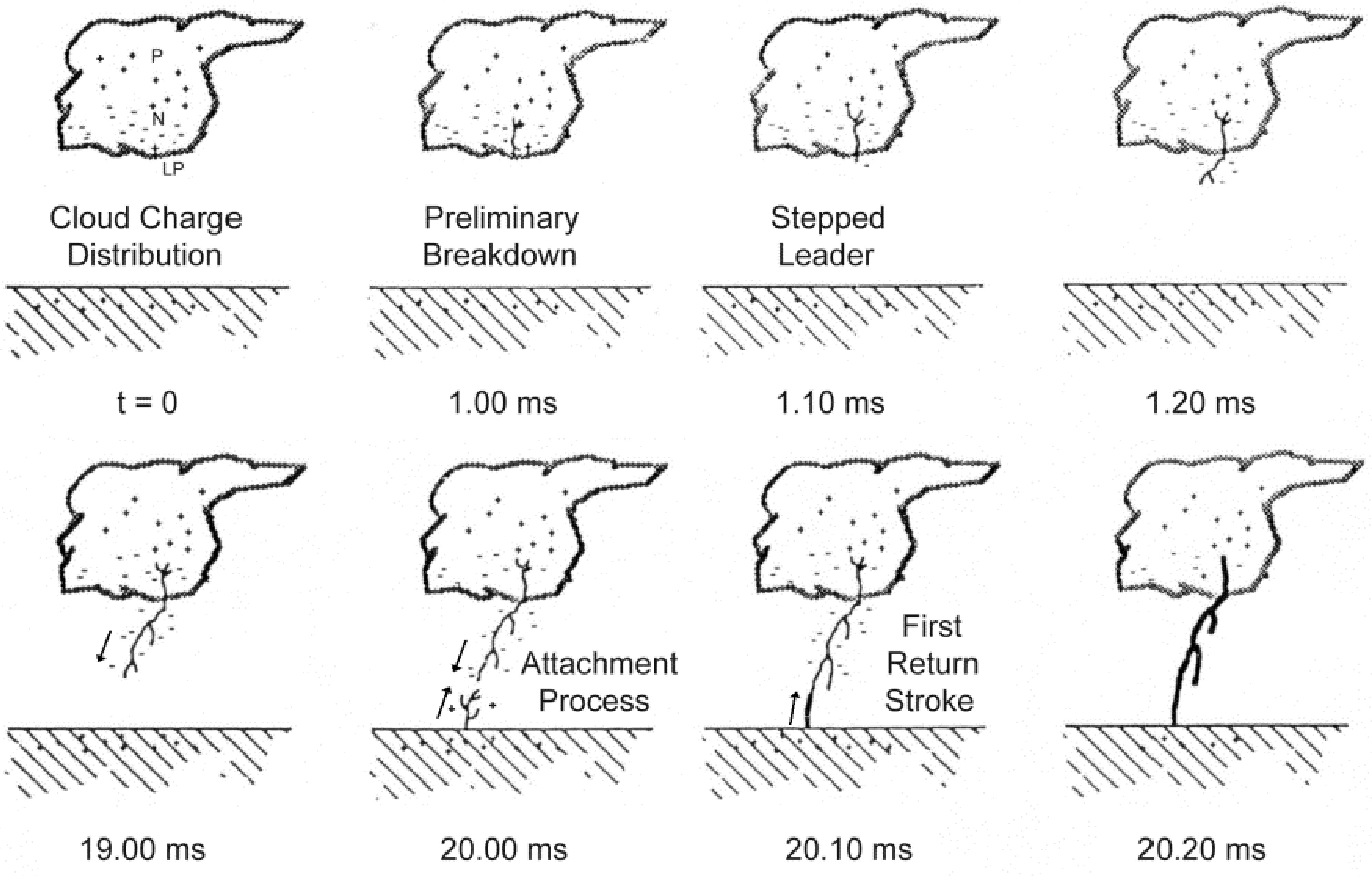
LOFAR for Lightning Interferometry and Mapping

