Increased absorption due to localized resonances

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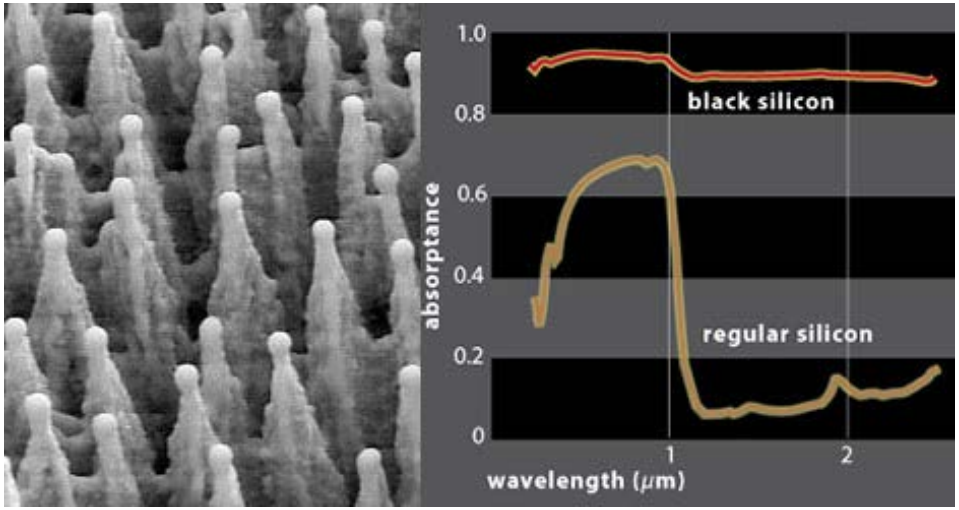
Wave absorbers

Electromagnetic anechoic chamber

Road Noise Acoustic Barrier



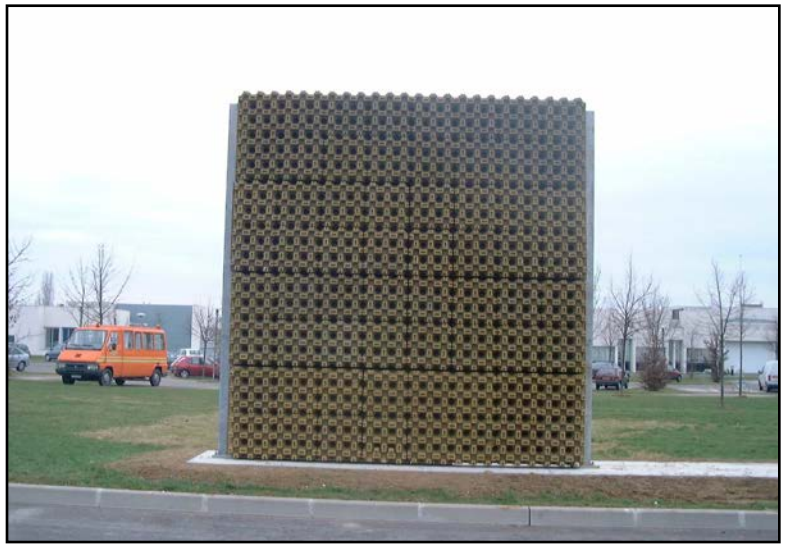
“Black” silicon

“Macroporous material” breakwater

The interaction of acoustic waves with matter depends on:

1. The **wave velocity** and **density ratios** between material and air,
2. The **geometry** of their separating **interface**,
3. This is **empirically** used in building noise-abating walls but poorly understood.

Road Noise Acoustic Barrier



COLAS

COLAS

COLAS

Material (known): cement-wood

2003
SIEMENS Prize for Applied Research
2004
Award of the International Road Federation
2008
Prize from the French Acoustical Society
Optics Valley Prize for Innovation

Patent Colas - Ecole Polytechnique 03/00881 , US patent 7308965B2 , Canada 2478579

Performance measurement

European norm EU 20354:
Frequency weighted average of

- Absorption in reverberation chamber,
- Standardized road noise,
- Standardized ear sensitivity.

