Measurement of Sensitive Current and Charge Motion Using Coherent Averaging of Remote Low Frequency Magnetic Field Observations

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Measuring lightning charge transfer, especially on time scales longer than several milliseconds, is a challenge. Instrumented towers can measure this quantity precisely but only for a tiny fraction of cloud-to-ground lightning. Electrostatic field measurements of lightning signals can provide robust estimates of this quantity, but the fast decay with distance of the electric field limits the measurement range to roughly 100 km at best. In contrast, low frequency and nearly-static magnetic fields from slowly varying lightning current decay much more slowly with distance and can therefore be measured at very long ranges. By measuring these low frequency magnetic fields, it is possible to broaden the geographic reach of lightning charge measurements. Sensitivity and noise, however, often limit these measurements to very large charge transfer lightning.

Using data collected via search coil magnetic field sensors, we show how time-aligned coherent summation of many signals from lightning in a small geographic window can dramatically reduce the noise and thus enable the measurement of average (not individual) lightning currents and charge motion with very high precision and sensitivity. These average values (especially for long continuing currents) are often below the noise floor of remote measurement systems, especially for systems operating at long ranges (thousands of km) from the individual lightning events. Furthermore, by calculating averages over many thousands of lightning events, it is possible to achieve robust averages of different types of lightning under different storm conditions. Increasing the number of events analyzed further decreases the average noise received by the system, thus yielding improved results.