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SIZE-INDEPENDENT METAMATERIAL RESONATORS.

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Abstract

The introduction of double-negative (DNG) metamaterials in which energy and phase propagate in opposite directions has recently allowed for the design of resonators, partially filled with DNG material, whose possible operating frequencies depend only on the dispersive properties of the metamaterial, but are independent of the dimensions of the resonator in terms of wavelength, therefore allowing, in particular, for the design of miniaturized resonators. These resonators are of two types: those in which standing waves are present, but phase compensation between the double-positive (DPS) and DNG portions leads to size independence, and those in which a progressive wave propagates along a closed path made of alternating equal-optical-path portions of DPS and DNG materials.

The first example of a resonator containing metamaterial leading to phase compensation was introduced by Engheta [1,2] for a one-dimensional structure, as a proof of concept. In practice, this resonator would work approximately as an open resonator if fringing effect were to be neglected. A fully enclosed metallic parallelepipedal cavity resonator with four sub-volumes containing alternating DPS and DNG materials and leading to size independence because of phase compensation was developed by Uslenghi [3] for the case of an electric field everywhere parallel to one of the coordinate axes. Even though the analysis was conducted for the case of an electric field parallel to a coordinate axis and independent of that coordinate, practical situations exist in which such field orientation occurs. For example, a zero-permittivity resonator made of a wire medium, in which the electric field is uniform and parallel to the wires, was developed by Couture et al. [4].

A generalization of the work in [3] to the case of a fully enclosed parallelepipedal cavity resonator consisting of eight sub-volumes of equal size containing alternating DPS and DNG materials and supporting fields without restriction on their orientation has recently been completed [5]. Resonators of different geometrical configurations are also discussed.

The concept of metamaterial rotators was first introduced by Uslenghi [6,7]. These are closed circuits of specified topological configurations along which a plane wave propagates by total transmission across planar interfaces separating DPS and DNG materials with opposite refractive index and equal intrinsic impedance. If the paths along the DPS and DNG portions of the circuits lead to exact phase compensation after a complete loop, then the resonator supports propagating waves independently of its size. A variety of such resonators can be designed utilizing only geometric considerations, without introducing a single formula or equation.

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