Integrated topology optimization of volumetric antenna substrates and conductor surfaces for broadband microstrip patch antennas

O. Sayginer [1], G. Kiziltas[1]
(1) Sabanci University, Orhanli, 34956, Tuzla, Istanbul, Turkey
E-mail: sayginer@sabanciuniv.edu, gkiziltas@sabanciuniv.edu

As technology matures, critical Radio frequency applications demand stringent multi-performance expectations. In parallel, traditional design efforts focus on the choice of limited available material with ad-hoc type of design approaches or limited design optimization studies. Only few studies exist in literature focusing on the antenna material properties directly allowing their design from scratch possibly via the use of formal optimization tools known to produce novel designs to meet the aforementioned challenging performance specifications. More specifically, traditional RF design applications mostly rely on parametric size and shape optimization studies of the conductor only. Dielectric materials for antenna substrates, on the other hand, are limited in the market and most of the time are only explored as discrete available material choices instead of their full exploration within a topology optimization setting. Also, it is well-known that inhomogeneous composite substrates with the combination of multiple material choices enable the design of miniaturized antennas with superior performance in bandwidth, radiation pattern and gain. To achieve these improvements, the volumetric material substrate as well as the conductor antenna shape are critical and are designed concurrently in this study. Towards that goal, an easy to use and flexible FEA based topology optimization framework is developed. More specifically, to improve the bandwidth and the radiation pattern of microstrip patch antennas, the material property of the substrate as well as the metallic patch are chosen as the design variables. Within the design framework, the topology of the metallic patch and the substrate material are divided into sub-domains/cells where each domain represent an independent conductor/dielectric material property. Also, the discretized design domain is imported into a simulation model for finite element analysis through Comsol Multiphysics 5.2 software. In order to find the best material and conductor configuration, unlike earlier topology optimization studies based on SIMP and complex sensitivity based optimizers, binary and integer programming schemes are chosen for the metallic patch and material substrate, respectively via MATLAB's genetic algorithm software, allowing topology optimization to be carried out in a much simpler to use optimization setting. Results show that the antenna bandwidth and pattern improve through its optimized dielectric material and patch topology while keeping its outer geometry constant. The flexibility, simple to implement and open architecture of the optimization framework in COMSOL should allow for integration with other level set and SIMP based optimization tools to address more challenging metamaterial designs possibly for high frequency applications. Fabrication efforts for the designed spatially variable material topology and validation studies are underway and will be presented at the conference.