Gives a single number **DLα** (in dB)

In 2009: DLα = **22 dB** **(best on the European market)**

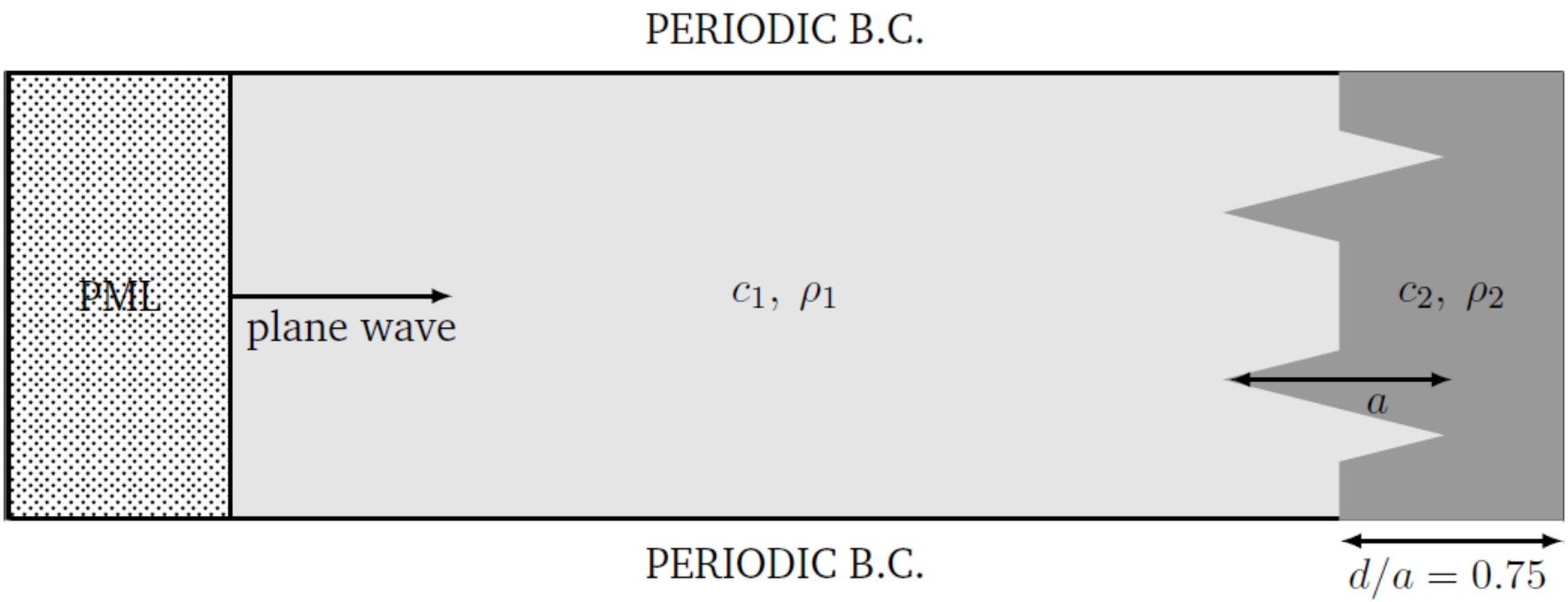
Why does it work?

Irregular barriers exhibit an increased number of resonances as compared to planar equivalents.

Some of these resonances are **localized** near the irregular surface:

