Perfect Absorption by an Array of Lossy Dipoles Located Close to a Ground Plane

Ofer Markish, Daniel Silverstein, and Yehuda Leviatan*
Department of Electrical Engineering,
Technion - Israel Institute of Technology, Haifa 32000, Israel

The study of structures that absorb electromagnetic power efficiently is important in many application areas ranging from radar cross section minimization to detection by thermal bolometers. The ability to attain perfect absorption by an array of perfectly conducting terminal-loaded dipoles above a ground plane was proven theoretically by Kwon and Pozar using a Floquet modal analysis. With such an array, perfect absorption is achievable for any height of the array above the ground and for any periodicity smaller than one wavelength. The thin profile of the structure and the tunability allowed by changing the load, make this kind of design a good candidate for the realization of absorbers. Moreover, the distance permitted between the elements, which is larger than that typically used in metamaterial absorbers, yields a structure with a less dense distribution of inclusions. However, in practice, especially when using low cost methods of antenna production, the dipoles are not perfectly conducting, and the question whether perfect absorption can be also attained in the presence of the losses, to the best of our knowledge, has not been addressed. In this work, we show that the optimal load that maximizes the absorption efficiency (power absorbed both by the load and antenna material) is different from the complex conjugate of the dipole's active impedance that is required to maximize the array load power. This maximum absorption efficiency can reach 100%, but, in contrast to array of lossless dipoles, not for all heights of the array above the ground. Below some threshold height, which depends on the periodicity, geometry, and finite conductivity of the dipoles, the absorption efficiency drops rapidly. Still this threshold height can be sufficiently small to allow designs of low-profile perfect absorbers. To experimentally validate the analysis, an array of dipoles made of silver-based conductive ink was designed, fabricated, and characterized. The array was designed for perfect absorption at 3.45 GHz when it is located one-tenth of a wavelength above the ground. The dipoles were printed on a flexible Kapton HN material backed by a rigid Rogers 4350B substrate. The printed array was then placed above an aluminum ground plane using plastic spacers and screws. To examine the fabrication results, the dipole lateral dimensions and cross-section were analyzed using SEM, profiler, and optical microscope and good agreement with the values assumed during the design was verified. The ink conductivity, which has a direct impact on the absorption properties of the array, was measured as well. Finally, absorption measurement were carried out using a transmit-receive outdoor setup and perfect absorption, exhibiting good agreement with the simulated results, has been demonstrated.