

META - Military

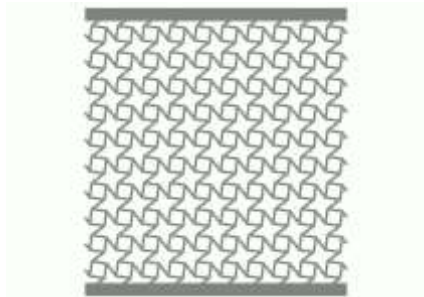
Johan Christensen

IMDEA Materials Institute

Calle Eric Kandel, 2, 28906, Getafe, Madrid, Spain



• The PhonoMeta gang



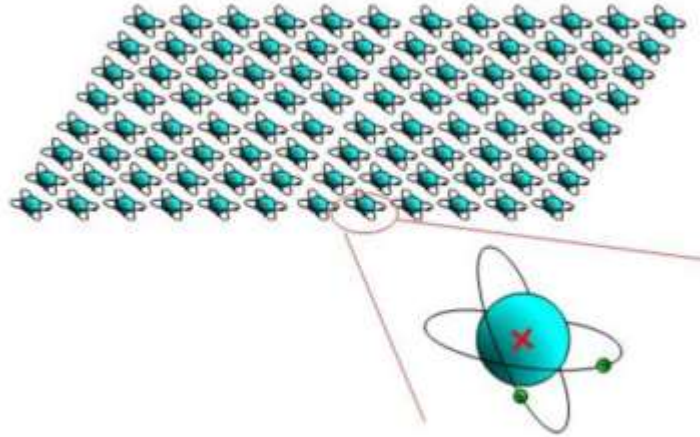
 institute
idea
materials



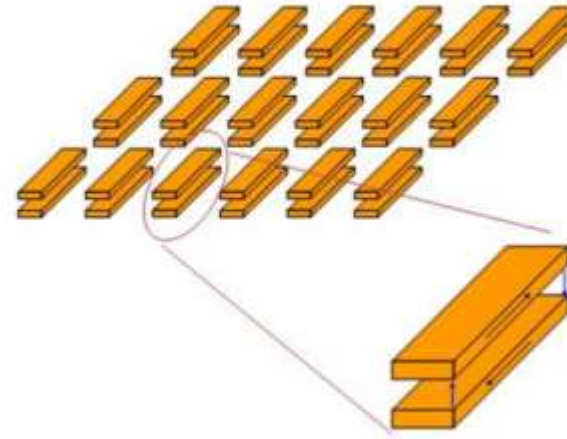
- **What are metamaterials?**
- **Why might they be of interest for defense purposes?**
- **Unhearability**
- **Zero radar cross section**
- **Large radar cross section**
- **Outlook**

What are metamaterials?

μετα = meta = beyond (Greek)

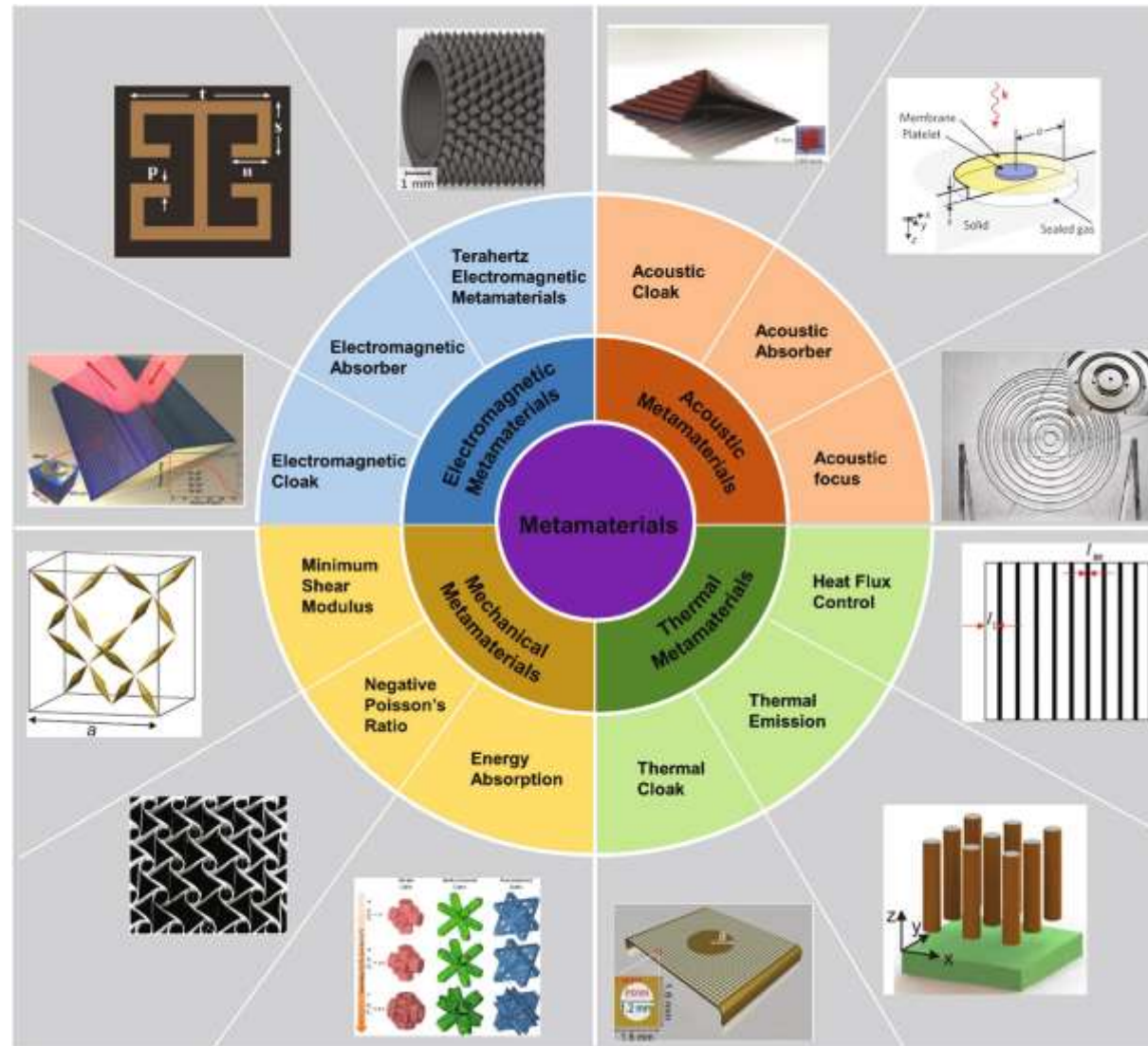


A natural material with its atoms



A metamaterial with artificially structured "atoms"

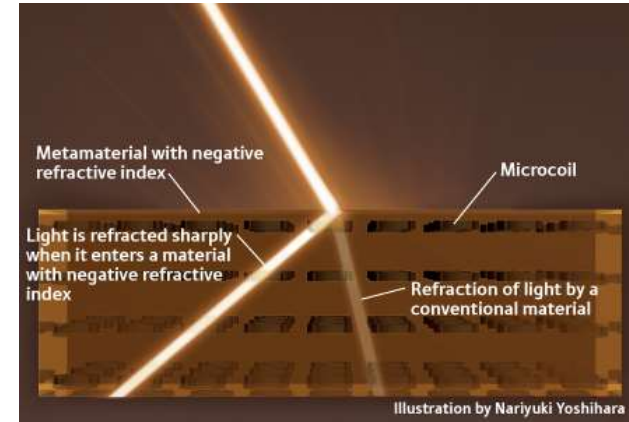
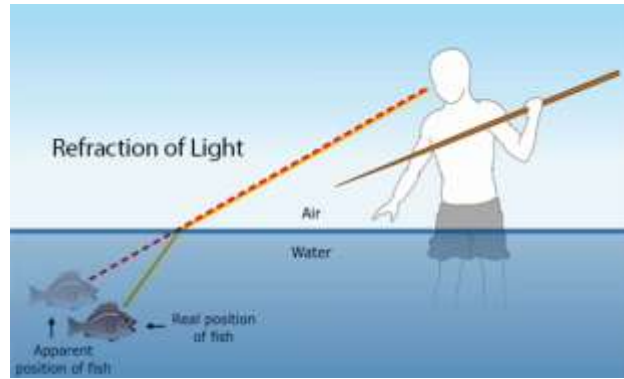
What are metamaterials?



MATERIALS
TODAY

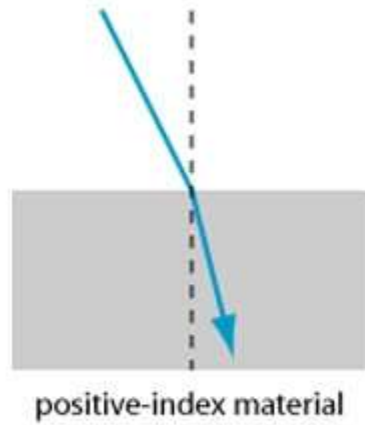
Volume 50, November 2021, Pages 303-328

What are metamaterials?

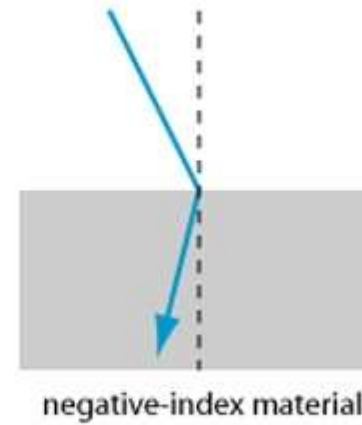


Nature **455**, 376 (2008)

