§18. Observation of Nonlinear Interaction between Coherent and Turbulent Magnetic Fluctuations on CHS

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A study of nonlinear self-regulation processes in plasma turbulence has crucial importance for clarifying the mechanism of anomalous transport in magnetically confined plasmas. Resent theoretical progress has highlighted the importance of nonlinear couplings between meso-scale structures and micro-scale turbulent fluctuations. In this report, we show an observation of nonlinear interaction between a low frequency coherent magnetic fluctuation and a few hundred kHz turbulent fluctuations in the H-mode edge plasmas of the CHS device. The coherent magnetic fluctuation has been intensively studied by a beam emission spectroscopy [1]. We have performed edge fluctuation measurements by the hybrid probe (HP) [2] for investigating edge nonlinear processes and contribution of the coherent fluctuations to transport. The HP has 4 electrodes. One electrode measured the ion saturation current fluctuation $I_{i,sat}$ and other three electrodes were used for floating potential fluctuation ϕ_{float} measurements.

Cross correlation is measured transport process. For instance, particle flux is estimated from a summation of quadratic spectra, $\Gamma_r=\mathrm{Re}\{\Sigma\langle(-ik_\theta n_e(f)\phi_p(f))/B_0\rangle\}$, where $n_e(f)$ is the density fluctuation at frequency f, and $-ik_\theta\phi_p(f)$ is the poloidal electric field, respectively.

Cross-biphase is useful in measuring nonlinear processes in convection. In the case that a (coherent) fluctuation has a density fluctuation and modulates other higher frequency density and poloidal electric field fluctuations (forward interaction), radial particle fluxes driven by the modulation, $n_e(f_1)E_\theta(f_2)$ is synchronized with the modulating fluctuation at $f=f_1+f_2$. This flux is not DC flux, but has a nonlinear effect on the modulating density fluctuation (f_1+f_2). The cross-bicoherence, $|\langle n_e(f_1)\phi_p(f_2)\, n_e(f_1+f_2)\rangle|^2/\{\langle|n_e(f_1)\phi_p(f_2)|^2\rangle\langle|n_e(f_1+f_2)|^2\rangle\}$ indicates the process that the modulating density fluctuation $n_e(f_1+f_2)$ is affected by the radial particle transport (backward interaction).

Figures 1 show quadratic spectra of ϕ_{float}. Three types of fluctuations were observed. First one is a low frequency coherent fluctuation around 4 kHz with a long-range poloidal correlation (Type A). This is the same fluctuation studied in Ref. [1] The second one is broadband fluctuations in several tens kHz. From correlation analysis, the second one has short poloidal correlation length (Type B). The third one is broadband fluctuations around a few hundreds kHz, which has also long-range correlation (Type C). Type A and C in $I_{i,sat}$ have significant correlation with magnetic fluctuations.

Figures 2 show results of bispectral analysis applied to the hybrid probe data. Auto-power spectra of $I_{i,sat}$, auto-bicoherence of $I_{i,sat}$, and total squared cross-bicoherence $\Sigma[|\langle I_{i,sat}(f_1)\phi_{float}(f_2)I_{i,sat}(f_1+f_2)\rangle|^2/\{\langle|I_{i,sat}(f_1)\phi_{float}(f_2)|^2\rangle\langle|I_{i,sat}(f_1+f_2)|^2\rangle\}]$ are shown in Figs. 2(a), (b), and (c), respectively. The significant nonlinear couplings between type A and C are observed, indicating that the coherent fluctuation modulates type C. In the total squared cross-bicoherence, we can observe a spectral peak around the same frequency as type A, and this identifies existence of modulated radial particle flux and its effects on the modulating MHD fluctuation. In this report, we have presented first observation that coherent magnetic fluctuations are interacted with the broadband fluctuations.
For quantitative identification of radial fluxes by the modulation process, conclusive cross-bispectra well above the significance level should be obtained, and this is a future task.

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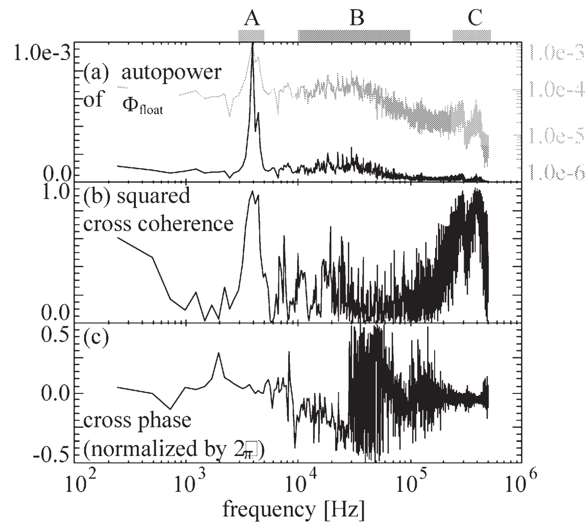

Fig. 1. Quadratic ϕ_{float} spectra. (a) Auto-power, (b) poloidal coherence, and (c) cross-phase. Gray line in Fig. (a) indicates same plots as black line in log scale.

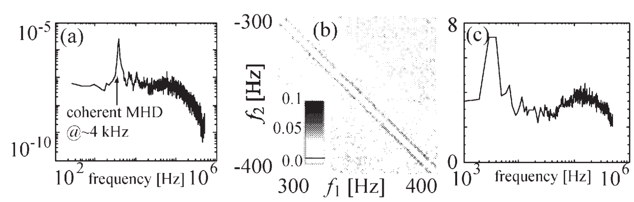

Fig. 2. Results of bispectral analyses. (a) Auto-power of $I_{i,sat}$, (b) auto-bicoherence of $I_{i,sat}$ in the 300-400 kHz range, and (c) the total squared cross-bicoherence, $\Sigma[|\langle I_{i,sat}(f_1)\phi_{float}(f_2)I_{i,sat}(f_1+f_2)\rangle|^2/\{\langle|I_{i,sat}(f_1)\phi_{float}(f_2)|^2\rangle\langle|I_{i,sat}(f_1+f_2)|^2\rangle\}]$.

Reference

1) Oishi, T., et al., Nucl. Fusion **46**, (2006) 317.
2) Nagaoka, K., et al., Plasma Fusion Res. **1**, (2006) 005.