NUMERICAL SIMULATION AND EXPERIMENTAL RESULTS OF A GRADED NEGATIVE INDEX OF REFRACTION LENS WITH A GENERAL ANISOTROPIC MATERIAL

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Numerical Simulation and Experimental Results of a Graded Negative Index of Refraction Lens with a General Anisotropic Material

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Abstract

In this paper we discuss the numerical simulation of a Graded Refractive Index (GRIN) lens with a general anisotropic medium and compare it with an equivalent non-graded Positive Index of refraction Material (PIM) one with isotropic medium. The lens performance is first evaluated with the help of a generalized eikonal equation for an arbitrary anisotropic medium. The methodology for the rigorous solution of the eikonal equation in a general medium will be fully discussed. We start with the general form of Maxwell Equations, apply the eikonal approximation and derive the corresponding dispersion relation for a general medium. The dispersion relation is the eikonal equation. This equation is a first order, non-linear partial differential equation. It is solved with the standard method of the characteristics and thus reduced to a set of seven ordinary differential equations. The software developed for the numerical integration of the ordinary differential equations in a Matlab environment will be described in detail. Subsequently, a full Finite Difference Time Dependent (FDTD) simulation was performed to verify the validity of the eikonal calculations. The performance of the GRIN lens improved significantly over the equivalent PIM one. The GRIN lens is also five to ten times lighter than the equivalent PIM. A GRIN lens operating at 15 [GHz] was fabricated at Boeing. The comparison between the simulation, by the eikonal equation and the FDTD, and the experimental results of this lens will be reported. The agreement between the experiment and the simulation is excellent. We will discuss several applications of Negative Index Material lenses and present experimental and simulation results for these applications.