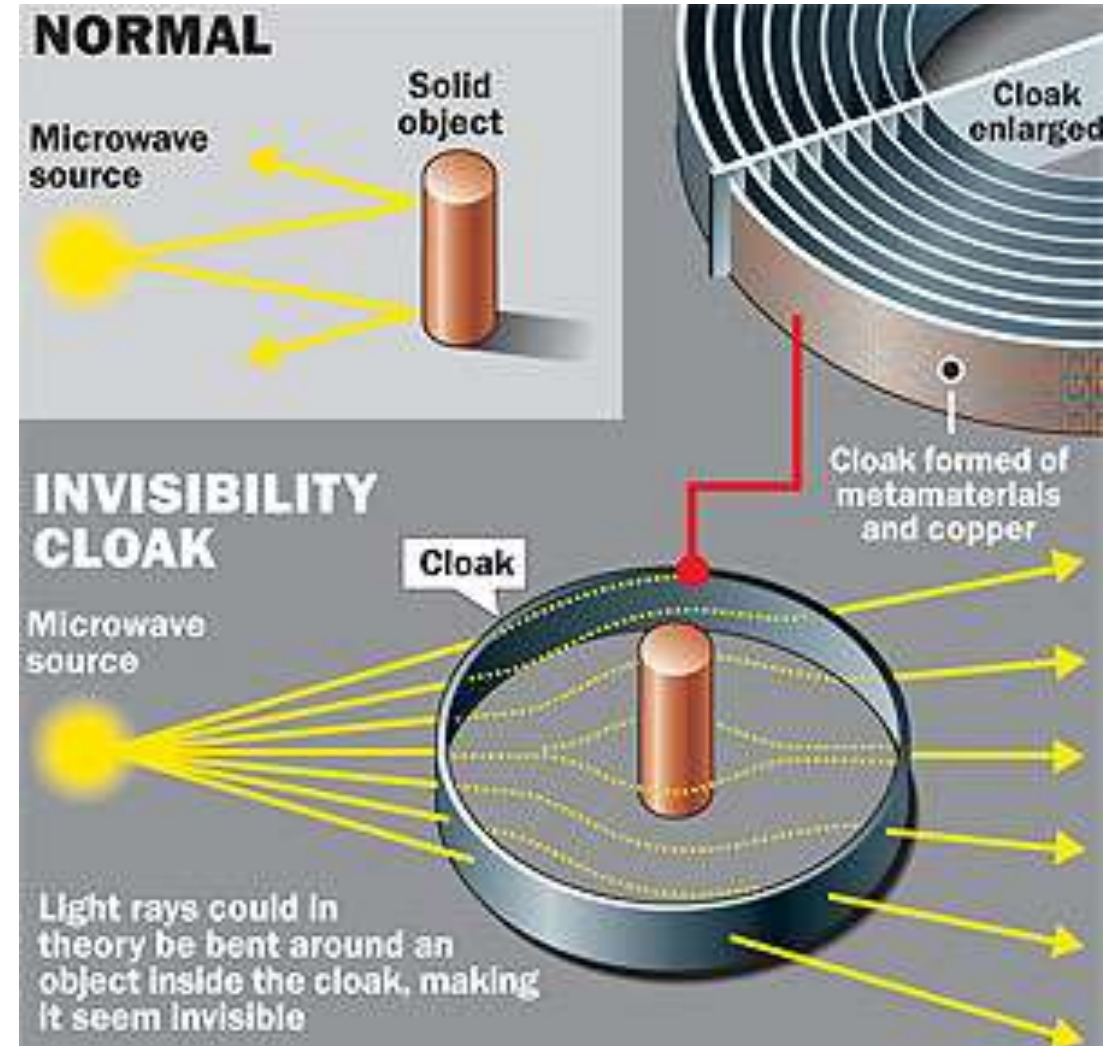
Conventional materials



Metamaterials



What are metamaterials?



Science 314, 977 (2006)



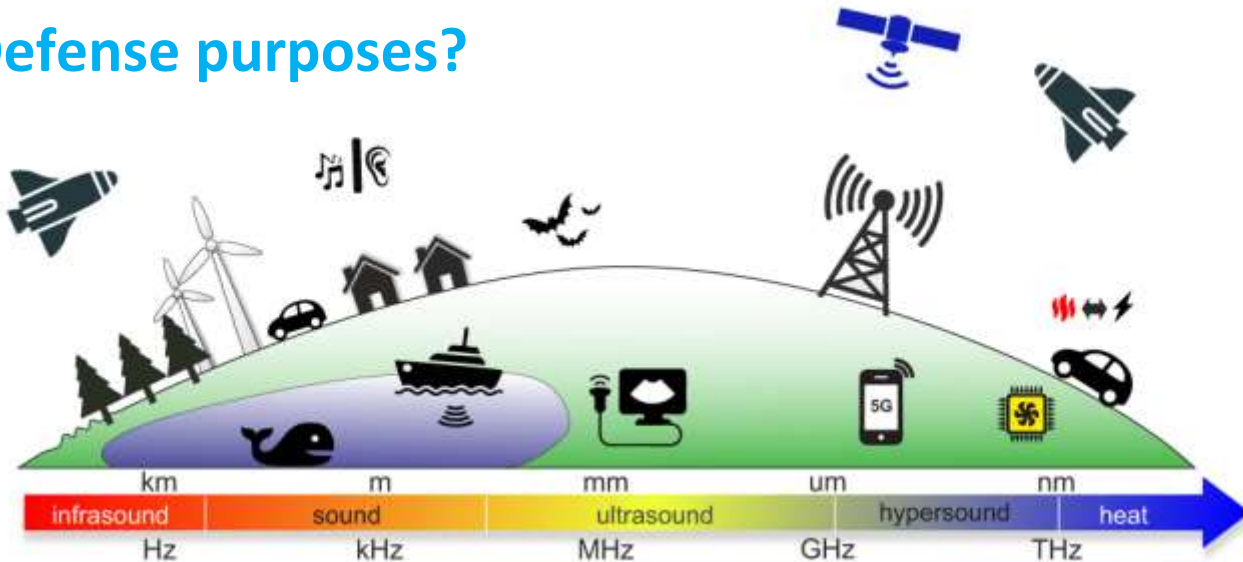
AI generated

Defense purposes?



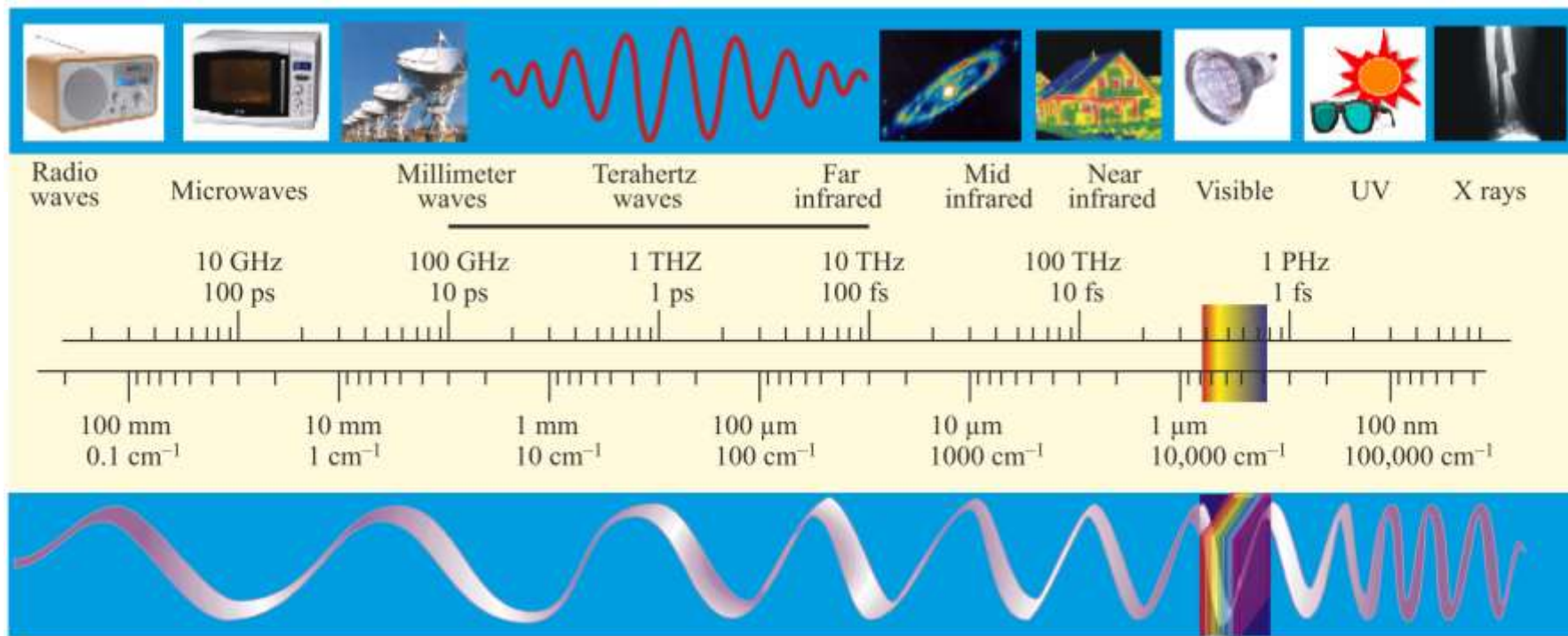
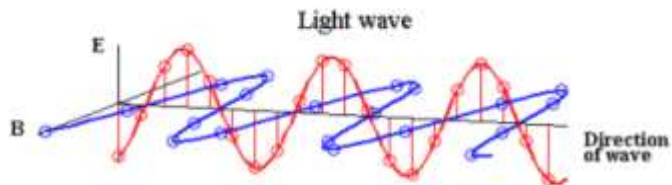
Defense purposes?

