Acoustic imaging with metamaterial Luneburg lenses

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Value Proposition

The Luneburg lens is a spherically symmetrical gradient refractive index (GRIN) device with unique imaging properties. Its wide field-of-view (FoV) and minimal aberration have lead it to be successfully applied in microwave antennas. However, only limited realizations have been demonstrated in acoustics. Previously proposed acoustic Luneburg lenses are mostly limited to inherently two-dimensional designs at frequencies from 1 kHz to 7 kHz. Designing three-dimensional acoustic Luneburg lens requires designing and fabrication of structures with complex three-dimensional geometries with overhanging structures at subwavelength precision. Therefore, it remains challenging to design a true three-dimensional acoustic Luneburg lens, particularly for the airborne ultrasonic frequency range.

Technology

A new design method for scalable and self-supporting metamaterials to demonstrate Luneburg lenses for airborne sound and ultrasonic waves. Two Luneburg lenses are fabricated: a 2.5D ultrasonic version for 40 kHz and a 3D version for 8 kHz sound. Imaging performance of the ultrasonic version is experimentally demonstrated. The method can be straightforwardly extended to design a large range of spatially inhomogeneous GRIN devices, such as transformation acoustics-based wave controlling devices.

Applications

Airborne ultrasound lens may be used in a variety of sensing applications that utilizes ultrasonic waves (mostly 30 kHz to 200 kHz) that propagate in air. Such as smart vehicles' ultrasonic sonars to sense the environment to assist self-parking or auto pilot. In addition, particle levitation and wireless power transfer for cable-free transmission of energy are emerging applications of airborne ultrasound. As well as the audible version may be used for improving the radiation pattern for speaker systems.

Advantages

- Minimal spherical aberration and a wide FoV.
- Scalable, build up in a layer-by-layer fashion to form a 3D spatially inhomogeneous device.
- Cubic unit cells are subwavelength and have isotropic effective wave properties.
- The design has broader bandwidth than resonant metamaterial structure and the refractive index contrast is relatively constant over about 25% of the central frequency.

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Inventor(s)

- Cummer, Steven
- Xie, Yangbo

Links

- Dr. Cummer's research website

College

Pratt School of Engineering

For more information please contact

Koi, Bethany
919-681-7552
bethany.koi@duke.edu

Publications

- Y. Xie, Y. Fu, Z. Jia, J. Li, C. Shen, Y. Xu, H. Chen and S. A. Cummer. (2018). Acoustic Imaging with Metamaterial Luneburg Lenses. Scientific Reports. 8. 10.1038/s41598-018-34581-7.