Presented at the COMSOL Conference 2009 Boston

Analysis of Transient Electromagnetic Dipole

J.S. Crompton, K.C. Koppenhoefer, S.Y. Yushanov

AltaSim Technologies, LLC

COMSOL Conference

8-10 October, 2009

Transient Electromagnetics - Outline

- Applications
  - Geological mapping
  - Human tissue interaction
- Analytical approach
  - Continuous
  - Transient
- Results

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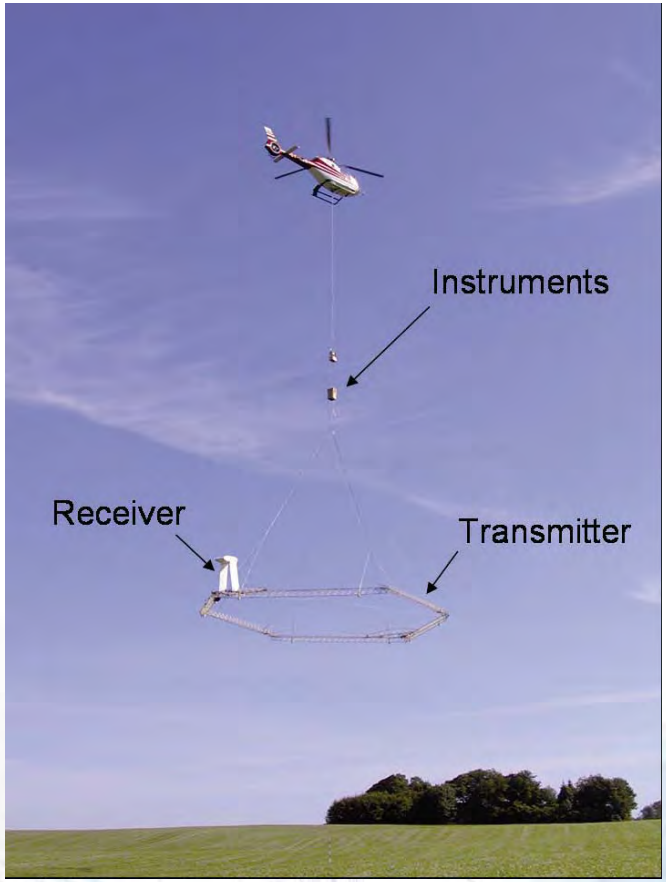
Transient Electromagnetics

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



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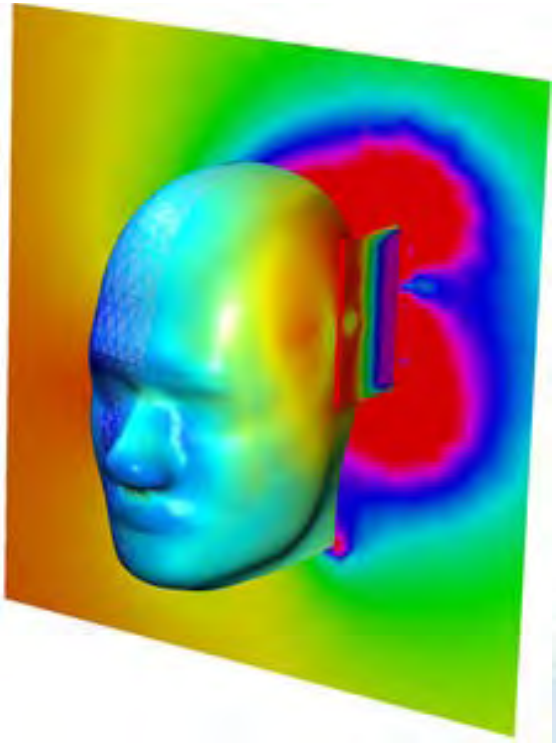
Transient Electromagnetics