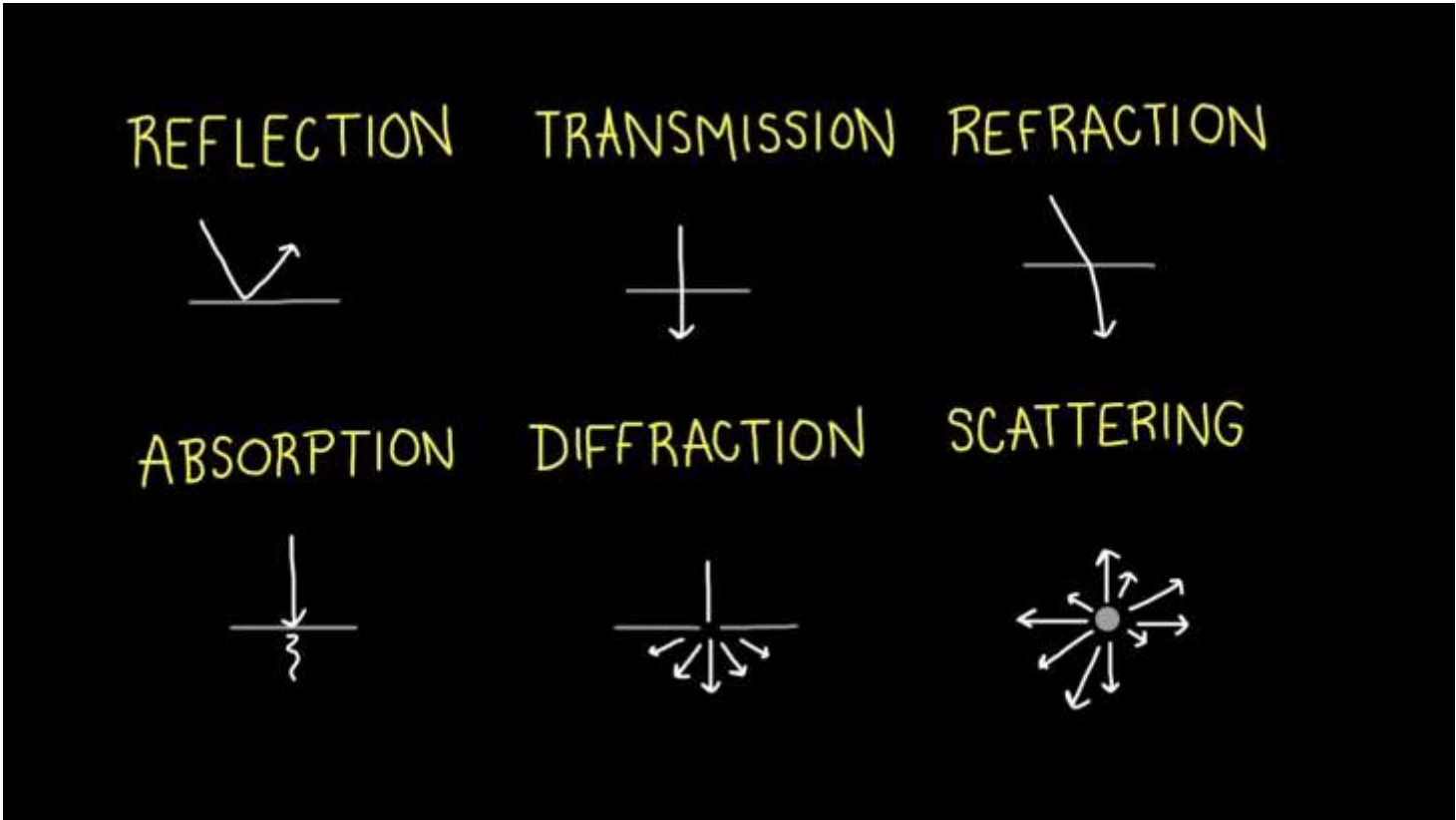
Acoustic spectrum



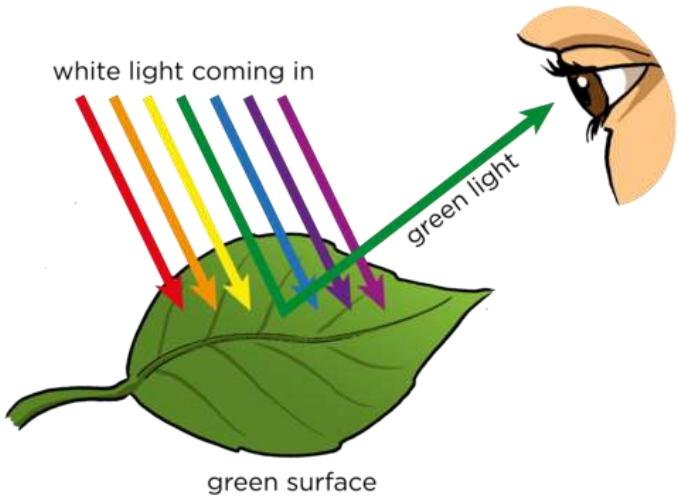
J. Appl. Phys. 129, 160901 (2021)

EM spectrum

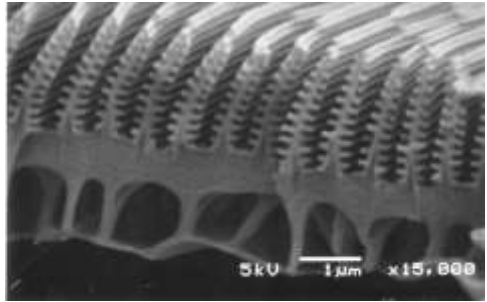




Defense purposes?

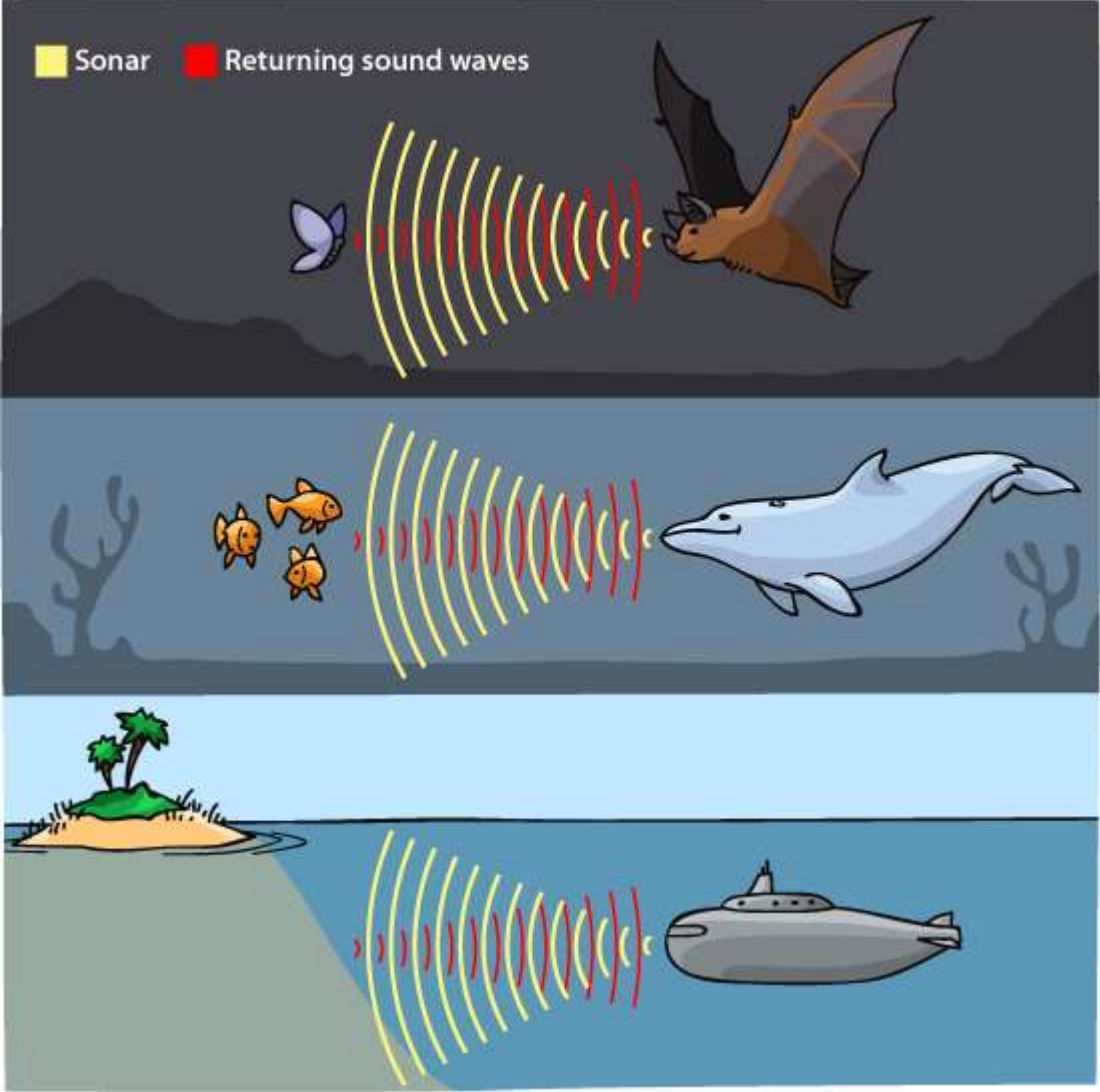


Emanuela Carratoni/iStock/Thinkstock

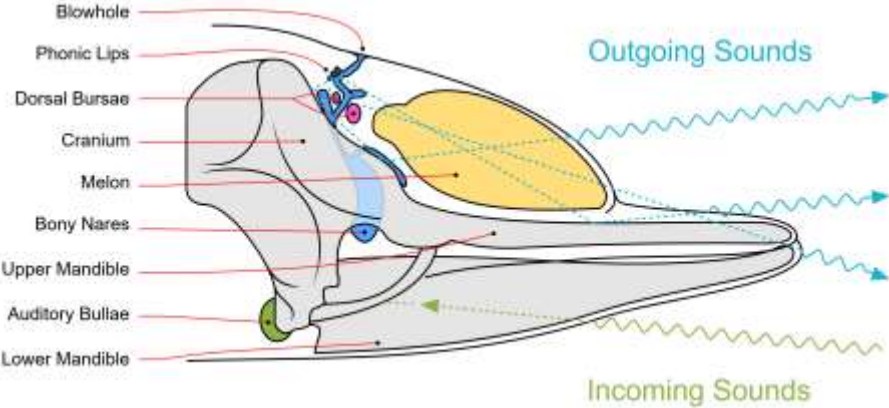


Defense purposes?

Animal echolocation



Arizona State University

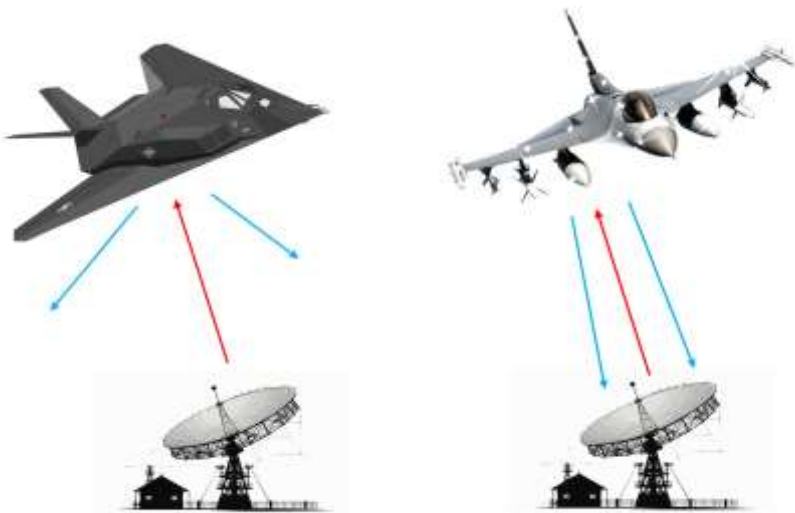


Wikipedia

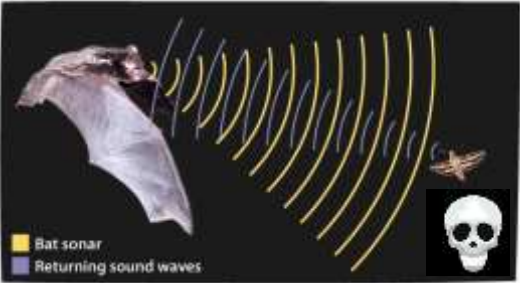
Defense purposes?

How to avoid detection?

Deflection



Deception (spreading of misinformation)



- Anti-bat ultrasound**
- Frighten
 - Jam
 - Deceive (Aposematism)



Tiger moths sound like toxic Whistling moths!

