Minimum Radiation-Q of Antennas with Arbitrary Polarizations

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In many wireless communication applications, small size antennas with a wide operational bandwidth and higher radiation efficiency have been required. The fundamental-limit theory on antenna size and performance addresses the theoretical limit relationships of size, bandwidth, and radiation efficiency; extreme size reduction will result in either reduced bandwidth or reduced radiation efficiency. Therefore, the fundamental-limit theory assists in obtaining an optimized antenna in terms of size and performance as well as avoiding a search for a small antenna with unrealistic performance parameters.

Since Wheeler (1947) first introduced the concept of fundamental-limit theory on antennas, there have been many investigations into the theoretical limitation of antenna performance versus size (Chu, 1948; Collin and Rothschild, 1964; McLean, 1996; Grimes and Grimes, 1999). These research efforts emphasized development of an accurate minimum radiation-Q formula with various approaches. The obtained minimum radiation-Q formulas were consistent between various approaches, though Chu's results have been considered as an approximation.

The previous approaches have also addressed the limits on dual polarized system. The minimum radiation-Q formulas for the classic approaches of linearly and circularly-polarized antennas were found to be different, even though the excited spherical TM and TE modes are orthogonal. Davis (2008) noted that the classic approaches did not consider the additional energy storage in the electric and magnetic sources. When the total non-radiating energy in the system, including the additional non-radiating energy in the sources, is considered, the minimum radiation-Q formulas of antennas with arbitrary polarizations are identical. For antennas connected to independent electronics, this conclusion would remain true and is intuitive. For a change in Q for orthogonally polarized antenna, one would need to consider the antenna interaction in a corporate-feed network.

In this presentation, the basic assumptions made in the classic approaches are clarified. Based on observations, the exact minimum radiation-Q formula of antennas with an arbitrary polarization will be derived in both time and frequency domain for some selected spherical modes.