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Solar Radio Observations at high spectral and temporal resolution with NenuFAR

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The Sun is an active star. The activity manifests itself by transient eruptive phenomena leading, among others, to the acceleration of energetic particles. Coherent radio emissions result from mildly relativistic electron beams, generated either at reconnection sites during solar flares or accelerated during the propagation of interplanetary shocks (Pick, 2004). Observed in the decameter range, these emissions provide the opportunity to diagnose the solar corona in a range of altitudes not reached by any spacecraft. Indeed, electron beams are the energy source of the bump-in-tail instability that leads to the generation of electrostatic Langmuir waves. Those waves then couple with ion-sound waves or other Langmuir waves to generate electromagnetic waves at a frequency close to the local plasma frequency ω_p or its harmonic $2\omega_p$, respectively. As the electron beams propagate in the corona and interplanetary medium, the radio emission drifts from high to low frequencies, following the density decrease with the heliographic distance. This drift thus enables an estimate of the electron beam velocity (once a density model is given). Therefore, the beam velocity related to solar flares is estimated to span between 0.3 to 0.6c, while the beams resulting from CME acceleration remain below 0.1c. Radio emissions linked to solar flares (the so-called Type III emission) are usually weakly to moderately circularly polarized. The degree of circular polarization is proportional to the ratio of the electron cyclotron frequency to the plasma frequency, enabling estimation of the weak coronal magnetic field, i.e. in regions where other technics (like Zeeman splitting for photospheric levels) fail (Willes & Melrose, 1997). Fine, slowly drifting emissions are often observed within Type III emissions. Called stria or Type IIIb emissions, their interpretation is still a subject of many studies. As recently shown, they can reveal the turbulent nature of the corona density, and their duration and drift depend on the local temperature (Reid & Kontar 2021).

NenuFAR is a large low-frequency radiotelescope recently deployed in France (Zarka 2012, 2020). It is a standalone phased array and interferometer, as well as a low-frequency extension of LOFAR. It covers frequencies between 10 and 85 MHz. Its large collecting surface (~53000m^2 at 25MHz) makes it very sensitive. Spectral and temporal resolution can be very high, respectively, down to δf=0.1kHz and/or δt=0.3ms (with a limitation at $\delta f \times \delta t \geq 4$). Such resolutions, associated with high sensitivity, is unique at low frequency. Each antenna is composed of two crossed dipoles allowing polarization measurements in the four Stokes parameters.

Observations were performed between December 16 and 25, 2021, for two hours around the maximum of Sun elevation. Several sunspot groups were present on the solar surface. In terms of flares, the activity was low during the observing time. Still, many Type III bursts were recorded, some with exceptional fine structures as stria or slowly drifting emission, others with a very weak signal. The capabilities of NenuFAR observations with such high resolution and polarimetric modes are presented. At the beginning of the solar cycle 25, the instrument provides unprecedented possibilities to study the solar corona.

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