§17. Measurement of ICRF Waves by Using High-frequency Magnetic Probes

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To study the characteristics of waves exited by ICRF antennas, two high-frequency magnetic probes in the different ports were used. Phase controllable HAS antennas at the 3.5 port were used to excite ICRF waves. High-frequency magnetic probes are located in 5.5U and 6.5U ports. Phase velocity is one of characteristics of waves. The phase velocity of the propagating wave v_ϕ can be determined with the assumption that the phase velocity is independent of the frequencies:

$$v_\phi = \frac{2\pi L}{d\Delta\phi / df} \quad (1)$$

where L is the distance between two separate probes, $\Delta\phi$ is the phase difference and f is the frequency. ICRF waves excited by antennas normally have the frequency of the excitation and the higher harmonics. There exist side bands around the frequencies, but they are too small to determine the $d\Delta\phi/df$. We developed the fast power modulation method. By the modulation of the power, large side band can be generated. Figure 1 shows the power spectrum density measured with the probes. The excitation frequency is 38.47 Hz for the minority ion heating where helium is majority and hydrogen is minority. Original side band level is less than 10^{-9} V^2/Hz. By the power modulation with the frequency of 10 kHz, power spectrum with a lot of peaks was generated. The difference of frequencies is 10 kHz. The peaked spectrums are also seen around the second harmonic frequency.

The damping ratio is estimated by the comparison of the signal intensity with the excitation or second harmonic frequencies. When the current phase is -91.6° (negative means the wave excitation to the probes or CW direction), large signal was detected. With the current phase of -177.7° (almost 0-π phase) the signal was decreased, and with the current phase of +65.4° the signal was decreased further. The damping ratio between 5.5U and 6.5U port is approximately -10dB. The damping of the second harmonic wave is weak, and signal at the 6.5U port can be larger than the signal at the 5.5U port. This means the existence of CCW propagation.

Figure 2 shows the phase difference with the coherence squared. When the current phases are -177.7° and -91.6°, positive slope of phase difference is clearly observed. In the case of +65.4° the slope is not clear but it seems to be positive around excitation frequency. With the eq. 1, the phase velocity was estimated to be 2.5×10^6 m/s for the case of -177.7° and -91.6°. This means the toroidal wave number and the refractive index are 97 m^{-1} and 120, respectively. Wave number is 33 times of the excited wave number parallel to the magnetic field line at the antenna in the case of -90°.

Figure 3 shows the simulated oscillating magnetic field in the case of -90°. Cold plasma approximation with the slab model was used. A wave is excited to the direction of the magnetic field line, and a weak wave is also exited to the opposite direction. This simulation qualitatively agrees with the experimental result of +65.4° current phase. The high wave number cannot be explained with this model but the existence of ion-ion hybrid resonance layer is a candidate for the cause of the large up shift of wave number.

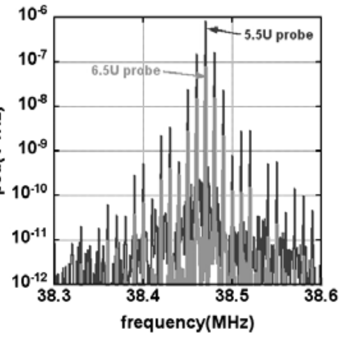

Fig. 1 Power spectrum around excitation frequency.

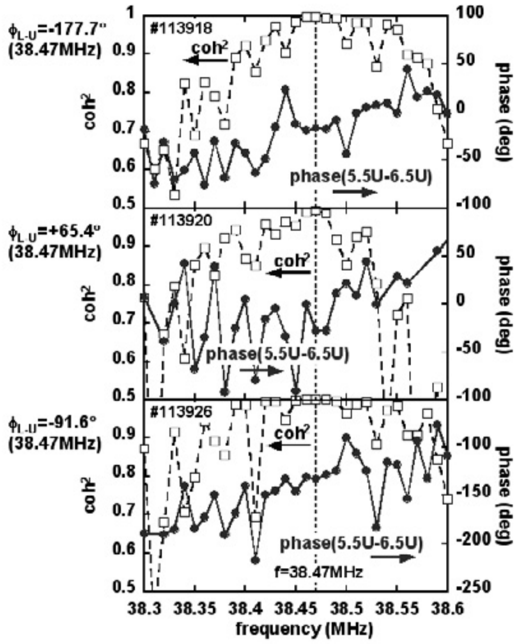

Fig. 2 Phase difference between two probes.

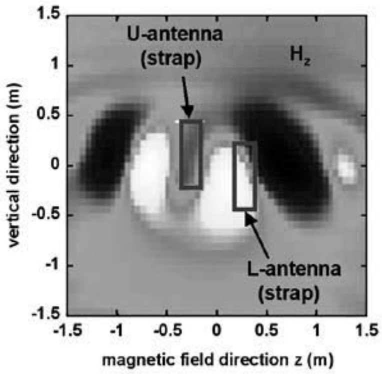

Fig. 3 Simulated high-frequency magnetic field.