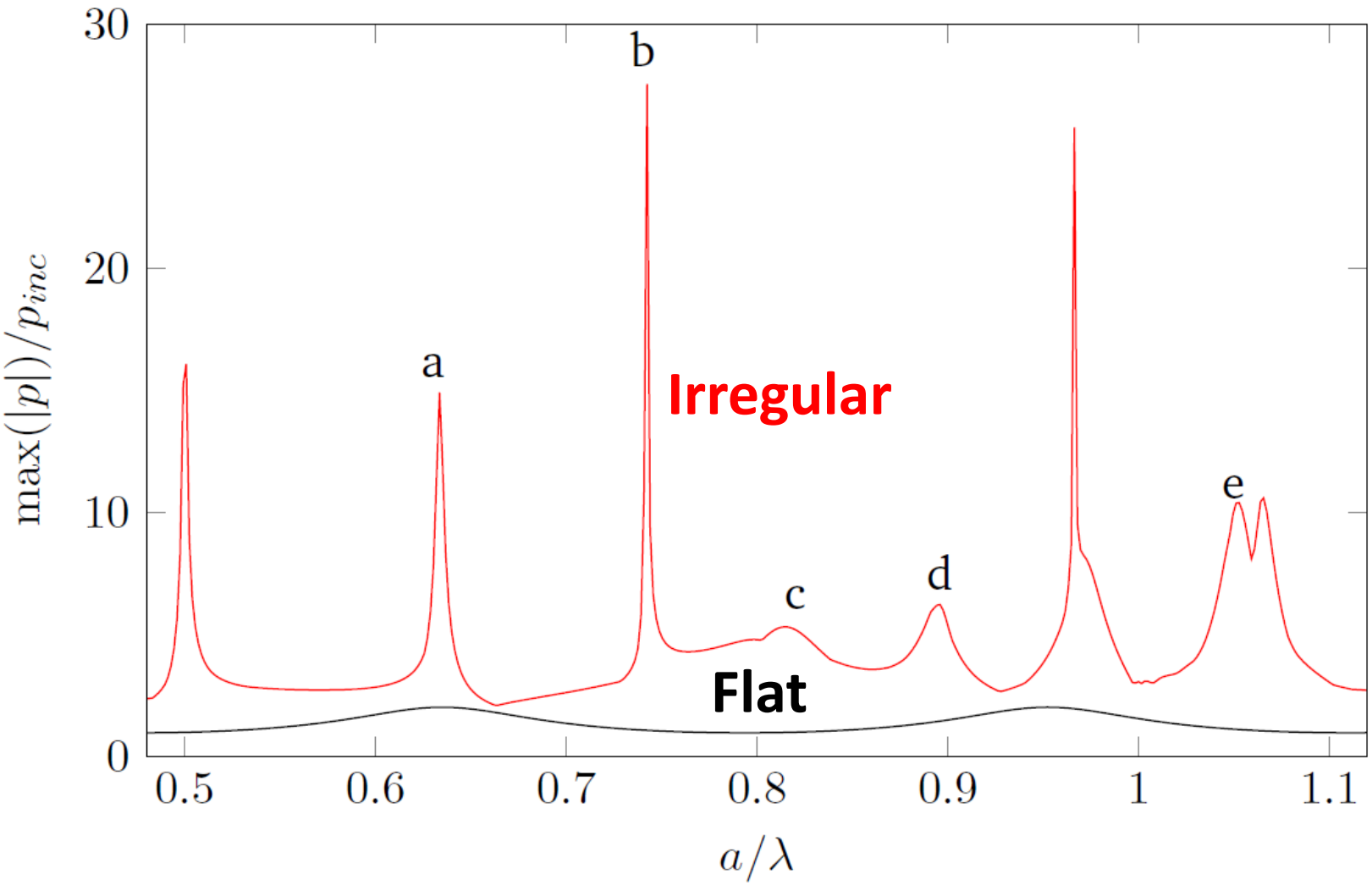
- the acoustical field is increased locally on the interface: better coupling with the incident wave and finally a stronger absorption.

