REVIEW OF FUNDAMENTAL LIMITS OF ANTENNAS AND IDENTIFICATION OF THE TERMS MISSING IN RECENT DEVELOPMENTS

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Fundamental limits of antennas has recieved periodic consideration over the half century. The fundamental work of Chu has been debated by many has being approximate. For small antennas, the arguments are rather mundane since all of the techniques lead to the same result. However, as the size of the antenna, newer approaches (McLean and Grimes in particular) claim higher bounds on the minimum radiation quality factor Q.

For the minimum Q, all formulations restrict the discussion to the TM01 mode, recognizing that higher-order spherical modes simply increase the Q. Chu developed his result from an equivalent circuit model for the wave impedance. McLean developed a new formulation based on the average electric-field energy of a equivalent infinitesimal dipole outside the ka sphere, a being the radius of the enclosing sphere of the antenna to be considered. He subtracted a term proportional to kr that represents the energy radiated to the far field and not reacting with the source. Grimes added a transient aspect to the development of McLean to compute the maximum stored energy in the system. If properly done, one would expect these results to provide the same result, since 2 times the average stored electric energy should equal the maximum stored energy in the system.

What went wrong? Both Grimes and McLean did not account for the energy delay in the radiation of energy. The energy does not travel outward at the speed of light, but has a slight delay as energy is stored locally on the way to the far-field. This can be seen from the Poynting vector of the field when separated into a radiated power and a stored energy transfer that should be orthogonal in phase. This term is small relative to the kr term that has already been deleted, but is sufficient to explain the differencs in all of the methods. When this energy delay is incorporated into both McLean's and Grimes' formulations, the end result is again Chu's forumulation for Q. The actual term that is missing will be presented and an observation about the derivative Chu made will suggest his forumulation provides the correct result rather than being an approximation. Equivalent bandwidths will also be demonstrated to further emphasize the point.

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2. B - Fields and Waves

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4. C - Contributed Paper

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