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Fine-scale Structure in the mid-Latitude Ionosphere: Broadband Observations of Scintillation Using LOFAR

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1. Extended Abstract

Observations of strong natural radio sources such as Cassiopeia A and Cygnus A taken using the Low Frequency Array (LOFAR – a radio astronomy array consisting of 38 stations across the north-east of the Netherlands and a further twelve stations internationally) over the frequency range 10-250 MHz show almost continual ionospheric scintillation. Dynamic spectra of these observations show scintillation progressing through the weak and strong scattering regimes and sometimes the effects of refraction due to large-scale structure in the ionosphere. Data taken routinely over the past two years illustrate in the dynamic spectra a wide range of scintillation conditions, some of which are seen only rarely, or even only once, or above only one or two single LOFAR stations. Delay-Doppler spectra (the two-dimensional power spectrum of a dynamic spectrum) sometimes show an arc structure which can be used to model parameters such as the distance to the scattering "screen" and the velocity of the scattering medium transverse to the line of sight.

For single observing frequencies, the normalised intensities received by each station can be plotted as images where each intensity pixel corresponds to the spatial location of the station. This results in a series of images where the scintillation intensity can be seen 'flowing' across the stations in movies created from them. Such movies demonstrate how the scintillation appears to flow across the compact core area of LOFAR (a set of 24 stations distributed over an area with a diameter of 4km) in waves at highly-variable speeds and sometimes appears instead as a swirling eddy.

Further information can be obtained from high-time-cadence "snapshot" all-sky imaging taken at a selection of observing frequencies using only the central core stations: Here, the intensities and positions of 50+ radio sources distributed over the whole sky can be recorded. The source positions can appear to vary about their expected locations, reflecting a phase change of the incoming signal due to refraction. Hence, these measurements can provide both a global context of the variation of amplitude scintillation over the sky, and similar information on the larger-scale density structures causing the refraction.

In this paper, we will describe the use of LOFAR for studying ionospheric scintillation and demonstrate how variable this can be, even when the ionosphere is otherwise seen as being quiet,