High-speed and Accurate Dielectric Constant Estimation Method Using RPM Boundary Extraction and FDTD Based Analysis

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Microwave UWB radars have a great advantage for high range resolution and penetrating ability for dielectric object, and are promising for non-invasive bio-medical applications, such as breast tumor detection in early stage, or non-destructive investigation for aged or cracked concreate road or bridges. There are various permittivity estimation methods aiming at the above applications, mainly based on the solution of the domain integral equation derived from Helmholtz equation. However, the existing methods require non-linear optimization process for multi-dimensional variables to obtain sufficient reconstruction accuracy. Then, their accuracy or spatial resolution strongly depends on the assumed pixel size, namely, the number of optimization variables. In addition, there is unavoidable problem that the conventional approaches cannot maintain the reconstruction accuracy around discontinuous region, e.g. the boundary between air and dielectric object.

To alleviate this problem, this paper introduces a recently established imaging method as RPM (range points migration) method for outer boundary extraction. This method has a remarkable advantage that its reconstruction accuracy can be achieved at the order of 1/100 transmitting wavelength, which contribute the dielectric constant estimation in dielectric object. Furthermore, this method firstly introduces the ray tracing based transmission delay estimation for high-speed solution of direct problem, and secondly employs FDTD data generation to maintain the accuracy. The optimization scheme is based on PSO (particle swarm optimization) to hold the efficiency and accuracy. The numerical simulations in 2-dimensional model verify the advantage of the proposed method against the conventional iterative Born approximation method in terms of computational efficiency and reconstruction accuracy. Figure 1 shows the reconstruction result, and verifies the advantage of the proposed method in terms of computational efficiency and reconstruction accuracy for dielectric constant.

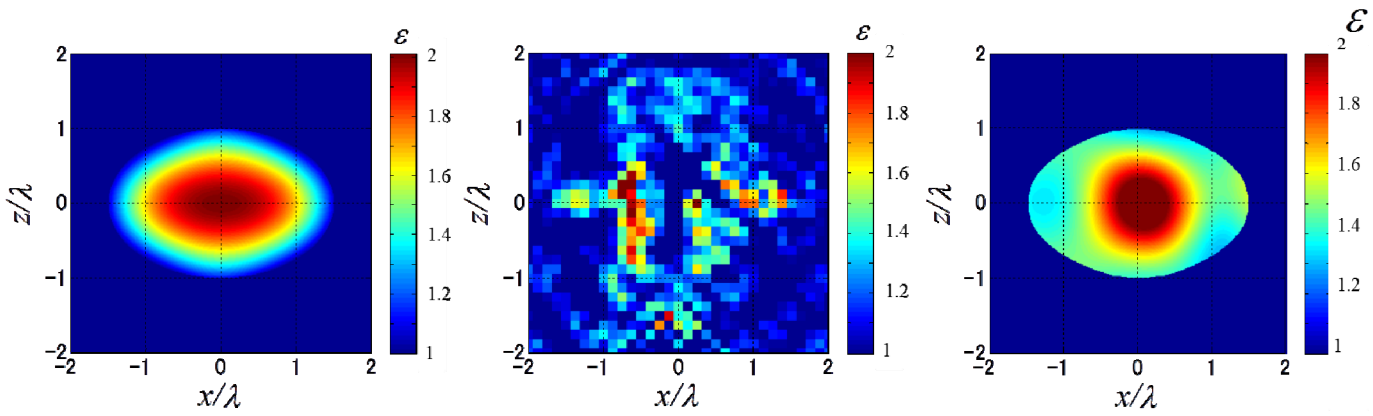

Fig. 1 Dielectric constant reconstruction (left: actual, center: BIM, right: Proposed)