Case study: 2D FEM simulation



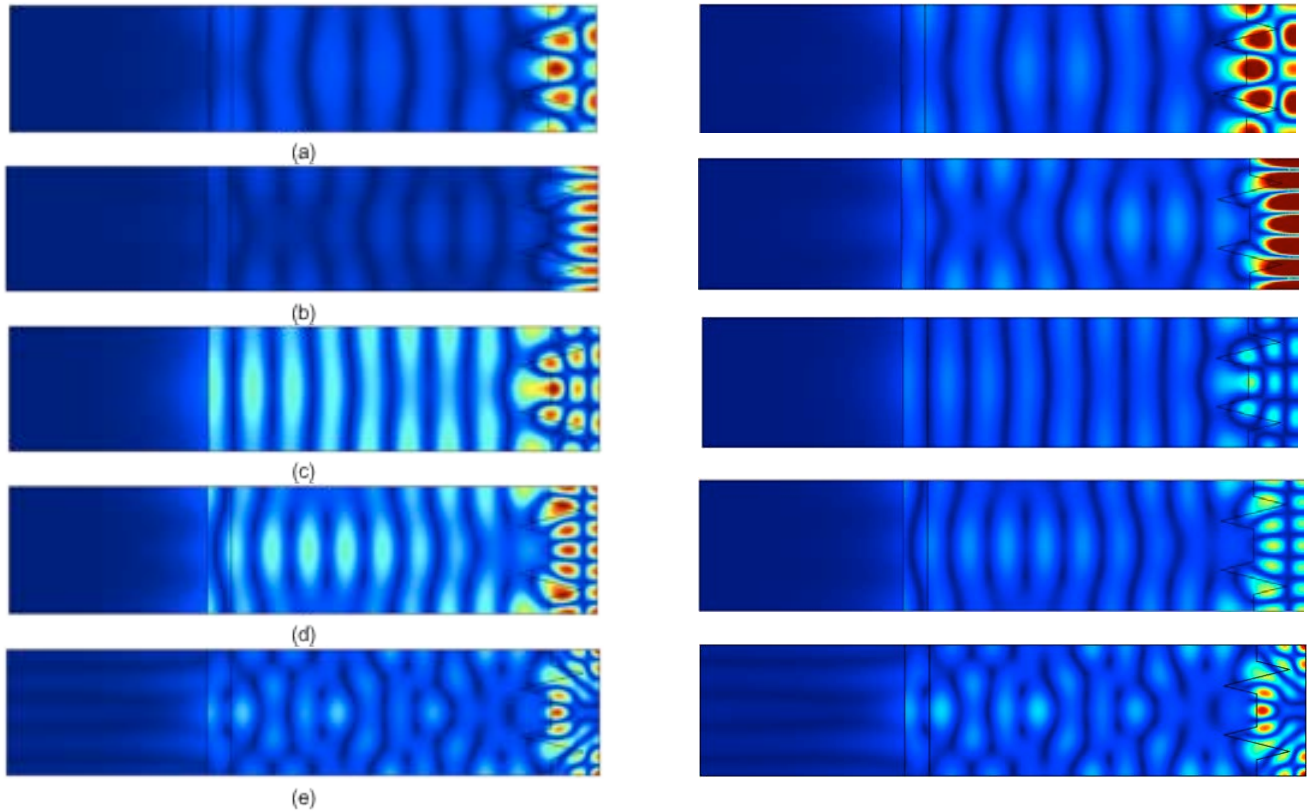
Lossless localization spectrum

Ratio of the peak acoustic pressure inside the material over the incident acoustic pressure



Pressure spatial distributions for the various resonances (no losses)

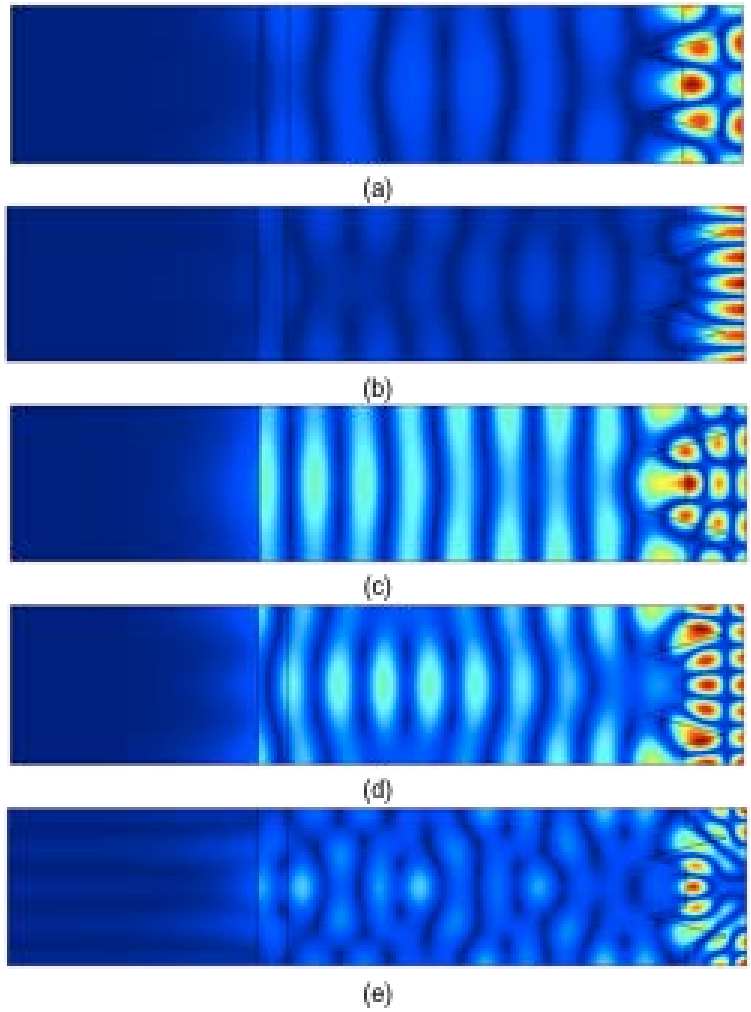
- (a)
- (b)
- (c)
- (d)
- (e)



