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Nano-metamaterial Antennas At Microwave Frequencies

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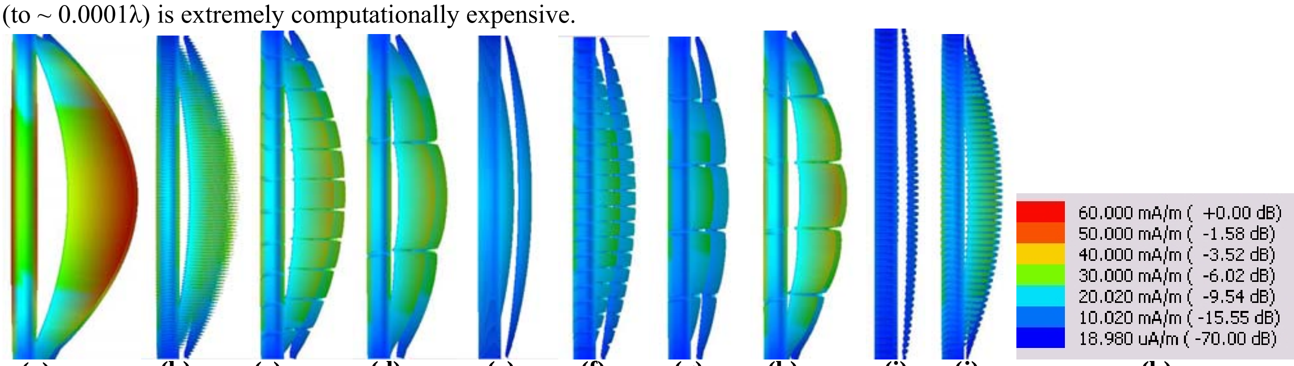
Abstract: This paper examines the possibility of creating novel microwave frequency antennas by suitably arranging metallic / dielectric nanoparticles. Simulation results show that the antenna must be composed of ≥ 99% metal (<1 % gaps).

Nanomaterials are by definition extremely small (~nm) and will be transparent at microwave frequencies (where the wavelengths are of the order of several centimetres). An exciting new research area of nano-electromagnetics is growing in popularity [1-2], however, this generally concentrates on higher frequencies. The impetus of this research is that when these nanoparticles are grouped together they can form larger objects which will resonate at microwave frequencies. This means that sheets of nanomaterials can be designed so that they are largely transparent at microwave frequencies except where an antenna has been created from groupings of nanoparticles. This will open up a whole new area of applying nanomaterials to form antennas based on repetitive structures. These periodic structures are expected to behave similarly to metamaterials. Using these nano-metamaterials will increase the flexibility and applicability of antenna design.

In this paper, EMPIRE commercial FDTD code (www.empire.de) has been used in simulations. An Ez polarised plane wave travelling in the Y-direction was used as a source. Initially, a 1mm thick and 15mm long metallic pin was placed at the centre of the grid and orientated along the Z-axis. This continuous pin resonated at 8GHz (see Fig. 1 (a)). The aim of these initial simulations was to understand how the size of the non-metallic gaps along the pin affected the behaviour of the electromagnetic fields. It was found that the addition of 0.001 to 0.1mm gaps had negligible effect on the resonance of the pin. Further experiments revealed that increasing the number of gaps along the pin, reduced the current and electric fields around the pin and increased the resonance frequency. The results showed that the number of gaps needed to affect the performance of the pin, varied depending on the size of the gaps. In fact, it was the total length of metal that was critical, with many small gaps causing similar behaviour to a few larger gaps. When the total length of metal in the 15mm pin was 14.9mm (~99.3%) (see Fig. 1 (b) –(d)), the current and electric fields were reduced and the resonance frequency shifted to 9GHz. When the total length of metal was 14.8mm (98.7%) the currents and fields were further reduced (see Fig. 1 (e)-(g)) and the resonance frequency increased to 10GHz (see Fig. 1 (h)). When the total length of non-metal gaps was increased to 0.5mm (pin = 14.5mm), the pin had negligible effect at 8GHz (see Fig. 1 (i)) but resonated at 13GHz. (see Fig. 1 (j)). Note, the resonance frequency does not increase linearly with the total length of the metal/non-metal sections.

These results show the potential for developing microwave antennas using groupings of metallic / dielectric nano-metamaterials. The presentation will include results of 2D grids of dots. Note, finely meshing the space in two dimensions (to ~ 0.0001λ) is extremely computationally expensive.



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

Fig. 1. The current (at 8GHz) - the amplitude is visually expressed to the right of the pin. (a) continuous 15mm pin, (b) 100 × 0.001mm gaps, (c) 10 × 0.01mm gaps, (d) 2 × 0.05mm gaps, (e) 200 × 0.001mm gaps, (f) 20 × 0.01mm gaps, (g) 4 × 0.05mm gaps, (h) 4 × 0.05mm gaps at 10GHz, (i) 50 × 0.01mm gaps, (j) 50 × 0.01mm gaps at 13GHz, (k) scale.

[1] Zhou.W, Rutherglen.C, Burke, P. "Nanotube arrays synthesis for microwave applications". IEEE Symposium on Antennas and Propagation, San Diego, USA. 5-12th July 2008.
[2] Bayram. Y, Zhou. Y, Volakis, J. "Conductive textiles and polymer-ceramic composites for novel load bearing antenna". IEEE Symposium on Antennas and Propagation, San Diego, USA. 5-12th July 2008.