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Superdirective Spherical Dielectric Lens Antennas

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Our ability to effectively tailor and control wave-matter interactions has a profound impact on a wide range of applications of utmost societal importance. Specifically, most advanced higher frequency wireless systems have an intrinsic need for higher directivity antennas that may enable strong power flows in preferred directions, while suppressing them in unwanted ones. In this regard, the present work reports on detailed analytical and numerical studies of superdirective dielectric lens antennas which are deeply rooted in higher-order transverse electric and magnetic spherical modes excited in custom-designed multi-layered spherical particles made of high permittivity materials. The superdirective properties are enabled through a tailored excitation of the lens antenna by a unidirectional mixed-monopole antenna (UMMA). This work may be regarded as a generalization of some of the previous two-dimensional (2D) superdirective efforts which were based on an infinite magnetic line source excitation of a multi-layered cylinder made of alternating negative and positive permittivity materials. While the 2D configuration only provides transverse magnetic modes, the spherical geometry gives access to both transverse electric and magnetic multipoles. These modes may be effectively excited at nearly the same frequency by the UMMA, thereby enabling superdirective behavior with unidirectional performance resulting in the ratio of the peak directivity in a specific direction to the directivity in the opposite of at least 10 dB. The present work will showcase analytical evaluations of potential ideal, analytically treated configurations, followed by numerical simulations of more realistic versions. Their near-field behavior, revealing the excitation of specific multipoles, as well as the radiated field patterns will be shown at the presentation together with comparisons with known directivity bounds to confirm their superdirective performance characteristics.