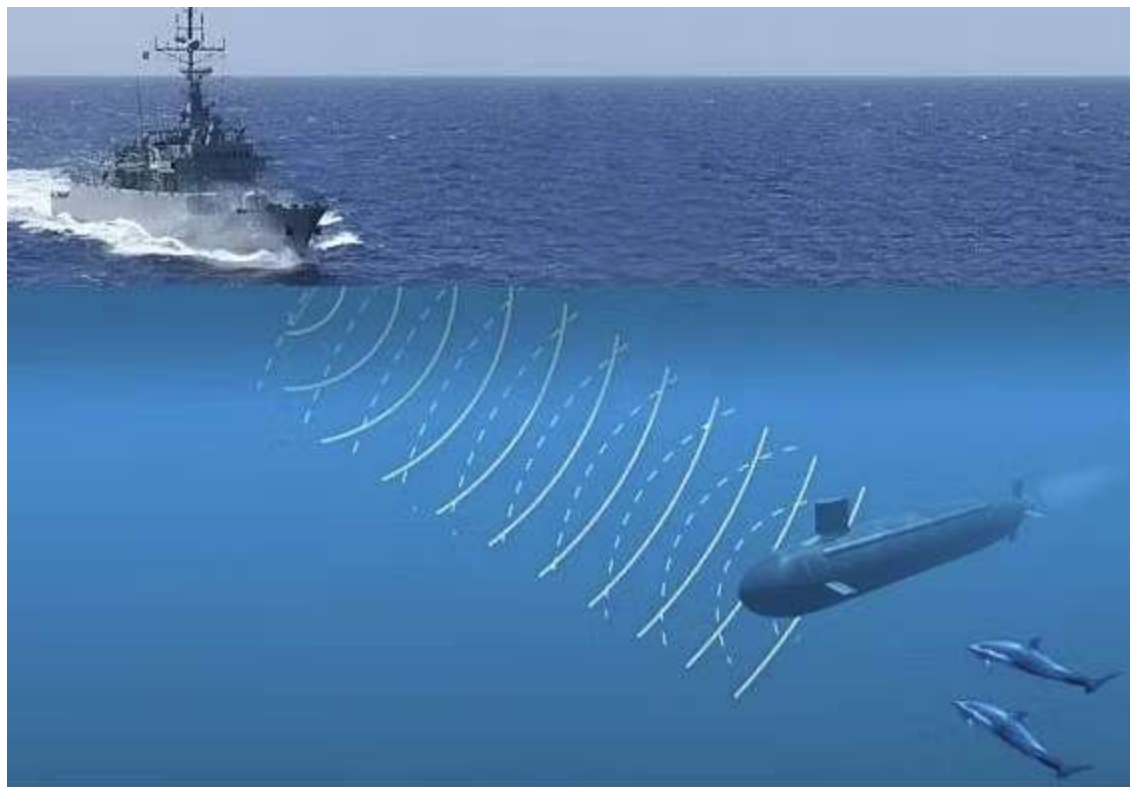
Camouflage



How to avoid detection?

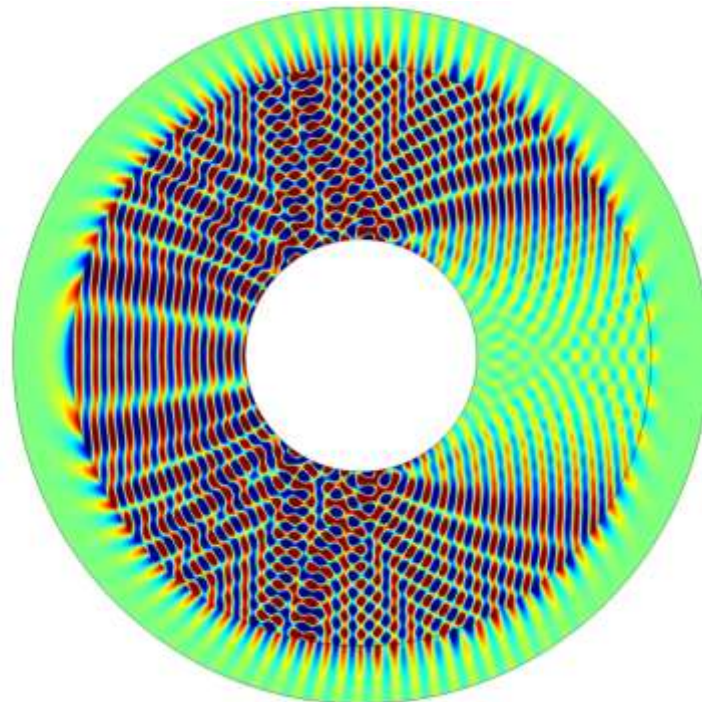
Complete absorption





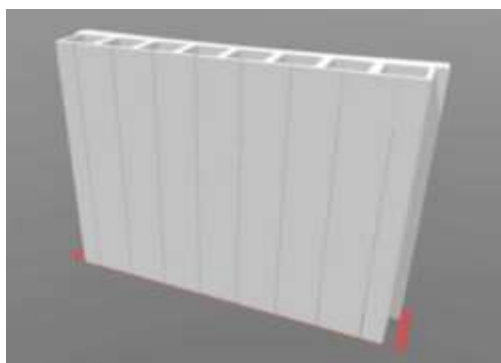
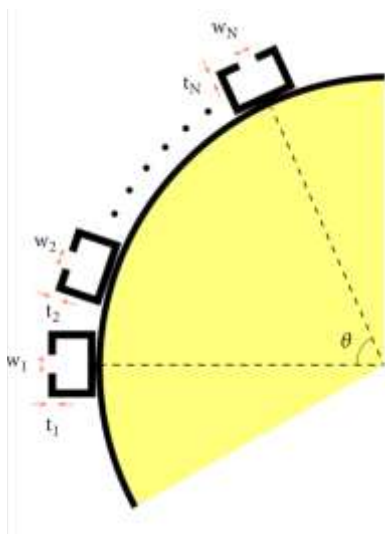
**Military•Aerospace
Electronics**

Wavefronts from left to right
impinging the submarine hull.

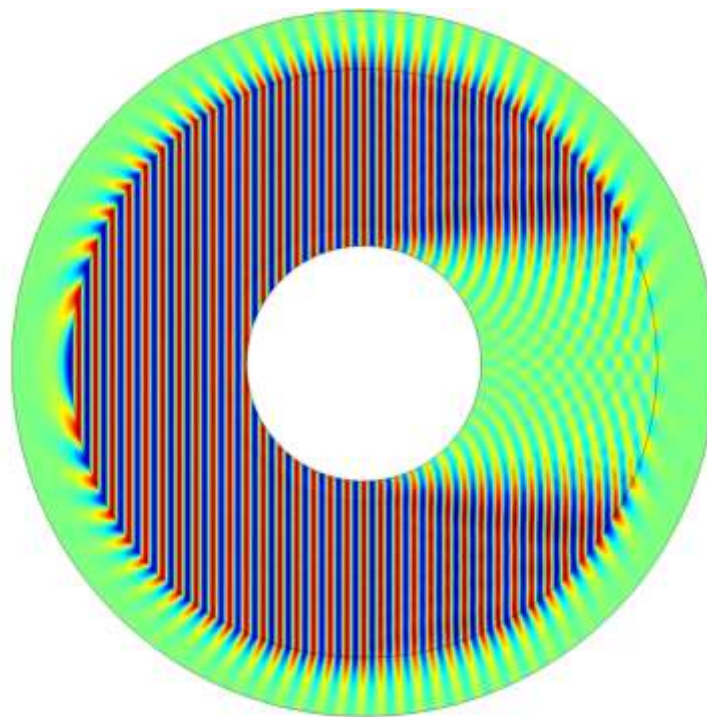


Strong reflection

acoustic “shadow”



Camouflage



acoustic "shadow"

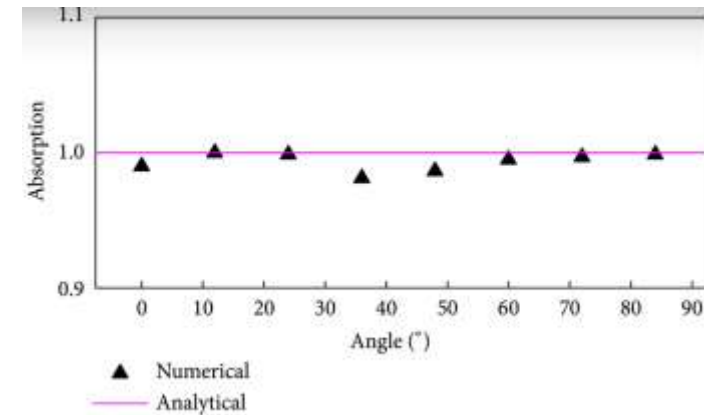
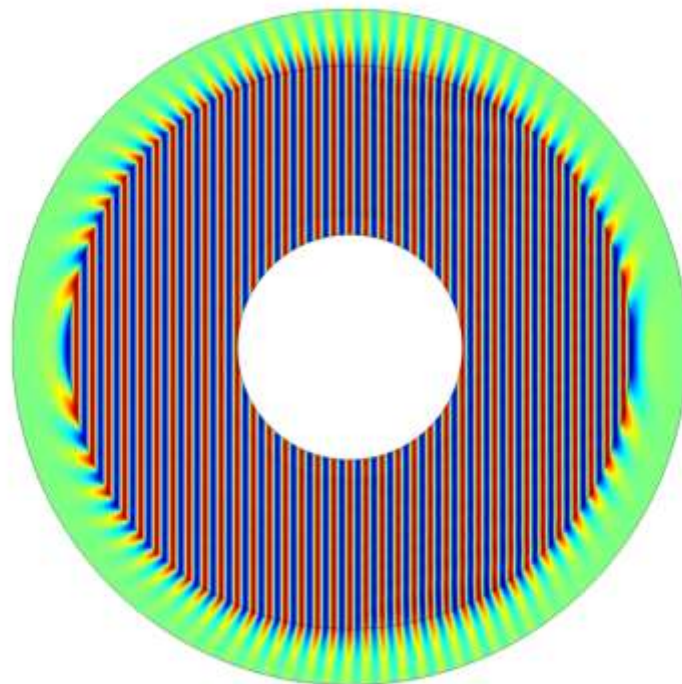
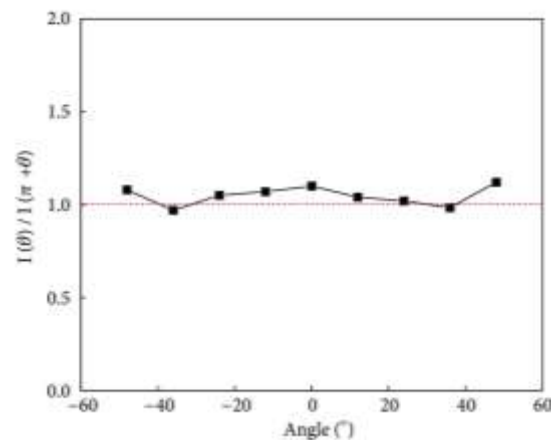
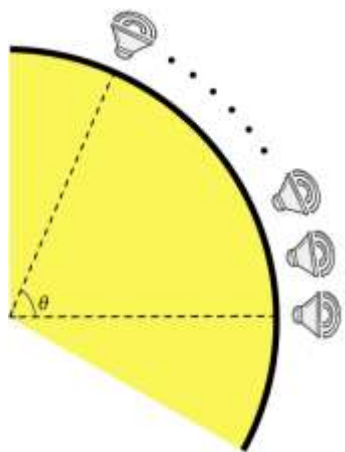
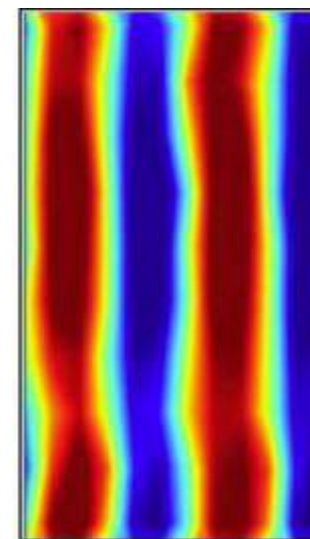
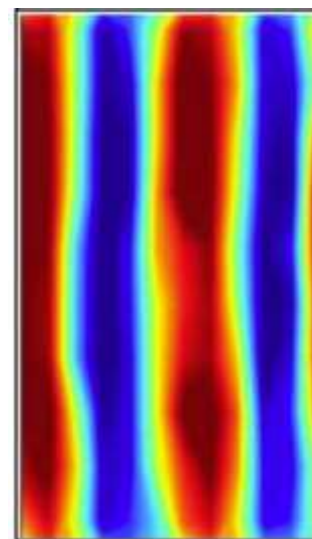


