§10. Application of Digital Correlation ECE Measurement Technique for LHD

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We have proposed and developed the Digital Correlation Electron Cyclotron Emission (DCECE) Measurement Technique [1] with a Giga Hertz sampling digitizer [2]. Recently, technology of the analog-digital converter (ADC) have made remarkable advance. The digitizer whose sampling rate is more than several dozen Giga hertz has been developed commercially. Because the frequency band of down-converted IF wave is Giga Hertz range, we can obtain the IF wave form digitally.In the conventional radiometer type ECE measurement [3], the power detector with filter bank for intermediate frequency (IF) is used. In case of the ECE measurement in the magnetized plasma, generally, the frequency band is up to tens of Giga Hertz. Instead of filter bank system, the IF digitizing technique is applied for DCECE. One of the advantages of this technique is to enable to choose the spatial and temporal resolutions after the plasma experiment. This characteristic is considered to be useful for the study of the multiscale dynamics which should determine the whole confinement in plasmas.

The conceptual diagram of DCECE is shown in Figure.1. We can reconstruct the electron temperature radial profile as the power spectra of IF signal, and also get the electron temperature fluctuation as the fluctuation of the power spectra of IF signal. Because the data length of IF wave form are fixed by the volume of memory is the ADC, we have to select the sampling rate for the target phenomena. If 512Mbyte each channel of ADC is assumed, the data length to get a shot is corresponding to 6.4ms in the condition of 80GHz-sampling. In case of measurement fluctuation excited by MHD instability, the sampling rate of IF should be set to 10GHz.

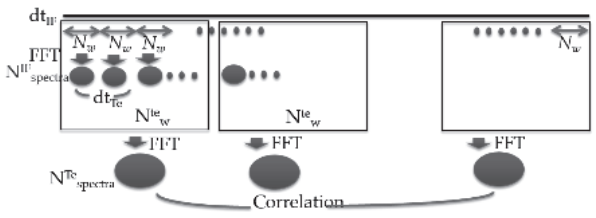

Fig. 1. Image of analytic procedure of DCECE. The electron temperature profile can be calculated from each data window N_w of IF waveform by FFT. The electron temperature fluctuation is obtained as the fluctuation of IF power spectra. The spectra of electron temperature fluctuation is also found by the FFT. For correlation analysis, the large $N^{Te}_{spectra}$ is desirable.

The IF digitizing technique was applied to the ECE of LHD plasmas. We can reconstruct the electron temperature flucutuaion profile and compare the analysis results of conventional radiometer type ECE and DCECE about 5 kHz flucuation. The data length of DCECE is 51 msec. The IF band from 0.5GHz to 4.5GHz can be digitally divided into any number of channels N_{ch}. Figure 3 shows the comparison between the results of conventional filter bank system ECE and DCECE. N_{ch} is 12, which corresponds to 3 times better resolution compared to conventional radio meter. The coherence of each channel is calculated by the correlation with the fluctuation of a spatially neighboring channel. It is confirmed that several kHz fluctuation with strong correlation is detected more sharply than conventional radiometer ECE. It is also found that the aspect of fourie analysis result depends not only on the sampling rate of digitizer but also the parameter of DCECE analysis such as IF resolotion and time resolution. In the rough division condition N_{ch} = 6, the fluctuation can not be detected. It is considered that the reason is due to the strong smoothing effect. On the other hand, in the condition of N_{ch}=96, the coherence is relatively lower than that of N_{ch}=12 or 24. The large number of N_{ch} means making a narrow IF band channel. The signal level of the narrow band channel decreases, which is observed in the case of the analog band pass filter. Moreover, it is considered that the decreasing signal level in DCECE has a similar effect.

1) Tsuchiya, H., et.al., Plasma Fusion Res. **9**, 3402021 (2014).
2) http://teledynelecroy.com/
3) Nagayama, Y., et al., Rev. Sci. Instrum. **70**, 1021 (1999).

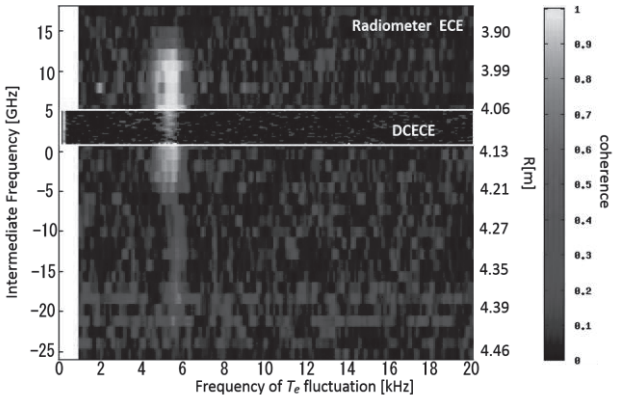

Fig.2 The coherence profile of Te fluctuation by conventional radiometer type ECE and DCECE. The profile by DCECE (IF= 0.5 to 4.5GHz) is drawn on the profile by radiometer ECE (IF=-25GHz to 17.5GHz). The IF resolution (left axis) is 166MHz in DCECE, and 1GHz in radiometer ECE. The radial position R[m] (right axis) is derived from ECE frequency.