Spatio-temporal analysis of LOFAR scintillation measurements.

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Scintillation of beacon satellite signals or distant cosmic radioemissions can provide interesting information on the cosmic medium itself, its internal spatial structure (spatial power spectra), basic evolution characteristics (drift velocity and its dispersion) etc.

In this talk we focus on drift velocity estimation of diffraction pattern observed on the ground using scintillation mode observation of LOFAR (Low Frequency Array) VLBI radiotelescope. The Low Frequency Array (LOFAR) is an excellent astronomical instrument as well as the very useful tool for studying irregularities in the ionosphere. Due to its operational frequency range (10-270 MHz), LOFAR is very sensitive even to very small changes in ionospheric electron density. The interferometric nature of the instrument allows for the multi-point observations, and, thus gives the possibility for ionospheric scintillation measurements over distances ranging from tens of meters to hundreds of kilometers.

The project for scintillation monitoring over the LOFAR stations has been carried out for several years and a large amount of data has been collected and stored in the Long Term Archive (LTA). Available data contain signal amplitude for a few strongest radio sources (A Team) measured at all core and remote stations. Based on the LTA data, correlation analysis between stations can be made in order to obtain information about the characteristics of ionospheric structures.

Derivation of medium evolution involves multipoint measurements analysis. When stationarity (homogeneity) assumption is reasonable the two methods are used to derive evolution characteristics the cross-correlation analysis, and the dispersive (cross-spectral) analysis. First relate characteristic features on auto- and cross-correlation function, the second makes use of phase of the cross-spectrum giving also information about dispersion and both can be related to one another by Wiener Kchinchin theorem.

Data used for this analysis come from observations of Casiopeia signal amplitude during three different geomagnetic conditions made by LOFAR core and remote stations. L547449 observations took place during the calm period, the L547785 is a phase of relaxation of a small geomagnetic disturbance, and L552177 was measured during the main phase of the magnetic storm.

Here we validated hypothesis of frozen-in drift of ionospheric plasma irregularities assuming weak scattering regime of propagation. The basic modeling gives linear dependence of time lag to the cross-correlation maximum on separation vector which is the case for at least disturbed periods. Moreover, it seems, that for quiet conditions the dependence can be nonlinear. The method presented gives estimate of drift velocity too, taking into account possible anisotropy of irregularities. It turns out that the magnitude of drift velocity depends on geomagnetic activity: the larger Kp index the greater velocity which is in agreement with previous observations. Similar scales of irregularities revealed by correlation analysis at given time instant in conjunc1tion with velocity estimates explain broadening of frequency power spectra - larger drift velocity shifts spatial structures in frequency domain according to the Doppler effect.