Modes ***c***, ***d***, and ***e*** are localized near the interface and more strongly coupled to the external field (*astride* coupling).

Pressure spatial distribution for the various resonances (no losses)

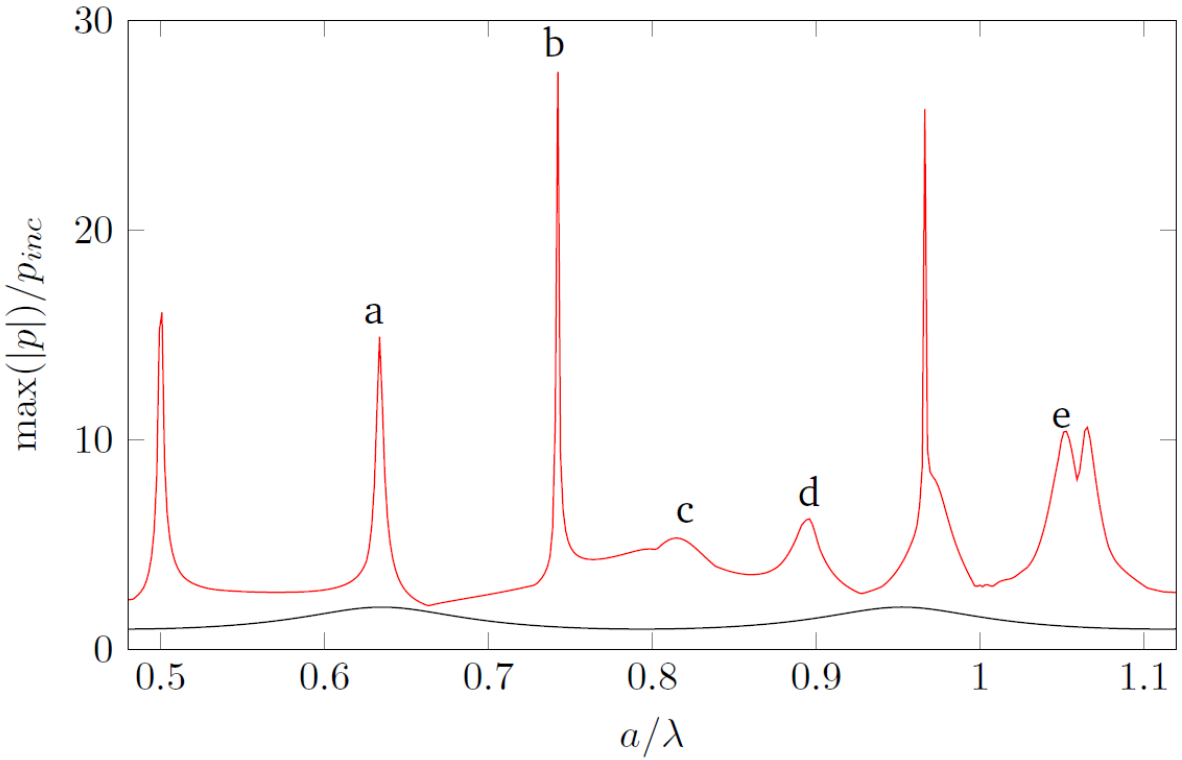
- (a)
- (b)
- (c)
- (d)
- (e)



These resonances are broader than ***a*** and ***b***.