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



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Analytical approach

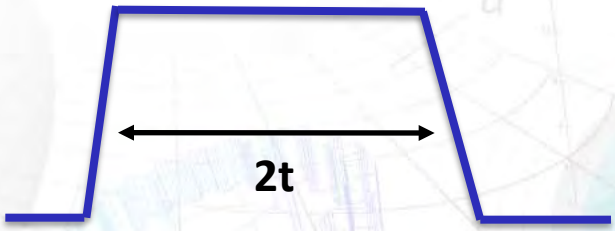
- Continuous field
  - Maxwell equations
- Transient field
  - Conductive dissipating medium
  - Shape and characteristics modified
  - Near, Intermediate and Far fields important
  - Shift from excitation pulse + near field response to spatial and time derivatives

Analytical approach

- **Pulse with non-zero rise and decay time:**

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

Rise/Decay time, $\tau_p = \dfrac{1}{\omega_p}$



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Analytical approach

- **Electric field perpendicular to dipole axis:**

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

D. Margetis, “Pulse Propagation in Sea Water,” *J. Appl. Physics*, 1995, Vol. 77 (7), No. 1, pp. 2884-2888.

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Analytical approach

- **Maxwell's equations magnetic vector potential:**

$$\mu\varepsilon\frac{\partial^2\mathbf{A}}{\partial t^2}+\mu\sigma\frac{\partial\mathbf{A}}{\partial t}+\nabla\times\left(\nabla\times\mathbf{A}\right)=0$$

- **COMSOL Multiphysics RF module**
- **Optimized solver settings**

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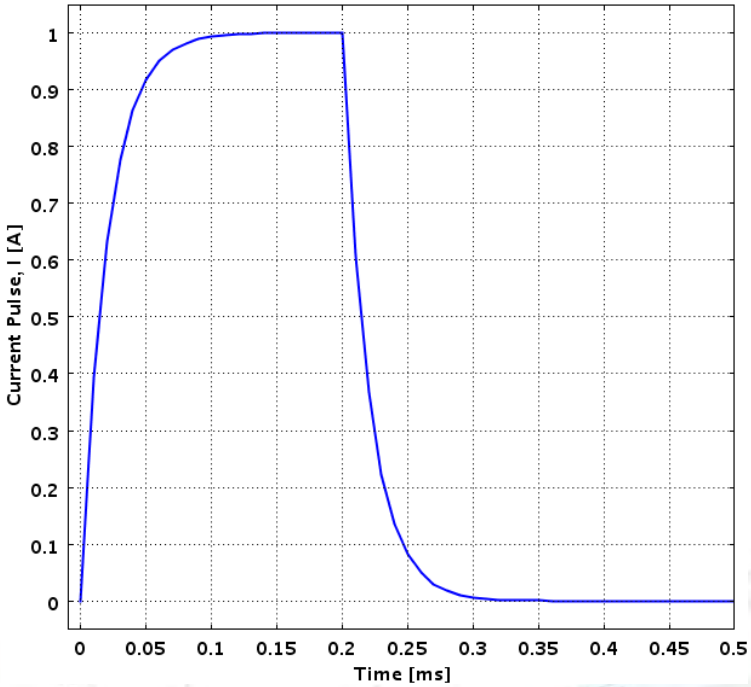
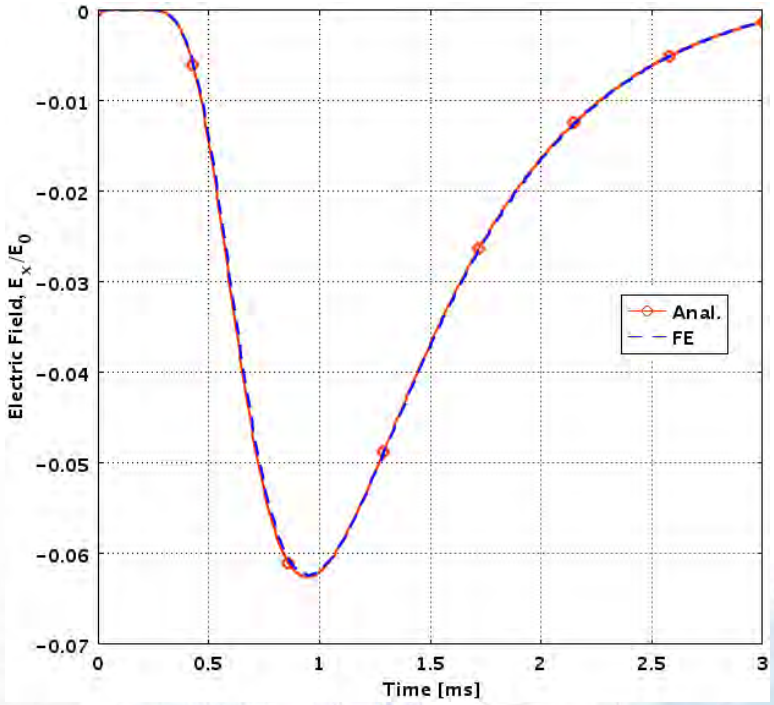
Analytical validation

