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# Two-temperature model for the thermoacoustic sound generation in porous materials

Pierre Guiraud<sup>\*†1,2,3,4</sup>, Stefano Giordano<sup>1</sup>, Olivier Bou Matar<sup>1</sup>, Philippe Pernod<sup>1</sup>, and Raphael Lardat<sup>2</sup>

<sup>1</sup>Institut d'Électronique, de Microélectronique et de Nanotechnologie (IEMN) - UMR 8520 (IEMN) – Ecole Centrale de Lille, Institut supérieur de l'électronique et du numérique (ISEN), Université Polytechnique Hauts-de-France, Université de Lille, Centre National de la Recherche Scientifique : UMR8520 – France

<sup>2</sup>Thales Underwater Systems (TUS) – THALES – France

<sup>3</sup>Délégation générale de l'armement (DGA) – Ministère de la Défense – France

<sup>4</sup>CINTRA UMI 3288 CNRS/NTU/Thales, Research Techno Plaza, 50 Nanyang Drive 637553, Singapore – Singapour

## Résumé

For now more than a hundred years the standard way to generate sound is to use an electroacoustic transducer or loudspeaker. A coil/magnet core electrically driven will induce the movement of a membrane thus imposing a particle velocity that generates sound waves. Those kind of transducers are mostly used in air for sound reproduction in the hearing range (20Hz to 20kHz) but are also used in other domain like underwater acoustics using piezoelectric devices.

The thermoacoustic principle is a novel way to generate acoustic wave by imposing a pressure boundary condition instead of a velocity one. An electrical current is applied to a material and the temperature profile of this sample will follow the electrical one. The rapid heating and cooling of the sample will induce a compression, expansion of the air in the vicinity of the sample thus imposing a pressure boundary condition and generating sound waves. Theoretically, unlike the regular electroacoustic transducer, this principle is non resonant and so should have a wideband frequency response going up to the MHz range. Furthermore, apart from the directivity, the size of the sample has no influence on the acoustical output, hence why thermoacoustic is gaining interest nowadays.

This principle was also known for more than a hundred year but requires material with a high thermal conductivity and a low thermal capacity. Those requirements have only been efficiently achieved recently due to the rise of the understanding and the ease of access of nanomaterials. Among the current nanomaterials used as thermophone there are various suspended metal wires (aluminium, gold...) or carbon based materials like carbon forest nanotubes or 3D carbon foam.

Those materials have been experimentally tested but thermoacoustic theory is still being developed on a case by case basis. This paper will propose a model describing the thermal response of a foam like material assuming that the thermal equilibrium is not achieved in

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\*Intervenant

†Auteur correspondant: pierre.guiraud@centraliens-lille.org

the foam by using a two temperature model for a single thermophone in free field in one dimension. The model's equations are based on the conservation of mass, momentum, energy in the fluid and the conservation of energy in the solid. This model will then be compared to the solution provided by one of the most recent approach for thermoacoustic generation (based on the one temperature model), assuming a continuous thermophone but considering the sound propagation in the solid.

**Mots-Clés:** Thermoacoustics, two temperature model, porous materials