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Wave Dynamics in a Hyperbolic Metamaterial Excited by a Two-Dimensional Periodic Array of Sources at its Surface

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In general, uniaxial materials exhibit ellipsoidal wave vector dispersion relations. Interestingly, under particular conditions, the material dispersion relation may turn into a hyperbola. This fact theoretically imposes no actual maximum bound on the spatial spectrum that is able to propagate within the uniaxial material leading to very interesting physical properties. Recently, there has been emphasis in the development of practical realizations of hyperbolic metamaterials (HMs) that are able to support waves with large transverse wavenumber, which would otherwise be evanescent in free space. It has been shown that homogenized models for HMs are inaccurate for very large spatial spectrum of waves because realistic HMs exhibit a large, but finite, propagating spectrum. Nonetheless, this large spatial spectrum has been shown to enhance the power emitted by impressed dipoles in proximity of the HM surface and to redistribute the radiated power mostly toward the HM (C. Guclu, et al., Phys. Rev. B., 86, 205130, 2012). These physical properties are of key importance and may lead to improvement of bandwidth and angular range of absorption when scattering is created by locating many micro or nano-scatterers at the HM surface, also supported by preliminary experimental data from other researchers. However, the analytical modeling of such structure has not yet been developed and it is of extreme importance as it would provide guidelines for future experimental developments.

Therefore, in this paper we analyze the field emitted by a two-dimensional periodic array of impressed sources with a given spatial spectrum on top of a hyperbolic metamaterial. We employ Green's functions and spectral theory to model the system. We calculate the amount of power that is directed inside the HM and study its dependence onto the geometrical parameters of the array of sources, sources' spectra, and the electromagnetic properties of the HM. These results represent a significant advancement to the understanding of the problem of periodic scatterers located on top of a HM.