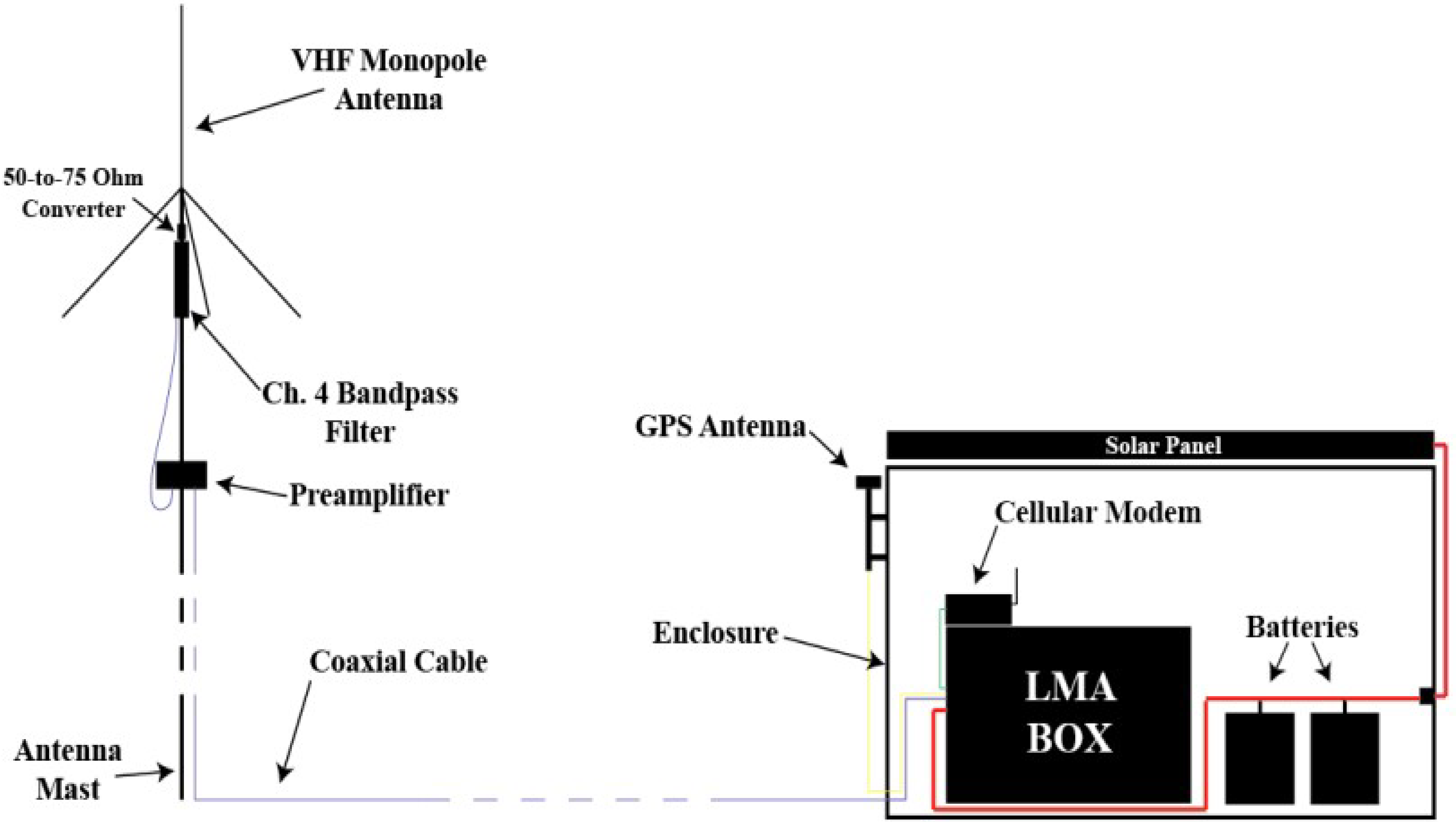
Brian Hare

A. Bonardi, S. Buitink, A. Cornstanje, U. Ebert, H. Falcke, J.R. Hörandel, P. Mitra, K. Mulrey, A. Nelles, J.P. Rachen, L. Rossetto, C. Rutjes, P. Schellart, O. Scholten, S. Thoudam, T. N. G. Trinh, S. ter Veen, T. Winchen

