Scattering from a temporal medium

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Abstract

The electromagnetic waves can be controlled either by space, as it happens in the case of photonic crystals, or by similar variations in time-dependent parameters of the medium. For a spatially homogenous medium, if there is a sudden increase or decrease in the permittivity of the medium, it gives rise to the reflection and transmission of incident waves. Earlier studies had proposed that the reflected wave travels backward in time while the transmitted wave follows a normal way. It is expected that a periodic variation of permittivity, with respect to time, might give rise to several interesting phenomena, like frequency band gap and generation of new frequencies. The medium with periodic variation of the permittivity is called "temporal photonic crystal (TPC)". In the frequency domain, the amplitude of the electromagnetic wave propagation through TPC may increase/decrease depending on the increase or decrease of the permittivity of the medium.

As the permittivity obeys causality and Kramer-Kronig relations, the incident wave convolves with time-varying permittivity. Thus, the displacement vector is the convolution of the permittivity and electric field. Using the finite-difference time-domain method on a one-dimensional spatio-temporal slab, it is possible to study the reflection and transmission coefficients. This paper reports an apparent violation of the conservation of energy that can be explained in terms of the work done by the medium on the wave. Various cases involving the switching time of the temporal permittivity would be discussed and analyzed.

Keywords— electromagnetic waves, photonic crystal, temporal photonic crystal, time-dependent permittivity, Kramer-Kronig relations, convolution