The Development of the Lightning Detection Network based on Boltek StormTracker hardware

Fedor A. Kuterin[1*] Alexey A. Bulatov[1] and Yuriy V. Shlyugaev[1]

[1]Institute of Applied Physics of the Russian Academy of Sciences

ABSTRACT: The Lightning Detection Network in Nizhny Novgorod region dedicated to the academic research of meteorological phenomena has being developed. Six Boltek StormTracker PCI-Receivers with LTS-2 Timestamp Cards with GPS and lightning detectors were integrated to PC-workstations running the Ubuntu linux operating system. These PC-workstations with integrated lightning detectors were installed at six observation points placed in Nizhny Novgorod and Nizhny Novgorod region. The PC-workstations are left on permanently in order to monitor lightning activity at all times. Each has wired Internet connection allowing almost instantaneous data transfer to a central server running MySQL database in Ubuntu Linux. Information collected in database is processed by a program developed by us called the LDN-processor. The LDN-processor analyses the data from each client and performs event triangulations using time-of-arrival and direction-finding algorithms. It uses the correlation analysis.

DIRECTION FINDING BASED ON MAGNETIC FIELDS MEASUREMENT

Two crossed magnetic antennas (one focused on south-north direction and one on east-west direction) recive magnetic field $\vec{B}(t) + \Delta\vec{B}(t)$ as two components $B_{SN}(t)$ and $B_{WE}(t)$ over the time from $t = 0$ to $t = T$, where $\Delta\vec{B}(t)$ is a random error. At any time, we can get the intended direction of the source of signal, based on the ratio of the component

$$\alpha(t) = \arctan\left(\frac{B_{WE}}{B_{SN}}\right) \tag{1}$$

To minimize error $\Delta\vec{B}(t)$ we intagrate vector $\vec{B}(t)$ by t and get its average value that used for obtainig direction α:

$$\alpha = \arctan\left(\int_0^T \mathrm{sign}(B_{WE})B_{SN}dt \Big/ \int_0^T |B_{WE}|dt\right). \tag{2}$$

Figure 1 illustrates this operation. Integration of $\vec{B}(t)$ corresponds to the curve shown in figure. Measure of precision (denote it γ) of determining α is a distance between start and end of this curve divided by its length.

$$\gamma = \sqrt{\left(\int_0^T \mathrm{sign}(B_{WE})B_{SN}dt\right)^2 + \left(\int_0^T |B_{WE}|dt\right)^2} \Big/ \int_0^T |\vec{B}|dt. \tag{3}$$

Using bearings from several observation points, we obtain the coordinates of lightning flash as a solution of the minimization problem

$$D(\varphi,\theta) \equiv \sum_i \gamma_i(\alpha(\varphi,\theta,P_i) - \alpha_i)^2 \to \min, \tag{4}$$

where P_i is observation point with number i, α_i is bearing to the signal source registered by the observation point P_i, γ_i is measure of precision of bearing determining, $\alpha(\varphi,\theta,P_i)$ is bearing to the point with coordinates (φ,θ).

*Corresponding author, email: xredor@gmail.com, Postal address: 46 Ulyanova street, Nizhniy Novgorod, 603950, Russia

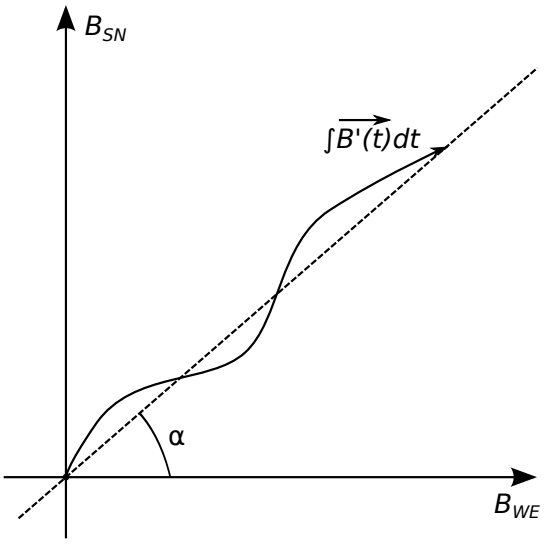

Figure 1: Averaging of vector $\vec{B}'$

TIME OF ARRIVAL METHOD

We consider source of electromagnetic signal recieved by few observation points (figure 2) Suppose there was a single lightning discharge at point A with latitude θ and longitude φ at the moment t_0. Electromagnetic signal from it was recieved at points P_1, P_2, P_3, at the moments t_1, t_2, t_3. In ideal case the equations are right:

$$t_1 - t_0 = \rho(A, P_1)/c, \quad t_2 - t_0 = \rho(A, P_2)/c, \quad t_3 - t_0 = \rho(A, P_3)/c, \tag{5}$$

where c is light velocity, ρ is distance on Earth surface.

We can determine the coordinates of lightning flash by solving of the minimization problem

$$U(\varphi, \theta) = \sum_{i \neq j} [(t_i - t_j) - (\rho(A, P_i)/c - \rho(A, P_j))/c]^2 \to \min. \tag{6}$$

COMBINED METHOD

The above-described methods for determining the position of the signal source can be combined. . We combine functions D from (4) and U from (6) using linear combination:

$$Q(\varphi, \theta) = \xi D(\varphi, \theta) + \psi U(\varphi, \theta) \tag{7}$$

While minimizing combined function (7) we can find the position of the source, based on both methods described below. Coefficients ξ and ψ define the degree of confidence to each method.

