A type of metamaterial device that allows better water-to-air sound transmission

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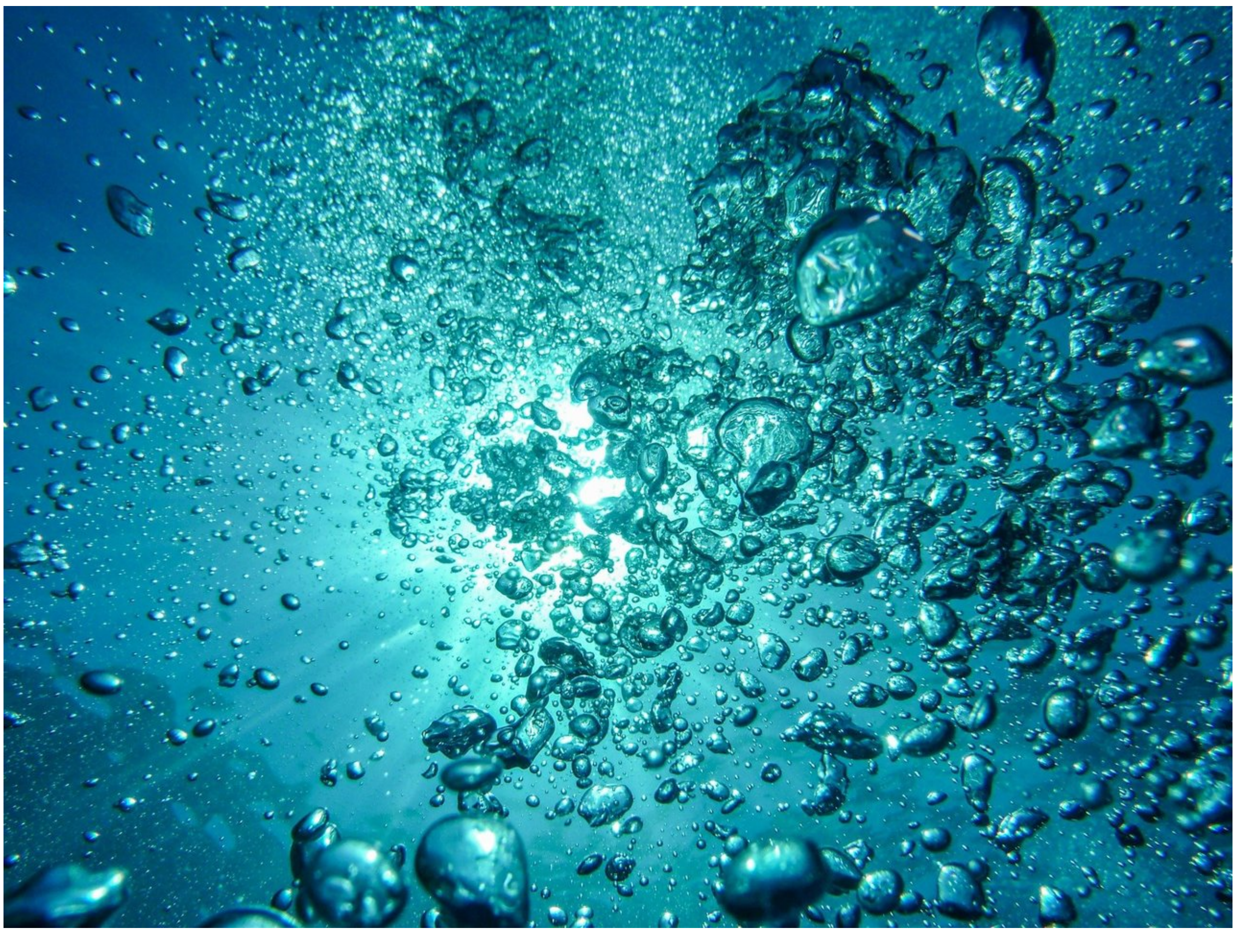

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A team of researchers from Yonsei University in Korea and Hokkaido

University in Japan, has developed a metamaterial device that allows for much better than normal sound transfer between water and air. In their paper published in *Physical Review Letters*, the researchers describe their device, how it works and the ways it needs to be improved.

Normally, it is nearly impossible to hear underwater sound from the air above—the same is true in reverse. This is because of acoustic impedance forming a sound barrier. Sound waves bounce off the barrier, preventing them from escaping. In this new effort, the researchers applied a metamaterial device (a metasurface) to the barrier that essentially serves as a tunnel between the water and the air, allowing more sound waves to pass through.

The metamaterial device the team built consists of a cylindrical metal outer shell that looks a lot like a car tire rim. It has a rubber segmented membrane at its center with a weight to keep it taut. The device floats on the water. A person hovering over it in the air can hear sounds from below the surface that are not normally audible.

Normally, just 0.1 or 0.2 percent of sound waves can penetrate the water/air barrier, but in testing their new device, the researchers found that it increased sound transmission to the extent that up to 30 percent of waves got through.

The device could theoretically be used to help with human communications between people in the water and those above the surface, or to listen to sea creatures stirring below—but it has two major drawbacks that will likely limit its use. The first is that it is only able to pass through sounds waves that come from directly below it—diagonal waves are still bounced away. The second problem is that it only works for a certain limited range of frequencies—from approximately 600 to 800 Hz. Potentially, both problems could be solved by building arrays of individual devices that could pass different frequencies and enough of them to cover a large area.

More information: Eun Bok et al. Metasurface for Water-to-Air Sound Transmission, *Physical Review Letters* (2018). DOI: 10.1103/PhysRevLett.120.044302

ABSTRACT
Effective transmission of sound from water to air is crucial for the enhancement of the detection sensitivity of underwater sound. However, only 0.1% of the acoustic energy is naturally transmitted at such a boundary. At audio frequencies, quarter-wave plates or multilayered antireflection coatings are too bulky for practical use for such enhancement. Here we present an acoustic metasurface of a thickness of only ~λ/100, where λ is the wavelength in air, consisting of an array of meta-atoms that each contain a set of membranes and an air-filled cavity. We experimentally demonstrate that such a meta-atom increases the transmission of sound at ~700Hz by 2 orders of magnitude, allowing about 30% of the incident acoustic power from water to be transmitted into air. Applications include underwater sonic sensing and