Transformation Electromagnetics Devices Based on Tensor Impedance Surfaces

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Since its introduction, the transformation electromagnetics design method (J. B. Pendry, et. al, Science, 23, 1780-1782, 2006) has been used to devise innovative microwave and optical devices such as beam-benders, beam-shifters, collimators, and invisibility cloaks. Transformation electromagnetics allows an initial field configuration to be transformed to a desired one via a change in material parameters prescribed by a coordinate transformation. The transformed materials are generally anisotropic and inhomogeneous. Along with volumetric designs, planar transformation-based devices using transmission-line networks have also been pursued. In this work, we present a method to implement planar transformation electromagnetics devices using tensor impedance surfaces.

The guidance properties of tensor impedance surfaces (TISs) have been studied in the past (H. J. Bilow, Trans. Ant. & Prop., 51-10, 2788-2792, 2003). It was shown that TISs can support TM, TE, and hybrid modes. The TIS boundary condition is defined as: $\overline{E_t} = \bar{\bar{\eta}}_{\mathrm{surf}} \hat{n} \times \overline{H_t}$, where $\bar{\bar{\eta}}_{\mathrm{surf}}$ is the surface impedance tensor and $\overline{E_t}$ and $\overline{H_t}$ are the electric and magnetic fields tangential to the surface. The demand to integrate antennas and other electromagnetic devices onto the surfaces of vehicles and other existing platforms has driven interest in TISs in recent years. Significant progress has been made in realizing practical, printed devices such as holographic antennas and polarization controlling surfaces, by exploiting the anisotropic properties of TISs (Fong, B. H., et al, Trans. Ant. & Prop., 58-10, 3212-3221, 2010).

In this work, a method for designing transformation electromagnetics devices using TISs is presented. When designing TISs, the surface impedance/admittance is the quantity of interest rather than the material parameters. Transforming the surface admittance in a manner analogous to material parameter transformations, necessarily results in the transformation of all space. When one does not wish to transform the free space above the TIS, but rather the TIS alone, another method for finding the transformed surface admittance must be found.

The method presented here allows TISs to be designed that support the tangential wave vector distributions and power flow directions specified by a coordinate transformation. A beam-shifter is designed that allows a surface wave with a Gaussian profile to be shifted laterally at 10 GHz. The design is verified with a commercial full-wave solver (HFSS). This work opens new opportunities for the design and implementation of planar devices that can guide or radiate electromagnetic fields.