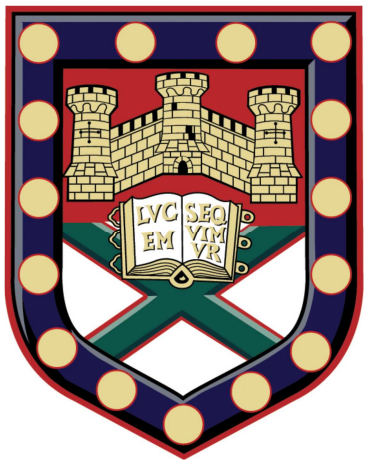
The Development of 3D Metamaterials with Independent and Controllable Electric and Magnetic Properties



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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

The work detailed within this thesis concerns the development of 3D metamaterials with independent and controllable electric and magnetic properties over a large frequency range.

Electromagnetic (EM) responses of 3D metamaterial structures are investigated and the effect of changing the shape of individual elements that make up the structure is explored. A novel broad-band metamaterial structure comprising an array of cubic elements made of cross-linked flat metal plates has been fabricated and characterised using a stripline technique. Forming a slab of metamaterial from a set of subunits has allowed the transmission and reflection characteristics to be obtained, from which the effective electromagnetic parameters of the metamaterial have been extracted. Results correlate well with finite element field simulations and show that by changing the structure of the individual elements it is possible to suitably increase the effective refractive index of the structure. The individual elements are changed so that capacitive effects between neighbouring elements, which dictates the permittivity, is maintained while the area subtended by the current loops, which dictates the permeability, is reduced. EM modelling of such structures also demonstrates that the electric and magnetic fields are decomposed into different regions of the structure.

EM modelling is used to investigate more elaborate metamaterial structures, where the field decomposition is exploited by filling different regions of the structure with ‘naturally’ high permittivity and permeability materials. Filling the structure gives further independent control of the electric and magnetic properties of the structured material. Varying the amount and type of spacer material between elements is also shown to introduce anisotropy into the structure.

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