Band-Diagrams and Wave Properties in Dispersive Media

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In recent years, periodic arrangements of dielectric, metallic or metallo-dielectric structures have been extensively studied because of their interesting and useful properties. Among them, (1) defects in regular band-gap/band-edge or electromagnetic bandgap (EBG) structures have allowed for high Q filters, (2) periodic Frequency Selective Structures (FSS) have been used as special filters for band-pass or low/high-pass applications, (3) a form of stacked FSS, referred to as split-ring resonators, have allowed for the creation of effective negative media, (4) periodic metallic or dielectric spheres within a volumetric configuration have also allowed for the creation of effective media, (5) anisotropic structures have been created using a combination of uniform dielectric layers with embedded FSSs and to form a new effective medium, (6) magnetic photonic crystals have led to strong anisotropies leading to both large Qs and excellent transmission properties making them applicable for antennas, and (7) periodic arrangements of circuits within a transmission line, in a surface or volumetric structure have allowed for wave slow-down, impedance control and modification of wave propagation properties.

The above structures have often been examined from an application viewpoint. However, they share common properties which can be exhibited within the k-ω band diagram or via a characterization of their Floquet modes. The finite element method (FEM) is especially suited for modeling the unit cells of infinite periodic media. In this paper, we pursue formal optimization methods in the context of finite element-boundary integral (FE-BI) methods for periodic structures to design specific effective media and k-ω diagrams subject to desired parameters. We also examine the accuracy of effective media theories using numerical techniques, specifically adapted for high contrast dielectrics occupying arbitrarily shaped volumes.