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Estimation of Lightning Current Waveform for Strike to Flat Ground from Electric Field Waveform for Strike to Tall Object

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Tall objects are often struck by lightning. Electric and magnetic fields at far distances, associated with a lightning strike to a tall object, are different from those associated with the corresponding lightning strike to flat ground. Specifically, in the case of strikes to tall objects, the waveforms are oscillatory because of current reflections at the top and bottom of tall strike object. It would be of great use if the waveform of current in the case of lightning strike to flat ground could be estimated from the measured waveform of far electric or magnetic field in the case of the corresponding strike to a tall object.

In this work, a procedure to reconstruct the waveform of far electric field due to the lightning strike to flat ground from the corresponding waveform of far electric field due to a lightning strike to a tall object. Once the effect of tall strike object is removed from the measured field waveform, the resultant flat-ground waveform (along with a return-stroke model) can be used [1] for inferring distribution of lightning current both along the channel and along the strike object. Computations of far electric fields due to lightning strikes to tall objects are carried out using the finite-difference time-domain (FDTD) method [2] in the 2D cylindrical coordinate system. The lightning return stroke is represented by the modified transmission-line model with linear current decay with height (MTLL) [3].

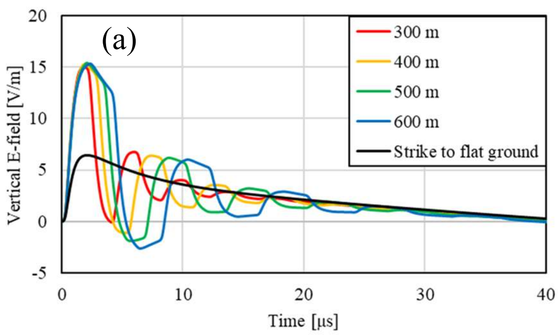
The electric field due to the corresponding lightning strikes to flat ground, estimated from the electric field due to a lightning strike to a tall object, is given as follows:

$$E_{z\_flat.est}(t) = \sum_{n=0}^{\infty} \frac{\alpha^n}{k_{tall}} \left[E_{z\_tall}\left(t - \frac{2nh}{c}\right) - \rho_{bot}\rho_{top} E_{z\_tall}\left(t - \frac{2(n+1)h}{c}\right) \right] \quad (1)$$

$$\alpha = \left[\frac{2k_{tall}}{(1+\rho_{bot})(1-\rho_{top})} - 1 \right] \left(\frac{E_{z\_tall.min}}{E_{z\_tall.max}} - \rho_{bot}\rho_{top} \right)$$

where n is zero or the positive integer, $t_{tall.max}$ is the time at which the electric field due to a lightning strike to a tall object attains its first peak, $E_{z\_tall.maximal}$ is the first peak of the field due to the lightning strike to the tall object, $E_{z\_tall.min}$ is the minimal value of the field due to a lightning strike to a tall object right after the first peak.

Figure 1 (a) shows FDTD-computed waveforms of electric field at a distance of 50 km from the lightning channel due to lightning strikes to 300, 400, 500 and 600-m tall objects and to flat ground. Figure 1 (b) shows waveforms of electric field, due to the corresponding lightning strikes to flat ground reconstructed from the FDTD-computed waveforms shown in Figure 1 (a).



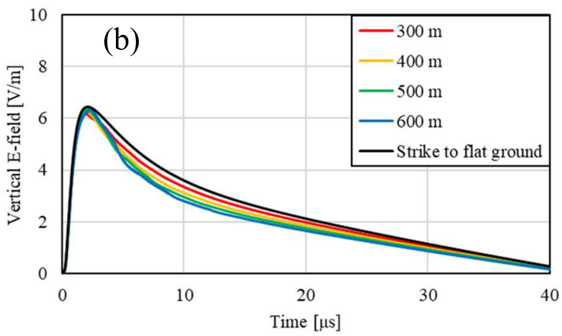


Figure 1. (a) FDTD-computed waveforms of electric field, due to lightning strikes to 300, 400, 500 and 600-m tall objects and to flat ground, at a distance of 50 km from the lightning channel; (b) Same as (a), but with the effect of tall strike object removed.

References

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