

## §21. Linear Response Region for Microwave Reflectometry

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Microwave reflectometry has been used to measure density fluctuations in many devices. According to a simplest picture, measured phase is proportional to density fluctuations. In this situation, reflectometry has a linear response to density fluctuations. Here we will show the parameter region for the linear response.

The interference of the reflected waves can destroy the linear relation, and this effect can be calculated by the Helmholtz/Kirchhoff integral. There are several studies by G.D.Conway. We have applied the method to the configuration of the reflectometer at the JIPP TII-U tokamak. Figure 1 shows the schematic drawing of the configuration. Density fluctuations are simulated as a sinusoidally modulated surface with the poloidal wavelength of  $\lambda_f$  and the amplitude of  $a$ . The average minor radius of the surface is 0.2 m, and the wavelength of the launched wave is 7.5 mm. The modulated surface rotates along the poloidal direction. Here we define the 'ideal case' as the situation that the measured phase represents the minor radius of the reflection point (P in Fig.1).

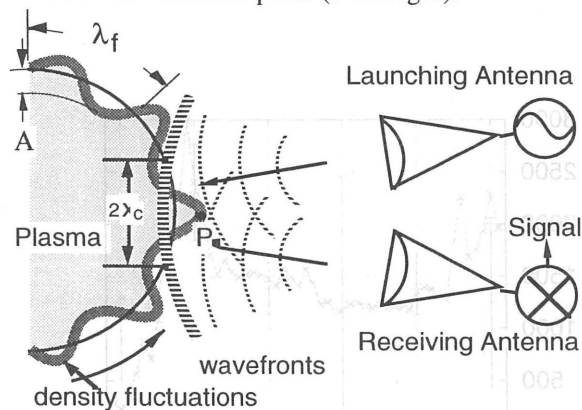


Fig.1. Schematic drawing of the configuration for the calculation.

When the modulated surface rotates, the phase in the ideal case shows sinusoidal behavior. This behavior is compared with the calculated phase. Figure 2 shows comparison of phase behavior (as a function of the poloidal distance) for three typical cases, and the qualitative classification of the behavior in  $\lambda_f a$  plane. The class of 'normal' (filled circle) represents the case that the phase behavior is similar to the ideal case. The class of 'negative' represents the case that the phase behavior has the opposite sign as the ideal case. The class of normal is the region where the reflectometer has a linear response to the modulation of the reflection surface.

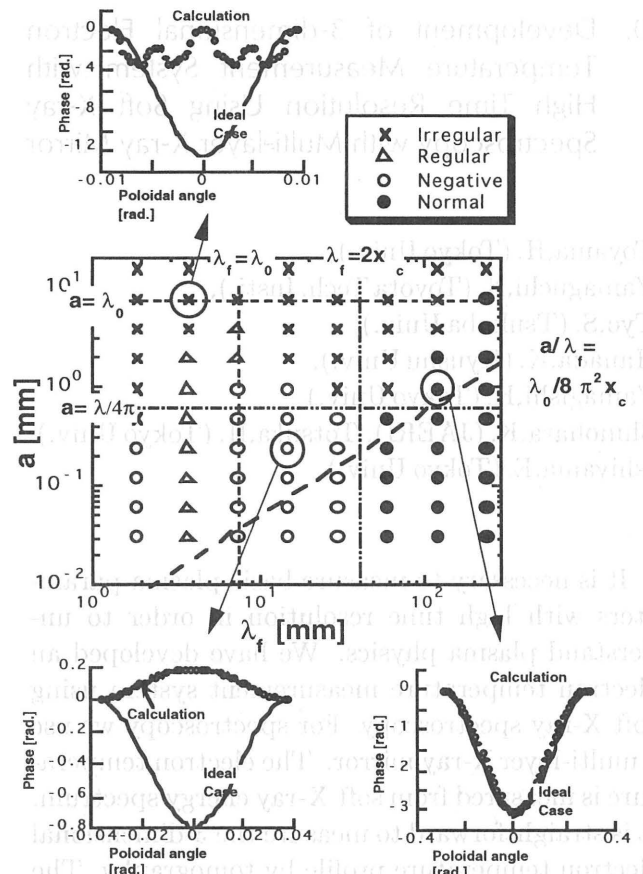


Fig.2. Qualitative classification of the phase behavior in  $\lambda_f a$  plane. Phase behavior as a function of poloidal distance is also shown for three cases.

This classification can also be derived by the following approximation for the detected signal

$$\int_{-x_c}^{x_c} dx \text{Exp}[i4\pi a / \lambda_0 \times \sin(2\pi x / \lambda_f + \phi_0)]$$

where  $\phi_0$  is the initial phase of the modulation.  $x_c \sim 20\text{mm}$  is the size of effective surface, which is the size of the Fresnel's first zone. When  $4\pi a / \lambda_0 \ll 1$ , and  $2\pi x_c / \lambda_f \ll 1$ , the phase corresponds to the ideal case (i.e.  $4\pi a / \lambda_0 \sin \phi_0$ ).

When  $4\pi a / \lambda_0 \ll 1$ , and  $2\pi x_c / \lambda_f > 1$ , the phase behavior can show same or opposite sign and the amplitude of the modulation decreases (class of 'negative' in Fig.2). When  $2\pi x_c / \lambda_f \ll 1$ , and  $(4\pi a / \lambda_0)(2\pi x_c / \lambda_f) \ll 1$ , the phase of the integral coincide with the phase of the ideal case.

Boundary lines for these conditions are indicated in Fig.2. Although the boundaries do not exactly coincide with calculation, these approximation can explain the phase behavior qualitatively. The normal class (filled circles) in Fig.2 is almost represented by the parameter region  $2\pi x_c / \lambda_f \ll 1$  and  $4\pi a / \lambda_0 \times 2\pi x_c / \lambda_f \ll 1$ .

This is the linear response region of the reflectometer.