

Thunderstorm observations by the operational VHF broadband digital interferometer

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The VHF broadband digital interferometer (DITF) is a system to locate the source of a wideband impulsive EM wave caused by lightning progression in VHF band. The source locations of the VHF impulses provide not only the image of lightning progression channel but also the charge distribution inside thunderclouds.

Lightning discharges, both CG and CC flashes, are the phenomena, which continue for one or at most two seconds. However, if we think about these phenomena from the aspect of science, like the comparison with the lifetime of free electrons in the atmosphere, various processes are occurred continuously and electromagnetic (EM) waves in corresponding frequency ranges are radiated. Hence the obtained information from the locations of the EM radiation source depends on the target frequency. For EM signals in VHF/UHF band, the whole lightning channel can be imaged in three-dimensions (3D).

A new type of lightning location and monitoring system has been developed based on a technique of VHF broadband digital interferometry. The remarkable feature of the VHF broadband DITF is its ultra-wide bandwidth and implicit redundancy for estimating the location of a VHF impulse source. The schematic of broadband digital interferometry is calculating phase difference between EM signals captured by two properly separating antennas, and this procedure is applied to each Fourier component of broadband EM pulses. Since it is well known that one lightning flash emits a few thousands of VHF impulses mainly from the tip of breakdown, the location for their sources are equivalent to imaging the lightning channel development. As a first step of the developing, we install an experimental system and conduct field campaigns for lightning observations.

The accuracy or error estimation of the VHF broadband DITF is discussed to validate the performance. A computational approach is carried out calculating the EM fields and the effectiveness of the proposed technique is demonstrated numerically. The obtained by the experimental DITF are compared with observations by video camera, classical narrowband interferometer, weather radar, and so forth. The error evaluations in terms of dispersions, Fourier components, and interactions are also discussed.

The use of the VHF broadband DITF to study charge distribution inside thunderclouds is proposed. Case studies focused to positive CG flashes during winter thunderstorm season, the altitude and the quantity of positive charges inside thundercloud, J- or K- processes, and the leader progressions especially its initiation of negative CG flashes are implemented.

The authors intend to realize an operational VHF broadband DITF for thunderstorm monitoring, recently. Real-time monitoring of thunderstorm is attempted. The advanced system is developed on the recent progress of electronics to obtain highly performance. A VHF broadband DITF on board a satellite is being planed as well.