ABSTRACT

The interaction of plane waves with periodic media is the starting point for numerous optical phenomena. Similar to the way in which electrons in semiconductors are confined to discrete energy bands, a periodic structure can exhibit a photonic band gap (PBG) which does not permit electromagnetic propagation. Within the PBG, incident radiation is completely rejected by constructive interference among the multiple reflections provoked by the periodic material discontinuities. The significant window of zero transmission associated with the PBG can be used to confine radiation for wave guiding, cavity resonators and optical filtering.

Even more interesting phenomena are possible when a designer is permitted to use more exotic selections of materials. By incorporating anisotropic dielectric slabs and gyrotropic ferrite material into an artificial *magnetic photonic crystal*, it is possible to generate a Bloch dispersion relation which possesses a *stationary inflection point*. This unique spectral feature leads to a unidirectional propagation phenomenon coined the *axially frozen mode;* a mode in which an incident RF pulse propagates with abnormally large amplitude and vanishingly small group velocity.

The frozen mode regime will be investigated here using a combination of analytical and numerical techniques. An eigenmode decomposition and transfer matrix model of general magnetic photonic crystals will be developed and used to demonstrate specific artificial crystals whose dispersion relations possess a stationary point. Results from classical wave

mathematics will be used to interpret what effect the stationary point will have upon pulse propagation.

To validate the “slow velocity” and “large amplitude” predictions associated with the axially frozen mode, the problem will be investigated from a computational standpoint as well. The *finite element method* (FEM) is a robust technique for solving various partial differential equations (PDEs) and is widely used in many scientific and engineering communities (most notably mechanical engineering, civil engineering and electromagnetics). Specific finite element codes for electromagnetic wave propagation within anisotropic materials will be developed from first principles. Both frequency domain and time domain codes will be applied. Special sections will discuss the conversion of a sinusoidal steady state FEM code to a time domain implementation, and the implementation of gyrotropic materials in the time domain.

Finally, extensive work on a two-dimensional photonic crystal problem will be presented as well. By loading a parallel plate waveguide with a combination of anisotropic dielectrics and magnetic materials, it will be demonstrated that the same stationary inflection point and associated frozen mode regime can emerge in more complicated structures. Just as was performed in the one-dimensional case, the parallel plate waveguide problem will be investigated using a combination of an analytical eigenmode solution and numerical FEM approach.