§14. Development of Microwave Imaging Technology

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Microwave imaging diagnostics[1,2] has been proposed for three-dimensional observation of the local electron density and temperature in magnetically confined plasma. Microwave Imaging Reflectometry[3] (MIR) and Electron Cyclotron Emission Imaging (ECEI) are improved as a combined system in Large Helical Device (LHD). The system development is expected to bring new findings to the plasma physics. The MIR basically need an optical system in order to capture the microwave pictures. Its spatial resolution is restricted by the optical system. An incident wave is reflected and scattered by the target and then it propagates and diverges to its peripheral space. In the absence of the optical system the microwave picture doesn't appear. The scattering wave keeps information about the target's shape, size, location, its electrical parameters, and so on. Mathematical analysis can reconstruct the microwave picture without the optical system. This imaging technique is the microwave Computer Tomography (CT). The conventional CT technique is applied to the transmission measurement as x-ray tomography for plasma and medical applications. The tomography technique can be applied to the scattering measurement. In the scattering wave system the incident wave propagates to the target, many receivers are located around the target or a single receiver is scanned around the target. The spatial resolution is well enhanced as the scanning range is wide.

Microwave CT was unavailable due to high device cost and low computing power for years. Recent progress in mobile communications is developing by effective and low-cost microwave Integrated Circuits (ICs). They help to reduce the cost of microwave CT system for basic science and industrial applications. In order to reduce the analysis time, boundary surfaces between different dielectric medium have to be well estimated in short time. The tomography system with pulsed microwave is utilized for searching the surfaces. In this research the pulsed microwave CT system is developed as the sub system of the microwave imaging diagnostics.

The prototype of the spiral antenna element has been developed for the pulsed microwave CT. The antenna transmits and receives the circular polarized waves. The circular polarized wave is usually utilized for the global positioning system (GPS) and the satellite television transmission. On the hemispheric surface of the Earth the circular polarized waves can be received by the receiver without restriction of the polarization direction. The circular polarized wave is better adapted for the three-dimensional diagnostics of the microwave CT. Figure 1 shows the photograph of the prototype of the spiral antenna element. The diameter of the spiral element is 22 mm. The antenna is made of the Printed Circuit Board (PCB) with the thickness of 0.254 mm. The PCB has teflon base with the relative permittivity of ε = 2.2. The antenna pattern is manufactured by the numerically controlled milling machine. The frequency range of the antenna is about 3 GHz to 20 GHz. The lower frequency limit decides the dispersion property of the antenna. The property deforms the transmission and reception waveforms on the antenna.

The pulse source has been developed by using a low-cost semiconductor device. The pulse source is consist of the semiconducting impulse generator and the function generator. The impulse generator is Herotek GIM100A. It outputs the short pulse with the pulse width of 100 psec. The impulse generator is driven by the external sine-wave generator with the frequency of 100 MHz and the driving power of +27 dBm. Figure 2 shows the output waveform from the pulse generator. The peak power is estimated to be about +10 dBm in the present setup.

The pulsed waveform of the spiral antenna is shown in Figure 3. The antenna dispersion causes the waveform distortion with several peaks and bottoms. The base frequency is nearly equal to the lower cut off the antenna. In order to measure the Time of Flight (ToF) with accuracy, an pulse-waveform analysis should be developed in considering of the dispersion property. It is future work as well as the improvement of the frequency range of the antenna.

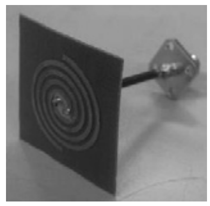

Fig. 1. The prototype of the spiral antenna.

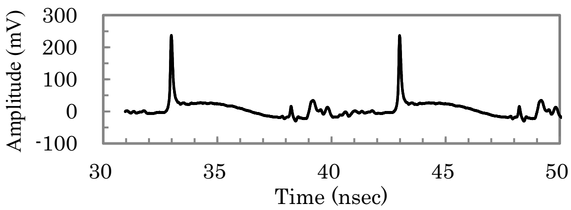

Fig. 2. The waveforms from the impulse generator.

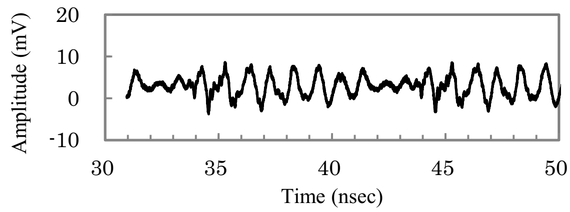

Fig. 3. The waveforms from the receiver antenna.

1) Mase, A. et al.: JINST **7** (2012) C01089.
2) B. Tobias. et al.: Plasma Fusion Res. **6** (2011) 2106042.
3) Nagayama, Y. et al.: J. Plasma Fus. Res. **87** (2011) 359.