Modeling of a Large Slotted Waveguide Phased Array Using the FDTD and Characteristic Basis Function (CBF) Approaches

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Stacked narrow-wall-slotted waveguide phased arrays find widespread use in practice. Modeling these arrays to determine their aperture field distribution is an important part of the design process, not only for predicting their radiation characteristics, but also for estimating the co-site interference problems when the array operates in a complex environment. To compute the aperture field of the slotted waveguide array, we propose to employ the Finite Difference Time Domain (FDTD). However, since the array we are configuration modeling is very large — comprising of more than 8000 elements — it is impossible to simulate even a single row of the array with the FDTD, let alone the compute complete one. Hence, to render the problem manageable we divide it into small sections, find the equivalent circuit model for each section, and finally combine them to solve a circuit problem. The aperture field over each slot is then computed, using the port voltages and currents, in the characteristics basis function formulation (CBF). (1) The use of the CBF method (CBFM) enables one to significantly reduce the number of unknowns, and this render the problem manageable. The details on CBFM, and the procedure for constructing these functions can be found in [V.V.S.Prakash and R.Mittra, Microwave and Optical Technology Letters, Jan. 2003; R. Mittra, Proceedings of IASTED International Conference, Wireless and Optical Communications, July 17-19, 2002, pp. 1-5, Banff, Canada].

In order to taper the aperture field distribution along both dimensions of the array, the feed couplers exciting each of the waveguides as well as the tilt angles of each slot are chosen to be different V.V.S. Prakash, *et al.*, IETE Technical Review, 16, 57-61, 1999]. Hence, we cannot apply the unit cell approach, typically employed to reduce the problem size in large arrays to a manageable size. Instead, we treat each coupler as a four-port network, and compute the coupling coefficients by using the FDTD. Rather them simulating each and every coupler — which will make the process extremely time-consuming — we only perform the simulation for a few selected ones, and use interpolation to determine the coupling coefficients for the rest. The same strategy is applied to obtain the circuit parameters of the slots whose number exceeds 8,000. To derive its parameters, we view the slot as a two-port network, which can be represented by an ABCD matrix. To account for the mutual coupling effects, we also include several neighboring slots in the simulation so that we can determine the 'active' circuit parameters for the center element. When the circuit parameters are determined for all the slots and couplers, the port voltage and currents can be calculated by solving the equivalent circuit problem.

To obtain the aperture field distribution above a single slot, we assume that it is a combination of two characteristic basis functions, corresponding to the two traveling waves inside the waveguide. These functions are extracted by solving a set of linear equations once the circuit parameters have been determined. The actual aperture field is represented as a combination of the two basis functions, weighted by the strength of the incident wave. The interpolation of the basis functions as functions of the slot angle is more complicated than that of the circuit parameters. We begin by smoothing the aperture distribution with a low pass filter, while making sure that the far field pattern is unaffected. The reduced sampling rate is approximately 4 samples per wavelength and can be interpolated very easily. This method is valid because, in our application, the scatterers are located sufficiently far from the antenna such that it is in the far field of the sub-array even though it is in the near field region of the entire array.

Extensive numerical results will be presented in the paper to illustrate the application of the method described above.