The extended model to simulate the Quetzal echo at the Mayan pyramid of Kukulkan at Chichen Itza in Mexico

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Introduction

It is well known [1-8] that a handclap in front of the staircase of the pyramid produces an echo that sounds similar to the chirp of the Quetzal bird. This phenomenon occurs due to diffraction. There exist some publications concerning this phenomenon and even some first attempts are reported to simulate it. Recently, it has been shown [Declercq et al, J. Acoust. Soc. Am. 113(4), 2189, 2003] that it is possible to reproduce the echo by means of a simulation which is based on the theory of the diffraction of plane waves and which takes into account continuity conditions. The latter theory is the building block for a theory that tackles the diffraction of plane waves. By means of these principles it is possible to simulate the echo following a handclap in front of the staircase. This paper shows results obtained by means of an extension of the model where also reflections on the ground are considered as well. Hence, the handclap is only spherical if observed on the staircase. The diffraction theory of Claey et al that is applied here can be found in the literature [9-11]. The theory is based on the decomposition of the diffracted acoustic field into pure plane waves. Basically, each of the reflected and transmitted wave fields are decomposed into a series of plane waves, each plane wave of order m having a wave vector

\[ \mathbf{K}^m = k_x^m \mathbf{e}_x + k_z^m \mathbf{e}_z \]  

with

\[ k_x^m = k_x^{inc} + m \frac{2\pi}{\sqrt{2}q} \]

and \( k_z^m \) determined by \( k_x^m \), the material properties of the considered medium and the dispersion relation \( k^2 = \omega^2 / \nu^2 \), omega being the angular frequency and \( \nu \) being the plane wave velocity. The sign of \( k_z^m \) is chosen such, as to fulfill the necessity of plane waves to propagate away from the interface and, whenever \( k_z^m \) is purely imaginary, the amplitude must decay away from the interface. The continuity conditions demand continuity of normal stress and normal particle displacements on each spot of the pyramid’s staircase. It can be found in Claey et al [9-11] that this leads to a set of equations that is periodical in \( x \), whence the discrete Fourier transform can be applied, resulting in an equal number of equations and unknown amplitudes of all diffracted orders. It can also be found in Claey et al [9-11] that this discrete infinite set of equations and unknowns can be chopped to a square linear matrix equation that can be solved by a computer.

Numerical simulations vs experiments

The fact that an echo appears that sounds like a Quetal bird, in front of the stairs of the pyramid at Chichen Itza, is widely known [1-8]. It is also known that diffraction is involved. Thanks to the work of David Lubman [13], we have got to know the dimensions of the pyramid, the stairs and the position of the observer, as well as some .wav files that enabled us to compare our simulations with experiments. The calculated echo coming from an incident delta like
Conclusions
This paper, together with the presentation, shows that the echo that is produced by a handclap at the pyramid of Chichen Itza, is the result of diffraction and is pretty much determined by the frequency contents of the incident handclap itself. This is in contrast to what many people previously believed. It is also shown that the presence of reflections on the ground does not alter the echo very much.

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References