5th Applied Electromagnetics Conference (AEMC 2015)
IIT Guwahati | 18-21 December 2015 | Assam, India

A new Look at Transformation Optics (TO) Approach for Designing Electromagnetic Devices such as Flat Lenses, Reflectarrays and Cloaks

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In this tutorial presentation we will discuss the basics of the Transformation Optics (TO) method, *aka* the Transformation Electromagnetics approach, to designing a number of “microwave” devices such as: cloaks; flat lenses; and reflectarrays. Recently, there has been considerable interest in using the transformation optics (TO) algorithm, which is based upon transforming the geometry of an object from real space to virtual space while keeping the Maxwell’s field solutions from real space to virtual space intact, because it provides an alternative (to traditional) and innovative way to design a class of EM devices. However, the caveat is that the TO algorithm typically leads to designs that call for anisotropic epsilon and mu values in real space, in order to preserve the field variations as we navigate from the real space to virtual space and vice versa. Furthermore, depending on the geometry of the problem, the values may be very unrealistic to realize in practice, even when artificially synthesized materials *aka* metamaterials (MTM) are employed for the realization, whose use often leads to designs that are narrowband, lossy, dispersive and polarization-sensitive—attributes that are clearly undesirable for practical applications. We show how we can address this problem encountered with the TO by using an algorithm based on “Field Transformation (FT),” as opposed to geometry transformation. The FT algorithm has been designed to transform the electromagnetic field distribution in an input aperture, generated by a given source distribution, to a desired distribution in the exit aperture. We show how we can cast the design problem into a Scattering Matrix approach, where in the case of RCS reduction problem the design is based on controlling only the Magnitude of S11, whereas for the Lens or Reflectarray problems, we are specifying only the desired Phase of S12 without being concerned about its magnitude. In contrast to this, the TO imposes strict conditions on both the magnitude and phase characteristics of S11 and S12, which in turn calls for anisotropic dielectric and magnetic metamaterials. The Scattering Matrix/Field Transformation approach avoids these problems altogether and is able to work with epsilon-only materials for the lens and reflectarray problems, and with realizable mageto-dielectrics with complex Mu and epsilon materials, which have wideband characteristics and which do not suffer from the shortcomings of the MTMs, for thin and wideband radar absorber designs.

A number of practical examples will be included in the presentation, not only to point out the shortcomings of the TO, but to also show how we can get around its difficulties in a systematic way when dealing with some real-world problems.

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