TABLE I. Geometrical parameters of the Helmholtz resonators

Element (i)	1	2	3	4	5	6	7	8
Angle (°)	0	12	24	36	48	60	72	84
w (mm)	0.08	0.08	0.08	0.08	0.08	0.06	0.06	0.06
t (mm)	0.096	0.098	0.099	0.104	0.144	0.090	0.132	0.540



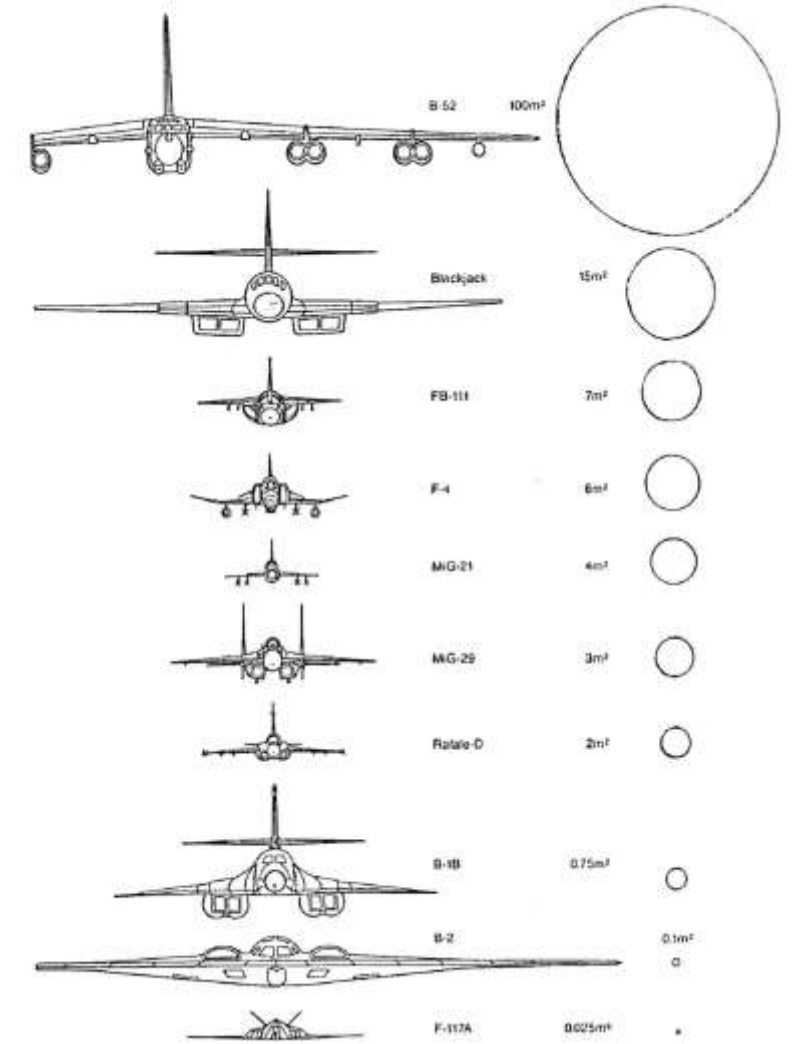
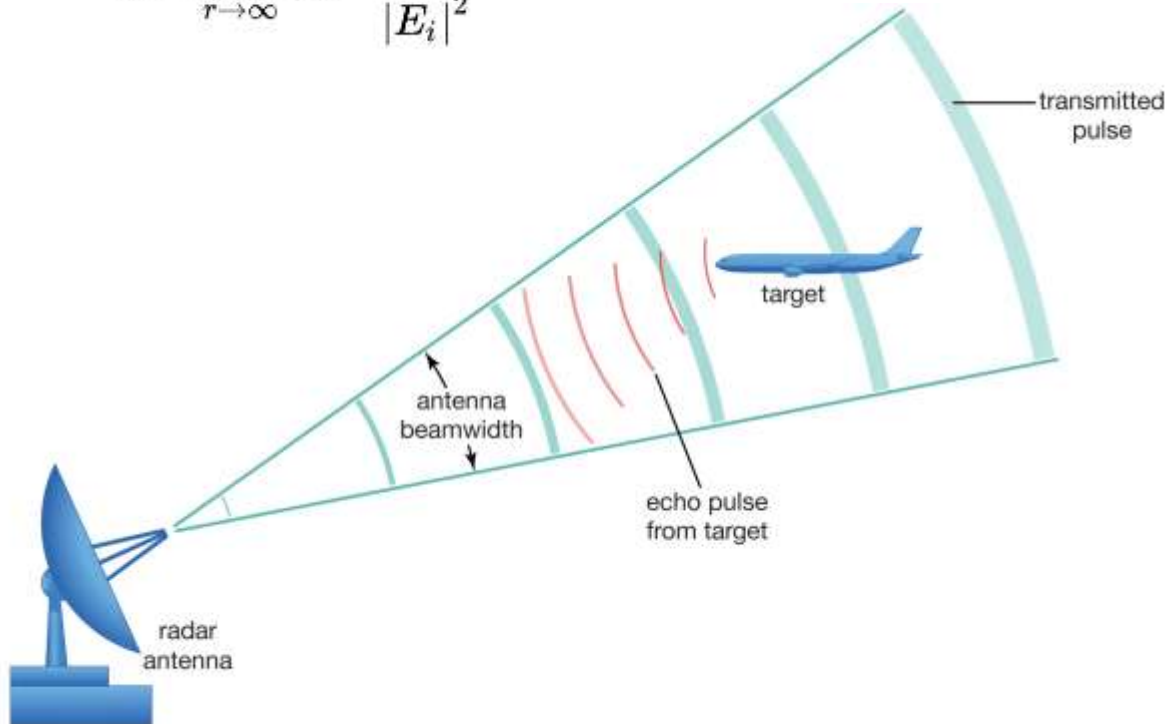
Sound-absorbing Cotton



Perfect unhearability

Zero radar cross section

$$\sigma = \lim_{r \rightarrow \infty} 4\pi r^2 \frac{|E_s|^2}{|E_i|^2}$$

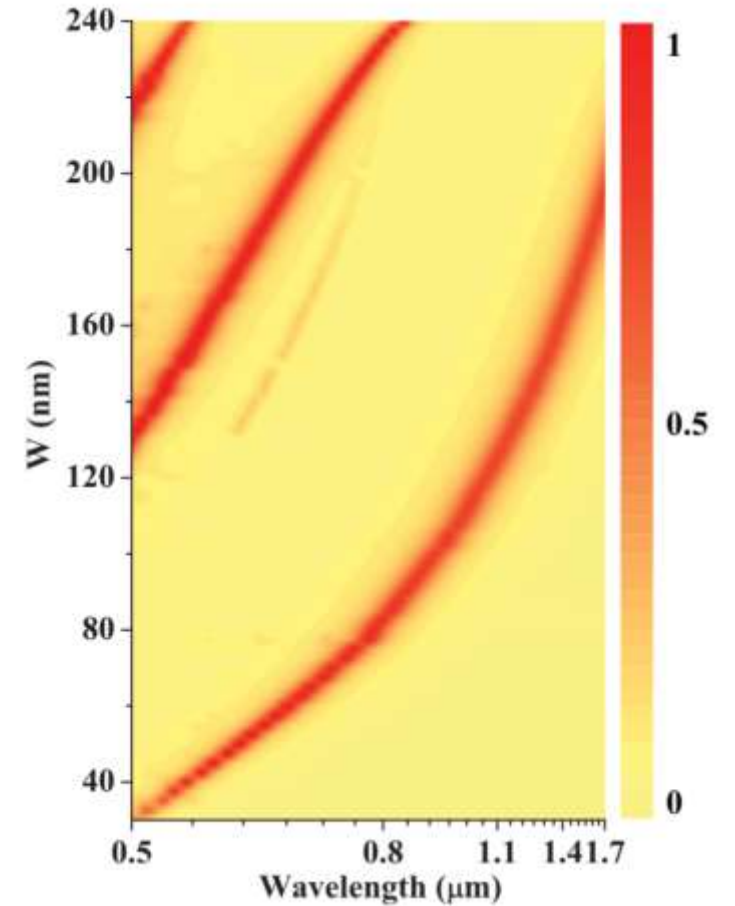
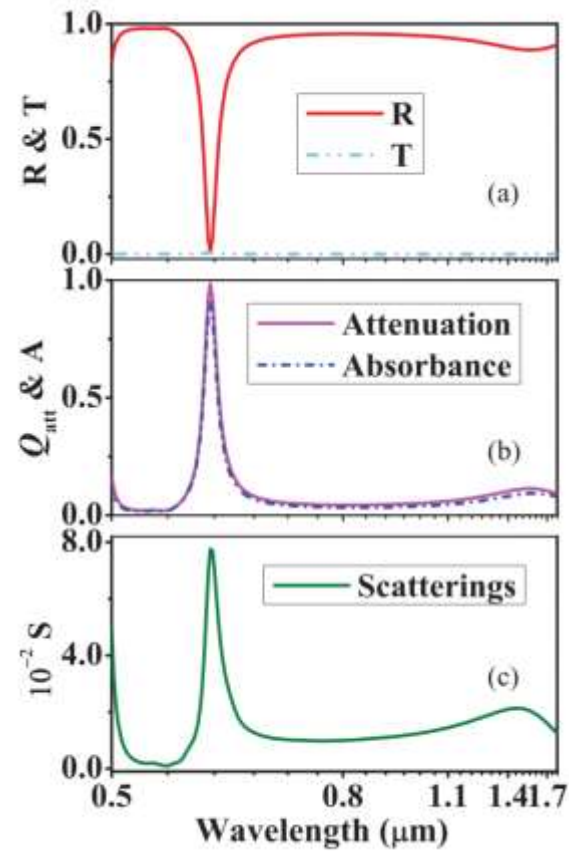
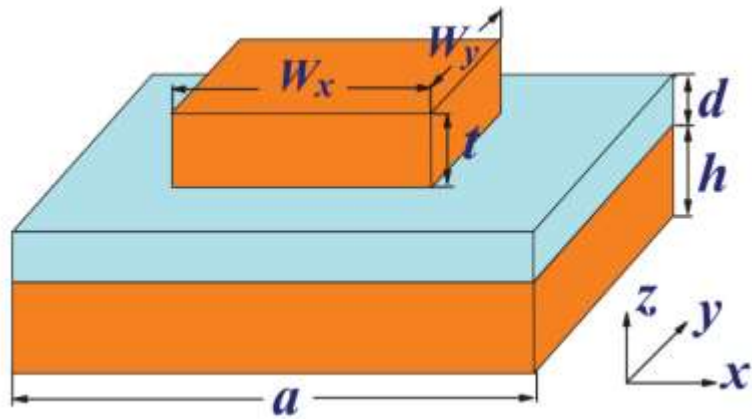


