Divide and conquer strategy in the design of high-performance antenna arrays

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Modern electromagnetic simulation tools greatly facilitate the design and optimization of antennas and antenna systems. By using Finite Element or Finite-Difference Time Domain simulation methods one can analyze an antenna with truly arbitrary shape. The increasing computational power of the computers allows tackling bigger problems. However, in many cases it is not advised or even not feasible to start the design with the complete model of the antenna. This applies especially to antenna arrays where a complex structure leads to a big number of design variables and design options. Instead, one can try to divide the system into smaller building blocks. If the division is done in a clever way and a proper interface between directly connected building blocks is ensured, all of the pieces can be designed and optimized separately. Moreover, using hybrid simulation techniques, it is possible to forecast the performance of the complete system from the performance of the building blocks. This last property is particularly interesting since it allows optimizing small parts of the system separately, while simultaneously checking the influence of the applied changes on the complete system performance.

In this paper, a synthesis of two antenna arrays is presented to illustrate the proposed approach. The first one is a high-performance antenna array for space applications realized in the suspended stripline technology. Tight constraints are put on the input matching, polarization purity, losses, radiation pattern shape, as well as on the maximum dimensions of the structure. In the second design a Substrate Integrated Waveguide (SIW) Beam Forming Network (BFN) is used to feed patch antennas backed with SIW cavities. For both designs a functional analysis is performed and the structure is divided into functional groups, i.e. a transition between the feeding guide and the BFN line, BFN, and an array of radiating elements. Then, the smallest building blocks (i.e. transitions, power dividers, bends, or radiating elements) are identified and designed separately. Moreover, some elements are first developed in the simplified versions in order to speed-up the initial tuning process. Simultaneously, analytical antenna array analysis methods are combined with numerical optimization in order to find an amplitude-phase law that would result in the required radiation pattern. In the next step, a hybrid simulation method is used to predict the performance of the complete system. These results are used to tune the elements for an optimal operation. At the end, a complete system is simulated and fine-tuned. The predictions of the numerical simulations are compared with the measurement results. On all stages of the design different simulation methods are used in order to obtain accurate results in the shortest possible time.