Analysis of Transient Electromagnetic Dipole

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Transient Electromagnetics - Outline

• Applications
  – Geological mapping
  – Human tissue interaction

• Analytical approach
  – Continuous
  – Transient

• Results
Transient Electromagnetics

- Geological mapping
  - Ocean floor
  - Subterranean
  - Minerals, Water
- Pulse characteristics
  - 1-20ms on/off
  - 1-30µs ramp
- Ground penetration
  - Several hundred meters
Transient Electromagnetics

- Environment emissions
- Mobile communications
  - Human body interaction
  - Continuous vs transient/pulse exposure
Analytical approach

- Continuous field
  - Maxwell equations

- Transient field
  - Conductive dissipating medium
  - Shape and characteristics modified
  - Near, Intermediate and Far fields important
  - Shift from excitation pulse + near field response to spatial and time derivatives
Analytical approach

- Pulse with non-zero rise and decay time:

\[
I(t) = \frac{1}{2t_1} \left\{ \left(1 - e^{-\omega_p t}\right)H(t) - \left[1 - e^{-\omega_p (t-2t_1)}\right]H(t - 2t_1) \right\}
\]

Rise/Decay time, \( \tau_p = \frac{1}{\omega_p} \)
Analytical approach

- Electric field perpendicular to dipole axis:

\[
E_x(\rho, t) = \frac{\mu_0 a I(t) ds}{16\pi t_1} \begin{cases} 
0, & t = 0 \\
E(\rho, t), & 0 < t < 2t_1 \\
E(\rho, t) - E(\rho, t - 2t_1), & t > 2t_1 
\end{cases}
\]

Analytical approach

- Maxwell’s equations magnetic vector potential:

\[ \mu \varepsilon \frac{\partial^2 A}{\partial t^2} + \mu \sigma \frac{\partial A}{\partial t} + \nabla \times (\nabla \times A) = 0 \]

- COMSOL Multiphysics RF module
- Optimized solver settings
Analytical validation

- Short pulse with non-zero rise/decay:

Current pulse

Electric field

Electric field lasts longer than input pulse
Electric field development

- Short pulse non zero rise/decay

 transient dominant
Analytical validation

- Long pulse with non-zero rise/decay:

Current pulse

Electric field

Electric field similar in length to input pulse
Electric field development

- Long pulse non zero rise/decay

\[ \log_{10}|E_x| \quad t = 2 \text{ ms} \]

Transient dominant

\[ \log_{10}|E_x| \quad t = 22 \text{ ms} \]

Quasi-static dominant
Summary

• Method to analyze transient pulse applied to an electromagnetic dipole has implemented

• Resulting field is complex and consists of 2 terms:
  – Response to rectangular pulse
  – Response to step discontinuity