Broadband metasurfaces for the design of planar lenses

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Abstract— Metasurfaces have demonstrated to be a low cost solution for development of directive antennas at high frequency. One of the opportunities of metasurfaces is the possibility to produce planar lenses. However, these lenses usually present a narrow band of operation. Those limitations on bandwidth are more restrictive when the required range of refractive index is high. Here, we present a novel implementation of metasurfaces with low dispersion that can be employed for the design of broadband planar lenses.

Metasurfaces are thin metamaterial layers which can be employed to produce unusual reflection properties of incident plane waves, or to guide surface waves \[1\]. In the first case, metasurfaces are employed in an similar approach of fresnel lenses or reflect-arrays to produce directive radiation patterns from a feeding source, such as a dipole or horn antenna \[2\]. Here, we will focus on the second case: guiding surface waves. Metasurfaces, as common metamaterials, are usually designed by a periodic repetition of unit cells. Changing the geometry of each single element or its lattice the propagation constant of the surface/guided mode can be modified, and therefore to achieve equivalent refractive indexes \[3\]. Therefore, a proper combination of different geometries can be employed to create two-dimensional lenses, i.e. flat lenses \[4\]. Those lenses find application on directive antennas for communications at high frequency where arrays and phase shifters are not a feasible solution due to their elevated cost and complexity \[5\].

The most common configurations for metasurfaces are patches and holey metallic surfaces placed over a dielectric slab \[6\]; and the bed of nails \[7\]. Here, we propose the use of the complementary configuration of bed of nails, that is the metallic holey surface \[5\]. The configuration is shown in Fig. 1. In its simplest case, it is composed of a metallic slab which has air holes, and above, there is a thin air gap with a metallic top layer. Fig. 1 shows also the dispersion diagram for this configuration when the air gap thickness is modified. This thickness is one of the most crucial parameters in the design since the propagation constant of the guide mode is extremely sensitive to it. This parameter can be used to tune the equivalent refractive index.

In Fig. 2, the electric field, in the middle of the air gap, is represented for those values of air gaps that were previously represented in Fig. 1, demonstrating the achieved variations in the propagation constant. As mentioned, these variations are more intense when the air gap

![Figure 1: Unit cell configuration and propagation constant of the metasurface under periodic conditions. The simulations correspond to several values of the air gap \((g)\), whilst the rest of parameters remain invariant: \(b = 0.5\) mm, \(l = 4\) mm, \(l = 0.5\) mm.](image-url)
Figure 2: Intensity of electric field in the middle of the air gap, at 10GHz for different thicknesses of the air gap between the meta-surface and the top metallic layer: $g = 0.1$ mm, $g = 0.5$ mm, $g = 1$ mm and $g = 2$ mm. The other dimensions are remaining as in Fig. 1.

become thinner, and they can be employed to produce low cost flat lenses with a broadband of operation, specially when double structures are employed.

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REFERENCES