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LOFAR for lightning-interferometery and mapping

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We show that a new observation mode at the Low Frequency Array (LOFAR) for Lightning-Interferometery and Mapping (LIM) allows for lightning observations with a resolution that is at least an order of magnitude better than presently operating Lightning Napping Arrays LMAs. Furthermore the polarization of the signal can be used to reconstruct the direction of the discharge.

LOFAR, consisting of many thousands of antennas, is a digital radio telescope, primarily build for astronomy observations. The Low Band Antennas (LBA) we use for this work are sensitive to the frequency range of 10 - 90 MHz and consist of two inverted V-shaped dipoles. The antennas are grouped in stations consisting of 48 LBA spread over an area with a diameter of about 30 m for which the relative timing is known accurately. The LOFAR core of approximately 2 km diameter contains 24 such stations located near Exloo in the north of The Netherlands. Remote stations for LIM may lie at a distance of 100 km from the core. Signals are sampled at 200 MS/s (sampling time of 5 ns). All antennas are equipped with ring buffers, that store the raw voltage traces for up to 5 s. When a trigger is received, for example with a lightning flash, the ring buffers are frozen and their contents are copied over the network to a central storage location.

We will show an initial analysis of data taken on June 19, 2013, for a thunderstorm at a distance of some 50 km from the telescope. The source location and emission time for each event (lightning step) is found by fitting the arrival times of the pulses for each separate antenna adjusting the station offsets, keeping them the same for all events. The fit reproduces the measurements with an accuracy of about 1 time sample.

Interestingly much fine structure is seen in the time-traces and examples will be shown for some events. The time traces for antennas in different stations are very similar and thus not due to noise. We also see a clear polarization-dependent structure for the pulse.

The strongly linearly polarized nature of the pulses is corroborated by model calculations showing that this as well as the angular distribution of the emitted radiation can be used to determine the direction of the discharge step. The fine structure of the measured pulse should reflect the time profile of the currents.

We are developing an interferometric procedure which will allow us to go beyond single-sample (5 ns) precision to achieve sub-nanosecond timing accuracy. Combined with base-lengths in excess of 50 km this will give us an improvement in resolution by one order of magnitude over existing LMAs.
It is of much interest to combine the LOFAR-LIM observations with our recently developed non-invasive method for determining the electric-field in thunderclouds.