A Dedicated Numerical Technique for Field Simulations of Antennas on Electromagnetic Band-Gap Substrates

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In astronomy and atmospheric research interest has risen in electromagnetic phenomena in the so-called THz regime. Possible applications in medical imaging and airport security systems are attractive. To disclose this frequency range, a prototype imaging array is currently being developed. To support an imaging array of antennas, a substrate is required. In order to reduce cross-coupling and to suppress surface waves that would be present in homogeneous dielectric substrates, electromagnetic bandgap (EBG) structures would comprise a viable alternative. Owing to progress in technology and manufacturing it has recently become feasible to construct EBG substrate slabs. Other devices may be created in EBG technology as well, e.g., directional couplers, filters and resonant cavities.

In order to assess alternative designs for antennas mounted on EBG substrates, flexible, accurate, and reliable numerical modelling methods are required. A genuine EBG structure is periodic in every direction. Its electromagnetic band-diagram can be analysed with the aid of the plane-wave method. Once non-periodic sources are considered, the computational complexity increases considerably. Upon regarding a practical EBG structure, one also has to account for its finite extent in one or more directions. As a consequence, a basis of homogeneous plane waves ceases to be efficient, which again adds to the computational complexity.

We are interested in the design of arrays of patch antennas that are mounted on top of an EBG substrate of finite thickness. Central to this problem is the calculation of the Green's function associated with a single current cell. This should be achieved as efficiently as possible. For flexibility and accuracy, we employ a domain integral equation for the electric field. Initially, we assume phased periodic sources in the transverse directions so as to exploit the pertaining periodicity, resulting in an infinite system of coupled 1-D integral equations. In the vertical direction, we expand the field in terms of piecewise linear splines. The complexity of the resulting efficient matrix-vector product is dominated by FFTs. The resulting linear system is solved with the aid of an iterative technique for a sequence of consecutive phases, in order to go from phased periodic sources to localised sources via array summation, or for a sequence of frequencies, in order to obtain the reflection/transmission properties of the EBG slab inside the band-gap and beyond. Despite the large number of unknowns, storage requirements are limited, while the computation time taken by the iterative solver is kept in check through the use of initial estimates based on results generated earlier in the sequence.

Once the Green's functions for all possible source and receiver cell combinations have been stored, one can search for the optimum antenna design with the aid of a discrete optimisation algorithm, involving an electric-field integral equation at every stage.