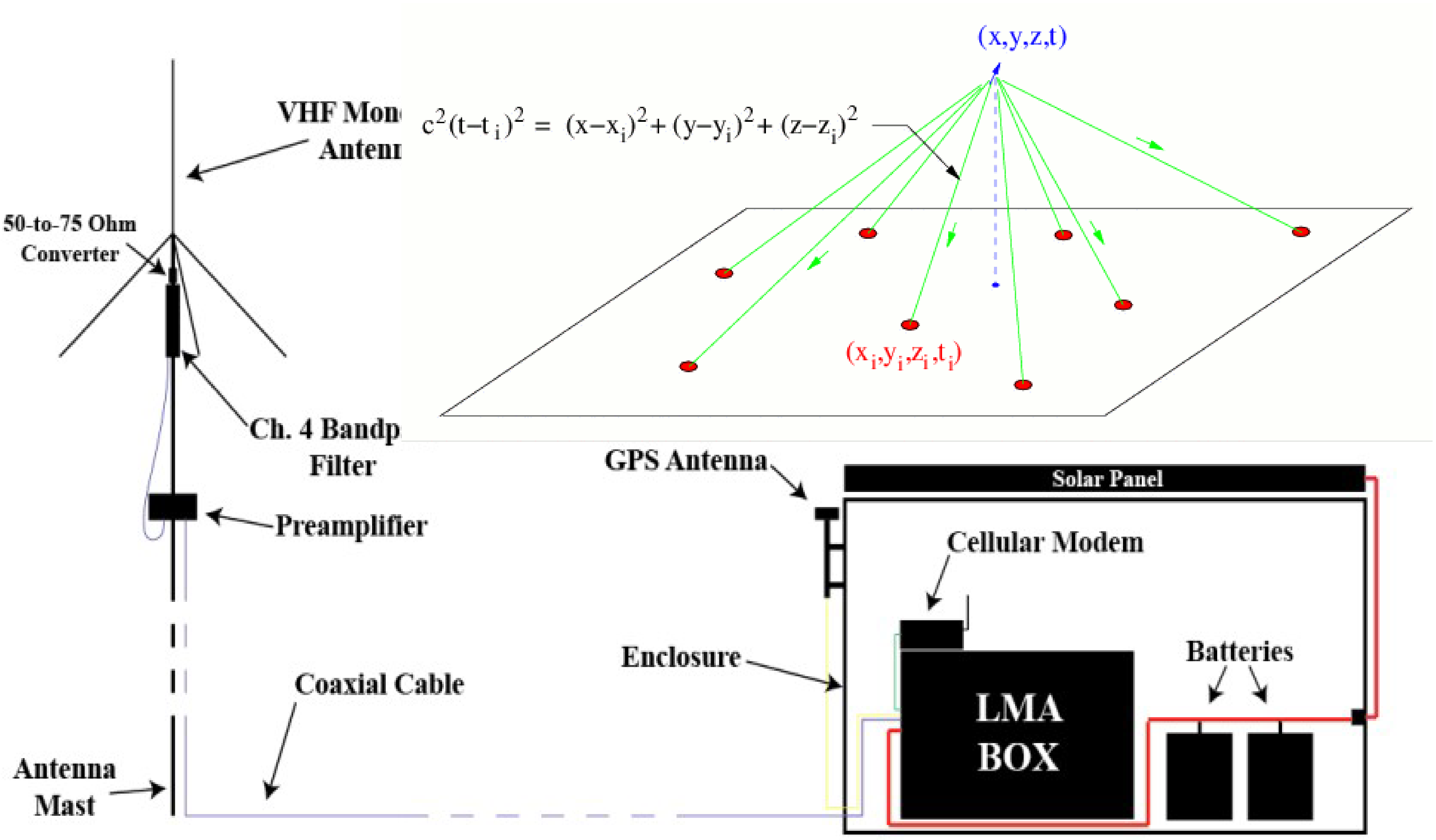
Processes During Downward Negative Lightning



Lightning Mapping Array



Lightning Mapping Array



LOFAR	Typical LMA
Nanosecond timing precision	70 nanosecond timing precision
Nanosecond resolution between different pulses	Only the strongest pulse in 10 microseconds
Save raw antenna trace data	Only save time and amplitude of each pulse
Save Polarization Information	Only sensitive to z-component of electric field
Broad band: 10 Mhz to 90 Mhz	Narrow band: 66 Mhz to 72 Mhz
Operates in Triggered Mode	Continuous Monitoring

