Computation of the Q Limits for Arbitrary-Shaped Antennas using Characteristic Modes

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Current and emerging wireless protocols drive an increasing need for reliable antenna solutions integrated within light weight and multifunctional subwavelength mobile terminals. Often, these antennas are small fractions of a wavelength, known as electrically small antennas (ESAs). Due to their small size, ESAs are inherently plagued by poor radiation efficiency, narrow bandwidth, and a pattern restricted to linear combinations of the 1^{st} order spherical modes. Although efficiency and bandwidth are quantities the designer is ultimately concerned with, a more inclusive quantity to consider in ESA design is the antenna Q, which is inversely proportional to bandwidth for single-resonance ESAs. Additionally, and more importantly, since Q can be cast explicitly in terms of Maxwell's equations, there exist fundamental lower bounds on Q, providing a powerful ideal benchmark when designing an ESA.

In this presentation, we present an efficient and direct method for computing the lower bound on Q for arbitrary-shaped antenna geometries. We begin by deriving a new formula for Q based on the currents induced on the antenna/scatterer and the method of moments (MoM) impedance matrix [Z]. We can then use this formula in conjunction with the theory of characteristic modes to find lower bounds on arbitrary-shaped ESAs. Current excitations which yield the minimum possible Q are also given, providing powerful insight into the physical factors that affect Q, and offer guidelines for improving ESA designs constricted to arbitrary physical volumes. Several supporting examples are investigated, and appropriate comparisons to the literature are given to demonstrate the flexibility and effectiveness of our approach.