Optimization of metamaterials for microwave devices.

B. Vial[1] and Y. Hao[1]

[1]School of Electronic Engineering and Computer Science, Queen Mary University of London, London E1 4NS, United Kingdom.

Abstract— We report the design of an all-dielectric cloaking device using topology optimization and provide a quantitative assessment of its performances in the microwave regime. The physical mechanism leading to the cloaking effect is investigated through a modal analysis. We also discuss potential improvements and applications of optimization methods, including bandwidth enhancement and dispersion engineering.

1. OPTIMIZATION TECHNIQUE APPLIED TO CLOAK DESIGN

Invisibility cloaks obtained analytically by Transformation Optics (TO, [1]) require extreme material properties (anisotropic, spatially varying permittivity and permeability). Such complex properties are not available in nature and have been achieved based on the use of metamaterials with microstructure much smaller than the wavelength. Those devices rely on resonances with narrowband and lossy response and are difficult to realize in practice, which calls for other approaches for invisibility cloaks.

Recently, gradient-based topology optimization have been proposed to realize all-dielectric cloaks with low index contrast [2, 3]. We apply this idea to the design of a cloak made of ABS ($\varepsilon = 2.69 - 0.02i$) for TE polarization working at 10 GHz. It is designed to cloak an ABS dielectric cylinder of radius $r = \lambda$. The results are presented together with a quantitative analysis of the performances of the cloak [4]. In addition, we study the cloaking mechanism through modal analysis, and show that it is different from the one at stake in TO-based cloaks.

We finally discuss potential improvements the optimization technique, and its potential applications such as bandwidth enhancement, angular tolerance and dispersion engineering.

ACKNOWLEDGMENT

This work was funded by the Engineering and Physical Sciences Research Council (EPSRC), UK under a Programme Grant (EP/I034548/1) The Quest for Ultimate Electromagnetics using Spatial Transformations (QUEST).

REFERENCES

1. Pendry, J. B, Schurig, D. and Smith, D. R, "Controlling electromagnetic fields," *Appl. Phys. Lett.*, Vol. 98, No. 021112, 2006.
2. Andkjr, J. and Sigmund, O., "Topology optimized low-contrast all-dielectric optical cloak," *Science*, Vol. 312, No. 5781, 1780–1782, 2011.
3. Lan, L., Sun, F., Liu, Y., Ong, C. K. and Ma, Y., "Experimentally demonstrated a unidirectional electromagnetic cloak designed by topology optimization," *Appl. Phys. Lett.*, Vol. 103, No. 121113, 2013.
4. Bao, D, Mitchell-Thomas, R.C., Rajab, K.Z. and Hao, Y, "Quantitative Study of Two Experimental Demonstrations of a Carpet Cloak," *IEEE Antennas Wireless Propag. Lett.*, Vol. 12, 206–209, 2013.