A quantum graph approach to metamaterial design

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Abstract

We consider a quantum graph approach for designing metamaterials. An infinite square periodic quantum graph, constructed from vertices and edges, acts as a paradigm for a 2D metamaterial. Wave transport occurs along the edges with vertices acting as scatterers modelling sub-wavelength resonant elements. These resonant elements are constructed with the help of finite quantum graphs attached to each vertex of the lattice with customisable properties controlled by a unitary scattering matrix. The metamaterial properties are understood and engineered by manipulating the band diagram of the periodic structure. The engineered properties are then demonstrated in terms of the reflection and transmission behaviour of Gaussian beam solutions at interfaces between different metamaterials. We demonstrate negative refraction, beam steering and wave vector filtering among other effects both within our model and in experiments based on interconnected acoustic tubes.

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