Per-Simon Kildal and Design of Electromagnetic Structures: Outstanding Combination of Scientific Concepts and Engineering Intuition

Zvonimir Sipus, Juraj Bartolic and Silvio Hrabar
Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia
zvonimir.sipus@fer.hr, juraj.bartolic@fer.hr, silvio.hrabar@fer.hr

The aim of this paper is to present an approach to the design of electromagnetic structures and devices that Prof. Per-Simon Kildal had applied in his work and had passed to his Ph.D. students and associates. Prof. Kildal was a highly respected researcher, whose ideas, related to innovative electromagnetic structures and algorithms, will inspire many of us. He always began with a clear electromagnetic concept of a device he wanted to design. Without it, running a commercial electromagnetic solver with an optimization option would lead to the design of device of questionable quality. Furthermore, Prof. Kildal was an excellent teacher and the author of a reference work in the field of antennas (P.-S. Kildal: *Foundations of Antenna Engineering*, 2000 and 2015). Last, but not the least, he created several successful start-ups, such as Bluetest AB and GapWaves AB.

Efficient, engineering-based design of electromagnetic structures will be illustrated on the examples of collaboration between Chalmers University of Technology and University of Zagreb. The complexity of electromagnetic problem can be reduced drastically if the largest part of the analysed structure is described by an appropriate Green's function. In 1997, a general algorithm for calculating Green's functions of one-dimensional structures (called G1DMULT algorithm) was developed at Chalmers and later upgraded at the University of Zagreb (Z. Sipus et al., *Applied Computational Electromagnetics Society Journal*, Nov. 1998). The structure of the program is an example how the equivalence principle can be used as a powerful tool in design of a large class of electromagnetic structures.

The complexity of the analysis of periodic structures can be simplified by using appropriate boundary conditions. The basic assumption is that the periodicity of the considered structure approaches zero. By this, one obtains a simple and rigorous model suitable for the initial design of the structure. We have demonstrated that the properties of EBG structures, soft and hard surfaces, and gap-waveguide components can accurately be predicted in this way.

One of the activities of Prof. Kildal's group was miniaturization of waveguides and related components (M. N. M. Kehn, P. -S. Kildal, *Proc. IEEE AP-S, 2003*). Following this initial effort, Prof. Kildal strongly encouraged work on metamaterial subwavelength waveguides at University of Zagreb, which yielded several novel devices based on backward-wave propagation in anisotropic structures (M.N. Kehn, S. Hrabar, S. Skokic, S. Maci, P.S Kildal, *Proc. IEEE AP-S 2005;* S. Hrabar, J. Bartolic, Z. Sipus, *IEEE Trans. AP*, pp. 110-119, 2005).