Present Steps in Mapping Procedure

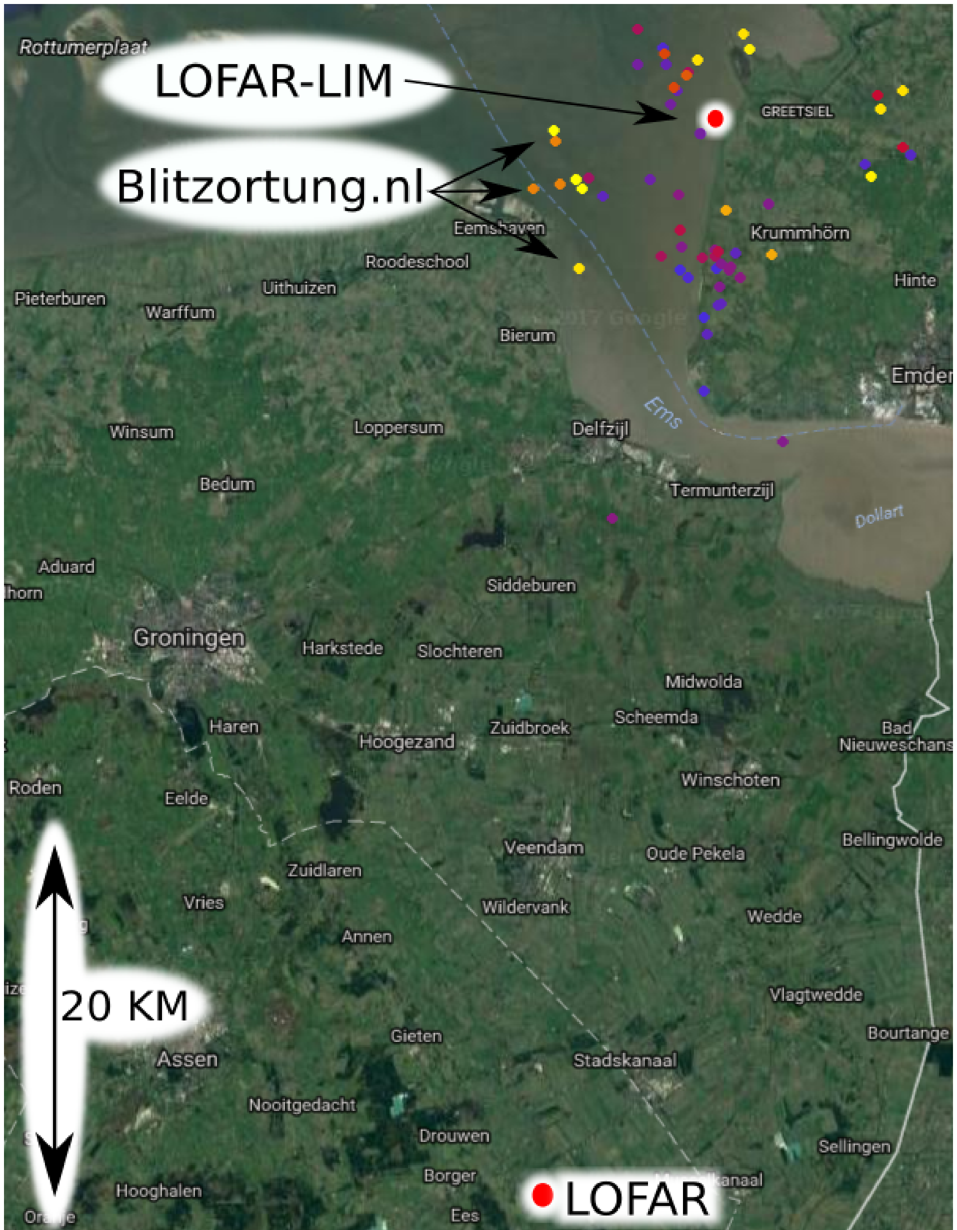
1) Find pulses in TBB data

2) Find station timing offsets
   a) Groups pulses in a station into plane wave events
   b) Group strongest plane wave events into point source events
   c) Simultaneously fit locations of point source events and station timing offsets

