Accurate and efficient modeling of gain patterns of multiband pixelated antenna by deep neural networks

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Pixelated microstrip antennas present considerable versatility to antenna designers in that their geometries can assume a great variety of shapes and sizes. The design process however usually entails significant computational expense, as evolutionary algorithms in conjunction with direct full-wave simulations need to be used in order to discover an optimal antenna geometry that would best yield the desired performance characteristics – e.g. thousands of full-wave simulations of candidate geometries may be required before this objective is attained. This suggests the need for computationally inexpensive machine-learning-based models that can be used as surrogates for the full-wave simulations.

Unfortunately the modeling of pixelated antenna structures poses unique difficulties, as these geometries cannot be readily parametrized like the geometries of antennas with standard shapes (e.g., microstrip patch antennas and variations thereof). The geometries of standard shape antennas can typically be represented by a handful of geometry dimensions. Hence a neural network model of, for example, the gain pattern in one of the principal planes of a probe-fed microstrip patch antenna could take the patch length and width and the substrate dimensions as input variables, and sampled values of the gain pattern as output vector. Geometry instances of pixelated antennas, on the other hand, are defined by their pixel configurations. These configurations can be arrived at by, among other means, the addition and/or removal of pixels with respect to some initial arrangement of pixels, yielding irregular overall antenna shapes while possibly also containing apertures that are irregularly shaped. These geometries cannot be readily represented by only a few geometry dimensions.

Recently, a framework was introduced for accurately modeling the resonant frequencies of a dual-band pixelated microstrip antenna [1]. The framework was based on deep neural network regression models that take a representation of the entire pixelated surface of the antenna as input (as opposed to a handful of geometry dimensions as in the case of antennas of standard shape). Of the models considered, a convolutional neural network achieved the best predictive results.

The present study extends the work in [1] to the modeling of full responses of a multiband microstrip-fed pixelated antenna (as opposed to the modeling of a few meta-characteristics such as resonant frequencies [1]). The responses focused on here are gain patterns in selected reference planes of the antenna. A number of convolutional neural network architectures were considered, and carefully selected hyperparameters were tuned conjointly by means of Bayesian optimization. Model outputs were a vector of gain pattern values sampled over the full range of elevation angles. Training, validation and test data were generated in CST Microwave Studio [2]. Very good predictive results were obtained with respect to the gain patterns of previously unseen test antenna geometries, e.g. a normalized root-mean-squared error of less than 1.8% was achieved with respect to gain patterns in the reference plane normal to the pixelated surface of the antenna and parallel to its feedline, thus corroborating the validity of the modeling approach.

1. J.P. Jacobs, "Accurate Modeling by Convolutional Neural-Network Regression of Resonant Frequencies of Dual-Band Pixelated Microstrip Antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 12, 2021, pp. 2417-2421.

2. CST Microwave Studio, ver. 2020. (2020). Dassault Systemes.

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