Radiation Q and Efficiency of Ideal Dipoles inside a Spherical Shield

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In this paper an account is given of the effects of a semitransparent (low-loss) dielectric or magnetic shield on the operation of electrically small antennas. An obvious motivation for the work is that mobile terminal antennas are nowadays often embedded within the equipment. Two parameters form our principal interest here; 1: the quality factor, Q, computed from the ratio between the energy stored and the power accepted by the antenna, and 2: the radiation efficiency, η, or the proportion of radiated power to net power delivered to the antenna. Our approach is theoretical; we describe a method for calculating these quantities for azimuthally symmetric electric (TM) and magnetic (TE) multipoles surrounded by a semitransparent spherical shield of variable thickness, dielectric and magnetic constants with losses. Thus, a boundary value problem for the electromagnetic fields is formed. For its solution, a matrix method is applied to relate the transverse field components at each pair of adjacent interfaces. The method is hereupon applied to the case of a shield consisting of a single homogeneous layer. The Q and efficiency for such a structure are determined by computing numerically the energy stored in the near field of the multipole as well as the power radiated and dissipated in the shield. The performances of TM and TE multipole radiators are compared as a function of frequency. Hence, it is seen that even a very thin layer of a lossy dielectric considerably degrades the radiation efficiency at low frequencies, however, more severely for electric dipoles than for magnetic ones. Therefore, the electric dipole has a lower radiation Q than its magnetic counterpart. However, with a growing frequency the differences between the two types of dipoles are seen to balance. Low-frequency series expansions as well as high-frequency asymptotic expansions of the efficiency are given to elucidate the importance of the material parameters of the shield. We also derive some closed-form expressions for the dielectric permittivity of the shield and its outer and inner radii, which minimises the Q.