Interfering Dipoles: Near-Field Energy Flow Vortices and Nodal Lines

Abstract

We investigate near-field energy transport in electric dipole radiation by computing and visualizing the time-averaged Poynting vector for two separated oscillating dipoles. The time-averaged energy-flux field is obtained from the cross product of the electric and magnetic fields after separating real and imaginary components and averaging over one oscillation period. For a fixed dipole separation of 4π, we analyze two representative configurations: (i) both dipoles oscillating at $\pi/4$ relative to the y-axis, and (ii) dipoles oscillating in opposite directions at angles 0 and π. In both cases, the mapped Poynting-vector field reveals singular structures in the x–y plane, including vortex-like circulation around points where the energy flow vanishes. We identify zero-magnitude locations (where the Poynting vector is zero) and observe extended zero-flux lines in the x–y plane, which indicate that the net energy flow locally redirects out of the plane (along z). In the anti-parallel configuration, these features repeat at regular intervals in y, consistent with an interference-driven pattern. These results highlight how dipole–dipole interference can structure electromagnetic energy flow into vortices and nodal lines, motivating follow-on analysis in complementary planes (e.g., z–y) to directly resolve the inferred out-of-plane transport.