§15. Development of Microwave Imaging Reflectometry (MIR)

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Visualization is one of the most promising ways to progress science. Digital camera, which is a 2-D detector array, has been developed for from infra-red to X-ray. While radar is the oldest imaging system, a microwave camera has not been developed. Cross talk and interference among detector channels are serious for it. In LHD, we have been developing a Horn-antenna Mixer Array (HMA).[1,2] In HMA, those problems were solved by using horn antenna. So far, a combined system of 3-D microwave imaging reflectometry and 2-D ECE imaging has been installed in LHD by using 2-D HMA with 7×7 channels. Since ECE use the X-mode microwave and the electron density profile is hollow, we have measured X-mode.

Figure 1 shows an example of coherence between a reference channel (toroidal ch. No.=3, poloidal ch. No.=3) and other channels on the reflection surface at R=4.5 m, which is very close to the plasma boundary. Here the coherence is defined as

$$C_{xy}(\omega)^2 = \frac{|S_{xy}(\omega)|^2}{S_{xx}(\omega)S_{yy}(\omega)}$$

where

$$S_{xy}(\omega) = \left\langle \left\langle X^*(\omega)Y(\omega) \right\rangle_{t-\Delta t}^{t+\Delta t} \right\rangle_{\omega-\Delta\omega}^{\omega+\Delta\omega}$$

Here bracket (<>) indicates ensemble average, and $X(\omega)$ and $Y(\omega)$ are Fourier transform of signals $x(t)$ and $y(t)$, respectively. It was expected that the coherence is high on the same field line, but the observation with MIR is different as shown in Fig.1. The cutoff frequency of X-mode is

$$f_R = \frac{1}{2}\left\{ f_{ce} + \sqrt{f_{ce}^2 + 4f_{pe}^2} \right\}$$

where

$$f_{ce}[\mathrm{GHz}] = 28B[\mathrm{T}], f_{pe}[\mathrm{GHz}] = 28.4\sqrt{n_e\left[10^{19}\mathrm{m}^{-3}\right]}$$

So the reflection surface of X-mode is not on the same equi-density surface or the flux surface, in other words, the density fluctuation on the same field line cannot be observed with the X-mode MIR.

Present HMA is for V-band (50 – 75 GHz), but the frequency of O-mode is in Q-band (30-50 GHz). In order to measure O-mode, development of new HMA begins in collaboration with Institute for Molecular Science. Fig. 2 shows prototype of 16ch 1D HMA for lower frequency microwave. By using new HMA, the observation area will be increased more than 50 %. However, signal frequency band width is reduced as multi-channel connector is used. Since the resolution will be doubled, new application other than plasma diagnostics can be expected.

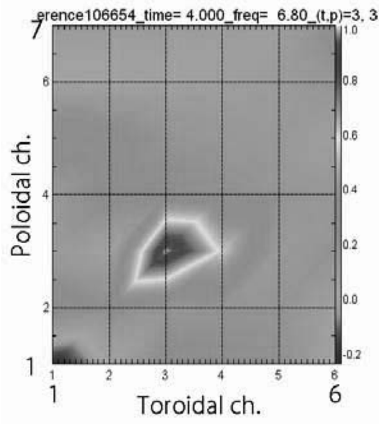

Fig. 1. Coherence in the radial cross-section (R=4.5m). Channels are separated by 2cm each.

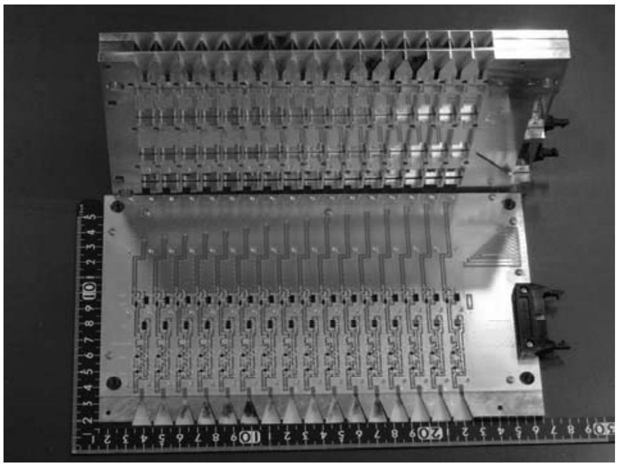

Fig. 2. Prototype of 16ch 1D HMA.

This work was supported by the NINS Imaging Science Program (KNSI001), the NIFS Imaging Diagnostics Project (KEIN1111), and the LHD Project (ULPP008).

1) Kuwahara, D. et al: J. Plasma Fusion Res. SERIES **8** (2009) 649.
2) Nagayama, Y. et al: Rev. Sci. Instrum. **83** (2012) 10E305.