§3. Two Frequency Wave Excitation Experiments Using Two Antennas

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In order to perform controlled nonlinear wave physics experiments, we have proposed two frequency wave injection. By launching waves at two frequencies, we can cause nonlinear wave excitation under controlled conditions. In fiscal year 2013, we installed a new capacitively coupled combline antenna (CCC antenna) on the TST-2 device, in addition to the existing waveguide array antenna (grill antenna). Using these two antennas, we performed two frequency wave excitation experiments by injecting waves with two frequencies around 200 MHz, which are in the rage of lower hybrid wave, through each antenna. The advantage of this two-antenna scheme is that we can avoid nonlinear wave excitation at the tetrode power amplifier part, where nonlinear power amplification is required to generate high power RF wave. Since these two antennas are located at different toroidal locations, we can expect nonlinear wave excitation only due to the plasma.

The target spherical tokamak plasma was generated noninductively by launching RF powers of 15 – 30 kW (200 MHz) from the grill antenna. A plasma current of 6 kA was sustained. RF power of up to 0.4 kW was launched from the CCC antenna, and the frequency was modulated between 200.3 – 200.5 MHz (Fig. 1). Thus, we can expect nonlinearly generated beat waves with the frequencies of 0.3-0.5 MHz. Signals from a magnetic pickup coil (i.e., δB_z) and a microwave interferometer were monitored, and we observed beat components in the pickup coil signal, but not in the interferometer signal.

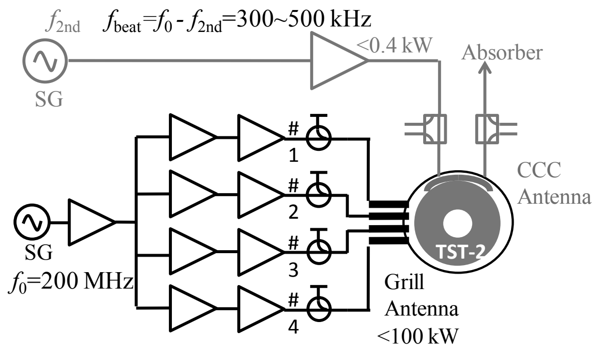

Fig. 1 Schematic drawing of the RF systems for two frequency wave excitation experiments.

Figure 2 shows the response of the pickup coil, where the launched power from the grill antenna was about 15 kW, and that from the CCC antenna was 0.4 kW. The horizontal axis shows the beat frequency (i.e., the frequency difference between the two frequencies). The spectrum has a narrow peak (~ 320 kHz), a narrow dip (~ 350 kHz) and a broad peak (~ 400 kHz). These structures are stable and do not depend on the plasma current, whereas these frequencies are in the range of Alfven eigen modes. The insensitivity to the plasma current suggests that the beat frequency components are not Alfven eigen modes. This frequency range is also the ion cyclotron frequency range. The deuterium (bulk ion) cyclotron frequency in front of the antenna was 440 kHz, however, we never observed evidence of ion heating during these experiments. In order to identify the wave and to study the nonlinear wave excitation, further studies are required.

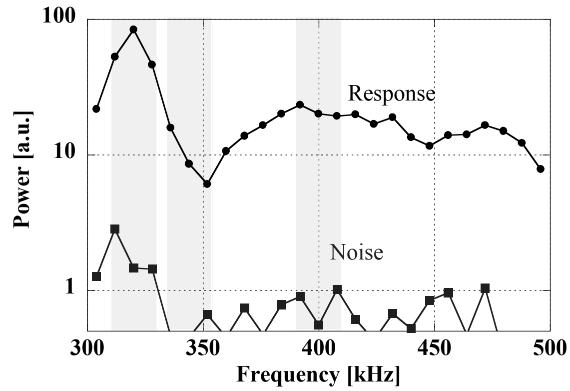

Fig. 2 Response of the pickup coil as a function of frequency difference.

In order to reveal the feature of the nonlinear coupling, the relationship between the launched CCC antenna power and the response of the magnetic pickup coil was investigated. Figure 3 shows the power of the pickup coil signal at the three characteristic frequencies (see yellow green hatched region in Fig. 2). The power response increases almost linearly with the launched power. Assuming an MHD like response, the magnetic perturbation is proportional to the pressure perturbation. In addition, the two frequency RF wave power can distort the plasma pressure through the poderomotive force, or through plasma heating. In both cases the perturbed pressure is proportional to the heating power, and we can expect magnetic perturbation power is proportional to the squared pressure perturbation. Considering that the beat wave arises nonlinearly from the product of the RF field amplitudes, the linear dependence shown in Fig. 3 is reasonable.

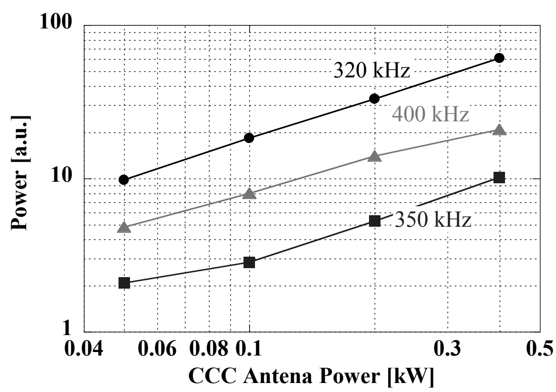

Fig. 3 Response of magnetic pickup coil at three frequencies (320, 350 and 400 kHz) as a function of the CCC antenna power. The grill antenna power was fixed at 15 kW.