Calculating Q of small antennas of different shapes and complexity using FDTD method

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The antenna radiation Q factor is a quantity of practical interest for small antennas which provides an indication of the antenna's bandwidth and can be defined and determined independently of the feed line characteristic impedance. The fundamental definition of Q is given by: $Q = \omega \widetilde{W} / P_{rad}$, where ω is the radian frequency, $\widetilde{W}$ is the sum of the electric and magnetic average stored energies and P_{rad} is the radiated power.

The study of the lower bound of lossless antenna Q which fits inside the smallest circumscribing sphere (as defined by Wheeler 1947) can be traced back to Chu (1948). A lot of related studies have been done since then (Collin and Rothschild 1964, Fante 1969, Hansen 1981, McLean 1996). This lower bound has been found to be elusive to achieve in practice since it doesn't take into account the energy stored in the near field of the antenna (inside the sphere).

From the point of view of antenna design, it would be interesting to be able to predict an exact value of antenna radiation Q. Therefore, Thiele and al. have recently used the far field approach (2003) to obtain a more realistic value of Q as well as Mclean using an ellipsoidal volume (1999). Geyi (IEEE TAP, 51, 8, 2003) also proposed analytical formulas for small simple antennas deduced from the combination of the Poynting Theorem in time and frequency domain, taking into account the energy stored in all the space and this permitted to obtain a higher value of Q approaching the real one.

More recently, Yaghjian and Best introduced another method based on the derivative of antenna input impedance (A.D. Yaghjian and S.R. Best, IEEE TAP, 53, 4, 2005) to obtain a more precise value of Q. The approximate expression of Q obtained by them is the following: $Q \approx \omega \left| \frac{\partial Z}{\partial \omega} \right| \Big/ 2R$, where Z is the input impedance of the antenna and R its real part.

In earlier work, we proposed a simple method for numerically determining the radiation Q of an antenna using the FDTD method (Finite Difference in Time Domain) (IEE Electronics Letters, 41, 12, 2005). We used the same fundamental definition of Q where we first computed the total energy in a specified cubic volume in the near field and the far field of the antenna and then we deduced the non-propagated energy by subtracting the radiation energy from the total energy. The main advantage of using FDTD is that we can obtain an accurate value of the Q factor and that it can be used to characterize antennas of any shape or complexity.

The quality factor of small linear and elliptical polarized antennas like Pifa, helix… is calculated and compared to the other methods. Some details of the FDTD method and results will be shown during the conference.