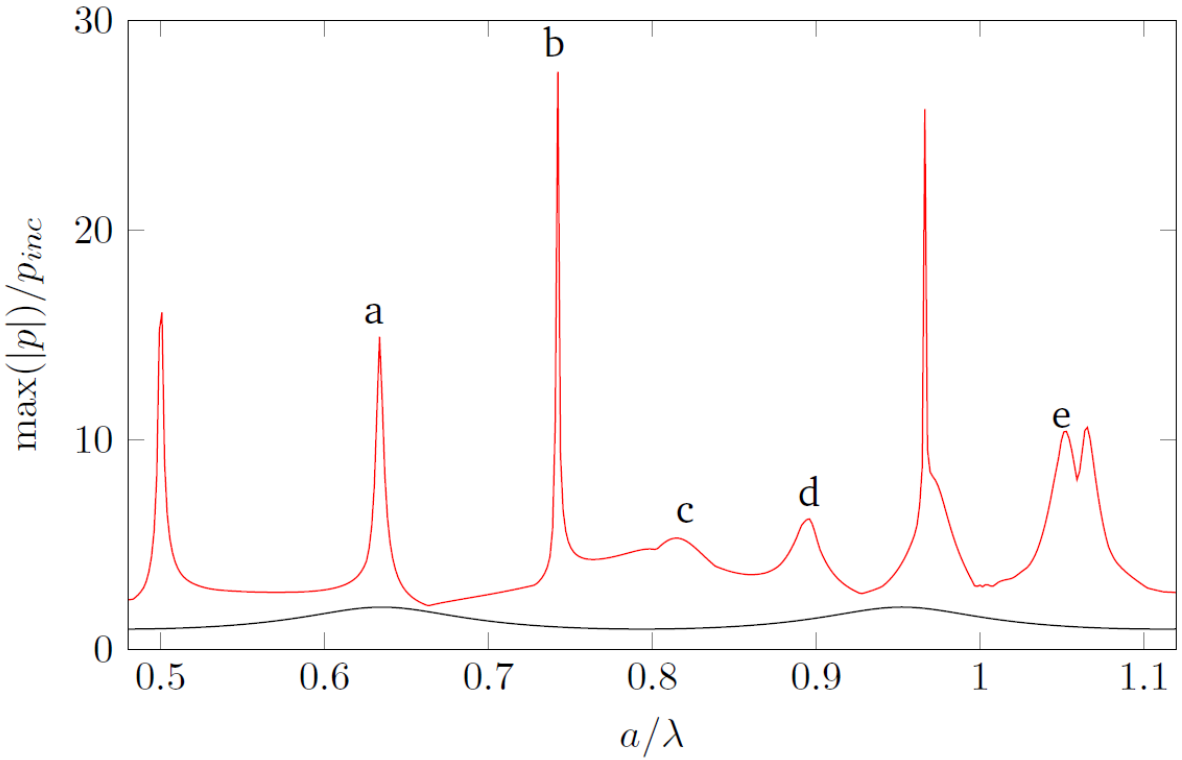
The broadening is due to **radiation damping**.

Radiation damping
(no losses in the material)



If at time *t=0*, there exists an acoustic pressure inside the material distributed like one of those modes, it will disappear in a finite life-time due to **acoustic radiation**. Hence, the resonances **widths**.

