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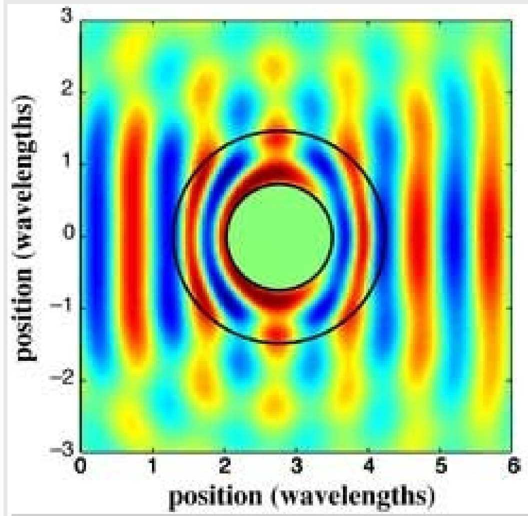
Hiding in Plain Sound

Nancy McGuire

Ping, ping ... nothing?

What if you could "cloak" a submarine so that sonar signals from another submarine flowed around it and didn't bounce back? Could you really make a submarine invisible (or inaudible)?

A submarine sends out a sonar "ping"—a burst of sound waves that travels through the water. If the sound waves encounter a solid mass, perhaps another submarine, some of the waves bounce back and return to the first submarine. Sonar receivers pick up this echo, which contains information about the location and distance of the object ahead. No echo, no sonar signature.



Sound and cloaked submarine
The acoustic pressure with the same scatterer surrounded by the cloaking shell.
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An acoustic cloak is feasible, according to computer models developed by Duke University electrical engineers Steven Cummer and David Schurig. Last year, Schurig and his colleagues from Duke and London's Imperial College demonstrated a working model of an optical "invisibility cloak" that caused light waves to flow around an object rather than reflecting back. Could the same concept be applied to sound waves?

Cummer and Schurig determined that, in two dimensions, acoustic waves behave like electromagnetic waves with regard to the symmetry properties that would allow someone to build an acoustic cloaking device. This symmetry is not present in three dimensions, so presumably such a cloak would only hide a submarine from another submarine at the same depth, not one that was sending sonar upward or downward.

Cummer and Shurig based their calculations on a cylindrical shell. They showed that if you get the right balance between spatial distribution of mass density and bulk modulus (resistance to compression) of the cylinder and the surrounding fluid, the cylinder will bend incoming waves around itself with very little echo and only a slight "shadow" on the far side of the cylinder.

One limitation of this model is its requirement that the surrounding fluid have an anisotropic mass density distribution. That is, it must have different densities in different directions, such as a layer of oil floating on water, or bands of particles suspended in a liquid. This is not a typical property of your average ocean, but the Duke researchers note that there is hope for an experimental realization of their idea. They claim that cloaking over a limited range of wavelengths is possible for materials with isotropic mass distributions but anisotropic bulk moduli, which may be easier to achieve.

Some progress has been made toward making "real-world" acoustic metamaterials, sound-wave analogues to the optical metamaterials that provide invisibility cloaking. Fluids loaded with particles can, at least in theory, provide the necessary properties, and existing one-dimensional acoustic waveguides could contribute to a real-world device.

Here on the surface, acoustic cloaks might one day be used to improve the acoustic properties of concert halls or other rooms—maybe even block out your neighbor's stereo.

Find out more:

Cummer, Steven A.; Schurig, David. 2007. *New J. Phys. 9,* 45.

Chang, Kenneth. Light Fantastic. *New York Times*, June 12, 2007, D1, D4.

First Demonstration of a Working Invisibility Cloak. Duke University, Pratt School of Engineering, press release, October 19, 2006.

Pendry, J. B.; Schurig, D.; Smith, D. R. 2006. *Science 312*, 1780–1782.

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