Acoustically camouflage

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Motivation

✓Conceal an object at one place and emerge at another place

✓Many potential applications. For example, mislead enemy to make a chance to steal with submarines

Our train of thoughts

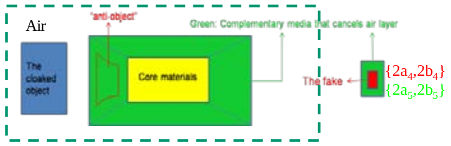
I. Acoustically conceal the object A with an acoustical cloak

[For remote electromagnetic cloaks, see PRL 102, 093901 (2009)]

II. Enhance the acoustically scattering capability of a smaller object B to get the same pressure distribution as A in the absence of the cloak

[For electromagnetic superscatterers, see Opt. Express 16, 18545 (2008)]

Rectangular version



Region size

Region size	Core material	$\{2a_1,2b_1\}$
	Complementary media	$\{2a_2,2b_2\}$
	Air	$\{2a_3,2b_3\}$

The coordinate transformation from the air layer to core region (yellow)

$$\begin{cases} x'' = \dfrac{a_1}{a_3} x \\ y'' = \dfrac{a_1}{a_3} y \end{cases}$$

The complementary media region is divided into 4 subdomains to accomplish coordinate transformation. For subdomain I

$$\begin{cases} x' = -\dfrac{a_2-a_1}{a_3-a_2} x - \dfrac{a_3-a_1}{a_3-a_2} a_2 \\ y' = -\dfrac{a_2-a_1}{a_3-a_2} y - a_2 \dfrac{a_3-a_1}{a_3-a_2} \dfrac{y}{x} \end{cases}$$

The mass density and bulk modulus obtained by using

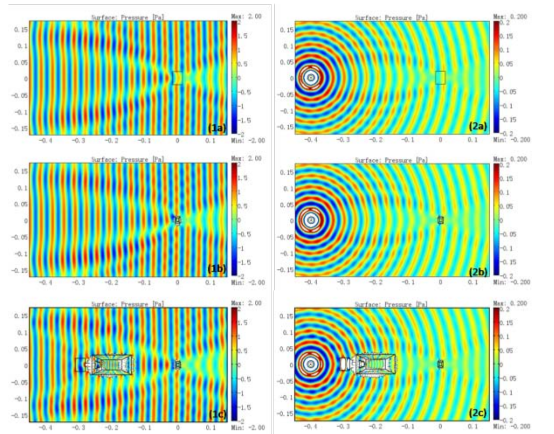
$$\rho_{i'j'} = \det(\Lambda)^{-1}(\varepsilon_{i'k'z}\Lambda_k^{k'}\varepsilon_{kiz})(\varepsilon_{j'l'z}\Lambda_l^{l'}\varepsilon_{ljz})\rho_{ij}$$

$$\lambda' = \det(\Lambda)(\Lambda_z^{z'})^{-2}\lambda$$

The coordinate transformation from the air layer to green layer subdomain I

$$\begin{cases} \rho_{x'x'} = \dfrac{(a_3-a_2)^2 x'^4 + a_2^2(a_3-a_1)^2 y'^2}{(a_3-a_2)x'^3\Delta} \\ \rho_{x'y'} = \rho_{y'x'} = -\dfrac{a_2(a_3-a_1)y'}{(a_3-a_2)x'^2} \\ \rho_{y'y'} = \dfrac{\Delta}{(a_3-a_2)x'} \\ \lambda' = \dfrac{(a_2-a_1)^2 x'}{(a_3-a_2)\Delta} \end{cases}$$

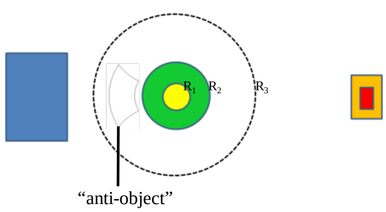
Simulation results of rectangular version



Snapshots of the pressure fields under an incident acoustic (1a)-(1c) plane wave , (2a) -(2b)cylindrical wave. (1a) and (2a) A rectangular object of size {0.03m,0.04m} . (1b) and (2b) The scattered pressure field distribution of the rectangular object of size {0.0075m,0.01m} is the same as the one of the object of size {0.03m,0.04m} . (1c) and (2c) With a rectangular object on the left, the scattered pressure distribution is same to (1b) and (2b), respectively.

All objects have $\rho_0 = 5$ and $\lambda_0 = 16$.

Circular version

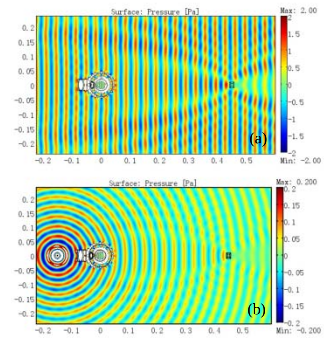


The coordinate transformation from the air layer to green layer

$$\begin{cases} r' = -\dfrac{R_2-R_1}{R_3-R_2} r + \dfrac{R_3-R_1}{R_3-R_2} R_2 \\ \theta' = \theta \end{cases}$$

Simulation results of circular version

Snapshots of the distribution of pressure fields under (a) an incident acoustic plane wave , (b) a cylindrical. Distributions of pressure fields of single object are similar to (1a),(1b),(2a) and (2b).



Discussion and conclusion

• With our design we can make a feint to the east but attack in the west ("声东击西").

• All simulations obtained by using finite-element solver Comsol Multiphysics 3.5.

References

[1] B. Liu and J. P. Huang,"Acoustically conceal an object with hearing", European Physical Journal – Applied Physics (in press, 2009)
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[3] Y. Lai, H. Y. Chen, Z. Zhang, and C. T. Chan. Phys. Rev. Lett., 102: 093901, (2009).
[4] S. A. Cummer, D. Schurig. New J. Phys, 9: 45, (2007).