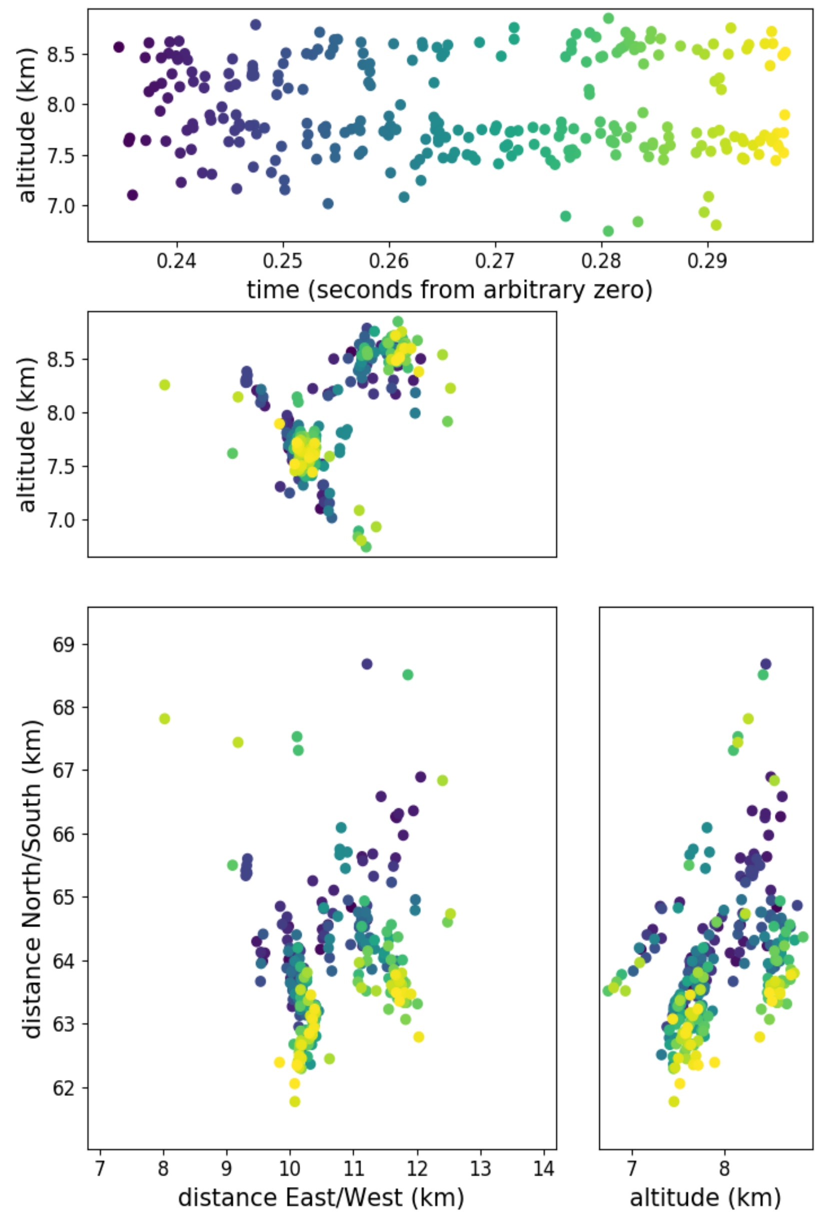
3) Group as many pulses as possible into point source events, fit location of each event

