Antena Array Synthesis using Digital Phase Control via Integer Programming and 3D FEM

J. Ignacio Echeveste [1], Miguel Á. González de Aza[1], Jesús Rubio[2], and Juan Zapata[1]

[1] Universidad Politécnica de Madrid (UPM), Madrid, Spain,
[2] Universidad de Extremadura (UNEX), Extremadura, Spain

Antenna array synthesis problems have been studied for the last decades. There has been a focus on enhancing array characteristics as side lobe level, beamwidth, directivity or cross polarization level using analytical or numerical methods. Very difficult or even impossible feeding schemes will be obtained if the designer does not apply some restrictions to the feeding weights to be synthesized. The addition of the restrictions usually makes the problem non convex and much more difficult to deal with.

There are plenty of methods where the dynamic range ratio (DRR) of the excitations is minimized. Minimizing DRR facilitates the fabrication and avoids huge difference between elements weights, however, an array with a small DRR may need the same amount of phase shifters and power dividers that with an arbitrary DRR. Phased arrays are usually designed with phase-only procedures where the amplitudes are fixed in advance in order to reduce the costs of the antenna. Several procedures have been applied as analytical methods, or numerical synthesis as the alternation projections algorithm. If the array is going to be built with phase shifters with a fixed number of states, the phase obtained with the phase only method is then discretizised. Although good solutions are usually obtained, this methodology has two main drawbacks, the discretization process may cause suboptimal solutions, and the appearance of phase discretization error. Some global methods, as genetic algorithms, provide good results where any restriction to the solution obtained can be imposed. However, they are not usually efficient and a global solution is not assured.

In this work a method for the optimization of antena arrays patterns composed of complex array elements, based on mixed integer linear programming, and where the decision variables are restricted to be binary values is proposed. The amplitudes of the weights are assigned in advance, and the phases are optimized with the restrictions that they have to be provided with phase shifters with a fixed number of bits. The method takes into account real radiation patterns and the mutual coupling between elements using a full wave analysis that is merged in the optimization process. The array is characterized with a hybrid technique based in the 3D finite element method and the spherical wave expansion. A multibeam pattern with specified directions and beamwidth, minimizing the side lobe level is synthesized, with feeding weights with preassigned amplitud and phase shifters of a fixed number of bits.