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Phase tracking with Hilbert transform and nonlinear mode-mode coupling analysis on HL-2A and Heliotron J

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Recently in energetic-particle physics study, nonlinear mode-mode interaction has been noticed to play key roles in production of new modes. Bispectral analysis is the common way to identify the nonlinear interaction. However, a number of statistical ensembles are necessary for the bispectral analysis. In this presentation we propose to use Hilbert transform to detect the nonlinear mode-mode interaction. Hilbert transform could directly give the phase of a coherent mode. If the phase difference between two coherent modes is randomly changing, the two modes are independent of each other and there are no nonlinear interaction between them. If the phase difference between two coherent modes keeps constant, there are nonlinear interaction between them.

Two examples are given for the detection of nonlinear mode-mode interaction using Hilbert transform. One example is, production of new low-frequency sidebands through the nonlinear interaction between a beam-driven low-frequency mode (LFM)【1】and a very low frequency mode (VLF), as shown in Fig.1. Another example is, production of new TAE sidebands through the nonlinear interaction between TAE (toroidal Alfvén eigenmode) and TM (tearing mode) on HL-2A tokamak 【2,3】.

Fig. 1 Phase difference of two sidebands of LFM (Band1-Band2) and
the phase of VLF are roughly synchronized

References

【1】L.G. Zang et al, Nucl. Fusion 59 056001 (2019).
【2】P.W. Shi et al, Nucl. Fusion 59 086001 (2019).
【3】L.G. Zang et al, Nucl. Fusion 61 026024 (2021).

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