Monopole Antenna Radiation Pattern Control via 3D-Printed Dielectrics Optimized with Machine Learning Methods

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3D printing technology has gained attention of many researchers, especially in the area of antenna design as a new prototyping and manufacturing technology. Recent advancements in this technology have enabled printing of complex 3D structures with lower cost and shorter prototyping time. In this work, we will present an efficient methodology to control antenna radiation pattern of a quarter-wavelength monopole antenna. To achieve this, spatially varying dielectric loading surrounding the antenna can be applied and radiation pattern of the antenna can be modified from its conventional donut-shaped pattern to one-beam or multiple-beam patterns. In our earlier work, genetic algorithm has been applied to find appropriate dielectric loading profile to achieve different goals such as single beam, two-beam and three-beam radiation patterns [(J. Wu, A. H. Abdelrahman, X. Yu, M. Liang, and H. Xin, IEEE Trans. Antennas Propag. vol. 65, no. 8, pp. 3869-3876, Aug. 2017,)]. However, in that case, to achieve different goals, independent simulations and search procedure need to be performed each time. It is proposed here to use machine learning (ML) techniques as an efficient design approach. In this case, training data set is first collected, then a general model is obtained based on the required goal. This way, many different goals can be achieved using the same training dataset without needing additional simulations.

Once the dielectric loading profile is obtained for the required goal, it can be physically implemented in the design based on effective medium approximation. According to this approximation, the effective dielectric constant can be controlled by adjusting the material filling ratio in the unit cell scale. 3D printing technology enables arbitrary filling ratio and thereby realizing effective dielectric constant control. Hence, by utilizing the benefits of both machine learning and 3D printing techniques, efficient control of the radiation pattern of quarter wave monopole antenna is demonstrated. More details regarding design, optimization and manufacturing will be presented.