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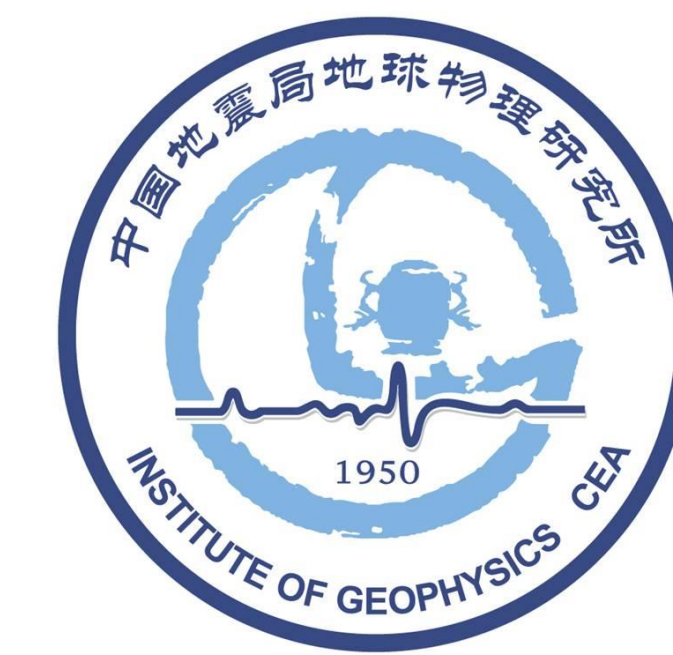
Dipolar Approximation and Propagation of Pre-Earthquake Electromagnetic Signals

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Abstract

In this work we propose an approach where pre-fracture electromagnetic sources are modeled like punctual-transient electric dipoles, embedded in a layered conductive medium. In this way, although the source is strongly simplified, part of the complexity of the crust and the zone of measurements is considered. Maxwell's equations are solved using the Schelkunoff potentials method to calculate the electromagnetic field on air-ground surface.



Introduction

Electromagnetic emissions are widely reported in relation with fracture processes such as earthquakes, land slides or mine collapses. Laboratory scale experiments address the origin of these emissions.

However, electromagnetic signals produced by underground fracture processes can be strongly attenuated by the electric conductivity of the medium. For a harmonic plane wave the solution of Maxwell equations in conductive materials shows this effect:

