Multipole Engineering: A Practical Approach to Compact, High Directivity Antennas

Prof. Richard W. Ziolkowski

Department of Electrical and Computer Engineering, The University of Arizona, Tucson, AZ 85721, USA
ziolkows@arizona.edu

Highly directive antenna systems are in demand to address the perceived needs of current and FutureG wireless systems and their applications. Practical alternatives to complex, power-hungry phased arrays for space-limited applications are truly desired. A potential approach is to develop and employ compact superdirective systems.

The concept of "needle" radiation was introduced by Oseen over 100 years ago. A number of theoretical papers then followed over the last half of the last century that discussed the interesting attributes of unlimited directivity, i.e., superdirectivity, from arbitrarily small source regions. Recent explicit solutions of Maxwell's equations based upon vector spherical wave expansions confirm this notion. Unfortunately, the consensus in the electromagnetics (EM) community generally has been that superdirective systems are impractical for reasons such as very low radiation resistance/efficiency; very large sensitivity to fabrication and component tolerances; and extremely narrow bandwidths. Nevertheless, a turning point in the history of superdirectivity occurred early this century with a set of successes in which electrically small, two-element endfire arrays of electric elements were demonstrated to be superdirective. Several superdirective multi-element endfire arrays of a similar nature have been substantiated in the last decade using either electric or magnetic dipole elements.

My presentation will highlight current superdirective criteria to appreciate the theoretical, computational, and measurement results being presented. Historical aspects of superdirective systems from the 20th century and the electromagnetics – both physics and engineering features – of those and their 21st century innovative realizations will be briefly reviewed. A recent groundbreaking strategy based on electric and magnetic dipoles and their combinations to realize higher order multipoles (HOMs) and mixtures of them will be emphasized. This *multipole engineering* paradigm has yielded a variety of unidirectional mixed-multipole antennas (MMAs) with superdirective performance. Their practical realizations have surmounted the concerns of efficiency, bandwidth, and fabrication/assembly tolerances. Prototypes of both superdirective endfire and broadside radiating systems have confirmed their very attractive attributes.

Beyond single-source antennas, compact superdirective arrays based on azimuthal HOMs radiated by sectors of uniform circular arrays whose radiating elements are a particular unidirectional MMA, the Huygens dipole antenna, have also been demonstrated. Furthermore, compact superdirective spherical dielectric lens antennas based on morphology-based mixtures of electric and magnetic multipoles excited in multilayered dielectric spheres by unidirectional MMAs formed as independently driven electric and magnetic dipoles have been developed. Relevant features and performance characteristics of both will be described.

Overall, my Distinguished Lecture hopes to encourage further superdirective research activities since it will demonstrate that practical compact, superdirective radiating systems are, in fact, achievable.