Probing Ionospheric Structure Using LOFAR Data

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To obtain high quality images with the Lofar low frequency radio telescope, accurate ionospheric characterization and calibration is essential. The large field of view of LOFAR (several 10s of square degrees) requires good knowledge of the spatial variation of the ionosphere. In this work to probe the ionospheric structure, we first carried out initial calibration on LOFAR data. Afterwards, we extracted ionospheric information from the antenna based calibration solutions.

For our study we only used the Dutch Lofar stations, consisting of a dense inner core of 24 stations with baselines up to 2 km and a further 12 remote stations contributing to baselines with lengths up to 100 km. The phase information of the dense inner core gives an instantaneous view on the small scale ionospheric fluctuations. The sparser distributed remote stations contribute to the estimate of larger scale structures. Our data set consists of 200 hrs of nighttime observations of the 3C196 field during the winter of 2012-2013 in the 110-180 MHz range. The time resolution of the phase solutions is 10s. Instrumental errors are separated from the ionospheric phases using the difference in frequency behavior and the large bandwidth. Since an interferometer is only sensitive to phase differences we measure in this way the TEC difference between a large number of stations with a separation in the range from 80 m to 100 km. From this we can extract the time variation, including traveling ionospheric disturbances moving over the array. We also measure the spatial ionospheric structure function and night to night variations thereof. We confirm the power law behavior of the ionospheric structure function over a large range of distances, although the the exponent differs and is in general larger than the expected 5/3 for pure Kolmogorov turbulence. The large coverage allows us invest to split the data per baseline according to angle with the Earth magnetic field. We observe a splitting of the ionospheric structure depending on this angle, pointing to an non-uniform elongated structure of turbulent patches in the ionosphere.