Radiation damping
(no losses in the material)

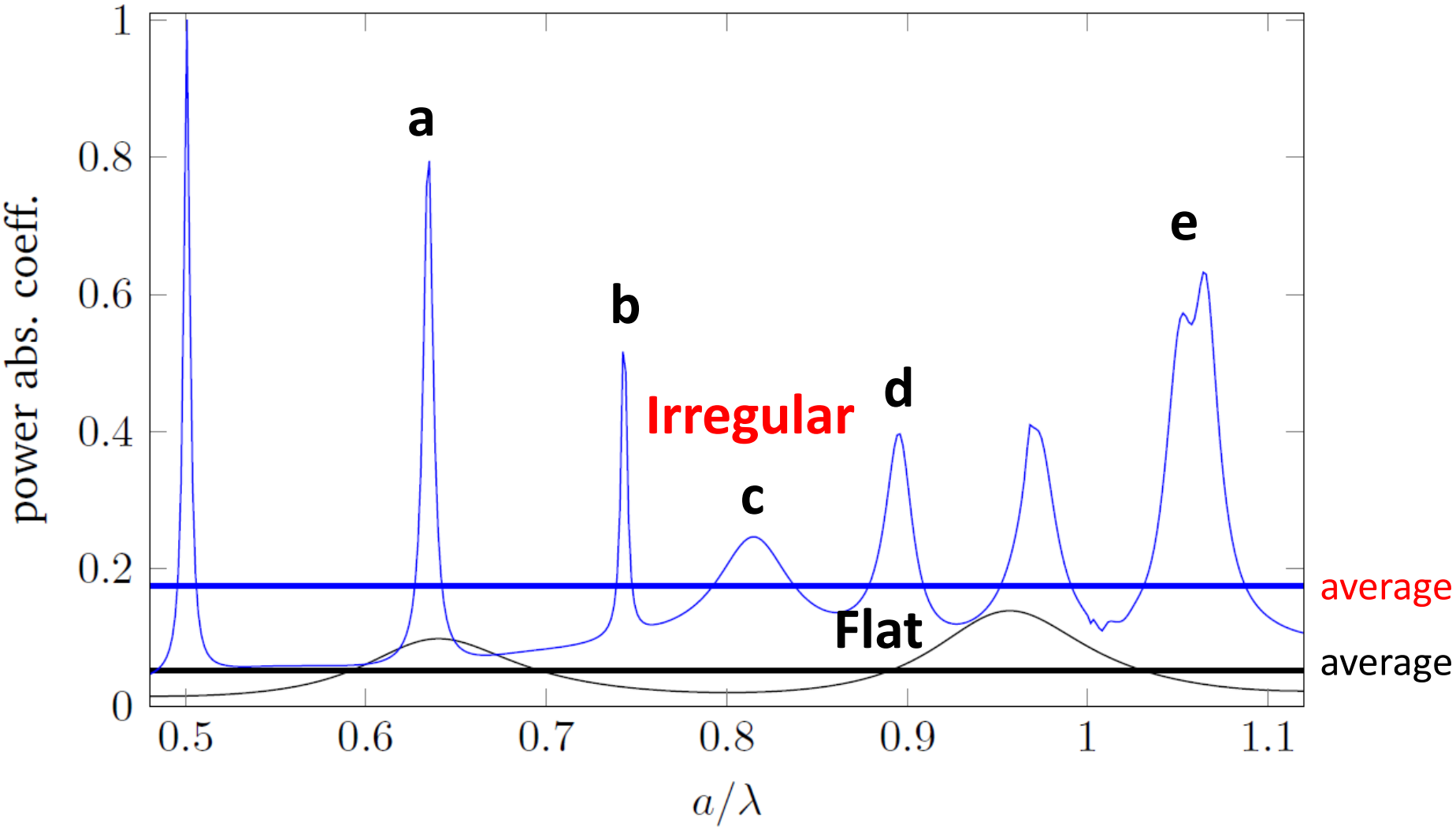


The stronger the coupling (*c*, *d*, and *e*), the shorter the life-time, and the broader the resonance.

But the **stronger** the coupling, the **better** the energy absorption should be if the material is **dissipative**.

