§20. Developments of Advanced Microwave Diagnostics for Future Fusion Plasma Reactor Approaching by Doppler Reflectometry

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In the future fusion reactor, microwave reflectometer is one of the possible diagnostics, because it can be measured the electron density profile, MHD oscillation, flow speed, etc. From the point of view of accessibility from the outside into the plasma, the monostatic antenna is suitable, because it is not only the cost reduction but also the angular range of view. For checking the performance of the monostatic antenna, we have installed the monostatic antenna system as a transmitter/receiver antenna for the Doppler reflectometer in GAMMA-10 central cell.

Figure 1 shows the monostatic antenna system. It consists of the scalar horn, the flat mirror, and the focusing concave mirror. The scalar horn can radiate the Gaussian beam that has the symmetrical beam shape in E- and H-plane. We can easy to change the launching microwave polarization (usually X-mode is used) by rotating the scalar horn. The concave mirror, which focusing point is at the plasma edge, can be controlled for changing the launching angle. It is utilized for selecting the purpose of reflectometry that is a normal reflectometry which the wave launches to the normal to the plasma surface or a Doppler reflectometry which the wave launches with the finite angle. This antenna optics has been installed in the GAMMA-10 central cell as shown in Fig. 2. When the installation, the laser level is used for the fine alignment and the installation error is estimated less than a few mm.

First monostatic antenna test is carried out by the application of Doppler reflectometer. In the operation of Doppler reflectometer, the frequency components of the scattered backward wave has the Doppler shift responded by the plasma flow $v_\perp$ and the launching angle θ_t which is described by

$$f_D = v_\perp k_\perp / 2\pi = 2 v_\perp \sin\theta_t / \lambda_0 . \quad (1)$$

Here, f_D is the Doppler shift, $k_\perp$ is the wavenumber, and λ_0 is the launching wavelength. Doppler frequency shift scanning the launching angle is obtained with fixed probing frequency of 11.9 GHz as shown in Fig. 3. In Fig. 3, the frequency shift changes almost linearly with θ_t. It suggests that in the current situation of scanning θ_t range the assumption $\sin\theta_t \approx \theta_t$ is allowed in Eq. (1). In an ideal condition f_D as a function of θ_t is expected to trace a straight line passing through the origin, however, the frequency shifts in Fig. 3 have finite values at θ_t=0. This can be due to several reasons, for example, an antenna misalignment, a launching angle setting error, and a shift of plasma position from its geometrical position. Therefore, we continue to study the monostatic antenna characteristics.

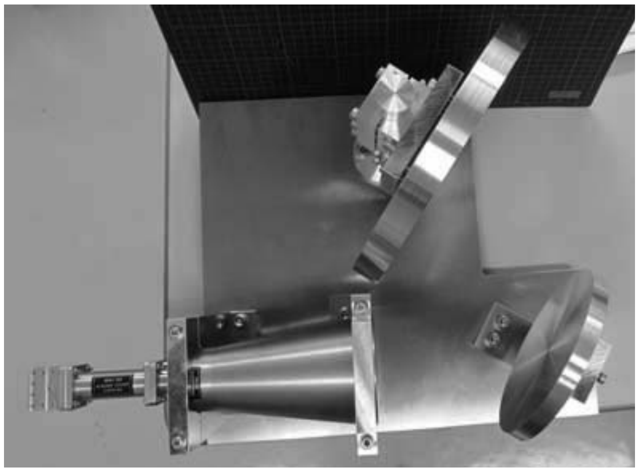

Fig. 1. Photograph of monostatic antenna system for the Ku-band microwave reflectometer.

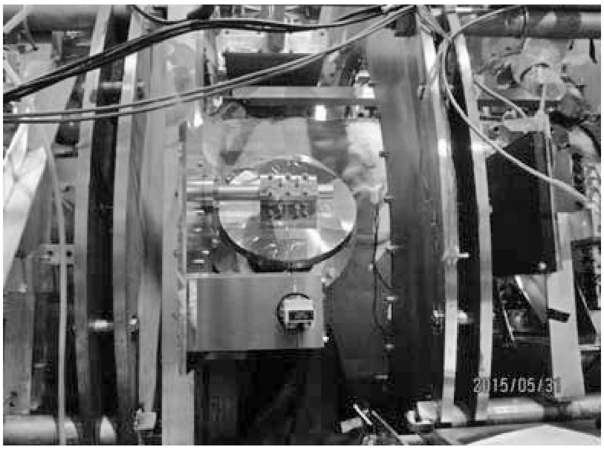

Fig. 2. Photograph of the antenna system installation in GAMMA-10 central cell.

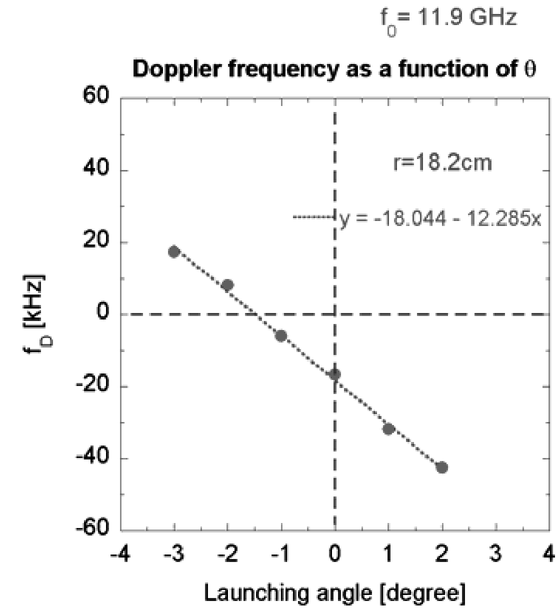

Fig. 3. Doppler frequency shift of the scattered backward wave as a function of the launching angle with probing frequency of 11.9 GHz.