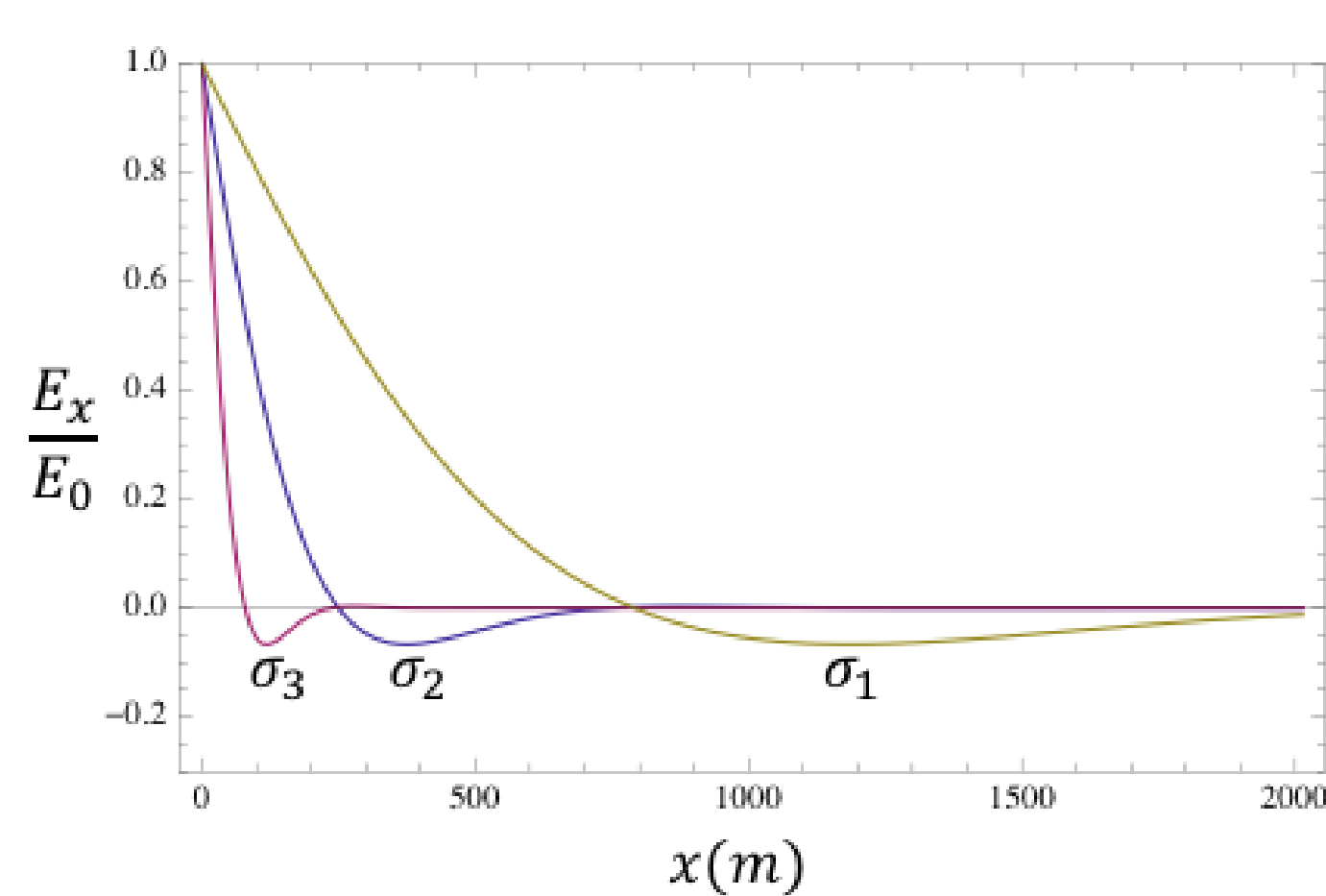


Fig 1. Electric Field attenuation for a plane wave in three different conductive medium.

A similar behavior is found for pulse-like plane signals.

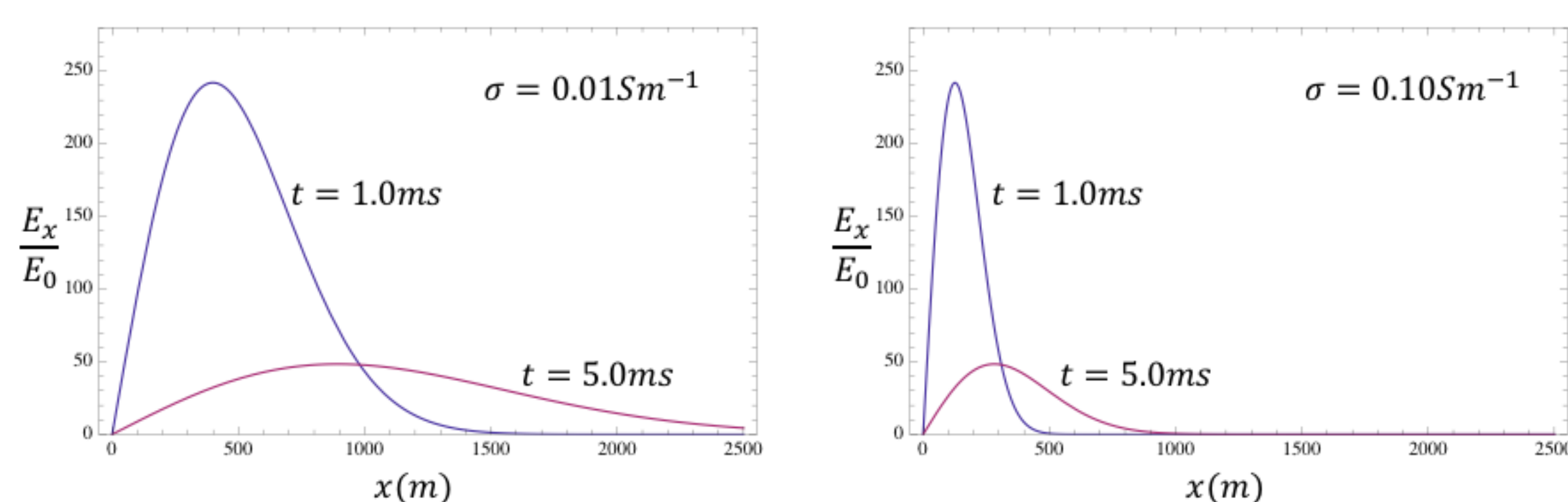


Fig 2. Electric Field attenuation for an electromagnetic pulse in two conductive medium for two different times.