The 19 June 2013 Flash

zoomed out



zoomed in

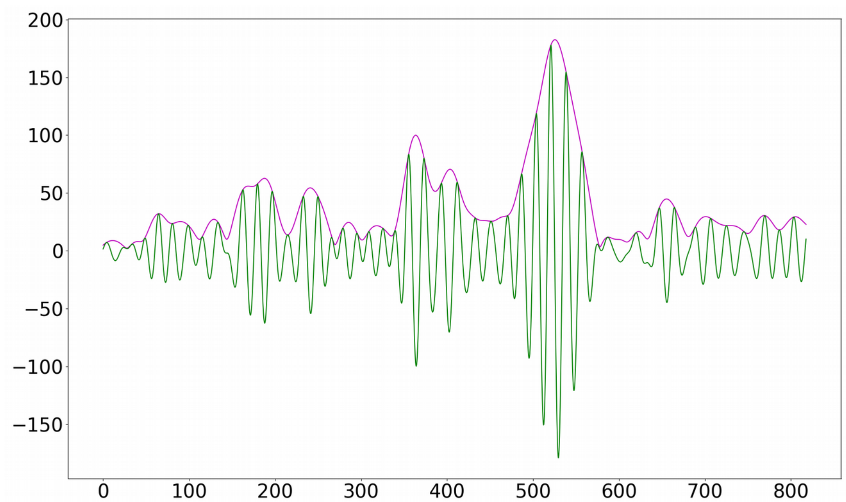


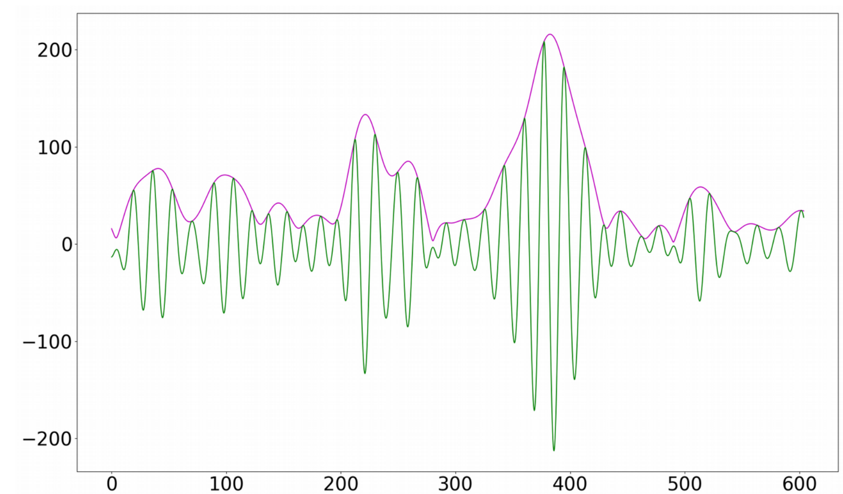
Rich Pulse Structure

Core Station

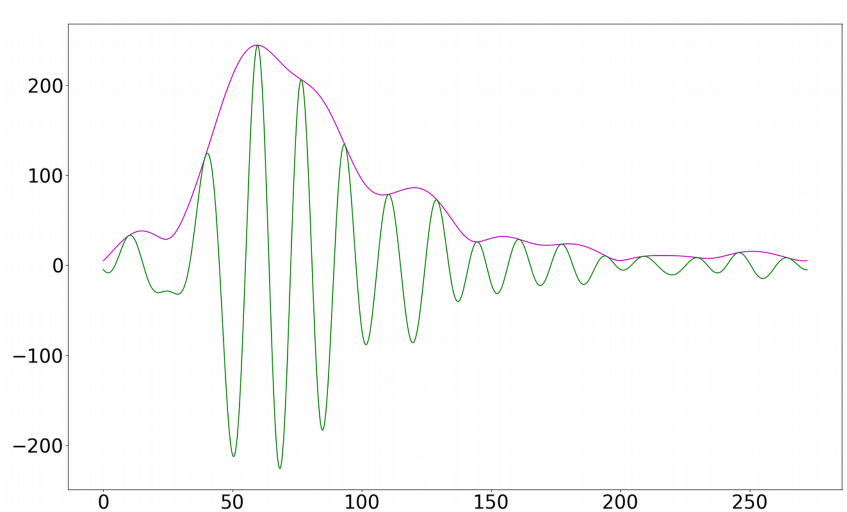
Remote Station
3 km north of core

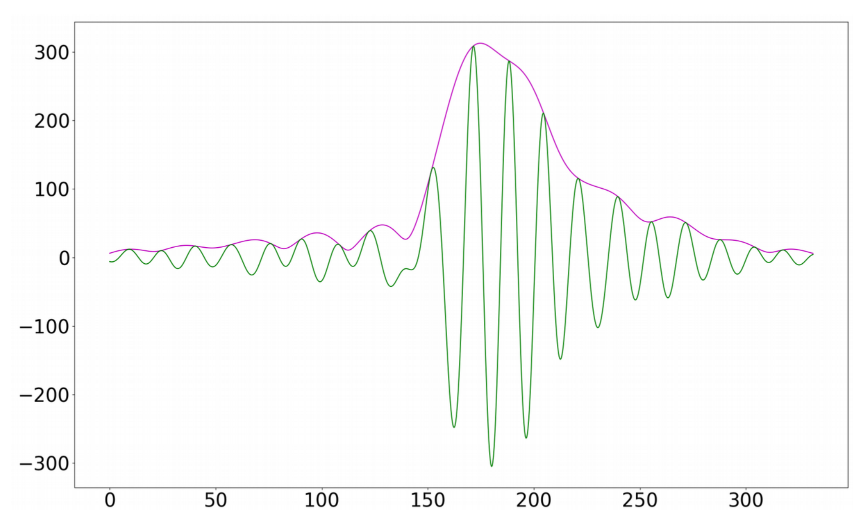
Event 1





Event 2





Time (ns)
arbitrary zero

Time (ns)
arbitrary zero

Rich Pulse Structure

differences in polarization

North-South Polarization

East-West Polarization

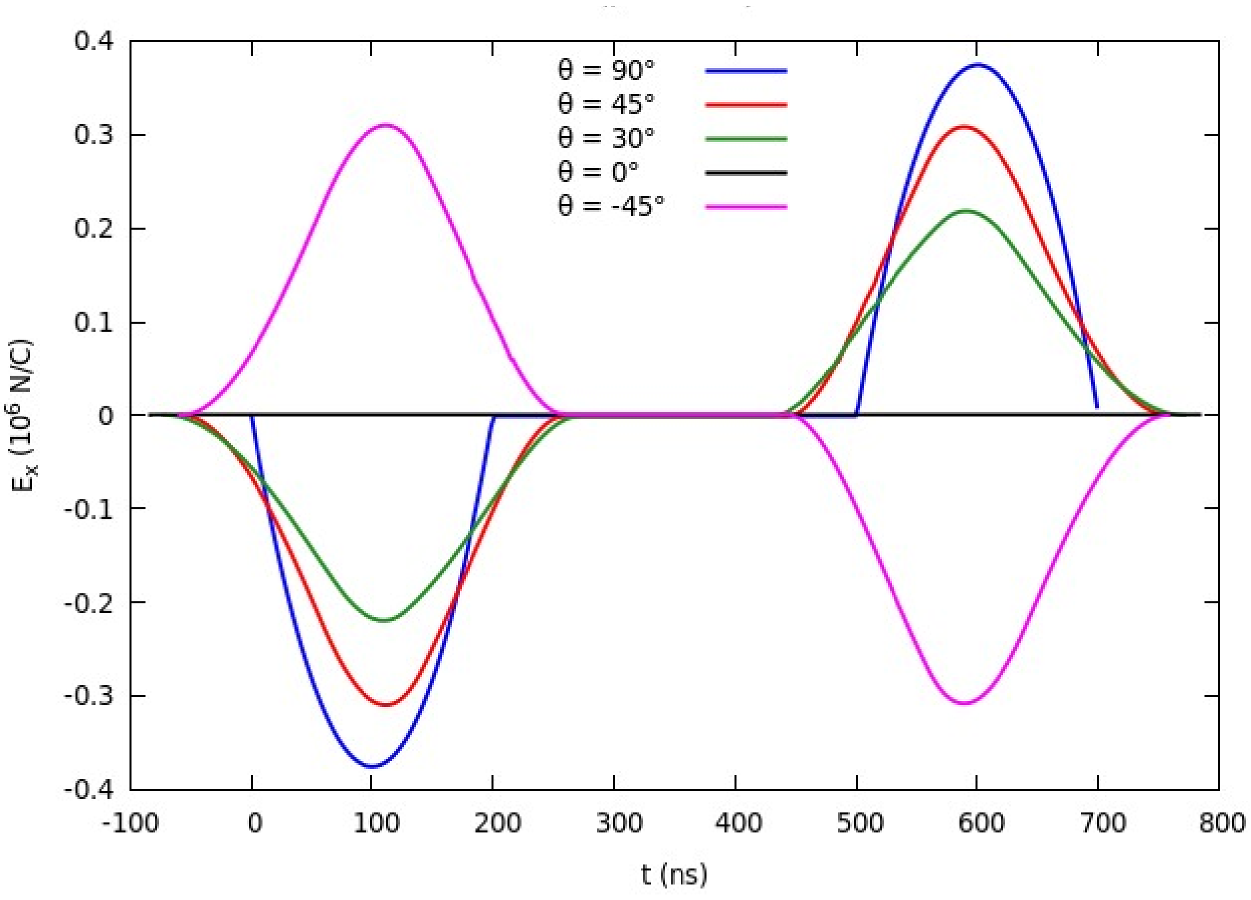
Event 1

Event 2

Time (ns)
arbitrary zero

Time (ns)
arbitrary zero

Interpretation of Pulse Structure



- Each leader step could be viewed as charge jumping forward
- Each jump will produce a bipolar pulse
- Simulation (to left) shows electric field due to charge jumping forward with parameters:
  - 50 m step size
  - 200 ns rise time
  - V_{max} = C/3

Conclusion

- We can map lightning with LOFAR with order of magnitude better precision and resolution than typical lightning mapping arrays.

- Trace data contains rich structure in a frequency regime that is not well studied in lightning science

- LOFAR can be instrumental to making progress in lightning science