§8. Transmission Power and Polarization Detection Circuit in Electron Cyclotron Heating System

Notake, T. (Nagoya Univ.),
Idei, H., Kubo, S., Shimozuma, T., Kobayashi, S.

In the research of electron cyclotron heating (ECH), it is important to study the absorption mechanism of the electromagnetic wave injected to the plasma. For the purpose of more detail analysis, we should measure precisely incident power (i.e., millimeter wave power injected to plasma) in real time. Incident power of the present ECH system of LHD is evaluated by the preliminary estimation. In this estimation, millimeter wave is injected to a water dummy load, and then temperature rise is measured. Since only averaged power can be measured with this test, the power measurement with time evolution, for example in modulated power experiment, is not available.

Also, in plasma heating by electron cyclotron wave, for efficient heating, it is necessary to control millimeter wave polarization. For example, the absorption efficiency changes with polarization of an incidence millimeter wave. Moreover, for oblique injection which was intended to current drive, it is required that not only the direction of polarization ellipse but also the ellipticity of elliptic polarization are simultaneously controllable. Thus, it has been indispensable condition to measure millimeter wave polarization in real time for research of ECH. Then, polarization is controllable to optimize for LHD plasma experiment using two polarizers installed the ECH transmission line. Therefore, the monitor system which can detect ECH incidence power and millimeter wave polarization in real time has been developed in ECH group.

The millimeter wave was detected through small coupling holes of reflecting plate at the miterbend installed ECH transmission line. That leaked millimeter wave is collected by two fundamental waveguides (which collect crossed electric components mutually) installed in the back-side of the reflecting plate. The transmission power and millimeter wave polarization are evaluated by letting it pass in the different waveguides circuit, respectively. (see Fig.1)

The millimeter wave coupled at these small holes of the reflecting plate are guided from port #2 to E-plane port at Magic Tee with/without additional phase of 90 degrees by Phase Shifter. This is divided to two detectors (Detectors #1 and #2) with the phase difference of 180 degree. The coupled millimeter wave with the other polarization is guided from port #1 to H-plane port at Magic Tee. This is also divided to Detectors #1 and #2 with same phase. The millimeter wave powers detected at Detector #1 after mixture of two polarization components are expressed as the terms of P_0 and P_90 for the cases with and without the additional phase of 90 degrees by Phase Shifter. The powers detected at Detector #2 are also described as P_180 and P_270. In principle, the phase difference between two polarizations is obtained as

$$\delta_x - \delta_y = \arctan\left[(P\_90 - P\_270)/(P\_0 - P\_180)\right]$$

The total power P_total is

$$P\_\text{total} = P\_0 + P\_180 = P\_90 + P\_270$$

Where, as Δ is phase difference by the phase shifter

$$P\_0 = (E_x^2 + E_y^2)/2 + E_x E_y \cos(\delta_x - \delta_y) \quad (\Delta = 0\ \text{deg})$$
$$P\_90 = (E_x^2 + E_y^2)/2 + E_x E_y \sin(\delta_x - \delta_y) \quad (\Delta = 90\ \text{deg})$$
$$P\_180 = (E_x^2 + E_y^2)/2 - E_x E_y \cos(\delta_x - \delta_y) \quad (\Delta = 0\ \text{deg})$$
$$P\_270 = (E_x^2 + E_y^2)/2 - E_x E_y \sin(\delta_x - \delta_y) \quad (\Delta = 90\ \text{deg})$$

If PIN Switch works in order to disable the power to transmit, only one polarization (port #2) power is detected. The power ratio may be measured as a ratio of the port #2 power to the total power.

The power is transmitted from a Gyrotron is 500kW in the maximum. Since the coupling degree of the coupler in the miterbend is evaluated as -77dB at low power test, the incidence level to port#1 and #2 is 10mW or less. Furthermore, since insertion loss at the wave guides circuit between ports and detectors are 10dB without last attenuators, the signal level finally detected becomes below -10dBm (0.1mW). The detectors are operated in the square-low detection. This method may detect transmission power and millimeter wave polarization, without influence on the main transmission mode itself.

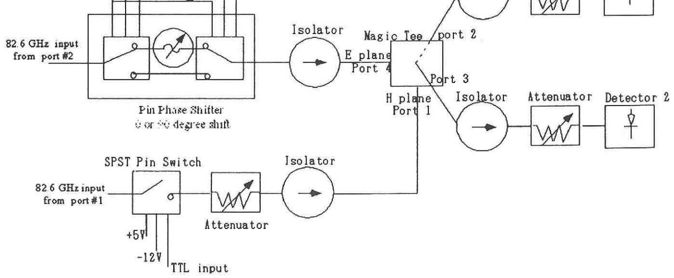

Fig.1. Transmission Power and Millimeter Wave Polarization Detection Circuit