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FDTD Simulation of Electric Fields at Ground Level Generated by Compact Intracloud Discharges

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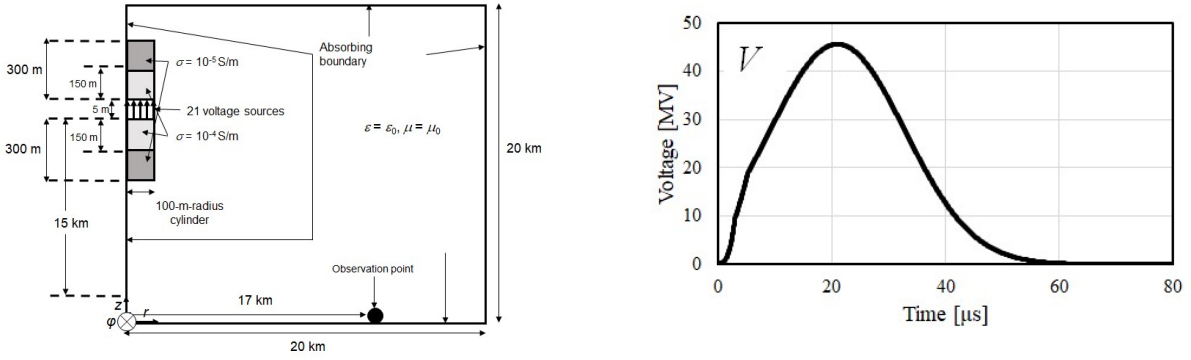
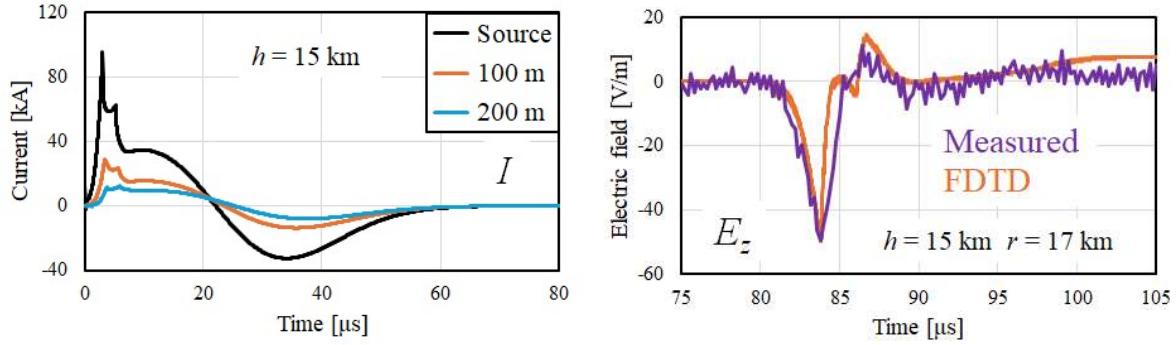
A compact intracloud discharge (CID) is characterized by a low-temperature (< 1000–2000 K) streamer structure, with conductivity orders of magnitude lower than that of ordinary lightning. The conductivity is estimated to be about 10^{-5} S/m, with higher-conductivity regions expected to be present. Its transverse dimension is estimated to be tens to hundreds of meters, while its longitudinal dimension is hundreds of meters.

In this paper, using the finite-difference time-domain (FDTD) method [1] in the 2D cylindrical coordinate system for solving Maxwell's equations, we represent CID as a large cylinder shown in Figure 1 (a), having a length of about 600 m, a radius of 100 m, and conductivity $\sigma = 10^{-4}$ to 10^{-5} S/m. It is placed at an altitude of h = 15 km above ground, excited by a pulsed voltage source at the center. The voltage source generates a voltage pulse shown in Figure 1 (b). Figure 2 (a) shows FDTD-computed waveforms of current carried by the cylinder at z = 0 (excitation point), 100, and 200 m from the voltage source. The peak value of the current at z = 0, 100, and 200 m is about 95, 30, and 10 kA, respectively. Figure 2 (b) shows the FDTD-computed waveform of vertical electric field E_z on the ground surface at a horizontal distance of 17 km from the CID-representing cylinder. Also shown in Figure 2 (b) is the corresponding E_z waveform measured in Florida, USA [2]. It appears from Figure 2 (b) that the elevated vertical cylinder shown in Figure 1 (a) can reproduce the measured CID waveform for a kiloampere-scale current pulse with duration of a few tens of microseconds.



(a) (b)

Figure 1. (a) Configuration of the computational domain in the 2D cylindrical coordinate system used for calculating vertical electric field E_z produced by a CID. (b) Waveform of excitation voltage adjusted to reproduce the measured waveforms of E_z. The peak is 45 MV, and the half-peak width is about 30 μs.



(a) (b)

Figure 2. (a) FDTD-computed waveforms of current carried by the cylinder shown in Figure 1 (a) at z = 0, 100, and 200 m from the voltage source. (b) FDTD-computed waveform of E_z on the ground surface at a horizontal distance of 17 km from the CID. Also shown is the corresponding measured CID waveform taken from [2].

References

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[2] A. Nag, and V. A. Rakov, *J. Geophys. Res.*, vol. 115, no. D14115, 2010.