TECHNICAL NOTES

Common structure of lightning detection system is shown on figure 3. It contains few observation points, permanently collecting information throughout the convective season, and a central processing server that stores, structuring and analyzing information.

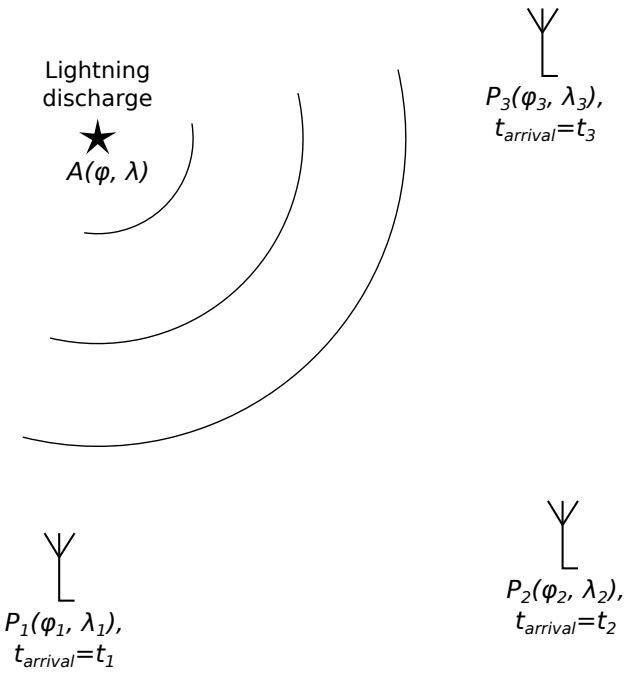

Figure 2: Multipoint lightning detection system

Lightning detection point

Observation point is a personal computer, equipped with PCI-card Boltek Stormtracker with LTS-2 extension. Two crossed magnetic antennas and one whip electric antenna plugged to Boltek Stormtracker card. For precision timestamping used GPS reciever. Magnetic antennas used for raw magnetic field writing and electric antenna used for determining of moment of arrive electromagnetic signal from lightning discharge. To recording and sending data we develop special software. For stability reason data stored on local machines at the observation point and in cenral database. In case of disconnection recorded data will be transferred after the reconnection.

Lightning detection processing center

MySQL database used for storage of raw data and calculation results. Special software called LDN-Processor used for calculation of lightning positions by raw data measurements. Data processing software numerically implements the methods described previously:

1. Recognizes among the discharges the space-time clusters.
2. For each cluster solves the problem of finding minimums of the function (7).
3. Solves clusterization problem for local minimums of the functions (7) on earth surface.

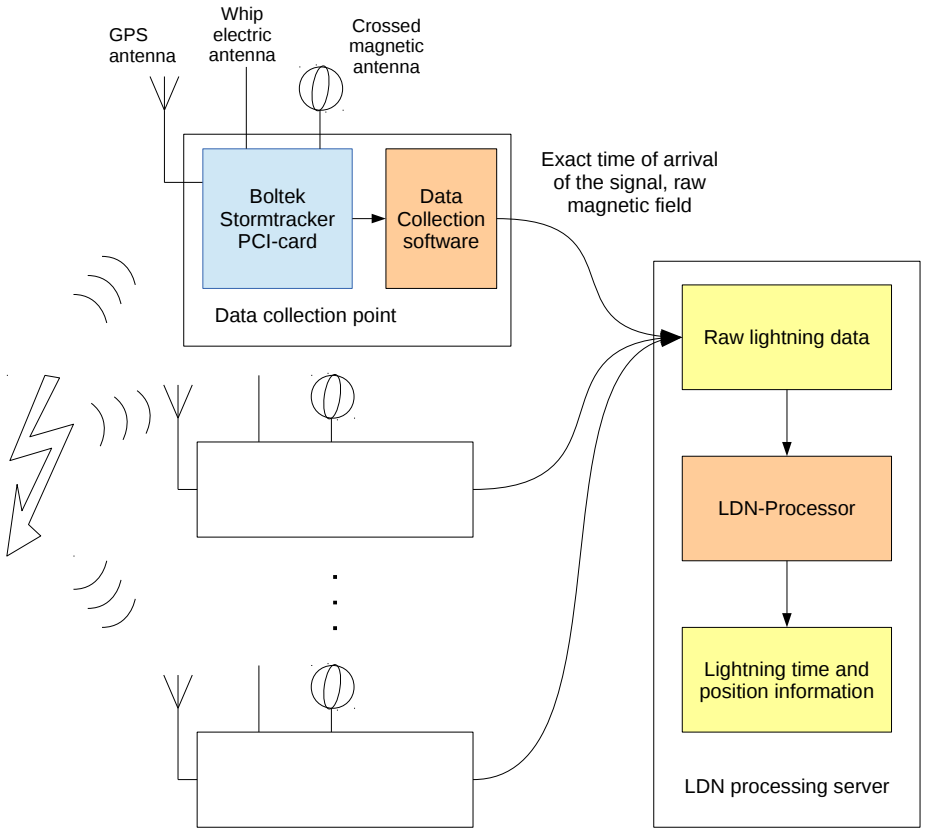

Figure 3: Lightning detection system

CONCLUSIONS

The Lightning Detection Network in Nizhny Novgorod region dedicated to the academic research of meteorological phenomena has being developed.

Effective methods of determining the position of lightning discharges are implemented.

The visualization software also developed.

ACKNOWLEDGMENTS: This work was supported by the Russian Government (contract No. 14.B25.11.0023) and the RFBR (project No. 13-05-12103).

References

Boltek, http://www.boltek.com/.