SIMULATING LIGHTNING LOCATING TECHNIQUES

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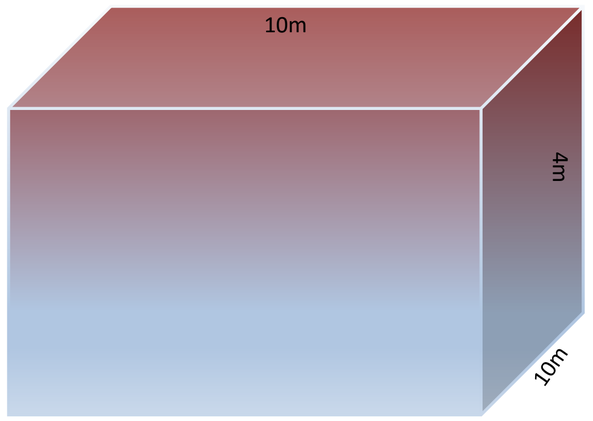
Introduction

Lightning is an electrostatic discharge that begins within charged regions of a cloud. Impulsive electric currents are generated during lightning. These currents produce electromagnetic fields, which can induce unwanted voltages on electronic systems and may cause serious damage to practically all electronics, particularly the communications systems. On the other hand, the electromagnetic signals from lightning can be measured to learn about their source processes, for example, the temporal and spatial properties. In order to do this, one must develop an accurate approach for predicting electromagnetic signals due to lightning. There are many techniques for simulating transient electromagnetic fields. One of such techniques is the volume integral method (VIM). In this poster, the VIM method is used to calculate electromagnetic fields for a volume distributed current at a set of distant observation points, which simulate observation sites of a lightning locating/mapping array. The accuracy of the VIM model is first validated against the finite different time domain technique; then electromagnetic fields are calculated for source currents with varying geometries simulating different lightning processes. The volume current density is assumed to be varying in time as a Gaussian pulse with 25 MHz bandwidth. The simulations are done for different sets of parameters such as source geometry, current distributions, and added noise. Using these calculations, we investigate how the source property and measurement noise may affect the accuracy of a lightning locating system.

Problem Statement

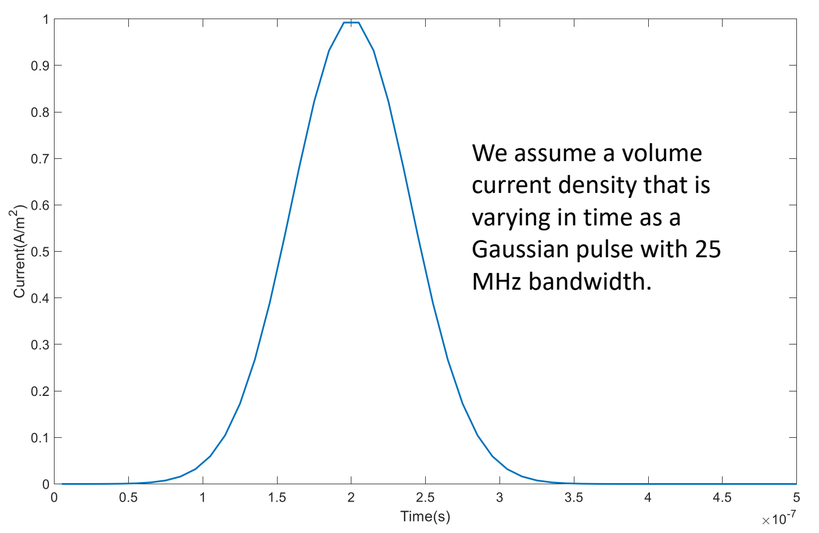
- **Lightning** is an electrostatic discharge (ESD)
- The ESD happens between:
  - ✓ electrically charged regions of a cloud.
  - ✓ two clouds
  - ✓ clouds and the ground.
- During ESD a strong electric currents are induced.
- The induced currents produce EM fields.
- Our goals are:
  - ✓ model EM field due to lightning currents.
  - ✓ Create an accurate forward model for locating the source of these currents

