Time-Domain Analysis of High-*Q* Antennas

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The transient response of antennas becomes significant when antennas are used in a time-varying fashion. Radiation properties of the antennas are usually defined, calculated, and measured in the frequency domain and/or the steady-state time-harmonic regime. Frequency-domain analysis characterizes the antenna irrespective of the physical time-dependent aspects and neglects the transient properties of the antenna. When it is required to switch between different narrowband radiation mechanisms or different sources in a time-varying radiation configuration, it is important to have a comprehensive knowledge of the transient behavior of the antenna. In a high-*Q* antenna, an extensive amount of energy must be stored in the near-field before effective far-field radiation begins. The higher *Q* factor results in a longer time duration for the antenna to reach the maximum radiation efficiency. In a switched-antenna application, this transient effect dominates the performance of the antenna if the switching period is not long enough to let the near field build up the entire stored energy.

In this paper, we focus on the transient aspects of high-*Q* radiators and present a comprehensive investigation on the time-domain behavior of resonant-type antennas. The concept of energy storage and its connection with size and *Q* factor is described by means of an equivalent circuit of the radial-wave impedance for spherical modes. The impact of antenna structure on the field response is studied by analyzing the transient radiation of the Planar Inverted-F Antenna (PIFA) as a typical example of small antennas. The transient mismatch characteristics due to the high amount of stored energy are observed by evaluating the time-domain reflection at the input terminal. Without loss of generality, damping factor and *Q* factor associated with the fundamental mode for different PIFA designs are compared to those of an equivalent RLC resonator and it is shown that for $Q \gg 1$, time-domain characteristics of the fundamental radiated mode is very well matched to that of a high-*Q* resonator. Early-time response to the Gaussian pulse in the near and far-field is closely observed and its correlation with the exciting pulse is studied. Furthermore, the transient response to a sinusoidal-modulated pulse is investigated and the impact of source impedance on the time constant and *Q* factor of the fields is studied.