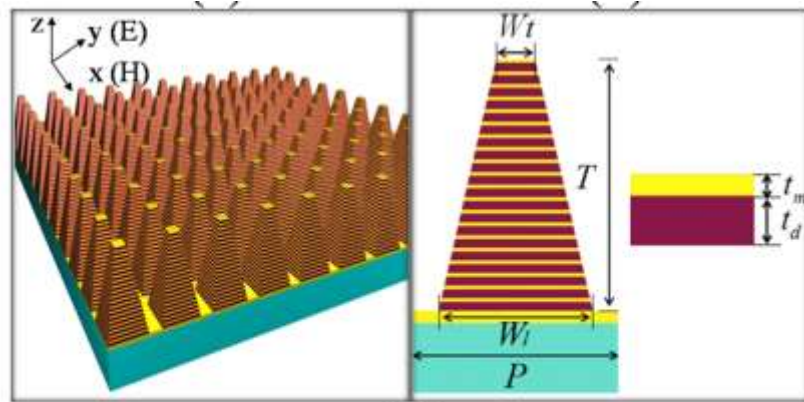
Rohan Bhavsar

PHYSICAL REVIEW B **83**, 165107 (2011)

Nearly total absorption of light and heat generation by plasmonic metamaterials

Jiaming Hao,¹ Lei Zhou,² and Min Qiu^{1,3,*}





(c)

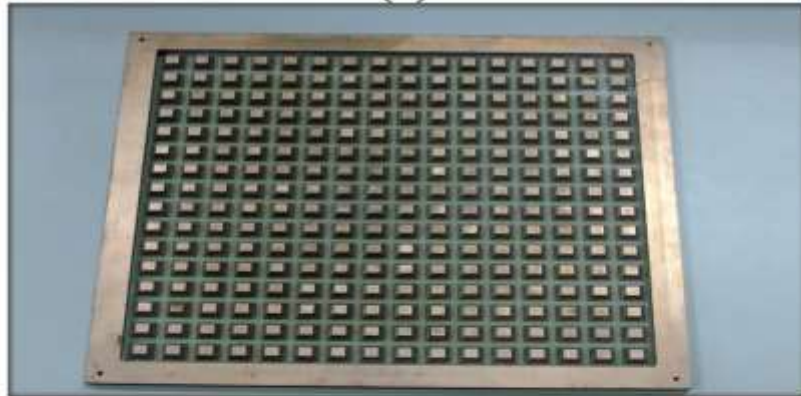
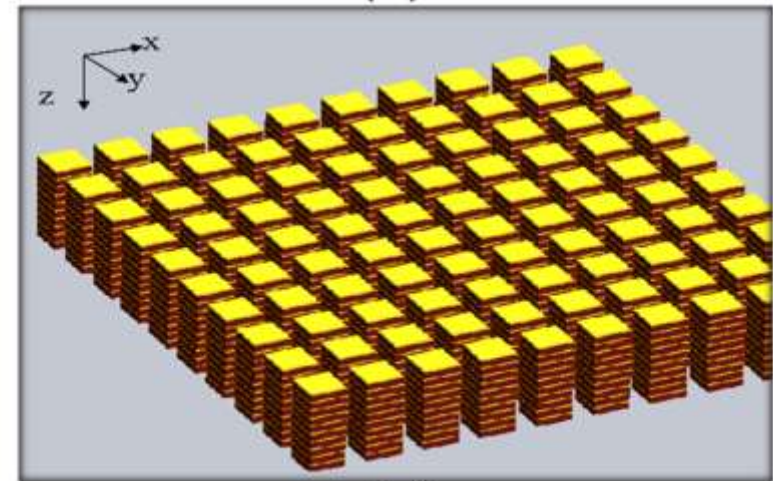
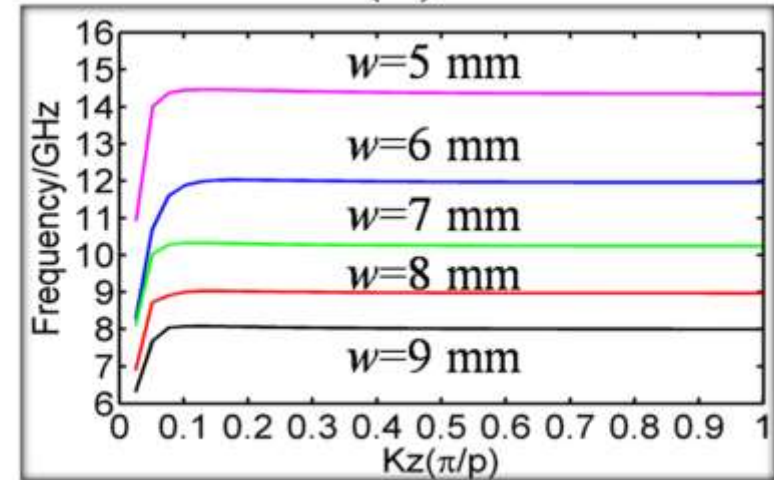
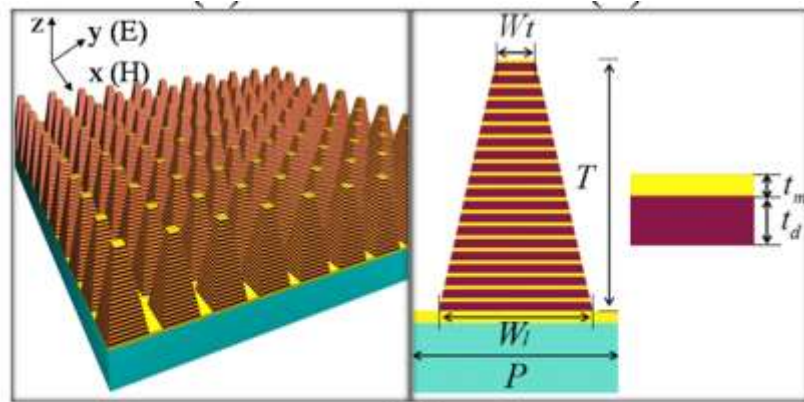


FIG. 1. (Color online) Design and fabrication of a microwave ultra-broadband MA. (a) Three-dimensional illustration of the simulated MA, (b) schematic of a MA unit cell, and (c) photograph of the fabricated sample. The optimized dimensions of a unit are $W_t = 5$ mm, $W_b = 9$ mm, $P = 11$ mm, $t_m = 0.05$ mm, $t_d = 0.2$ mm, and $T = 5$ mm. Subscript “m” represents copper, and “d” for FR4.



(b)





(c)

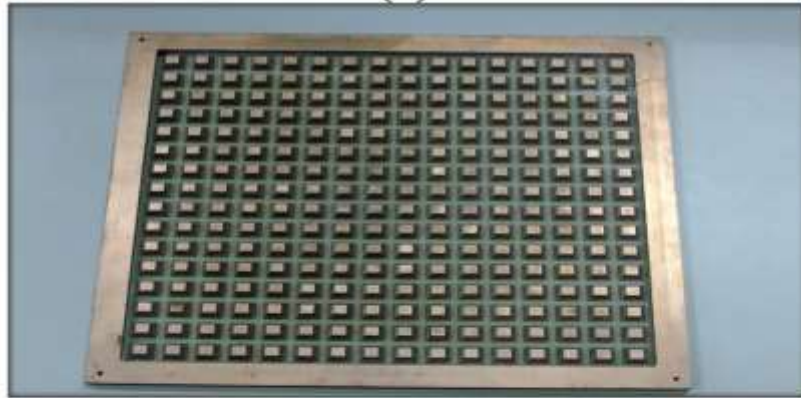
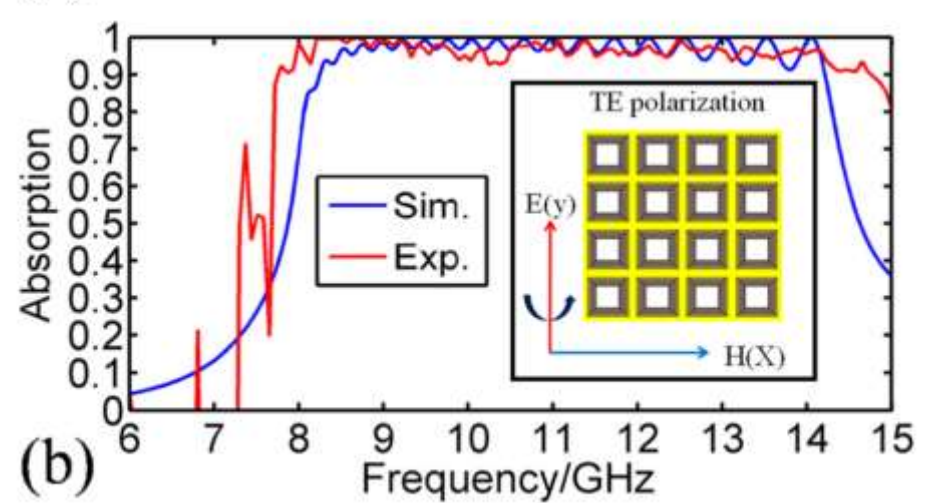
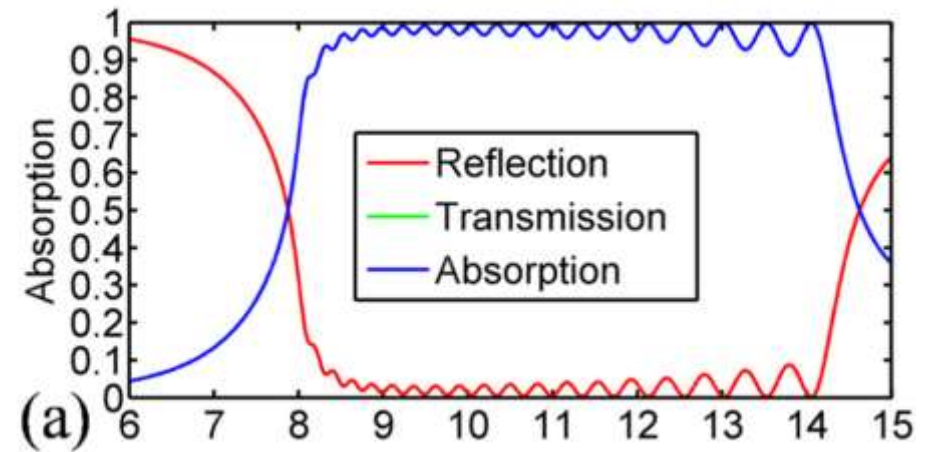


FIG. 1. (Color online) Design and fabrication of a microwave ultra-broadband MA. (a) Three-dimensional illustration of the simulated MA, (b) schematic of a MA unit cell, and (c) photograph of the fabricated sample. The optimized dimensions of a unit are $W_t = 5$ mm, $W_b = 9$ mm, $P = 11$ mm, $t_m = 0.05$ mm, $t_d = 0.2$ mm, and $T = 5$ mm. Subscript “m” represents copper, and “d” for FR4.



