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Technical note

# A maze structure for sound attenuation

Hsiao Mun Lee *, Kian Meng Lim, Heow Pueh Lee

*Department of Mechanical Engineering, National University of Singapore, 9 Engineering Drive 1, Singapore 117576, Singapore*

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ABSTRACT

Sonic crystals are periodic arrangement of scatterers made of material with low acoustic impedance or sound hard materials [1]. Sonic crystals have numerous applications such as green belts and sound barriers. Here we showed that a typical maze structure at children playground can attenuate noise effectively for frequencies ranging from 12.5 Hz to 20,000 Hz. The original designer for the maze structure probably does not have that in mind. The maze structure can be viewed as a sonic crystal structure with sound attenuation characteristics. We found that the maze was able to attenuate noise up to 17.9 dBA for frequency range below 1000 Hz and 23 dBA for higher frequency range up to 20,000 Hz. The maze structure was able to mitigate noise at a wide range of frequencies in addition to the center frequency ($f_c$) of 478 Hz which was estimated based on the Bragg's Law. The periodic effects of the maze was also proven by numerical studies. Our results demonstrated that the maze structure commonly found in children playgrounds was able to attenuate noise covering the whole human hearing range.



## 1. Introduction

With the growing interest for sustainable energy development, new sonic crystal structure or material more respectful to environment is highly desired. Measurements conducted by Martinez-Sala et al. [2] showed that tree belts were able to attenuate low frequencies noise more effectively if they were arranged in a lattice configuration. They concluded that sonic crystals can be created using trees as scattering centres. The position of the attenuation peaks obtained along a certain range of frequencies depends on the angle of incidence at which the sound strikes the barrier and the type of lattice used. The level of attenuation obtained depends on the filling fraction of the tree belts. Road traffic noise propagation through a vegetation belt of limited depth (15 m) containing periodically arranged trees along a road was numerically studied by Van Renterghem et al. [3] through three-dimensional finite-difference time-domain calculations. They found that with decreasing tree stem spacing and increasing diameter, traffic noise insertion loss (IL) was more pronounced for each planting scheme considered. They concluded that vegetation belts can compete to the noise reducing performance of a classical thin noise barrier with a height of 1–1.5 m in a non-refracting atmosphere. Lagarrigue et al. [4] studied the acoustic transmission coefficient of a resonant sonic crystal made of hollow bamboo rods through theoretical and experimental methods. Their results showed that a sonic crystal made from natural materials with some irregularities could exhibit a clear transmission band gap between 1600 Hz and 2500 Hz. The bamboos were drilled to transform the cylindrical rigid scatters into a sonic crystal with Helmholtz's resonators. These resonances added anomalies in the transmission coefficient at frequency of 300 Hz. The works from these publications indicated that it is possible to construct a natural and ecological sonic crystal noise barrier. However, their attenuation frequencies were limited to certain ranges which cannot cover the whole human hearing range commonly given as 20–20,000 Hz.

## 2. Methodologies

### 2.1. Field measurements

The measurements were conducted at a typical maze structure which is located at the children playground in Labrador Park Singapore as shown in Fig. 1. Labrador Park is located in the southern part of Singapore and it contains the only rocky sea-cliff on the mainland that is accessible to the public. The maze is square in shape with a width of about 8.2 m and it is constructed by square wooden columns with a width of 0.094 m and a height of 1.8 m. The on site experiments were carried out using a Bruel & Kjaer (B & K) sound level meter (model 2250, class 1) and a SONY boombox (model CFD-S50BLK). There were totally three sets of measurements. For these three sets of measurements, the boombox was placed at the center inside the maze and the sound level meter

* Corresponding author.
*E-mail address:* mpelhm@nus.edu.sg (H.M. Lee).

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**Fig. 1.** The maze at Labrador Park Singapore.

was placed at three different locations (center, right corner and left corner) outside the maze as shown in Fig. 2. After that, in order to obtain the IL (see Eq. (1)), both the boombox and the sound level meter were placed outside the maze (in a free field) to measure the sound pressure level (SPL) without the maze. The distances and angles between the boombox and the sound level meter are the same with the first three sets of measurements.

$$\mathrm{IL} = \mathrm{SPL(without\ maze)} - \mathrm{SPL(with\ maze)}. \quad (1)$$

Positive value of the IL indicates the ability of the maze structure to attenuate noise. For all measurements, both the boombox and the sound level meter were placed at about 1 m from the ground in order to minimize the ground effect. The correction of ground effect ($A_{gr}$) is given by [5]:

$$A_{gr} = 4.8 - (2h_m/d_{sr})[17 + (300/d_{sr})] \geqslant 0, \quad (2)$$

where $h_m$ is the mean height of the propagation path above ground (1 m) and $d_{sr}$ is the distance from the source to the receiver (7.2 m, 8.2 m and 10.3 m). $A_{gr}$ calculated from Eq. (2) when the sound level meter was located at the center, left and right corners of the maze are −11.50 dBA, −8.27 dBA and −4.16 dBA, respectively. According to ISO 9613-2 [5], negative values for $A_{gr}$ shall be replaced by zeros. Therefore, the ground effect is negligible in the present study.

