Efficient Radiation from an Electrically Small Antenna

Dr. Craig Grimes

The University of Kentucky
Department of Electrical Engineering
453 Anderson Hall
Lexington, KY 40506

AFOSR
801 North Randolph Street, Room 732
Arlington, VA 22203-1977

Approved for Public Release.

Applying the analytic technique, two antenna designs were found for which the radiation Q was below the limit determined by Chu for electrically small antennas. The simplest design is a turnstile antenna comprised of two perpendicularly oriented collocated electric dipoles that are phased to support circular polarization, for which the radiation Q is slightly less than a single electric dipole. The most intriguing antenna design consists of four spatially collocated equal power dipoles, a magnetic and electric dipole moment pair oriented along the x-axis, with the dipole pairs driven 90 degrees out of phase to support circular polarization. For this source the analytically predicted radiation Q is zero independently of the relative electrical size ka of the antenna, where a is the radius of the smallest virtual sphere that circumscribes the antenna and k is the wave-number of radiation.
Under the scope of program auspices the following milestones were achieved.

1. The first and only published analytic technique that correctly calculates the radiation Q of a general radiation field was developed [1,2].

2. Applying the analytic technique, two antenna designs were found for which the radiation Q was below the limit determined by Chu for electrically small antennas.
   The simplest design is a turnstile antenna comprised of two perpendicularly oriented collocated electric dipoles that are phased to support circular polarization, for which the radiation Q is slightly less than a single electric dipole.
   The most intriguing antenna design consists of four spatially collocated equal power dipoles; a magnetic and electric dipole moment pair oriented along the x-axis, and a magnetic-electric dipole moment pair oriented along the y-axis, with the dipole-pairs driven $\pi/2$ out of phase to support circular polarization. For this source the analytically predicted radiation Q is zero independently of the relative electrical size $ka$ of the antenna, where $a$ is the radius of the smallest virtual sphere that circumscribes the antenna and $k$ is the wave-number of radiation equal to $2\pi/\lambda$.

3. Numerical [3-5] and experimental [4,5] works have shown that the radiation Qs of the two different, multi-element antenna designs are a function of the relative phasing between the radiating elements.

4. The 'zero-Q' antenna has been experimentally and numerically characterized [5]. Experimentally, for the 'zero-Q' antenna of relative electrical size $ka = 0.39$, the measured Q is a factor of approximately three below the so-called Chu limit. Numerical simulations, with which we were able to characterize the antenna over a broader frequency range than possible with our experimental measurements, indicate that at $ka = 0.23$ the antenna Q is a factor of 20 below the Chu limit, and demonstrates wide-band operation indicative of self-tuning as discussed in [A]. Furthermore, while the energy field phasing required for low Q emission can be readily obtained in transmission, for reception the phasing for low Q operation is unlikely to be met by an incident wave, hence the antenna should operate as a non-reciprocal device [A].


5. A total of 13 referred journal publications, 1 patent, and 8 conference proceedings acknowledged AFOSR support.
Journal Publications Acknowledging AFOSR Support


Patents Acknowledging AFOSR Support


Conference Proceedings Acknowledging AFOSR Support