However, pre-earthquake signals are probably produced in small regions and are detected far away from the source, a point like approach is more convenient. The source can be modeled like a transient electric or magnetic dipole embedded in a conductive media.

Methodology

Propagation of electromagnetic signals is described by Maxwell equations in a conductive medium. Electric and Magnetic Fields follow wave equations with dissipation:

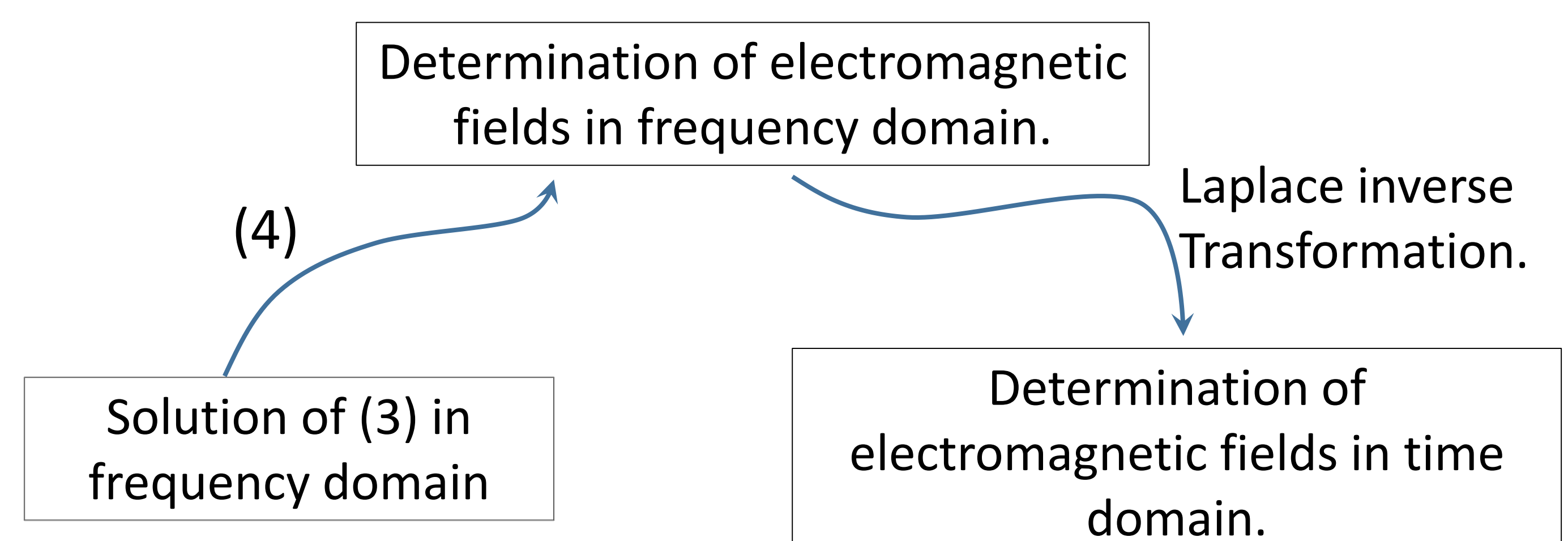
$$\begin{aligned} \text{Time Domain} \quad & \left\{ \begin{aligned} \nabla^2 \mathbf{E} &= \mu\epsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} + \mu\sigma \frac{\partial \mathbf{E}}{\partial t} \\ \nabla^2 \mathbf{B} &= \mu\epsilon \frac{\partial^2 \mathbf{B}}{\partial t^2} + \mu\sigma \frac{\partial \mathbf{B}}{\partial t} \end{aligned} \right. \quad (1) \\ \text{Freq. Domain} \quad & \left\{ \begin{aligned} \nabla \times \mathbf{E} + i\mu\omega \mathbf{H} &= -i\mu_0\omega \mathbf{M}_s \equiv -\mathbf{J}_m^S \\ \nabla \times \mathbf{H} - (\sigma + i\epsilon\omega) \mathbf{E} &= i\omega \mathbf{P}_s \equiv -\mathbf{J}_e^S \end{aligned} \right. \quad (2) \end{aligned}$$

EM sources

Schelkunoff potentials, frequently used in geophysical prospection, are an adequate way to solve (1) and (2)

$$\begin{aligned} \nabla^2 \mathbf{F} + k^2 \mathbf{F} &= -\mathbf{J}_m^S & \mathbf{E} &= \nabla \times \mathbf{F} \\ \nabla^2 \mathbf{A} + k^2 \mathbf{A} &= -\mathbf{J}_e^S, & \mathbf{H} &= -\nabla \times \mathbf{A}. \end{aligned} \quad (3) \quad (4)$$

