New Strategies for Antenna and Cloak Designs Using Electromagnetic Field Manipulation

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***Abstract*— In this paper we take a fresh look at the problems of antenna and cloak designs, and present a strategy for addressing this problem somewhat differently from the traditional approach of "Geometry Modification" via coordinate transformation, which forms the basis for the Transformation Optics (TO) paradigm for such designs.**

I. Introduction

In this paper we take a fresh look at the problems of antenna and cloak designs, and present a strategy for addressing this problem somewhat differently from the traditional approach of "Geometry Modification" via coordinate transformation, which forms the basis for the Transformation Optics (TO) paradigm for such designs.

We begin with aperture-type antennas—for instance lenses, horns and reflectors—that are non-resonant in nature, for which typically our objective is to either render them low-profile, or to improve their aperture efficiency, without sacrificing their bandwidths. Later, we briefly touch on the problem of designing cavity-type antennas—for instance the Fabry-Perot (FP) types—for which our goal is to enhance their performance characteristics, say their directivity.

As for the cloaks, we restrict our attention in this paper to designing blankets that reduce their scattering characteristics. Such cloaks are useful, for instance, in a scenario where a reflector and a monopole antenna were sharing the same platform, and the obstruction caused by the monopole was causing the far-end side lobes of a reflector to rise.

II. Field Manipulation

The TO is a well-established approach [1-55] for antenna design, and it is very general in nature; hence, it behooves us to provide an explanation as to why we need to look for alternatives to the TO in the first place. There are several issues and caveats that surface in the conventional application of the TO, which begins by translating the geometry in the physical domain into a desirable one in the virtual domain via coordinate transformation. The TO paradigm enables us to find the requisite material parameters in the physical domain in a precise and systematic way, by providing a recipe for utilizing the Jacobian matrix of the co-ordinate transformation to relate the medium parameters in the two domains. However, the TO neither guarantees the physical realizability of the parameters in the physical domain, nor does it provide us a clear direction as to how we might realize them, even if approximately. Furthermore, the narrow bandwidth, polarization sensitivity, strong dependence on the angle of incidence, and large thickness of the material region, all become important issues that are often difficult to deal with in the application of the TO to practical real-world problems .

Our objective in this work is to propose an alternative approach that attempts to mitigate the above problems encountered in the TO design procedure. Our strategy is to formulate the problem at hand as that of manipulating the electromagnetic fields by transforming a specified wavefront in the input plane of a region to the desired one in the output aperture plane, by choosing the material parameters of the intervening region (see Fig.1) to achieve the required field manipulation. Towards this end, we take a cue from Luneburg [56], who has provided a systematic procedure for finding the refractive index characteristics of the well-known Luneburg lens, in order to transform a spherically-diverging field into a planar wavefront. We embellish this technique and tailor it to our problem by generalizing the concept for the field manipulation problem we have described with the help of Fig.2.

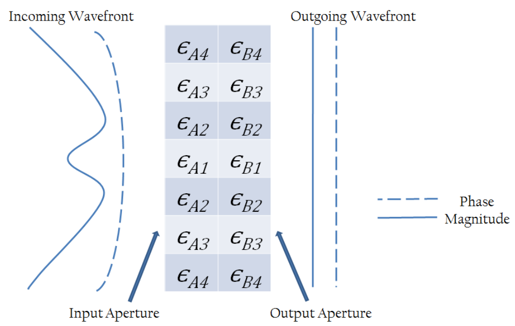

Fig. 1. Transforming the specified fields into the desired distribution by using multilayered materials

The paper will present a number of illustrative examples to demonstrate the efficacy of the method to real-world problems without having to be concerned with feasibility issues that are frequently encountered in the application of the TO to similar problems.

Finally, the paper will touch on the problem of designing Fabry-Perot (FP) type of resonant antennas, where the strategy is different from what we just described above. Here, rather than designing an intervening medium to perform the field manipulation, we choose the cavity to perform this task. Our strategy now is to design the overlay for the FP resonator, which serves two purposes. First, it provides partial reflection of the cavity fields impinging upon it from below, enabling the cavity to resonate. Second, it transmits the resonant modal fields of the cavity through the surface, so that they set up a field distribution immediately above the overlay, such that it has relatively uniform amplitude and phase distributions. This, in turn, provides the enhanced directivity to the exciter of the cavity, which may be a microstrip antenna strategically placed inside the FP cavity to optimize its excitation function, or a horn feeding the cavity from below.

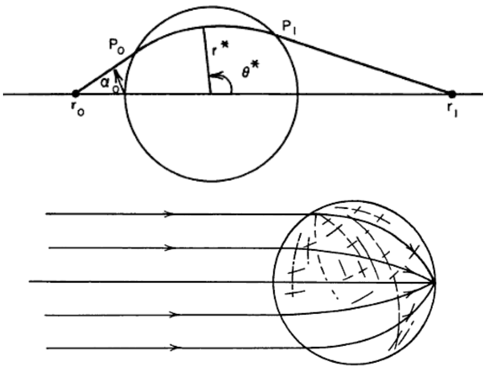

Fig. 2. (Top) Generalized raj trajectory for in a non-homogeneous sphere, (Bottom) ray trajectories of a Luneburg Lens

III. CONCLUSION

In summary, the paper presents an alternative to TO, based on Field Manipulation as opposed to geometry transformation, to circumvent some of the problems that limit the application of the TO to a whole host of practical problems of interest, such as designing flat lenses and blankets for arbitrarily shaped objects that help reduce their RCS, over a wide frequency band, regardless of the incident angle and polarization of the incident wave.

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