§16. Development of Microwave Imaging Technology

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Microwave imaging diagnosis[1,2] was 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) became a combined diagnosis system in Large Helical Device (LHD). The system development brings new findings to the plasma physics. MIR system needs to know both position and shape of a cut-off surface (reflection surface) on which density fluctuations are visualized as an image. The surface can be approximately estimated by Thomson scattering diagnosis in the present setup. It is better to use a direct method of precisely measuring the surface shape and position.

A pulsed-wave CT system was manufactured for measurement of a boundary surface among different medium. A schematic view of the system is shown in Figure 1. A function generator of Agilent 33522A outputs a sine wave of 30 MHz with +23 dBm power. The generator drives an impulse generator which outputs negative pulses with 0.3 ns pulse width. The pulsed wave is supplied to an transmitter of a spiral antenna which was reported in the NIFS annual report 2011. The incident wave is circularly polarized. Dispersion property of the antenna increases the pulse width to several nano-seconds as shown in Figure 2. Superposition of the incident and reflected waves is received on a receiver. The received wave is recorded by a sampling scope of LeCroy WE100H. The reflected waveform is extracted from the wave superposition. Spatial resolution of the system is decided by a time-of-flight of the pulsed wave. The spatial resolution is 45 mm in air, and it is 8 mm in an dielectric medium with a relative permittivity of 30 (ex. fat tissue of human body).

An image of an object surface is easily pictured by painting of several crossing spheroids in an analysis domain. When the transmitter and the receiver are respectively located on focal points of an spheroid, the reflection point exists on somewhere on the spheroid. The spheroid contacts on the object surface. Changing the positions of the transmitter and receiver and painting many spheroids, the object is surrounded by the many spheroids. The object outline appears in the analysis domain. This simple method can be used to picture the three-dimensional image of the boundary surface among the different medium easily.

In an initial experiment the CT system pictured an image of a low-permittivity ball in a high-permittivity medium. Experimental setup is shown in Figure 3. A small teflon ball (12.7 mm diameter and a low relative permittivity of 2) is buried in an oil clay (high relative permittivity of 30). Four pairs of a transmitter and a receiver painted the four spheroids as shown in Figure 4. The CT image is drawn with a solid-line, and the teflon ball is drawn with a dashed-line. The image has the diameter of 14 +/-3 mm, the diameter is almost equal with that of the teflon ball. The center distance between the teflon ball and CT image is 6 mm. The distance is less than the spatial resolution of 8 mm of the oil clay. The CT image can be pictured by such a simple way. This imaging technique can be widely applied to visualization of reflection surfaces in plasma, nondestructive examination, medical screening and so on.

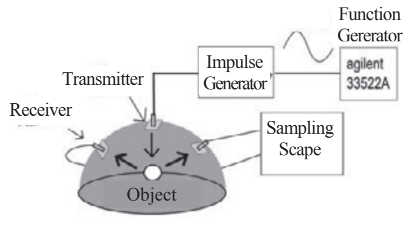

Fig. 1 Pulsed radar system

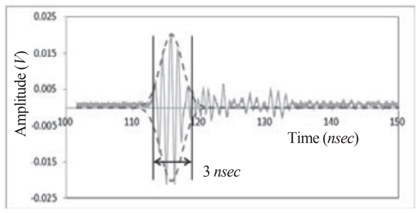

Fig.2 Incident wave pulse

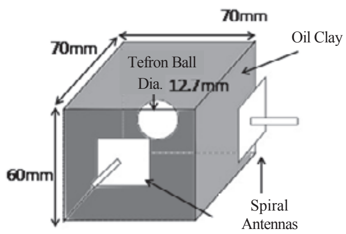

Fig. 3 Experimental setup

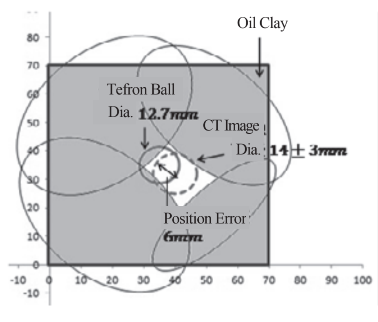

Fig. 4 CT image of the teflon ball

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.