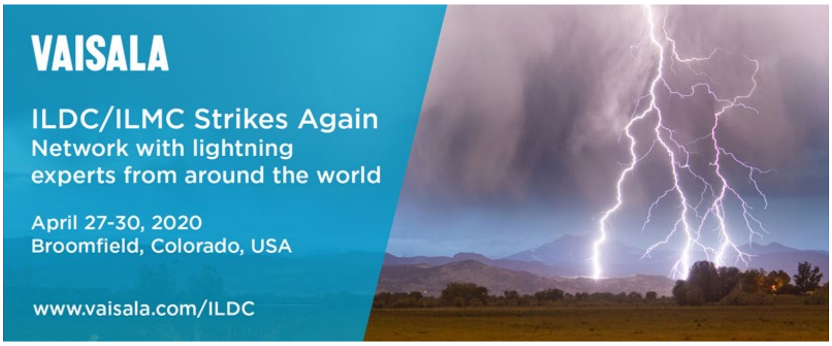

Application of Electromagnetic Time Reversal to Lightning Geo-Localization: Recent Advancements

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Abstract

The performance of LLSs is measured by their detection efficiency, location accuracy and the accuracy of their peak current estimation [1]. Time-of-arrival (ToA), Magnetic Direction Finding (MDF), and a combination of these two methods are the most widely used techniques by commercial Lightning Location Systems (LLSs) to locate lightning discharges [2]. The ToA method uses the onset time and/or the peak time of fields recorded at multiple sensors to locate the discharges. Hence, only some features of the field waveform information are used to locate the discharge and not the overall waveform. Moreover, the presence of scatterers and the terrain topography are generally not considered in these approaches.

Recently, Electromagnetic Time Reversal (EMTR) was proposed for the first time by Mora et al. [3] to locate lightning discharges. In the electromagnetic simulations required by the EMTR method to obtain the location of the lightning source, they removed the singularity produced by the 1/R distance dependence of the radiation field in the time reversed electric field propagation and they determined the point at which the back-injected wave-fronts from all the sensor locations are in phase. The developed method would need at least 3 sensors to locate the discharge. In following work by Lugrin et al., the effect of propagation along lossy ground was considered [4]. The practical implementation of EMTR-based LLSs was investigated by Karami et al. [5].

More recently, an EMTR-based VHF localization platform was implemented by Wang et al. [6]. Moreover, a combination of TDoA and EMTR was implemented in the VLF band to locate lightning discharges [7].

The EMTR source location process includes 4 steps: 1) The electric field waveform from the source (e.g., the lightning strike point) is calculated or measured by sensors in the so-called forward time. 2) The recorded electric field waveforms are time reversed. 3) The time-reversed signals are back-injected at the sensor locations using a numerical simulator (backward time). 4) A criterion is used to obtain the location of the source (e.g. maximum electric field or energy metrics).

However, in all of the above-mentioned studies, the 1/R attenuation of the wave in the back-propagation stage is not considered when the maximum field criterion is used in step 4. However, this assumption cannot be applied to numerical methods that are commonly used in many electromagnetic simulators, such as those in commercially available software. On the other hand, removing the 1/R dependence is not applicable in the case when the medium contains one or more scatterers in the computation domain.

In this paper, we propose a novel EMTR scheme based on a full-wave electromagnetic solution. In such an implementation, all features of the recorded electric field can be used to locate the lightning discharge rather than only the onset time and peak time values. The minimum entropy criterion suggested in [8] is used to obtain the proper time slice in which to look for maximum constructive interference of the back-propagated fields. We show that for a two-dimensional localization, in the presence of at least two scatterers, using only two sensors will provide lightning geo-localization.

Attachments

Screenshot_2019-10-29_at_12.05.16.png

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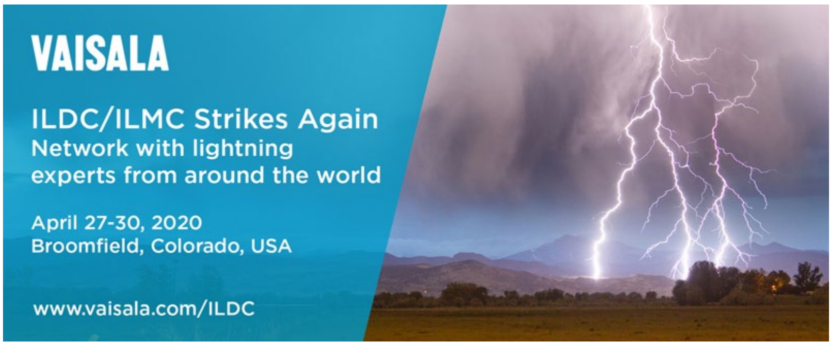

Topic Areas

Lightning Detection Systems Technology and Performance

Submission Format

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