Coupling gaps of dipole radiating structures with implications for fabricating antennas using nanomaterials

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The overall aim of this work is to investigate the feasibility of creating microwave antennas and radiating structures using metallic and non-metallic nanomaterials. Using nanomaterials is advantageous because the radiating structure, the substrate, the ground plane and feed system can be fabricated simultaneously therefore saving time and money compared to numerous printing and etching processes that are currently used. Furthermore, using nanomaterials will allow a wide range of bespoke substrate properties to be fabricated by adding metallic particles to the non-metallic nanoparticles (L. Lewin, Proc. IEE, vol. 94, pp. 65-68, 1947). By suitably arranging many metallic nanoparticles in a specific location, larger composite objects can be formed and the electromagnetic performance can be controlled by varying the local concentration of these particles.

In this paper, a 5000μm long passive dipole was excited with a vertically polarized plane wave using Empire commercial FDTD software (www.empire.de) and a high performance computer. The effect of fabricating a structure from metallic particles that may or may not be touching was replicated by adding a gap at the centre of dipoles with varying thicknesses. Note, several smaller gaps behaved similarly to one larger gap (i.e. 10’10μm gaps ≈ 1’100μm gap), see Fig. 1. Therefore, the gap is equivalent to the ratio of non-metal to metal and nanoparticles can be approximated with larger scale objects to save computational resources. As the size of the gap increased, the resonance frequency increased logarithmically with larger gaps causing a weak degree of coupling. The dipole coupled until the resonance frequency doubled (compared to the continuous dipole, $f_0$) and the dipole with a gap then behaved like two smaller dipoles. This coupling gap threshold was determined by the dipole thickness. Thicker dipoles coupled more strongly and therefore thinner dipoles require a higher ratio of metal to non-metal.
Fig 1. The increase in resonant frequency when gaps are added at the centre of a dipole.