

## §16. Utilization of Multi-channel Microwave Imaging System for Plasma and Dielectric Object Observations

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The microwave imaging reflectometer (MIR) and the electron cyclotron emission (ECE) measurement systems [1] are acquiring valuable data on LHD plasma with well-designed measurement systems of multi-channel, high spatial-temporal resolution antenna array. The measured raw data include rich information about 3-dimensional (3D) perturbations of temperature and density of LHD plasma and is waiting for effective 3D image analysis. On the basis of experiences that we got through construction of these systems, furthermore, we built a new diffraction microwave imaging system [2] for the purpose of high-resolution breast cancer diagnostics. The imaging system is expected to have high capability of getting information on the shapes of tumors, which are less than 5 mm in diameter at the early stage of cancer.

Firstly, with respect to the spatially direct 3D imaging of MIR/ECE in LHD, we have obtained a useful formula of time-space spectral analysis. When the signals of plasma fluctuation are observed at diverse positions with unequal intervals in plasma, the wavenumber spectrum estimation from the obtained cross-spectral data can be formulated as an inverse problem of Fourier type, that is, an inverse problem in which both the coefficient matrix and the data vector are complex-valued. This inverse problem can be solved, without any laborious modification, using our software library that we have built for the purpose of computerized tomography. We are now ready for analyzing the stored signal data of LHD. Time-space spectral analysis will well contribute to understanding the magnetic confinement of high temperature plasma.

Secondarily, with respect to the breast cancer imaging system, study has been made on a new possibility of obtaining useful information without suffering from the

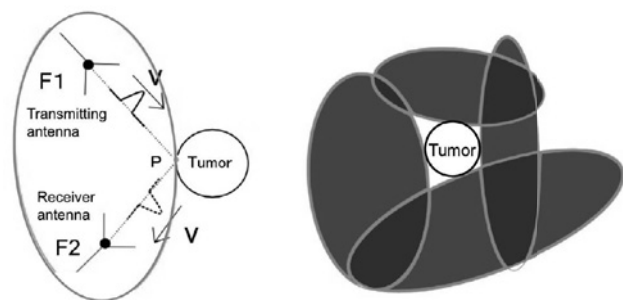


Fig. 1: Detection scheme for small cancer cells using the preprocessing pulse radar.

requirement of massive computational time and resources for the FDTD-aided image reconstruction in tomography [3]. The microwave system has been reinforced by attaching a preprocessing pulse radar subsystem. The radar consists of an array of 25 spiral antennas, which are set on the wall of a box that covers a breast. Fig. 1 illustrates an idea how the radar detects the area of a small tumor. The radar detects the boundary location by the surrounding ellipsoids contacting with the cancer area. These ellipsoids are drawn based on times of flight (TOF) of reflection microwave pulses between pairs of antennas. The cancer area specification significantly reduces the area of FDTD calculation, so the computational time and memory resources of the succeeding diffraction tomography are saved. The FDTD simulation of this microwave imaging as shown in Fig. 2 has proved that one can detect a 10mm diameter dielectric object by surrounding with 10 ellipsoids at most. FDTD calculations of diffraction for the normal and malignant objects have proved the possibility of high-resolution imaging performance of the system. Results of the FDTD simulation confirm that diffracted microwaves from two types of objects generate different patterns.

The simulation results have also pointed out that the accuracy of TOF measurement can be improved by separating the aimed pulse from the receiver signal that is contaminated with a directly transmitted pulse. Development of an effective method for signal separation remains as a further work. A detection test system using breast cancer phantoms made of acryl spheres has also been prepared. Software for the iterative image reconstruction method of inverse scattering tomography with FDTD calculation is under development.

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- 1) Kuwahara, D. et al.: Rev. Sci. Inst. **81**, 10D919.
- 2) Yamaguchi, S. et al.: Ann. Rep. NIFS 2011, p. 131.
- 3) Teranishi, M. et al.: Ann. Rep. NIFS 2011, p. 438.

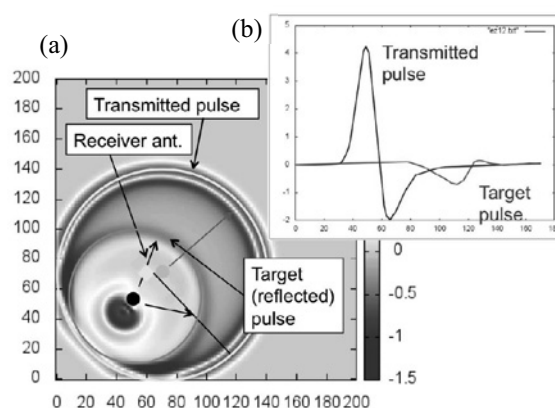


Fig. 2: (a) FDTD simulation of reflecting microwave pulse with a 10mm diameter dielectric object.  
 (b) Transmitted and target reflected pulses at the receiver antenna.