Applications to devices

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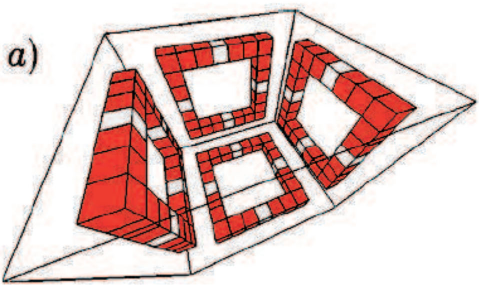
Why introduce effective parameters?

We need them in order to be able to solve electromagnetic problems for large and complex-shaped bodies — without these models we would need to solve currents on each individual particle of a composite, which is not possible.

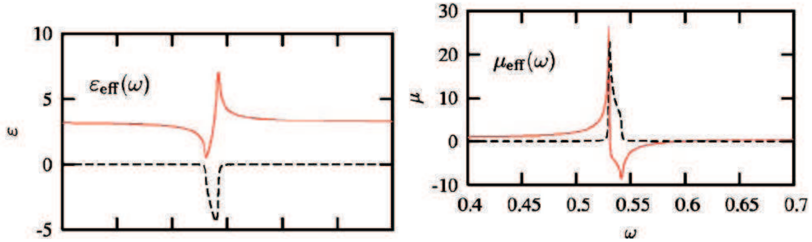
Models which do not allow us predictions of composite response in various electromagnetic environments, are practically useless.

An example

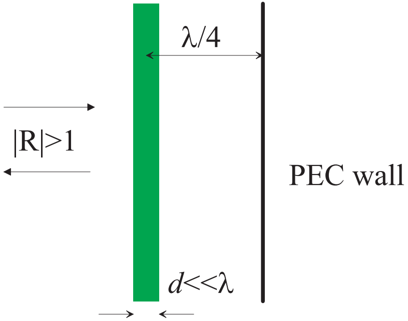


Th. Koschny, L. Zhang, C.M. Soukoulis, Isotropic three-dimensional left-handed metamaterials, *Phys. Rev. B*, vol. 71, 121103(R), 2005.

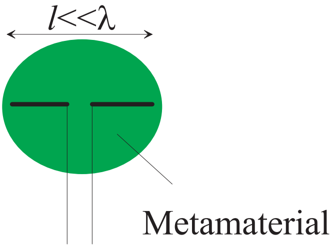
Extracted material parameters



Engineer "designs"

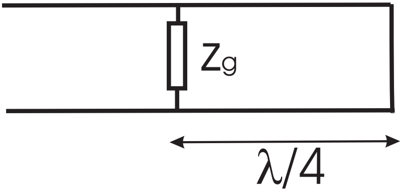


Amplifier with no power supply



Broadband matching

"Amplifier"



$$Z_g = \frac{\eta_0}{jk_0 d(\epsilon - 1)} = Z_{\mathrm{inp}}$$

$$R = \frac{Z_{\mathrm{inp}} - \eta_0}{Z_{\mathrm{inp}} + \eta_0}$$

$$|R| = \sqrt{\frac{k_0 d(\epsilon' - 1)^2 + (k_0 d\epsilon'' + 1)^2}{k_0 d(\epsilon' - 1)^2 + (k_0 d\epsilon'' - 1)^2}} > 1, \quad \text{because} \quad \epsilon'' > 0$$

"Matching device"

Antenna in free space:

$$Y_{\rm inp} = jB = j\omega\epsilon_0 C_0, \qquad \frac{\partial B}{\partial \omega} = \epsilon_0 C_0$$

Antenna in this "metamaterial" shell:

$$Y_{\rm inp} = jB = j\omega\epsilon(\omega) C_0, \quad \frac{\partial B}{\partial \omega} = \epsilon(\omega) C_0 + \frac{\partial \epsilon}{\partial \omega}\omega C_0, \quad \frac{\partial \epsilon}{\partial \omega} < 0 \qquad !!!$$

Antenna in a realistic metamaterial shell:

$$\epsilon(\omega) = \epsilon_0 \left(1 - \frac{\omega_p^2}{\omega^2}\right), \quad Y_{\rm inp} = jB = j\omega\epsilon(\omega) C_0, \quad \frac{\partial B}{\partial \omega} = \epsilon_0 C_0 + \frac{\epsilon_0 \omega_p^2}{\omega^2}$$