MINIATURIZED BROADBAND ANTENNA DESIGN VIA SIMP

G. Kiziltas[a], **N. Kikuchi**[a], **J. Volakis**[b]

[a]Department of Mechanical Engineering
The University of Michigan
Ann Arbor, Michigan 48109-2125
{gkizilta, kikuchi}@umich.edu

[b]The Electro Science Laboratory
The Ohio State University
Columbus, Ohio 43212-1191
volakis.1@osu.edu

Design optimization for electromagnetic applications has traditionally been a process based on the creativity and past experience of the designer focusing mainly on size optimization. Recent advances in fast and rigorous full wave simulators and the concurrent availability of inexpensive manufacturing techniques for intricate shape and composite materials provides the opportunity to revolutionize traditional design optimization processes to topology and material optimization. So far, examples in the literature on topology optimization of electrical devices have dealt with restricted or semi-analytic tools for magneto-static applications [1]. In this paper, we introduce the mathematical framework for optimizing the topology of dielectric substrates using the SIMP method. As an example, the SIMP method is extended here to design the material distribution of a dielectric substrate of a patch antenna subject to pre-specified bandwidth and miniaturization criteria. To our knowledge, this is the first ever integration of material topology optimization for performance improvement of Radio-Frequency (RF) applications. A key element of this extension is the use of the latest fast algorithms recently introduced in the FE-BI formulation [2]. For design optimization, the Sequential Linear Programming (SLP) and an exact sensitivity analysis based on the adjoint method is employed. The sensitivity analysis is crucial to integrating the solver, which is based on complex valued functions with the SLP optimizer.

As is well known, microstrip patch antennas are attractive, low-weight, low-profile antennas which however suffer from narrow bandwidth. Moreover, its bandwidth is further reduced as the substrate dielectric constant is increased for miniaturization. In this paper, we demonstrate the capability of the outlined design method to develop a miniaturized broadband patch antenna using high contrast substrates. The main goal is to improve the bandwidth performance of a chosen patch antenna by introducing a new substrate (metamaterial) distribution via SIMP. Pursuing the proposed design method, a two material composite substrate (mix of e_r =100 and e_r =1) is designed, which allows for 250% bandwidth enhancement of a square patch antenna. This is a substantial improvement given that the starting point of the design was based on a highly mismatched configuration. Finally, the design is filtered/solidified to achieve a manufacturable design with retained improved performance. The fabricated final design using Thermoplastic Green Machining demonstrates the ability to design and manufacture novel material compositions for dramatically new applications in a practical way. In fact, as demonstrated by the design example, by virtue of the generality and efficiency of the proposed method, there is great potential for designing novel RF devices subject to any performance criteria.

References

[1] D. N. Dyck and D. A. Lowther, "Automated design of magnetic devices by optimizing material distributions," *IEEE Transactions on Magnetics*, vol. 32, no. 1, pp. 1188-1192, May 1996
[2] T. F. Eibert and J. L. Volakis, "Fast spectral domain algorithm for hybrid finite element / boundary integral modeling of doubly periodic structures," *IEEE Proceedings: Microwaves, Antennas and Propagation*, vol. 147, no. 5, pp. 329-334, October 2000