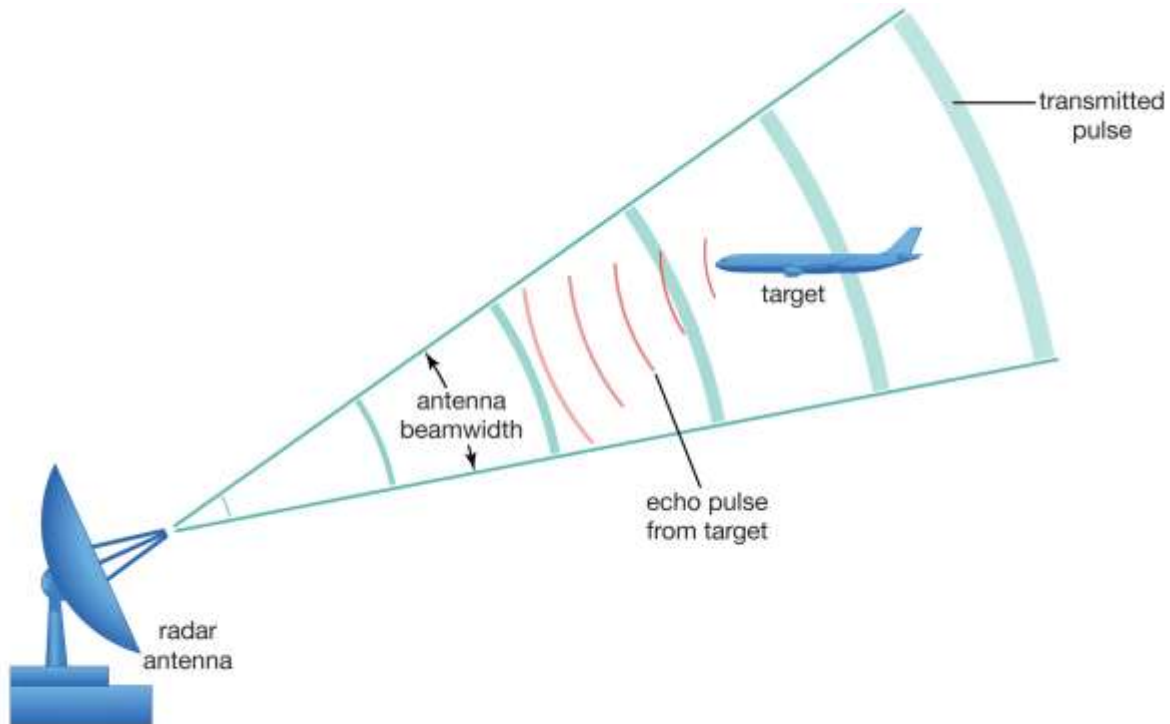
Deception (spreading of misinformation)

Anti-bat ultrasound

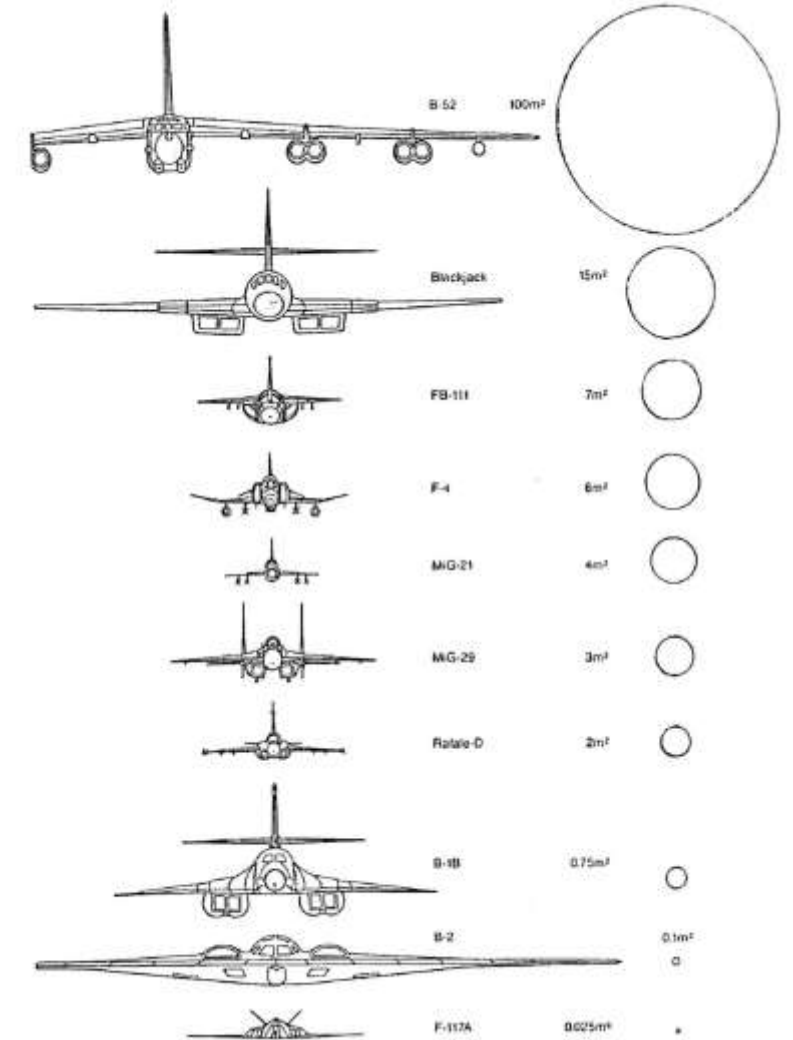
- Frighten
- Jam
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Tiger moths sound like toxic Whistling moths!



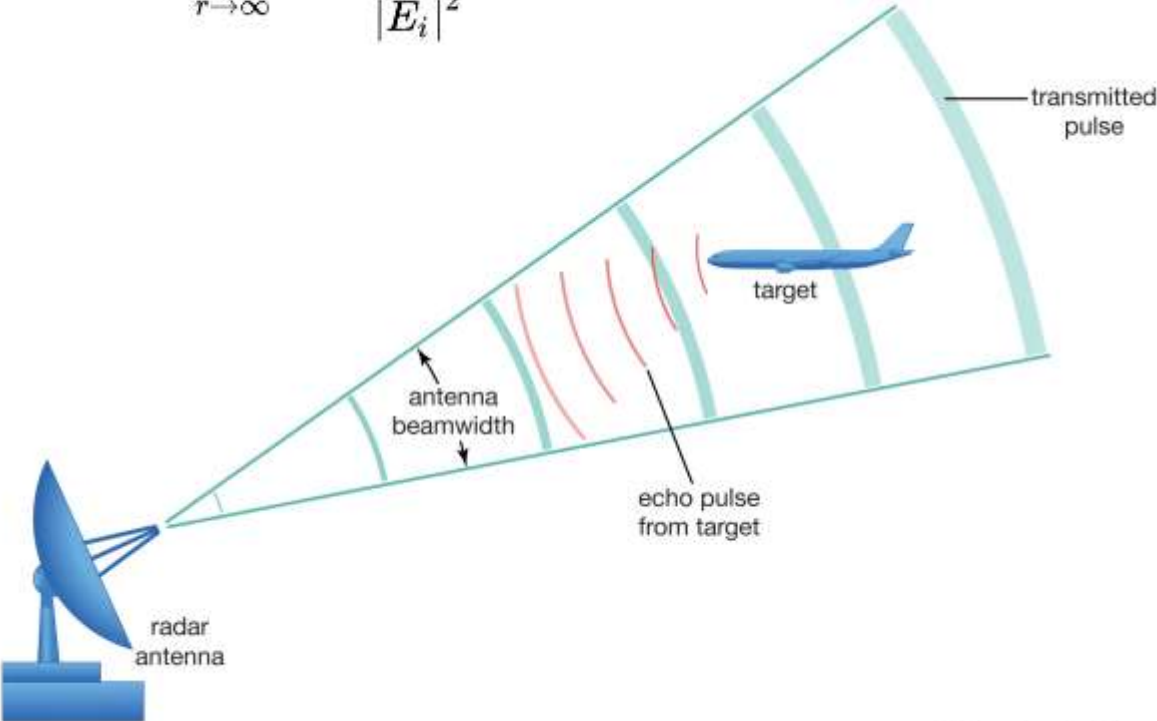
Large radar cross section



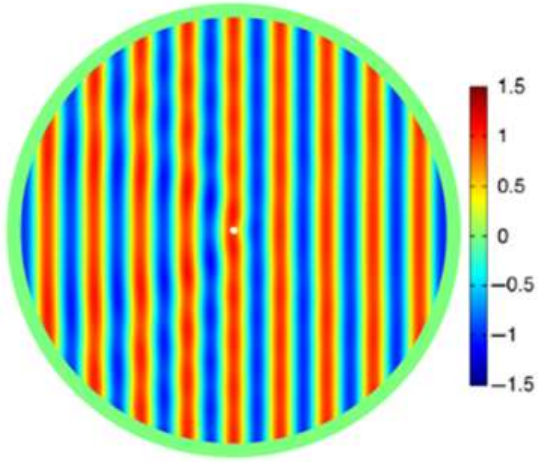
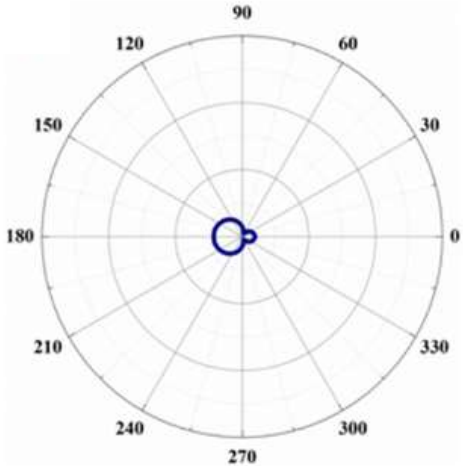
Rohan Bhavsar