- **Short pulse with non-zero rise/decay:**



Current pulse



Electric field

Electric field lasts longer than input pulse

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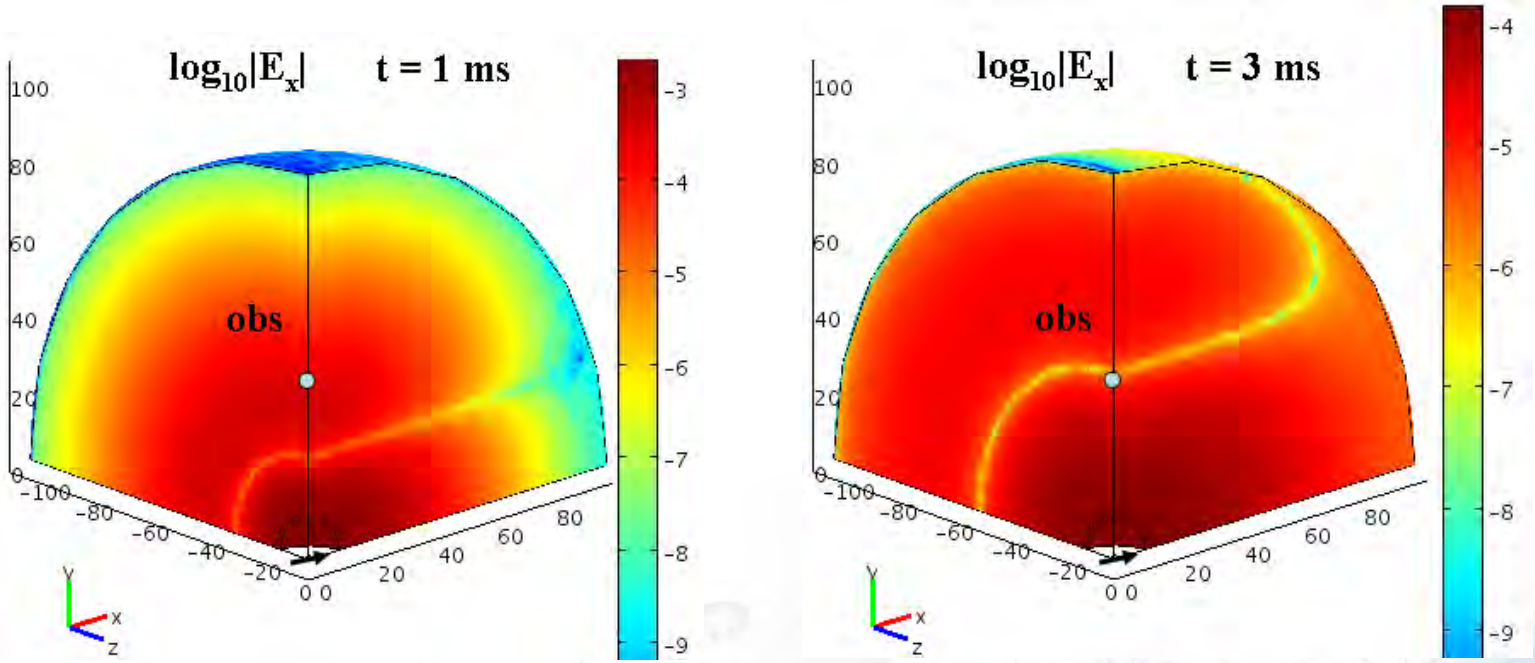
Electric field development

