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Feasibility of Instantaneous Time Mirror in Electromagnetics

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The Time Reversal Mirror (TRM) typically composes of an array of transducers. These transducers are used for recording propagations reflected off from a source, which are then processed by and re-emitted from the transducers back to the source location known as the time reversed propagation. The TRM technique has been studied in acoustics, water, and electromagnetic waves for various applications; commonly in medical imaging [1], non-destructive testing [2], underwater target detection [3], and seismic sources localization [4]. Although TRM is a well studied method, it is difficult to achieve perfect time reversed propagations converging to the source with high resolution due to the limited spatial sampling available [5]. Additionally, in medical applications, the heterogeneous lossy characteristic of human tissue is responsible for attenuation and dispersion, reducing the potential of obtaining perfect spatial resolution and accuracy at the source [6].

Instantaneous Time Mirror (ITM) is an alternative approach proposed by [5, 7]. The ITM exploits the time reversal symmetry in the wave equation by manipulating time boundaries, allowing time reversed propagation without transducers placed along a spatial boundary. This was shown experimentally in water waves by [5], where the introduction of ITM essentially replaces the role of transducers in TRM.

In this paper, we investigate the possibility of ITM application in electromagnetic waves using computer simulations. The theoretical concept behind the water experiment by [5] is adapted to electromagnetic fields and numerically modeled using the Finite Difference Time Domain method, which is made frequency-dependent by using the one pole Debye model.

We present our ITM implementation in electromagnetic waves via manipulation of a medium's complex permittivity, and provide numerical examples of ITM performance in heterogeneous and frequency-dependent propagation media. We will present results for both the focuses' accuracy and the focuses' resolution of time reversed waves produced using the ITM technique.

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