Metamaterials and Metasurfaces for UHF Antennas

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A common method to reduce size and improve antenna performance is by dielectric loading with a high-permittivity material. Ideally, the values of both the permittivity and permeability should be chosen to optimize antenna performance (A. Buerkle and K. Sarabandi, IEEE Trans. on Antennas and Propagation, vol. 53, no. 11, pp. 3436—3442, Nov. 2005). The main problem has been producing low-loss materials with the required electrical characteristics. Recent advances in metamaterials now make it possible to design inexpensive low-loss materials with arbitrarily chosen constitutive parameters.

A metamaterial can be generally defined as an artificial material with engineered electrical properties not commonly found in nature. A metasurface is a metamaterial so thin that it can be considered to be a two-dimensional structure; or more specifically, "A thin metamaterial layer that can be characterized by unusual boundary conditions, and therefore unusual reflection properties of plane waves and/or dispersion properties of surface waves" (S. Maci, "Metasurfing: Addressing Waves on Metasurfaces for Realizing Antennas and Microwave Devices," IEEE 978-1-4244-8268-9/11, 2011). Whereas much work has already been done developing metamaterials and metasurfaces in the GHz, THz, and optical frequency bands, relatively little has been published about their design and behavior below 1 GHz.

This work examines loaded dipole antennas in the 100 to 500 MHz frequency range. The profile of the dielectric loading and its permeability and permittivity are optimized in order to minimize antenna size, improve unmatched bandwidth, and shape the antenna's radiation pattern. The dielectric loading profile is then implemented by two methods, a bulk metamaterial and a metasurface, and each is incorporated into the dipole design. Comparisons are made between the metamaterial and metasurface designs and the advantages and disadvantages of each discussed. Prototype test results are compared with those of conventional dipoles and the improvements noted.