# §58. Optimization of Electron Bernstein Wave Heating and Current Drive by Real Time Phase Control

Idei, H. (Kyushu Univ.), QUEST Team

Electron Bernstein Wave Heating and Current Drive (EBWH/CD) experiments have been conducted in the Q-shu University Experiments with Steady State Spherical Tokamak [1]. The O-X-B mode conversion scenario was selected for the steady-state plasma current sustainment in the rather low-density operation. The oblique beam with an elliptical polarization was required in the O-X-B experiments. The phased-array antenna (PAA) with the 8 [4x2] square waveguide elements was developed for the EBWH/CD experiments to excite the elliptically polarized oblique beam. The measured fields radiated from the PAA in low power test facilities were well explained with a Kirchhoff integral evaluation.

The optimum incident condition depended on plasma current and density profile/gradient. The incident polarization and angle should follow to their time evolutions to attain high mode conversion efficiency into the B-wave from the O/X-wave. The fast 3 dB hybrid phase shifter has been developed and installed to the CW transmission lines. Figure 1 illustrates a fast 3 dB hybrid phase shifter. The phase shifter was composed of a 3 dB hybrid coupler and a plunger reflector controlled by fast scanning motor. Figure 2 shows the transmitted field distribution evaluated by a HFSS 3D full wave simulator. The Voltage Standing Wave Ratio (VSWR) was evaluated to be lower than 1.1 at the operating frequency of 8.2 G +/-0.05 GHz as shown in Fig.3. The plunger position of the phase shifter was scanned to control the transmitted wave phase. Figure 4 shows a time evolutions of the transmitted wave phase with the 3 dB hybrid phase shifter. The attained phase-scanning speed was $10^4$ degree/s. The polarization can be controlled within 9 ms from a linear to a circular polarization state. Figure 5 shows the fast beam steering within 5 ms using the phase shifter and the [4x2] PAA. The FPGA（Field-Programmable Gate Array control system, including the reflectometry diagnostics to measure the density profile, is preparing to control 16 phase shifters in parallel in feedback loops to obtain the optimum incident polarization and angle. Figure 6 shows the FPGA control panel for the 16 phase shifters.

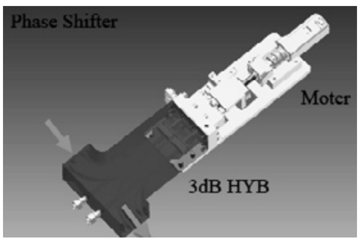


Fig.1: Fast 3 dB hybrid phase shifter.

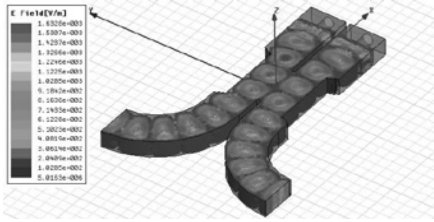

Fig.2: Transmitted field distribution evaluated by a HFSS 3D full wave simulator of the phase shifter.

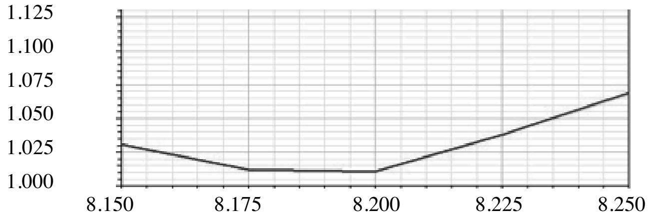


Fig.3: VSWR at the operating frequency of 8.2 +/-0.05 GHz.

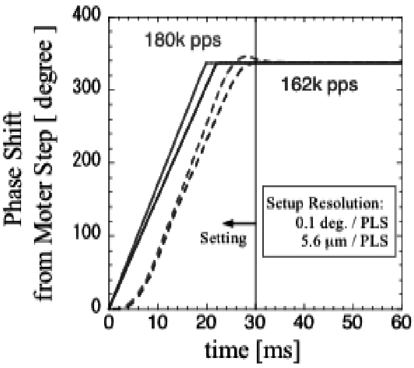


Fig.4: Time evolutions of the transmitted wave phase with the 3 dB hybrid phase shifter.

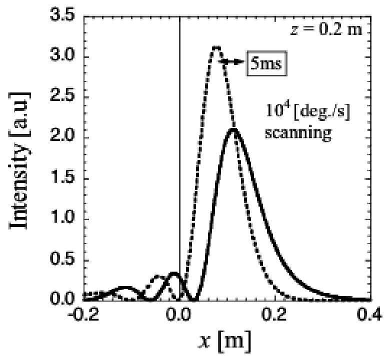


Fig.5: Fast beam steering within 5 ms using the phase shifter and the [4x2] PAA.

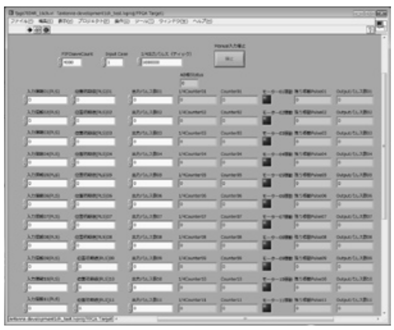

Fig.6: FPGA control panel for the 16 phase shifters.