Planar DNG superstrate for dipole antenna gain enhancement

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In this paper, a volumetric double-negative (DNG) superstrate based on grids of dipoles and wires for dipole antenna applications is proposed. As it is known, a layer of dipoles excited by an incident plane wave with the E field parallel to the dipoles presents a stop band around the resonant frequency, being transparent out of this frequency. However, in the case of two grids of dipoles, the electric and magnetic responses are excited as the same time producing a resonant behaviour which exhibits a narrow pass band. At that frequency, currents in the dipoles are flowing in opposite direction, producing a compensation of the total current in the slab. Since there is volume in between the grids, a magnetic dipole will be created allowing the power radiation.

When a grid of continuous wires is placed in between of the two grids of dipoles, another possibility to compensate the currents in the superstrate appears, producing a second transmitting frequency. By choosing properly the dimensions of the cell, both transmitting frequencies can be tuned in close proximity widen the pass band of the superstrate. The superstrate and unit cell geometries are shown in Fig. 1 (a) and (b) respectively. Compared to the conventional wire array / split-ring resonator configurations, a clear advantage of the proposed structure is a planar design that simplifies the manufacturing process.

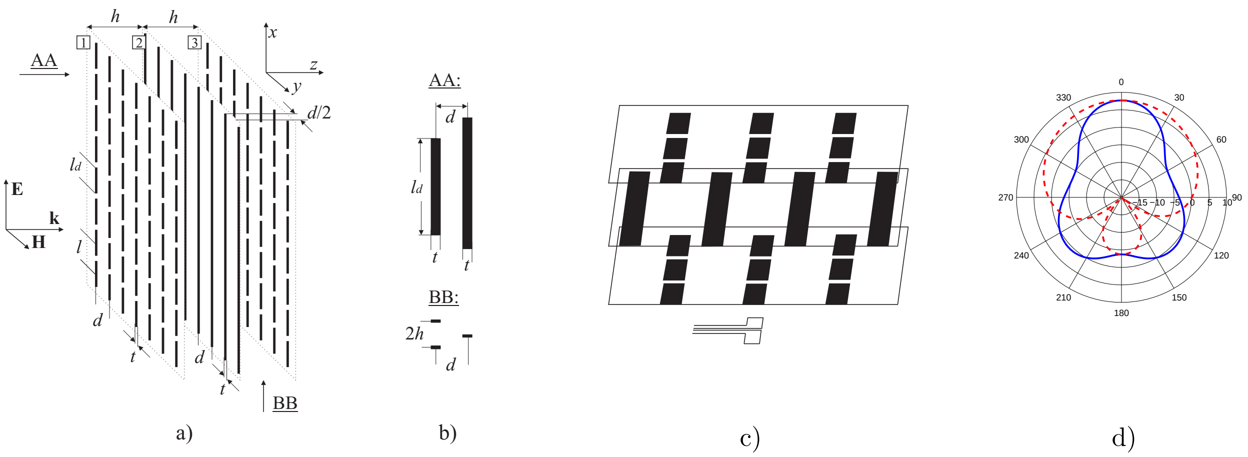

Figure 1: (a) Proposed superstrate geometry. (b) Unit cell geometry: l_d=9.17 mm, t=0.8 mm, h=0.787 mm, d=1.2 mm, l=10.17 mm, ϵ_r=2.2. (c) Dipole antenna and superstrate. Thickness $\approx \lambda_0/11$. (d) Radiation pattern at f_r H-plane (continuous line) and E-plane (dashed line).

In order to take advantage of the transmitting band of the superstrate, a dipole antenna is tuned to this frequency. The field radiated by the dipole will excite each unit cell of the superstrate producing a very uniform distribution of the currents along the surface. Consequently, the radiating area will increase and therefore the gain of the configuration. The geometry of the dipole antenna plus superstrate and its radiation pattern at the resonant frequency are shown in Fig. 1 (c) and (d) respectively. The thickness of the superstrate is $\lambda_0/11$ and the area 0.39 λ_0^2 at f_r=10 GHz. Directivity values at f_r of 8 dBi are obtained, which means an aperture efficiency $\eta_{\rm ap} = 1.28$.

Following this design, a second dipole can be tuned to the pass band of a higher resonant-frequency-superstrate in order to create a multi-frequency array. The behaviour of such array has been simulated with Ansoft-HFSS showing low coupling between elements due to the resonant characteristic of the superstrate and high gain and aperture efficiency.