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Integrating Half-Lens Antennas with a Reflectarray

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Summary

We present a half-lens antenna with an integrated reflectarray. The addition of the reflectarray to the mirror plane introduces additional degrees of freedom to the design process. We demonstrate that the performance of a conventional half-Luneburg lens antenna can be replicated using a lens with another refractive index profile integrated with a carefully designed reflectarray.

1 Introduction

Graded index (GRIN) lenses are of interest to the antenna design community because of their ability to manipulate a propagating wavefront to possess more desirable features. The planar Luneburg lens is a rotationally symmetric GRIN lens, which has the defining feature of generating a planar wavefront from a point source placed at the lens periphery [1]. This is of particular interest for antenna design, as a planar wavefront is indicative of a directive radiation pattern. The gradient in the refractive index profile can be generated in multiple ways, such as using a metasurface with a quasi-periodic structure [1, 2, 3]. Another option is to use a geodesic shape, where parallel metallic plates are curved in such a way to replicate the optical path length of the desired graded refractive index [4].

One disadvantage of rotationally symmetric lenses is their inherently large in-plane footprint. Using the symmetry of the lens, this can be reduced by 50% by the introduction of a reflective mirror along an axis of symmetry. This has been studied previously for cases with a smooth mirror plane [5, 6]. Modifying the structure of this mirror plane offers the potential for further improvements to the lens-antennas performance. An option that is explored in this presentation is the integration of a reflectarray to this mirror plane.

Reflectarrays operate by reflecting an incident wavefront in such a manner that the phase or direction (or both) of the wavefront is modified [7]. These generally operate in an unconfined environment, however can still function within a parallel plate waveguide (provided they are designed to do so). When combined with the mirror-plane in the half-lens antenna, the elements of the reflectarray should be selected depending on the desired outcome of its presence. Two useful cases are to compensate for a lens with a reduced maximum refractive index or to mitigate against feed blockage near the flare. We explore the first case in the following.

2 Operation of Lens

The refractive index profile used for the lens is a modified version of the Luneburg profile and is given by

$$n(r) = X\sqrt{2-\left(\frac{r}{R}\right)^2} + (1-X) \tag{1}$$

where R is the radius of the lens, r is the radial position in the lens ($r \leq R$), and X changes the maximum refractive index of the lens ($0 \leq X \leq 1$). The term $(1-X)$ maintains a refractive index of 1 at the lens edge (where $r = R$) and hence is matched to the free space. For the ideal Luneburg lens case ($X = 0$), a planar wavefront is generated from a point source at the lens periphery. For non-zero values of X, the exiting wavefront will be curved, and the extent of this curvature is dependent on the value of X. Lowering the maximum refractive index required for the lens is desired as the range of refractive indices needed to generate the lens is reduced.

3 Integrated Reflectarrray

The reflectarray is placed between the reflective mirror plane and the lens, as illustrated in Figure 1. This reflectarray can consist of discrete dielectric slabs of various permittivities, each of the same thickness. Another option is to use a 1-D array of metallic patches, where the dimensions of each patch are varied. The distribution of the dielectric slabs/patches is selected in such a manner to compensate for the reduced refractive index profile of the lens or to tilt the beam to a more desirable direction.

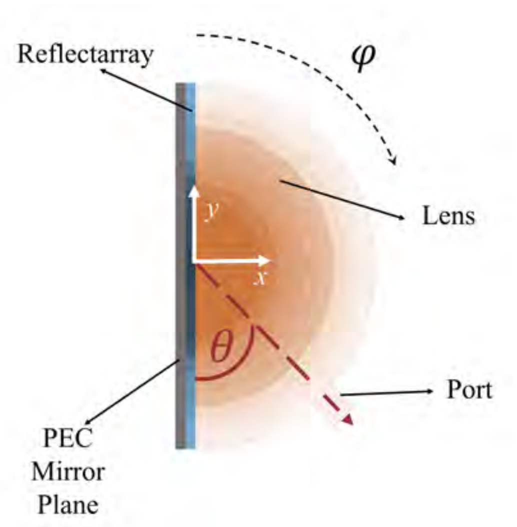

Figure 1. Integrated lens and reflectarray. The lens is fed with a waveguide port.

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