Problem Geometry



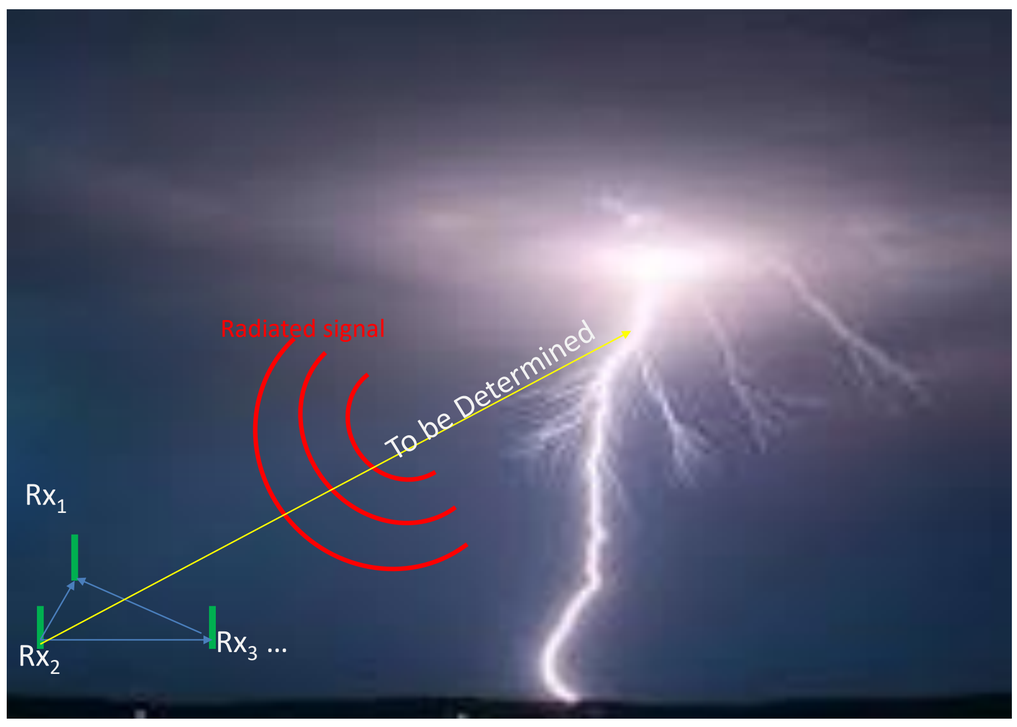
A 10x10x4 meter cube is simulated and divided into 20x20x20 cm sub-cells. Inside each sub-cell, a vector current in arbitrary directions is assumed. The magnitude of the currents were varying in time as a Gaussian function.

Currents inside Simulation Volume



$$\mathbf{J}(t) = J_o\hat{\mathbf{z}}\, e^{\frac{(t-t_0)^2}{2\alpha^2}};\ \text{where } t_0 = 2\cdot 10^{-7}[\text{sec}];\ \alpha = \frac{1}{25\cdot 10^6}[\text{sec}];\ J_0 = 1[A/m^2]$$

Goal: predict source location



Volume Integral Method Formulation

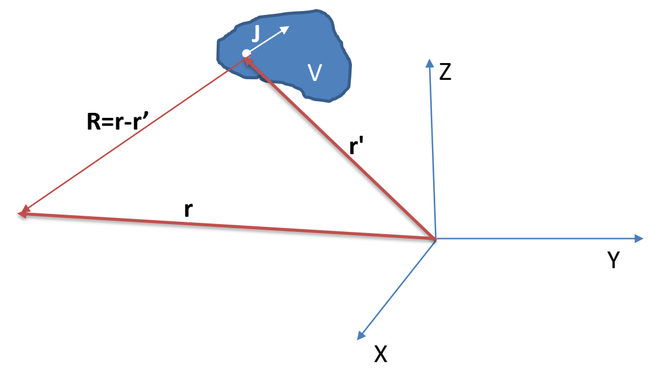
Volume integral method assumes that currents are distributed in a volume and it calculates electric and magnetic fields at a **r** observation point as

Electric field

$$\mathbf{E}(\mathbf{r},t) = \frac{1}{4\pi}\int_V \left\{ \mu \frac{1}{R}\frac{\partial \mathbf{J}(\mathbf{r}',\tau)}{\partial \tau} - \left[\frac{\rho(\mathbf{r}',\tau)}{R} + \frac{1}{c}\frac{\partial \rho(\mathbf{r}',\tau)}{\partial \tau}\right]\frac{\mathbf{R}}{\varepsilon R^2}\right\} dv$$

