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Author: Sayyed Saleh Sayyed Mousavi Mohammad Saeed  
Majedi Hossein Eskandari



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# Design and simulation of polarization transformers using transformation electromagnetics

Sayyed Saleh Sayyed Mousavi<sup>a,b</sup>, Mohammad Saeed Majedi<sup>b,\*</sup>  
, Hossein Eskandari<sup>a,b</sup>

<sup>a</sup>Communications and Computer Research Center, Ferdowsi University of Mashhad, Mashhad, Iran

<sup>b</sup>Department of Electrical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

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## Abstract

In this paper we design polarization transformers using transformation electromagnetics method. We introduce a new coordinate transformation that by compressing or expanding the space, creates a desired delay on one component of electromagnetic fields and therefore causes the polarization of electromagnetic wave to change. Linear to circular, right (left) hand to left (right) hand circular and linear to linear polarization transformers have been designed and analyzed. The proposed polarization transformers are homogeneous and reflectionless and they can also be non-magnetic. COMSOL Multiphysics software is used to validate our results.

*Keywords:* polarization transformer, transformation electromagnetic, non-magnetic medium, coordinate transformation.

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## 1. Introduction

In 2006 an article was published that introduced a systematic methodology capable of controlling the electromagnetic field by defining appropriate permittivity and permeability tensors for the medium [1]. This method is called transformation electromagnetics or transformation optics. The design procedure suggested by transformation electromagnetics is frequency independent. Generally the permittivity and permeability obtained by this method lead to an inhomogeneous and anisotropic medium.

Transformation electromagnetics has a variety of applications in design of microwave and optic devices. There are several articles that used transformation electromagnetics in cloaking devices that was realized by metamaterial structures [2-6]. It is also used in planar photonic devices for integrated system including waveguide and photodetectors [7]. Furthermore, devices such as beam bender and expander [8], beam polarization splitter and rotator [9, 10], field concentrators [11, 12], flat focusing lenses [13] and wave collimators [14], have been proposed based on this method.

Polarization state is one of the most important properties of any electromagnetic wave. Changing the polarization of wave is a practical issue in microwave engineering and optics. In literature, there are several devices, such as wave retarders, that perform polarization transformation. Retarders exert a delay on one component of the electromagnetic fields and therefore change the polarization. Most popular types of retarders are well known full, half and quarter wave plates [15]. Also, Fresnel rhomb and Babinet compensator are examples of retarders [15]. Furthermore polarization transformation for a plane wave is done by transversely uniaxial chiral medium [16, 17]. There are also structures that composed of waveguides, two phase shifter, TE to TM converter and crystals that are capable of performing arbitrary polarization transformations [18, 19]. In some articles the polarization transformer is implemented by metamaterial structures such as split-ring resonators [20-22] or metallic helices [23].

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\*Corresponding author. Tel.: +98-513-880-5171  
E-mail Address: majedi@um.ac.ir.

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