Theoretical Study on the Radiation Efficiency of Electrically Small and Thin Spherical Shell Antennas

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Electrically small antennas have always attracted a lot of interest because these antennas have been utilized for the mobile communication system. However, these antennas have been suffered from low performance such as the low gain, the narrow bandwidth (high Q factor) and the low radiation efficiency. The radiation efficiency is especially important since this parameter affects the energy efficiency of the whole communication system. In recent years, electrically small folded spherical helix antennas have begun to draw attention since these antennas are employed to obtain low Q. A lot of antenna designers have challenged to design high efficiency antennas, while only a few researchers published results on the theoretical limitation of the radiation efficiency. Theoretical research on the property and the condition of extremely small antennas may enable us to propose a global strategy to design high efficient antennas.

In this study, an attention is focused on the radiation efficiency of electrically small and thin spherical shell antennas. Firstly, a current distribution of a spherical shell antenna is described in terms of vector spherical harmonics, and is decomposed into radiating and non-radiating parts. Secondly, the radiation efficiency of a spherical shell antenna may be expressed in terms of expansion coefficients of spherical wave. Then, by using a thin approximation, the radiation efficiency of a thin spherical shell antenna is derived. It is shown that the result of the radiation efficiency for thin spherical shell antenna is function of the antenna size, the material property and the spherical radiation modes. The validity of this result is confirmed by comparing with electrically small folded spherical helix antennas.