NUMERICAL METHODS AND MATHEMATICAL ALGORITHMS FOR CALCULATING THE THREE DIMENSIONAL INDUCTIVE AND ELECTROSTATIC FIELDS OF AN IMPULSE RADIATING ANTENNA

Isaac Chappell [(1)] and Ira Kohlberg [(1)]
(1) Institute for Defense Analyses, Alexandria, VA 22311

The signature of an Impulse Radiating Antenna (IRA) is the nearly ideal Delta function radiated waveform on bore-sight at distances of the order of kilometers for driving voltages with risetimes in the sub-nanosecond range. The generation of the radiated component, which varies as $(1/r)$, is accompanied by inductive and electrostatic components of the electric field which vary as $(1/r^2)$ and $(1/r^3)$ respectively. The complete field of an IRA antenna in polar coordinates (r, ϑ, ϕ is

$$E_\mu(r,\vartheta,\phi,t) = \Psi_{\mu 3}(\vartheta,\phi,t)\left(\frac{1}{r^3}\right) + \Psi_{\mu 2}(\vartheta,\phi,t)\left(\frac{1}{r^2}\right) + \Psi_{\mu 1}(\vartheta,\phi,t)\left(\frac{1}{r}\right),$$

where μ stands for either the r, ϑ, or ϕ component, and $\Psi_{\mu 1}(\vartheta,\phi,t)$, $\Psi_{\mu 2}(\vartheta,\phi,t)$, and $\Psi_{\mu 3}(\vartheta,\phi,t)$ describe the polar and time dependence of the respective components. In a recent paper (I. Kohlberg and C. Baum, Proceedings of ICEAA '05, Torino, Italy, Sept 12-16, 2005), the detailed three-dimensional time dependent structure of the radiated field of an IRA was presented along with some representative waveforms. Whereas the function $\Psi_{\mu 1}(\vartheta,\phi,t)$ has only one component, $\Psi_{\vartheta 1}(\vartheta,\phi,t)$, all components are present in the $(1/r^2)$ and $(1/r^3)$ terms. The numerical computation of these terms is substantially more difficult than for $\Psi_{\vartheta 1}(\vartheta,\phi,t)$, and if not done correctly can lead to erroneous singularities. These singularities arise from the use of transformed time variables: $T_x = (D/2c)\sin\vartheta\cos\varphi$ and $T_z = (D/2c)\cos\vartheta$ that appear in the denominator of transcendental functions; D is the diameter of the IRA and c is the velocity of light. Algorithms are developed that circumvent these singularities. Examples of time dependent inductive and electrostatic waveforms are rendered as a function of r, ϑ, ϕ and time for selected pulser waveforms. This information is useful to assess the vulnerability of electronic and communication equipment that operates near an IRA antenna.