The complete computation scheme is what follows:



Results

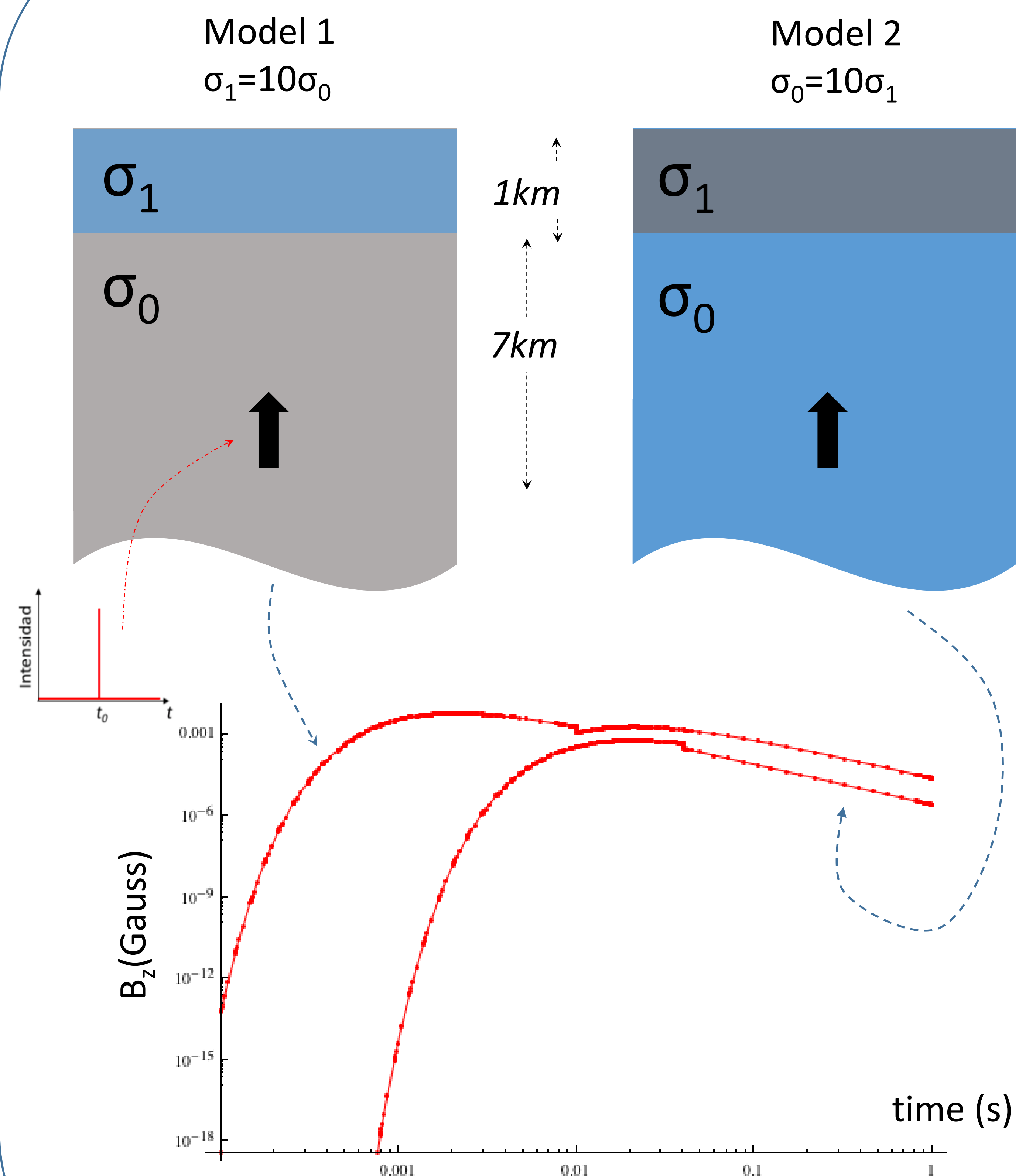


Fig 3. Magnetic Field on surface produced by transient electric dipoles embedded in conductive medium. Models 1 and 2 were assumed.

Conclusions

- The main effect in attenuation is due to the medium that contains the source.
- The top layer affects the magnetic field in the late time region.
- Similar results are expected for electric fields.
- Effects of lateral inhomogeneities, associated with faults, must be studied.