# §7. Edge Harmonic Oscillations at the Density Pedestal in the H-mode Discharges in CHS Heliotron Measured Using Beam Emission Spectroscopy and Magnetic Probe

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Edge harmonic oscillation (EHO) is an edge-localized MHD mode consisting of a fundamental frequency of several kilohertz and its harmonic components.[1] It has drawn attention because of its potential to provide moderate particle exhaust without ELM activities that may be desirable for the steady-state operation of forthcoming fusion devices.

Recently, EHO-like coherent MHD activities have also been observed in the compact helical system (CHS)[2] using a beam emission spectroscopy (BES).[3] BES showed that there are two groups of harmonic oscillations in the discharges having the edge particle transport barrier[4] in the CHS. One locates at ρ = 0.53 near the ι = 0.5 rational surface and has the mode number ($m$, $n$) = (-2, 1) (denoted “HO (core)”). The other locates at ρ = 0.95 near the ι = 1 rational surface and has the mode number ($m$, $n$) = (-1, 1) (denoted “HO (edge)”).[5]

Soon thereafter, HO (core) was recognized to be clearly observable using a magnetic probe. In the present study, the spatial structure of the HO (core) was investigated using the toroidal and poloidal magnetic probe array.[6]

We defined the phase of the $p$-th harmonic oscillation having ($m$, $n$) = (-2, 1) mode structure as a function of toroidal and poloidal coordinates and time:

$$\begin{aligned}\Phi_p(\phi, \theta, t) &= k_\phi R\phi + k_\theta r\theta - 2\pi pft + \Phi_{0p} \\ &= (\phi - 2\theta) - 2\pi pft + \Phi_{0p}. \qquad (1)\end{aligned}$$

Let $t_0$ be the time at which the phase of the first harmonic is zero at given coordinates;

$$\Phi_1(\phi, \theta, t_0) = (\phi - 2\theta) - 2\pi pft_0 + \Phi_{01} = 0. \quad (2)$$

The phase difference between the $p$-th ($p \geqq 2$) and first harmonic at $t_0$ can be described as

$$\begin{aligned}\Delta\Phi_p &= \Phi_p(\phi, \theta, t_0) - p\Phi_1(\phi, \theta, t_0) \\ &= (1 - p)(\phi - 2\theta - (\Phi_{0p} - p\Phi_{01}) / (1 - p)). \quad (3)\end{aligned}$$

Therefore, by plotting the phase difference at $t_0$ as a function of ($\phi - 2\theta$), one can determine the angle $\phi - 2\theta$, i.e., the 3-D spatial position where the $p$-th harmonic is in phase with the first harmonic. The least-square fit of the sinusoidal function to the experimental data was performed to the reconstructed Fourier component of each harmonic frequency of the HO (core).

The results obtained with poloidal and toroidal magnetic probe arrays are shown in Fig. 1 (a). In this shot, the 1st harmonic of 3 kHz, 2nd harmonic of 6 kHz, and 3rd harmonic of 9 kHz were observed. One can see that at $\phi - 2\theta = 0.2 \times 2\pi$ rad, every harmonic is in phase with the others. Then, Eq. (3) requires $\Phi_{01} = \Phi_{0p} = \Phi_0$ regardless of $p$. As the displacement with respect to poloidal or toroidal direction increases, the phase between the harmonics shifts at different rates, with a fitted slope almost equal to $p - 1$. This observation also indicates that each harmonic propagates at a different velocity along the ($m$, $n$) = (-2, 1) mode structure. This figure tells us that the higher harmonic mode arrives at the spatial position earlier. Moreover, these results indicate that the initial phases of the harmonic oscillations are locked at particular magnetic field line, but the harmonic modes propagate at the different phase velocity. This is why the shape of the raw signal changes depending on the angle $\phi - 2\theta$, as shown in Fig. 1 (b). These observations might be an effective test for theoretical models of EHO, or HO (edge/core), in the future.

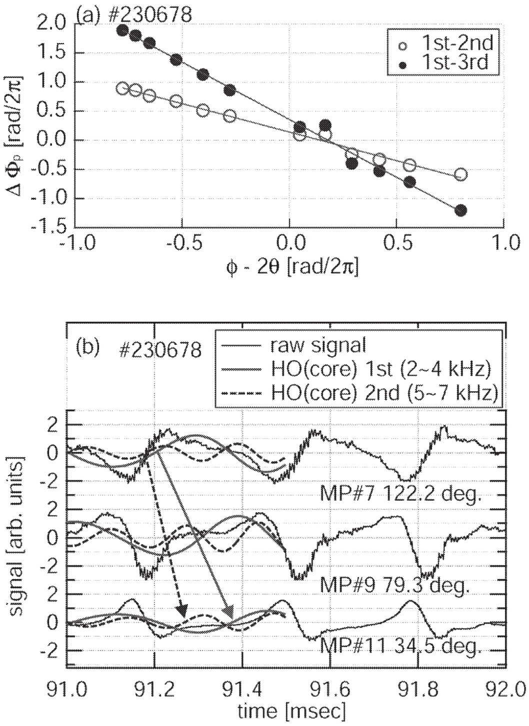

Fig. 1. (a) Phase difference between harmonics. (b) Interpretation of the change in the shape of the raw signals in different spatial positions.

Reference

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