Time Domain Method to compute Quality Factors and Bandwidths of characteristic modes of antennas

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The theory of characteristic modes can be used in applications such as the analysis of radiation and scattering, antenna shape synthesis and radiation pattern synthesis. An innovative method for computing the characteristic modes was proposed by these authors using a time domain Maxwell equation solver [N. Surittikul and R.G. Rojas, [*IEEE APS Proc.* 2005, vol. 2B, pp. 585-588]. This paper extends the development of the theory presented last year.

Previously, we calculated the resonances, characteristic modes as well as characteristic patterns for several types of antennas employing the Finite Difference Time Domain (FDTD) technique. A novel method for extracting relevant information, such as quality factors and bandwidths, is proposed here. The quality factor is defined as $Q_n = \omega_n/\tau_n$, where $\{\omega_n\}$ are the resonances of the structure and τ_n is the characteristic mode lifetime found from the exponential decay of the envelope of the field radiated by the n^{th} current mode, provided only a single resonance is excited. Calculation of the spectral resonances, ω_n, can be done using the technique proposed last year. The structure is first exposed to a very wide-band excitation to determine its resonances. To do so, the initial conditions on the electric fields in the entire computational domain are generated with random numbers having a uniform distribution. This is equivalent to exciting the structure with a very wide-band signal. After initializing the domain, the fields are then updated using the well known FDTD algorithm. However, at every time step, we record the time waveforms of the surface (conducting surfaces) or volumetric (material bodies) currents of the structure and simultaneously perform the DFT of these time dependent signals to obtain their frequency responses. The resonances, ω_n, of the structure are assumed to occur at the spectral peaks.

To compute τ_n, we first need to determine the characteristic modes of the structure. At each resonant frequency, the structure is illuminated with a narrow band signal. These narrow band signals are chosen to compute fields and/or currents at one particular frequency. The characteristic modes are captured by DFT-ing a time signature of the current on the body of the structure. After securing the characteristic modes, each current mode is afterward excited with a Gaussian pulse, and the field radiated by this particular current mode is also recorded. Note that τ_n is indeed the inverse of the exponential decay of the envelope of the field radiated by the n^{th} current mode. As a result, Q_n of each n^{th} current mode can be computed using the formula provided earlier. It is also worth noting that the bandwidth of the mode is inversely proportional to Q_n. Examples for various antennas will be provided to illustrate this proposed algorithm.