibrometers trigger in. The vibrometer, a Polytec PSV-400-M, was then set to measure a grid of 150 x 150 points corresponding to a plane in front of the egg box panel of 1 m x 1 m. For each point 2048 samples were recorded at a sample frequency of 51.2 kHz. To increase the quality of the measurements 25 averages were recorded at each point. This resulted in a scan time of 10 hours. Figure 3 shows the measurement data at a single point.

Figure 2 - Photograph of egg box panel alignment in a hemi anechoic chamber

There are two distinct peaks in the data, the first is the impulse as it radiates through the air and the second is the mechanical vibration of the retro reflective curtain. The second peak takes several milliseconds to settle and this dictates the minimum number of samples for each measurement. It is only the first eight milliseconds which are of interest. The results form a data matrix of x and y coordinates and time samples which can be used to create a video of the sound field.

Figure 4 shows eight frames, each 15 frames apart, taken from the video generated from the data. The central axis of the panel and loudspeaker is marked in frame 1. The higher frequency components contained within the impulse are scattered evenly and periodically by the egg boxes with some of the energy absorbed. The low frequency energy contained in the impulse is not effectively scattered and is reflected as a single strong reflection that trails the higher frequency scattering. This can clearly be seen in frame five highlighted by an arrow. There is also a strong reflection of the whole impulse from the small amount of uncovered wood surface at the top and bottom of the panel. This can initially be seen at the top of frame four highlighted by an arrow.

From this measurement it is clear that egg boxes have diffusion properties at higher frequencies. However, at low frequency they are effectively transparent. It would be interesting to explore what the subjective effects are of scattered high frequency energy trailed slightly in time by the unscattered low frequency energy of a reflection. For the purpose of the home recording studio it is unlikely to provide any benefit. Therefore the conclusion must be that egg boxes are not useful for their diffusion properties. A video of the full dataset will be available on YouTube soon.

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References

1. P.E. Straus and D.C. Perrone, Report: Sound Absorption Test RAL-A88-80, Riverbank Acoustical Laboratories, 28th of March 1988. http://www.acousticsfirst.com/docs/egg.pdf

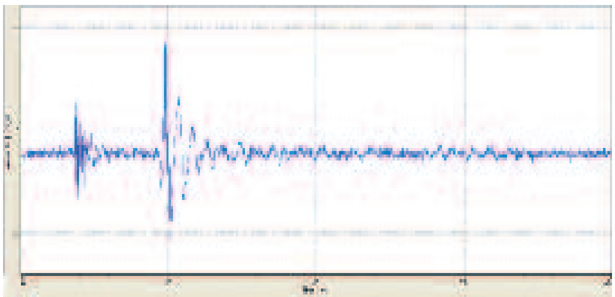

Figure 3 - Measured velocity data for a single point

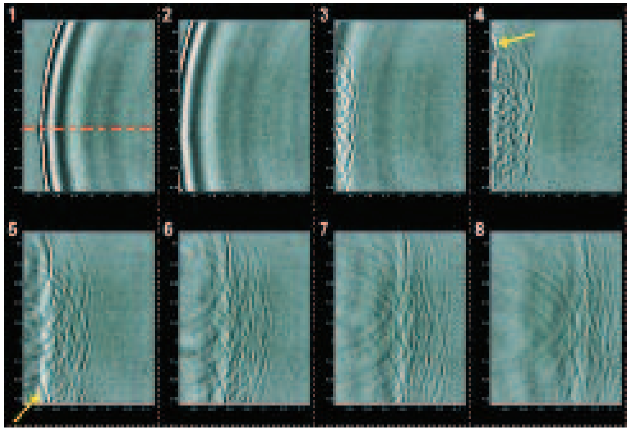

Figure 4 - Eight frames showing the scattering of an impulse by a panel of egg boxes