Antenna Radiation Pattern Control through 3D Printed Inhomogeneous Dielectrics

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Inhomogeneous dielectrics can be used as antennas or to control antenna radiation patterns. For instance, Luneburg lens antennas have the refractive index distribution of $n(r) = [2-(r/a)^2]^{1/2}$. They can achieve one focus on its surface and the other focus at infinity. Inhomogeneous dielectrics can also be used to increase the gain and narrow the beam width of a horn antenna. Moreover, inhomogeneous dielectrics can be realized by a fast and economic manufacturing method, additive manufacturing (AM), which is also called 3D printing technology. It enables 3D fabrication of arbitrary shape and structure by printing layer by layer. By changing the mixing ratio of multiple 3D printing materials, spatially varying dielectric constants can be achieved.

In this work, a novel antenna pattern control concept is proposed. Inhomogeneous dielectrics are placed surrounding a monopole antenna. By changing the distribution of the dielectric constants, different interesting antenna patterns can be obtained rather than monopole's donut pattern. To demonstrate this idea, an Ansoft HFSS antenna model is setup as shown in Fig. 1. The antenna is a 5 mm high monopole surrounded by a lattice of dielectric blocks. Each dielectric block is 4 mm long, 4 mm wide and 5 mm high. The size of the ground plane is 40 mm by 40 mm so that there are 10×10 dielectric blocks. The dielectric blocks are non-magnetic, having a permeability of 1. The dielectric constants, however, can be any value in a range from 1 to 2.7. By changing the dielectric constant distribution around the monopole, the antenna pattern is tailored. Three design examples at 16 GHz are shown in Fig. 1 with genetic algorithm based optimization. The optimization is done in the $\theta = 70°$ plane. The first example has a goal of achieving a maximal gain for $\varphi = 0°$ and a minimal gain for $\varphi \notin [-20°, 20°]$ (see Fig. 1(b)). The second example has a goal of achieving a maximal gain for $\varphi = \pm 60°$ and a minimal gain for $\varphi \in [-180°, -90°], [90°, 180°]\ and\ [0°]$ (see Fig. 1(c)). The third example has a goal of achieving a maximal gain for $\varphi = \pm 30°\ or\ 180°$ and a minimal gain for $\varphi \in [-150°, -60°], [60°, 150°],$ and $[0°]$ (see Fig. 1(d)). It can be seen that all three cases give good patterns corresponding to the optimization goals. Therefore, antenna radiation patterns can be controlled through constructing inhomogeneous dielectrics surrounding a monopole and which can be readily realized by 3D printing technology. Experimental prototypes will also be presented.

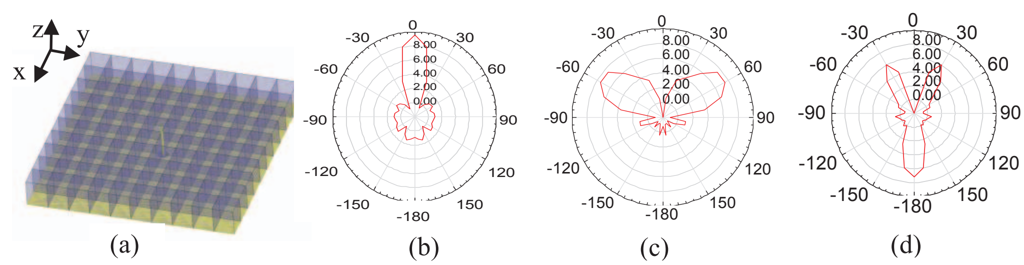

Fig. 1. (a) The Ansoft HFSS model of a monopole surrounded by inhomogeneous dielectrics. (b) Simulated $\theta = 70°$ plane radiation pattern of Example 1. (c) Simulated $\theta = 70°$ plane radiation pattern of Example 2. (d) Simulated $\theta = 70°$ plane radiation pattern of Example 3.