Data was collected for frequencies ranging from 12.5 Hz to 20,000 Hz. The duration of the recording for each measurement is 1 min. The data was analyzed by the B & K Measurement Partner Suite software [6] using fast Fourier transform method and the final output data is the frequency spectrum. The sampling frequency of the measurements is 48 kHz. The $f_c$ produced by the maze was estimated using the Bragg's Law:

$$f_c = \frac{c}{2d}, \quad (3)$$

where $c$ is the speed of sound in air and $d$ is the distance between adjacent wooden columns. The $d$ of the maze is 0.252 m, therefore, the dominant (diagonal) distance was found to be 0.252 m × 1.141 = 0.356 m which in turn produces the $f_c$ of about 478 Hz.

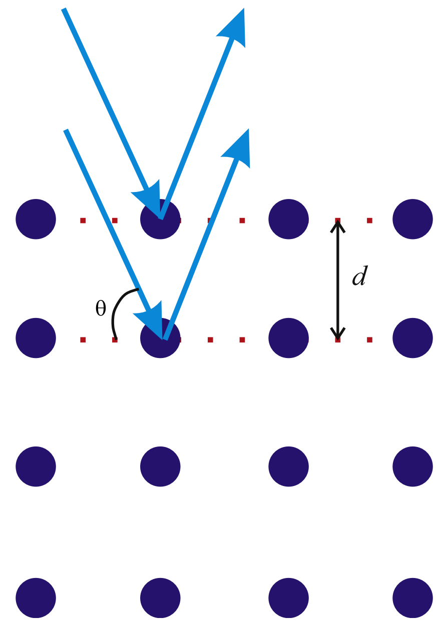


**Fig. 3.** Bragg's Law diffraction.

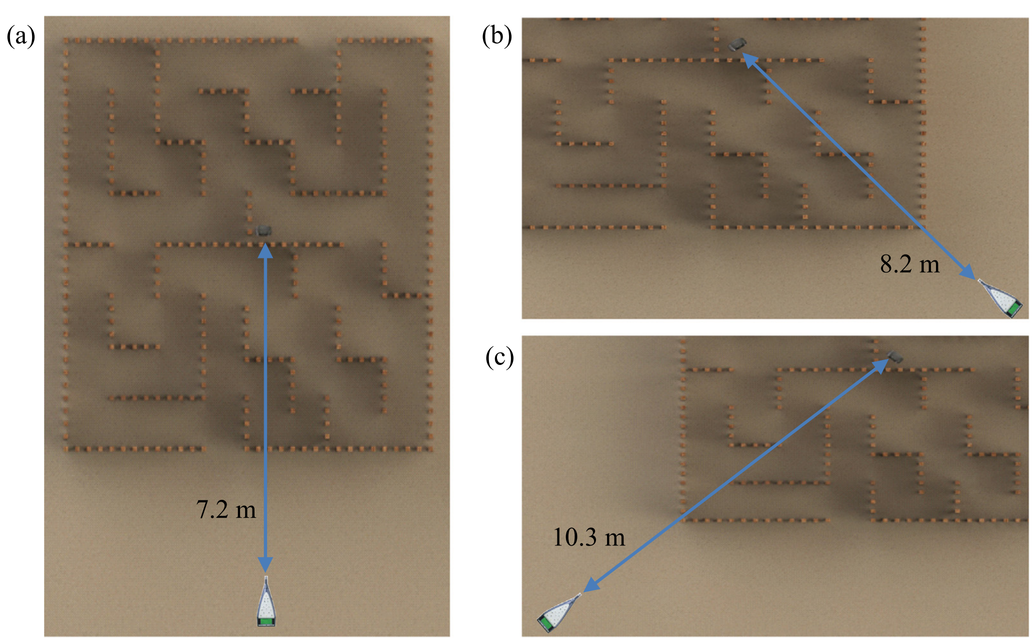


**Fig. 2.** Locations of the sound level meter outside the maze. (a) Center, (b) right corner, (c) left corner.