Duke University
Pratt School of Engineering

Graduation with Department Distinction Report
Department of Electrical & Computer Engineering

Designs and Simulations in Transformation Optics

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Introduction:

Transformation optics is an emerging field that makes use of the form invariance of Maxwell's equations and clever coordinate transformations to design electromagnetic devices. The goal is to describe a device using one set of coordinates, but have the system behave as if a different set of coordinates were used. The coordinate transformations are used to derive material parameters that act as a recipe for the desired device. These parameters correspond to a device that is complex and usually anisotropic. Through the use of metamaterials, many of these devices can be implemented.

My work began with designs for two unique electromagnetic devices, a square invisibility cloak and a cylindrical electromagnetic concentrator. For these devices, the incident wave reforms after passing through the device.

With the development of finite embedded coordinate transformations, the transformation optical devices were able to permanently alter the shape or direction of the beam. This method was extended to include beam bends of arbitrary angles and beam splitters of arbitrary angles. As these transformations naturally lend themselves to waveguides, finite embedded beam bends and sharp corners were embedded in waveguides to leverage the reflections and distortions from the bend.

Although the source terms were previously neglected, including them in transformations provides for important applications, such as conformal antenna design. A formalism was developed for applying source transformations and various confirmation simulations were conducted.

As a frontier field, the topics of interest in Transformation Optics have changed rather rapidly. Over the course of my five semester independent study I have investigated many different aspects of the field. As agreed upon by the department DUS, I have enclosed my published work in the field.

Contents: