§32. Higher Harmonic Electron Cyclotron Emission Diagnostics

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Electron cyclotron emission (ECE) measurement has been a main diagnostic to measure the temporal behavior of electron temperature profiles in plasmas. The 2nd harmonic ECE is widely used for the electron temperature diagnostics. The higher harmonic components are important to diagnose the non-thermal energetic-electron distributions in plasmas. The double-side-band (DSB) radiometer system has been newly developed to measure the higher (3rd) harmonic components as well as the fundamental and 2nd harmonic components. A fast frequency switching synthesizer system in a lower frequency range (12-15.6 GHz) was built for simultaneous three component measurements on LHD. The 6 times millimeter multiplier was prepared to obtain the fundamental ECE in 72-93.6GHz. An additional sub-harmonic mixer in 144-187.2GHz was also prepared for the 2nd harmonic ECE measurement. The 3 times multiplier and 8th harmonic mixer were prepared for the 3rd harmonic measurement in 216-280.8GHz. The minimum step of the frequency setting at the lower frequency part was 12MHz, and the arbitrary frequency setting was available. Figure 1 shows a frequency scanning result at two different frequency steps. The frequency switching time was 10 μs. In order to study the heat transport in the plasma, the fine frequency or fine profile measurement is important where there is the large temperature gradient, for instance, at the internal transport barrier. The DSB radiometers will be applied to the heat transport study in the LHD, together with the present radiometers. The DSB heterodyne radiometers were set in the present ECE transmission line. The transmission line is mainly composed of oversized circular corrugated waveguides with a diameter of 63.5 mm. Mating optics units were added in the transmission line The dichroic reflector (high pass filter plate) at the mating optics unit divided the transmitted emission into the three radiometers. The quasi-optical mirrors at the matching optics units coupled the emission into the WR10, WR6 and WR3 rectangular waveguides of the fundamental, 2nd and 3rd harmonic radiometers. The waveguide components were set in the ordinary polarization direction for the fundamental ECE measurement, and in the extra-ordinary polarization directions for the 2nd and 3rd ECE measurements.

The fundamental ECE spectrum was measured for the LHD plasma, which was produced and heated by electron cyclotron resonance heating method, to check the performance of the developed DSB radiometer system. The magnetic axis of the plasma was 3.6m, and the magnetic field was 2.85T. Measured frequency range was 72-79.2GHz. Thirteen frequency components by a 0.6GHz step were measured by a 0.5 ms interval. Figure 2 shows the time evolutions of the measured intensity at some frequencies. The sensitivities in the measured frequencies were not calibrated. The measured intensity will be relatively calibrated with the intensity, which was measured with the calibrated present diagnostic systems.

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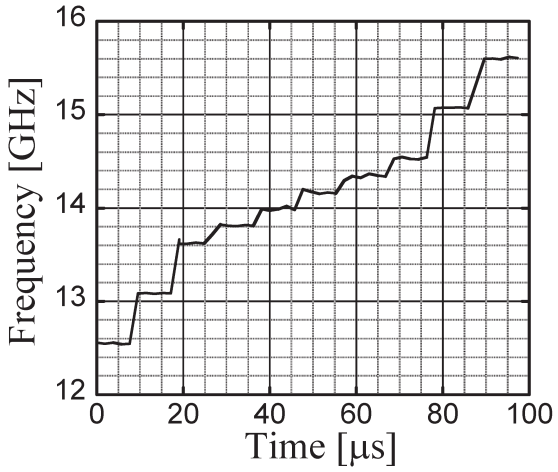

Fig. 1. Fast frequency scanning with two different frequency steps in the lower frequency part of the local oscillator.

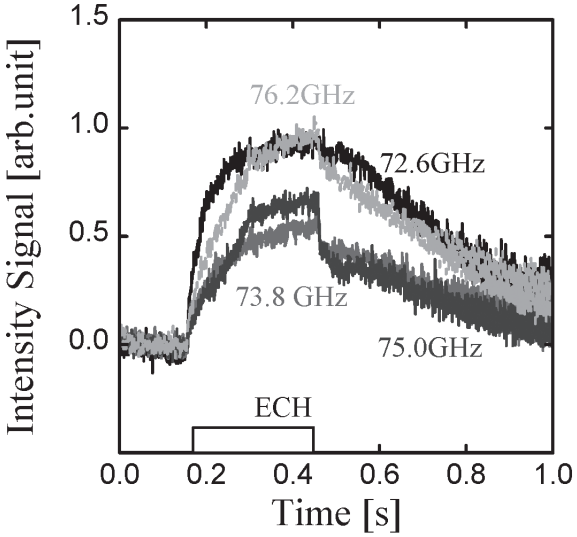

Fig.2. Time evolution of the fundamental ECE frequency spectrum in the LHD plasma which is produced and heated by electron cyclotron heating (ECH) method.