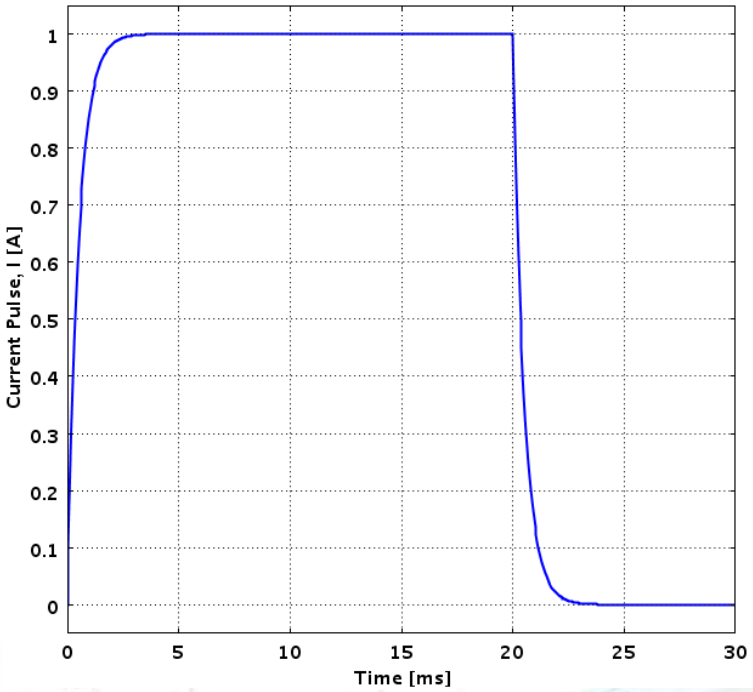
- **Short pulse non zero rise/decay**



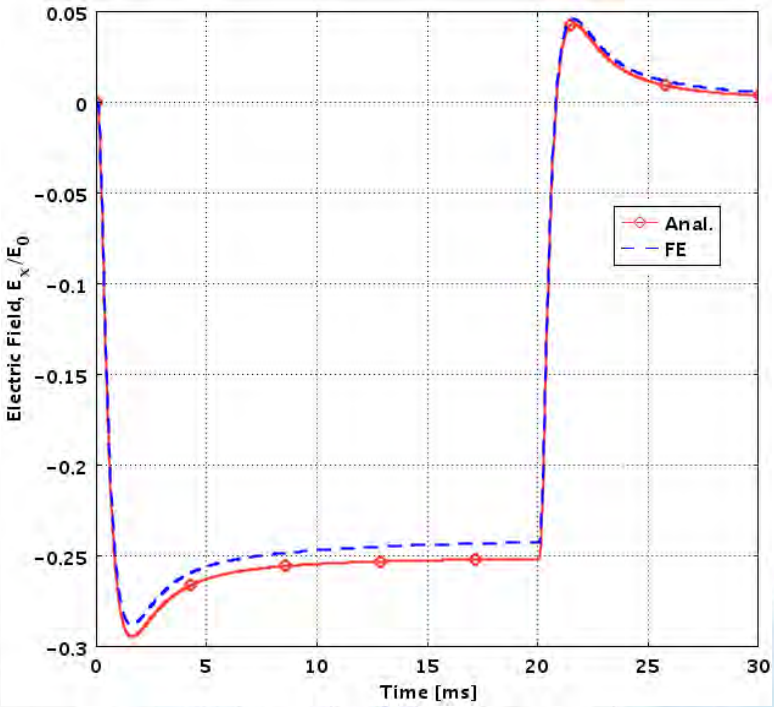
Transient dominant

Analytical validation

- **Long pulse with non-zero rise/decay:**



Current pulse



Electric field

Electric field similar in length to input pulse