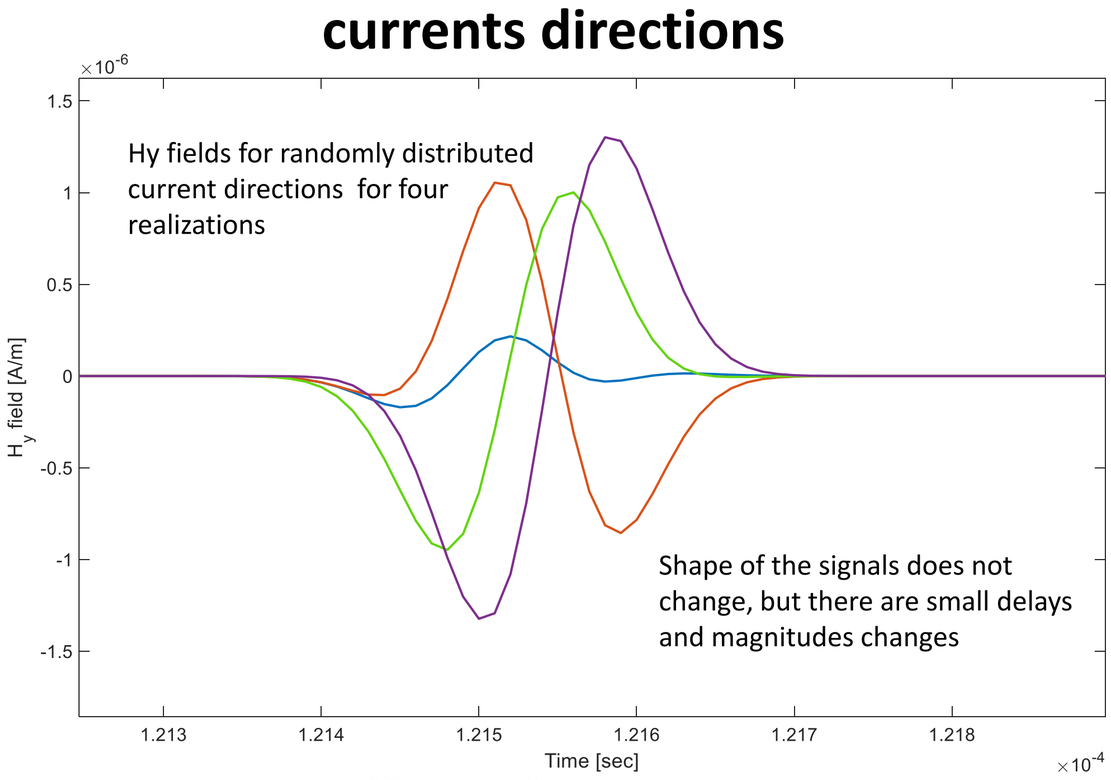
Magnetic field

$$\mathbf{H}(\mathbf{r},t) = \frac{1}{4\pi}\int_V \left\{ \frac{\mathbf{J}(\mathbf{r}',\tau)}{R} + \frac{1}{c}\frac{\partial \mathbf{J}(\mathbf{r}',\tau)}{\partial \tau}\right\} \times \frac{\mathbf{R}}{R^2} dv$$

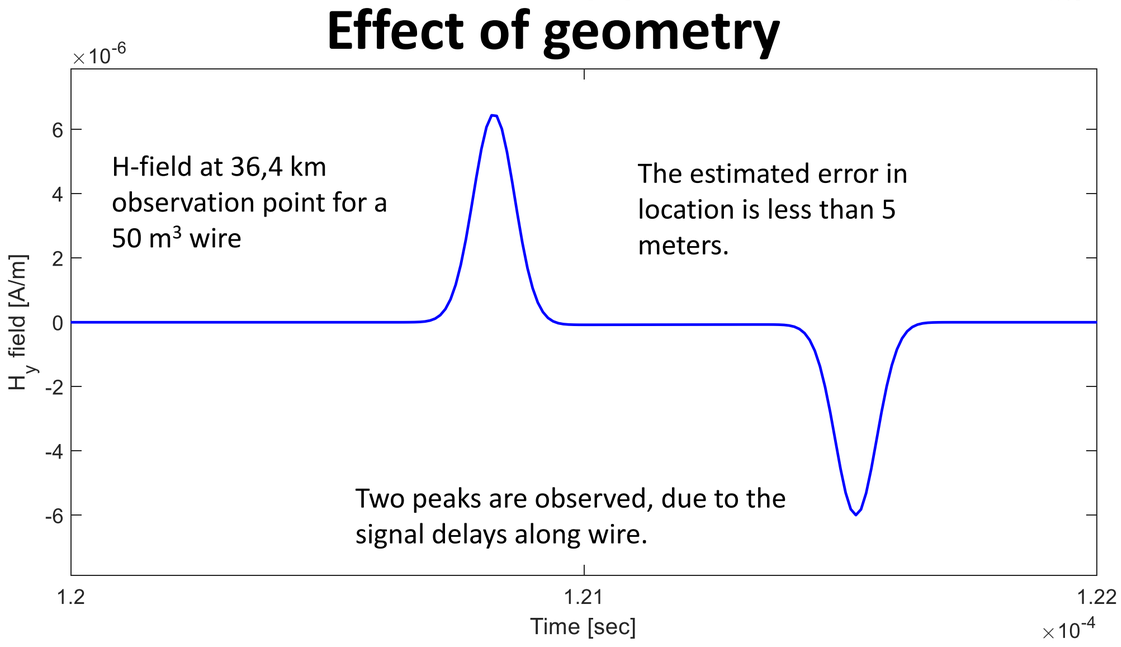


Where V is volume, **r** and **r'** are observation and source points, respectively. **R=r-r'**, R=|**R**|; c – speed of light,
ε and μ are permittivity and permeability, respectively; τ is delay time τ=t-R/c.

Effect of randomly normally distributed currents directions



Effect of geometry



Effect of additive Gaussian noise at an observation point