Dual-Band Antenna Array Optimizations Using Heuristic Algorithms and the Multilevel Fast Multipole Algorithm

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We consider design and simulations of dual-band antenna arrays and their optimizations via heuristic algorithms, particularly, genetic algorithms (GAs) and particle swarm optimization (PSO) methods. As shown below, these arrays consist of patch antennas of different sizes, depending on the target frequencies. The resulting radiation problems are solved iteratively, where the matrix-vector multiplications are performed efficiently with the multilevel fast multipole algorithm (MLFMA). MLFMA allows for realistic simulations of antenna arrays of finite extent, without any periodicity and similarity assumptions, while including all mutual couplings between the antennas. This way, we obtain effective and realistic optimizations.

Given an antenna array, it is of utmost importance to find optimal excitations of its elements for desired purposes, e.g., for maximum gain at specific directions. For such an optimization of an array involving n elements, we perform n MLFMA solutions per frequency, each corresponding to the excitation of an antenna while others are passive. The results obtained in these solutions can be combined via superposition, leading to efficient optimizations using heuristic methods. For the array depicted below, a total of 25 simulations are performed per frequency and the resulting far-zone radiation patterns are stored to be used by the optimization modules. For this array, which is located on the x-y plane, we optimize the directive gain at $(\theta,\phi) = (\theta,0)$, where $\theta = 0°$-$90°$, by changing antenna excitation phases. In a single-frequency optimization at 2.45 GHz or 5.8 GHz, the directive gain at these directions are maximized. In a dual-frequency optimization, however, the directive gain at a desired direction is maximized simultaneously at 2.45 GHz and 5.8 GHz. The results obtained by using GAs and PSO methods reveal that the directive gain can be optimized very efficiently, leading to directive arrays in comparison to standard feeds (e.g., shutting down large/small antennas at the higher/lower frequency). We also show that, for this kind of compact arrays, these optimizations are required instead of analytical methods and array-factor approaches, where mutual coupling between antennas as well as antenna characteristics are simplified or omitted. The presentation will include optimizations of alternative arrays, the results of these optimizations, and discussion of effective strategies for efficient optimizations.