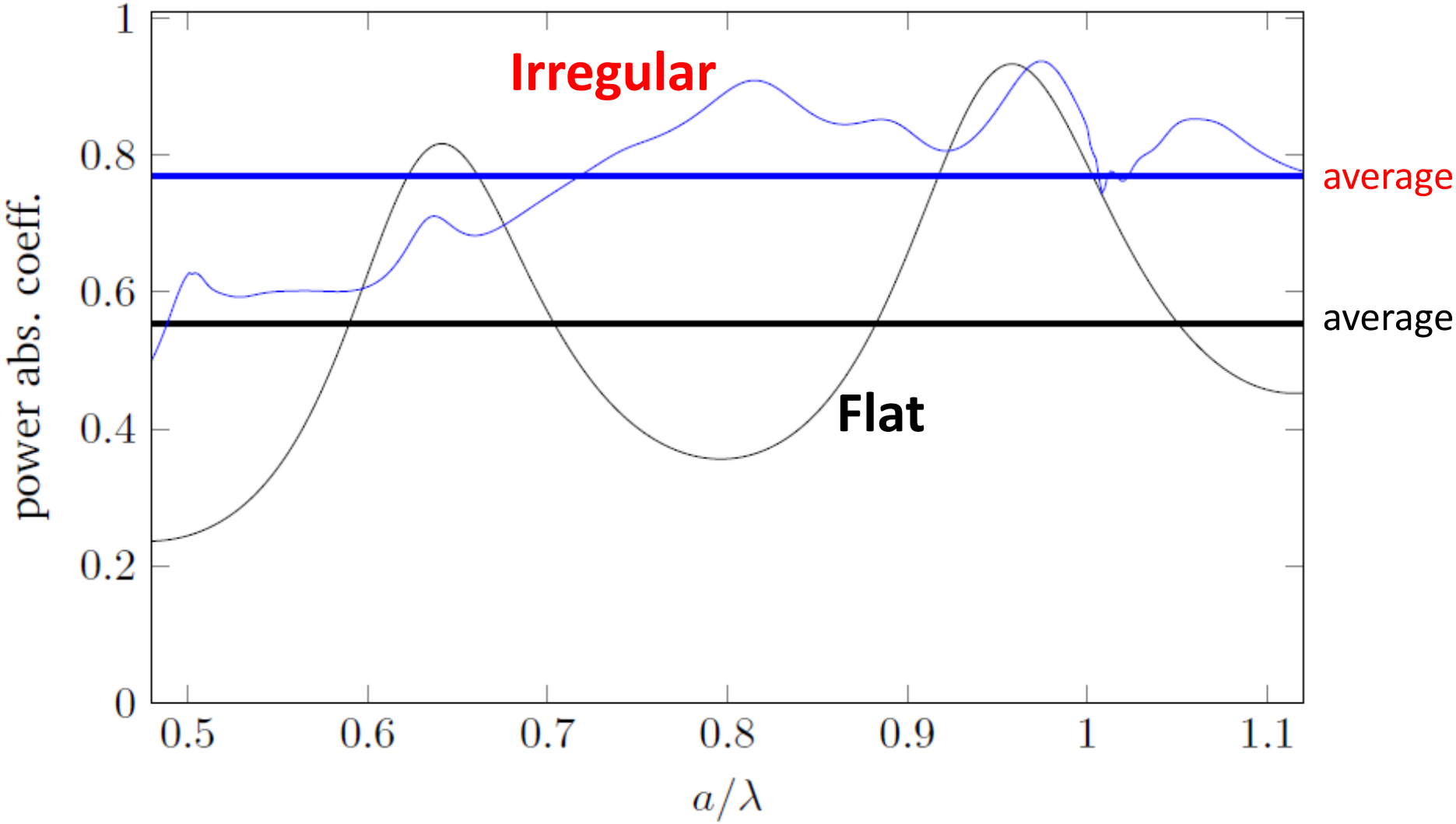
Power absorption spectrum for a weakly lossy material

(absorption length= 36 λ)



Power absorption spectrum for a more dissipative material

(absorption length= 3 λ)



Summary

Geometrical irregularity increases the acoustic absorption of a given quantity of absorbing material.

This is due to

1. Increased number of **resonances** in a given volume.
2. Some of the resonances are **localized** at the irregular **interface** between air and the material.
3. These localized resonances are more strongly coupled to external fields by **radiation damping**.
4. The **better absorption** properties of irregular absorbing walls are due to theses localized resonances.

Bibliography

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