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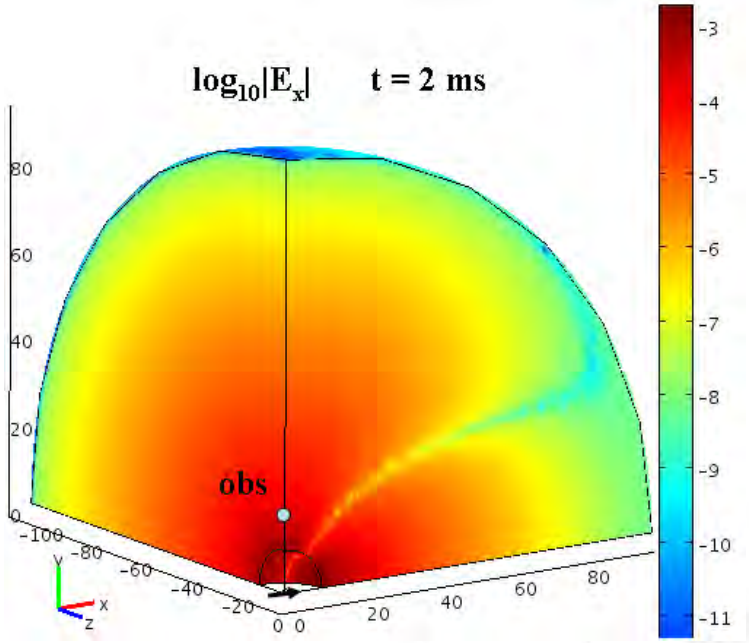
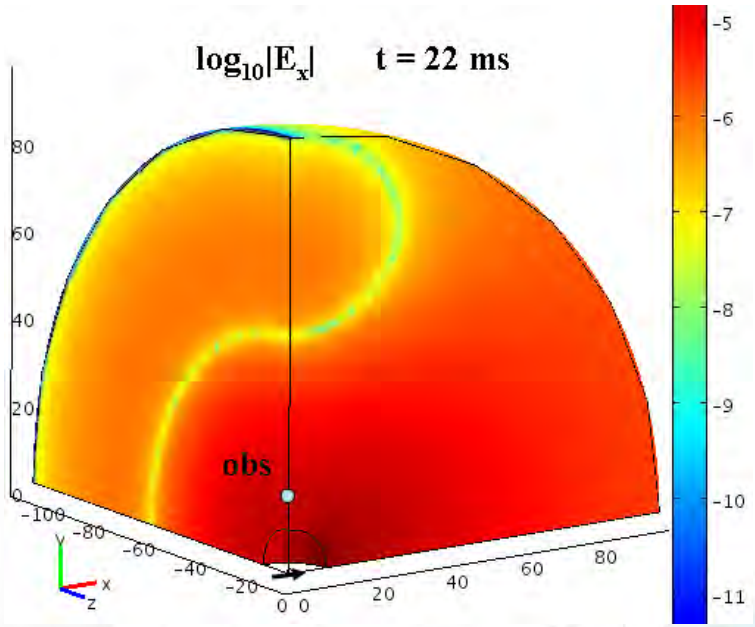
Electric field development

- **Long pulse non zero rise/decay**



Transient dominant



Quasi-static dominant

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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