4th URSI AT-RASC, Gran Canaria, 19 – 24 May 2024

Remote Sensing of Source Currents of Narrow Bipolar Events Using Measured Electric Fields

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Extended Abstract

Narrow bipolar events (NBEs), also known as compact intracloud discharges, are highly impulsive sources of electromagnetic radiation in the Earth's natural environment that occur in association with initiation of lightning discharges or in isolation inside thunderclouds. The electromagnetic signatures of NBEs are bipolar waveforms with a short risetime (1-2 μs), pulse width of few tens of microseconds, and opposite polarity half-cycle of lower amplitude and longer duration than the initial half-cycle [1, 2, and references therein]. A class of models known as transmission line models have commonly been employed for the interpretation of NBEs [e.g., 3, 4, 2]. They model the source currents which best reproduce the observed electromagnetic signals. However, these models require the tuning of several inter-dependent parameters that do not have a physical grounding or clear relevance to these isolated sources. In this work the wideband electric field waveforms of NBEs measured at remote locations are used to extract the exact current waveform of the source discharge. All calculations correspond to a vertical linear current source above a perfectly conducting ground plane. The current study uses standard frequency domain analysis of electromagnetic fields, and develops a deconvolution based technique to obtain exact reconstruction of the source current. The frequency domain formulation to calculate the electromagnetic radiation has never been employed in the context of lightning related discharges, and offers a simple and efficient alternative to conventional time domain calculations. The proposed method does not require the tuning of several parameters, and so improves upon previous modeling efforts. The developed model assumes that the observed radiation is emitted due to polarization of a conducting region in externally applied electric field [5]. The approach is grounded on previous first principles modeling of the polarization process, indicating that the polarization current should be maximum in the middle of the conducting region, and zero at the ends [5]. Such a polarization current results in a source that can be interpreted as an electric dipole, completely charaterized by its dipole moment. This first order physics based interpretation does not require specification of the ionization mechanism creating the conducting region, but allows exact reconstruction of the source current. The wideband NBE waveforms observed by Rison et al. [2], and Eack [1] are used to demonstrate and validate the results of the proposed method. The source currents obtained for each NBE using the proposed method exactly reproduce the respective observed electric field waveforms, including all their finer details.

References

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