§16. Study of Electron Temperature Turbulence Induced Transport with Correlation ECE Radiometer

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It is important to measure electron temperature turbulence in plasma for controlling turbulence induced transport. We have been developing and improving a correlation ECE radiometer (cECE), however, we have not had any evidences of successful measurement of turbulence. The measurement of the turbulence by the ECE is difficult, because, in principle, amplitude of the ECE contains noise which amplitude is proportional to the electron temperature. The small amplitude turbulence is easily masked by the larger noise component. So, cross-correlation analysis is applied between multi-channel data which measurement points are separated radially in plasma. To detect a turbulence signal with smaller amplitude, longer analysis time window and/or wider detectable IF frequency band are necessary. However, applicably of longer analysis window and wider IF band depend on temporal and spatial scale of target turbulence. Fig. 1 shows a block diagram of the cECE radiometer that we have developed. This radiometer utilizes first IF (2-26GHz) of the existent radiometer signal (RADH-L). The developed radiometer divides the IF signal into 4ch signals, and detects the amplitude of the signal with bandwidth of 50MHz at the selected frequency.

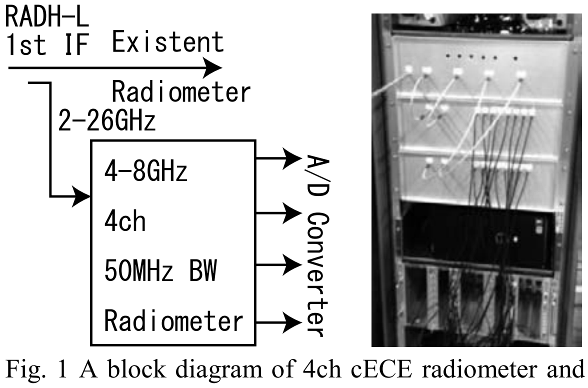

Fig. 1 A block diagram of 4ch cECE radiometer and a picture of the installed cECE radiometer system.

We have applied this cECE system to LHD plasma during 17th cycle experiment. Up to the present experiment, only noise has been measured by means of the cECE signals. However, signals taken by the LADH-L sometimes contain detectable amplitude of the electron temperature fluctuation, which is analyzed by the auto-correlation method, not by the cross-correlation. The LADH-L system has higher signal amplitude and better S/N ratio than the cECE system, because, IF bandwidth is 20 times wider than that of cECE. Utilization of the 4-way power-divider and the frequency-converter in the cECE system also degrades S/N ratio. Nevertheless the cECE system cannot detect this fluctuation by the cross-correlation method, we consider that the cECE signal also contains a fluctuation originated signal detected by the RADH-L. Figure 2 shows a cross-correlation result between the cECE and the RADH-L signals. We can find fluctuations around 4s and 5kHz. So, we have estimated the S/N ratio numerically as the following experiment. We add a monotonically sinusoidal signal to the raw data taken by the RADH-L. Here, amplitude of the added signal is adjusted to become equal to amplitude of the fluctuation , which is analyzed by the auto-correlation analysis. The S/N ratio of the RADH-L is estimated to be 2/5 by comparing amplitude of the added signal and the raw signal. Then, we analyze the cECE and the RADH-L signals by the cross-correlation analysis. Here, artificial sinusoidal signal is added to both signals. Amplitude of added signal to the RADH-L data is same to the fluctuation level. While, amplitude of the added signal to the cECE raw data is adjusted so both the cross-spectral density of the added signal and the fluctuation as to become same spectral density. We have estimated the S/N ratio of the cECE to be 1/70 by comparing amplitude of the added signal to the cECE signal and the raw data. This estimation seems to be consistent with estimation of the S/N ratio by means of components specifications utilized in the cECE system and RADH-L S/N ratio of 2/5.

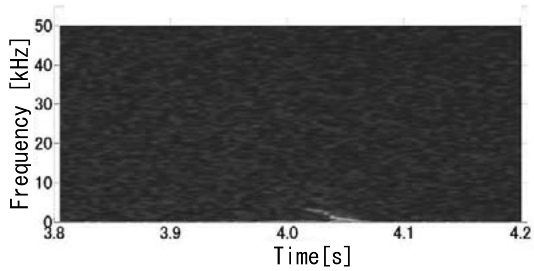

Fig. 2 Cross-spectral density between cECE and RADH-L data.

Further improvements need for our cECE system to detect turbulence, which amplitude is considered to be at least one tenth as low as the detected fluctuation level. We consider the cECE system needs dedicated receiver system with a large aperture antenna.