

Effective parameter definition and physical meaning

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Definition

of effective material parameters

Permittivity, permeability, chirality parameter, Tellegen parameter, grid impedance, surface impedance, refractive index, wave impedance, . . .

are **simple models** of electromagnetic response of complex multi-particle systems.

Physically sound (local) material parameters. . .

- ▶ Are independent of the spatial distribution of fields excited in the material sample
- ▶ Are independent of the geometrical size and shape of the sample
- ▶ Satisfy the causality requirement (Kramers-Kronig relations)
- ▶ Satisfy the passivity requirement (II law of thermodynamics)

for all linear passive media in thermodynamically equilibrium states.

in effective-parameter description of metamaterials:

- ▶ Period is not very small compared with the wavelength \Rightarrow Spatial dispersion is not negligible
- ▶ Number of layers/inclusions is not very large \Rightarrow Surface effect is not negligible
- ▶ Particles are resonant \Rightarrow Spatial dispersion can be significant not only near lattice resonances
- ▶ Inclusions have both electric and magnetic responses \Rightarrow Effective permeability is supposed to model both spatial dispersion near lattice (Bragg) resonance and magnetic polarization due to individual inclusions