Superscattering from small objects

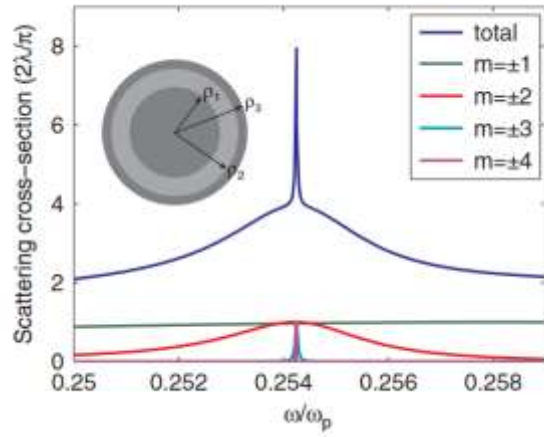
$$\sigma = \lim_{r \rightarrow \infty} 4\pi r^2 \frac{|E_s|^2}{|E_i|^2}$$



$$\sigma_{Max,m} = \frac{2\lambda}{\pi}$$

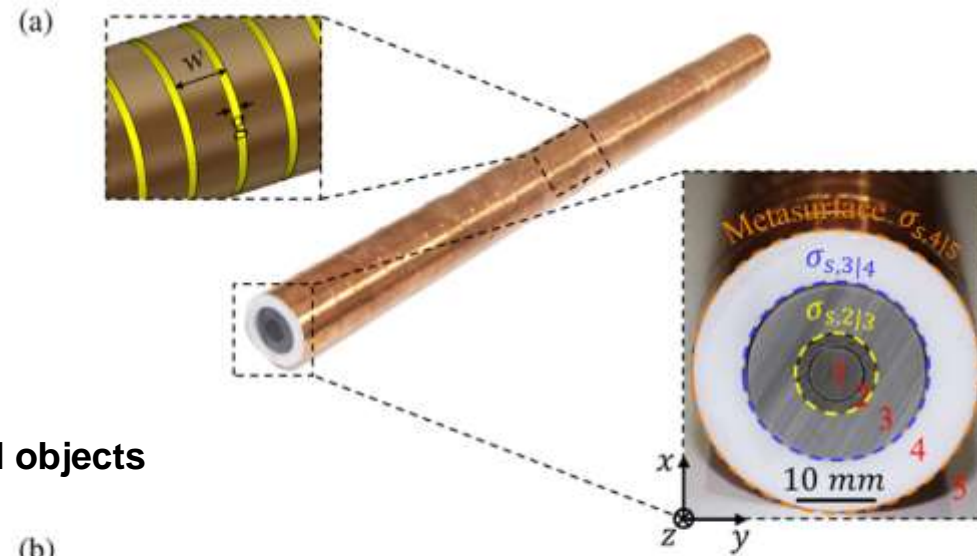


PRL 105, 013901 (2010)

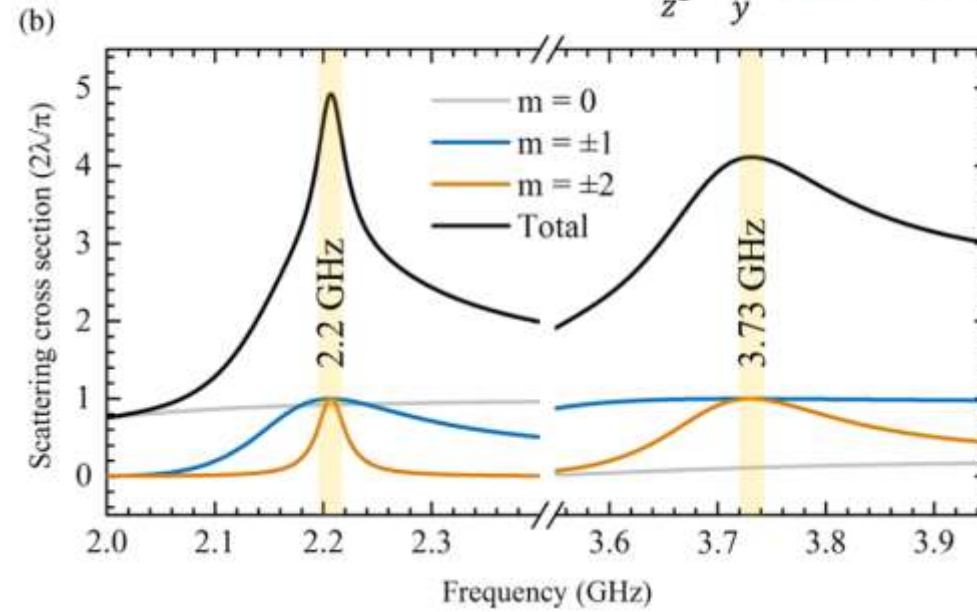
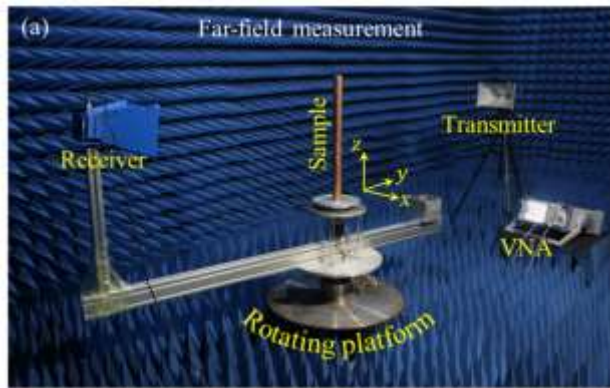


$$\sigma_{Max,m} = \frac{2\lambda}{\pi}$$

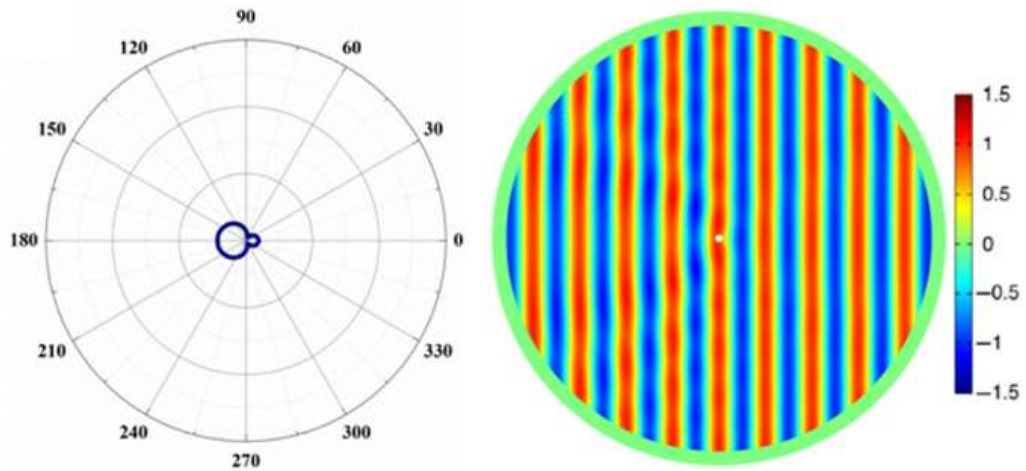
PHYSICAL REVIEW LETTERS 122, 063901 (2019)



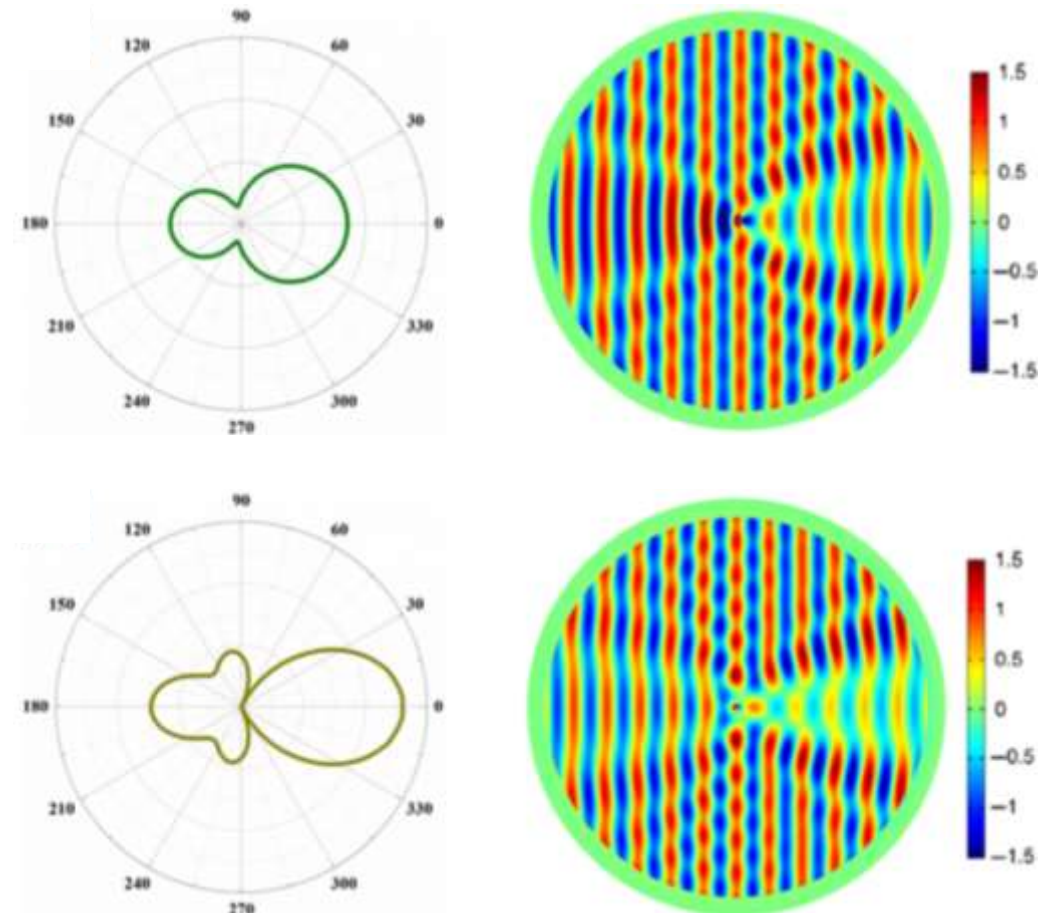
Superscattering from small objects



Ordinary small object



Metamaterial-superscatterer



- **Broadband ultrathin absorbers still missing!**
- **For radar waves, polarization insensitive.**
- **Testing superscattering with enlarged RCS.**
- **Weight and aerodynamics.**

Thanks for your attention!