ABSTRACT

Acoustic metamaterials need to be realized using sub-wavelength, anisotropic, inhomogeneous microstructures. By tailoring the microstructure of the underlying unit cell, different effective properties at the macroscopic may be achieved. These macroscopic properties can be related to the microstructure using homogenization theory [1], which allows an analyst to confirm the extent to which a candidate metamaterial microstructure meets the requirements for a pentamode cloaking material.

Norris [2] presented a theory of transformation acoustics that enables the realization of inhomogeneous pentamode acoustic materials having anisotropic elastic tensors, isotropic density and finite mass. This theory describes the spatially varying material properties of the pentamode continuum in terms of a mapping, which for separable geometries may be generated using a scalar function. This function, the constraints on its behavior implicit in the Norris theory, and the material equations constitute the defining relations for pentamode transformation acoustics. Previously, analytic work in transformation acoustics developed the material properties after having fixed a transformation. By reversing the process, constraining the material properties and determining transformations consistent with the Norris pentamode theory, we create a number of new families of pentamode cloaking materials. We discuss some of these families and their practical implications, and validate the concept with three-dimensional explicit transient finite element simulations.


BIOSKETCH

PhD, Cornell University, Ithaca, NY, 1992, Theoretical and Applied Mechanics
BS, Lehigh University, Bethlehem, PA, 1985, Mechanical Engineering
BA, Lehigh University, Bethlehem, PA, 1985, Applied Science
Dr. Cipolla has more than 19 years of experience in engineering mechanics, numerical simulations, planning and management, and developing customer relationships. He has expertise in developing and implementing advanced computational methods for acoustics, UNDEX, wave propagation and heat transfer, and providing industry-relevant solutions to these problems.

Dr. Cipolla was the principal architect of the ADQUES software for NAVSEA 05P and NSWC Code 60, which uses an innovative frequency-domain reduced-order model to assess the relative severity of thousands of UNDEX scenarios in minutes or hours. For NSWC Code 70, Dr. Cipolla led the development of the SPIFF code, used to compute far-field acoustic signatures from finite element results. Dr. Cipolla also led the development to compute the waterline equilibrium for arbitrary surface ships in the explicit FEM UNDEX code EPSA; this module is expected to be incorporated into NESM/Salinas under the CREATE program. From 1998 to 2008, Dr. Cipolla was the principal developer of the Abaqus Acoustics and UNDEX software.

Dr. Cipolla led the development of specialized finite element algorithms for coupled fluid-solid systems for a variety of applications. He is the Principal Investigator for an ONR Small-Business Innovative Research (SBIR) Project to develop Metamaterials for Acoustic Cloaking, and for an Air Force SBIR to develop air blast loading modules for analysis of aircraft structures using Lagrangian Explicit codes. He leads the Weidlinger team in a NAVSEA program to analyze composite surface ship deckhouse structures for AIREX vulnerability.