# Fast Imaging of a Target in Inhomogeneous Media for Pulse Radar Systems

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## 1 Background and Objectives

Many works have been done to develop efficient imaging algorithms for ground penetrating radars. We have already developed a new imaging algorithm SEABED for homogeneous media and confirmed its sufficient performance [1]. This algorithm has an advantage that the calculation time is quite short because it is based on a reversible transform. However, its performance for inhomogeneous media has not studied yet. In this paper, we examine the performance of SEABED for inhomogeneous media.

## 2 System Model

We scan an omni-directional antenna along a straight line. Pulses are transmitted at a fixed interval and received by the antenna. The received data is filtered, A/D converted, and stored in a memory.

We deal with a 2-dimensional problem and TE-mode wave. $x$ and $y$ are normalized by the center wavelength $\lambda$. We assume $y > 0$ for simplicity. The antenna is scanned along $x$-axis. We define $s(X, Y)$ as the received electric field at the antenna location $(x, y) = (X, 0)$, where we define $Y$ with time $t$ and the center frequency $f$ as $Y = ft/2$.

## 3 Boundary Scattering Transform

The relationship between a point $(x, y)$ on a target surface and a point $(X, Y)$ on the corresponding wavefront of $s(X, Y)$ is described as

$$X = x + y\mathrm{d}y/\mathrm{d}x, \quad (1)$$

$$Y = y\sqrt{1 + (\mathrm{d}y/\mathrm{d}x)^2}. \quad (2)$$

The wavefront of $s(X, Y)$ is called quasi wavefront. This transform is called Boundary scattering transform (BST). The inverse transform of BST is called IBST and is described as

$$x = X - Y\mathrm{d}Y/\mathrm{d}X, \quad (3)$$

$$y = Y\sqrt{1 - (\mathrm{d}Y/\mathrm{d}X)^2}, \quad (4)$$

## 4 Proposed Algorithm

First, we extract a quasi wavefront from $s(X, Y)$ in SEABED. Quasi wavefronts have to satisfy the condition $\mathrm{d}s(X, Y)/\mathrm{d}Y = 0$ and $|\mathrm{d}Y/\mathrm{d}X| \le 1$. We sequentially extract the set of points $(X, Y)$. Next, we select quasi wavefronts with large power and eliminate undesirable components. Finally, we apply IBST to the extracted quasi wavefront.

## 5 Simulation Result

We assume a round perfect conductor with radius of $1\lambda$. The media around the target has highly inhomogeneous dielectric, whose relative permittivity $\varepsilon_r$ is shown in Fig. 1.

We assume observations at 39 positions with an interval of $0.125\lambda$. We obtain a received signal $s(X, Y)$ with FDTD method for the assumed target. The undesirable clutters caused by the inhomogeneous media are eliminated by the quasi wavefront selection stage. Finally, the estimated target shape by SEABED is shown in Fig. 2. The solid line and broken line represents the true shape and the estimated shape respectively. The imaging took 40 msec with Xeon 2.8GHz processor. The estimated target shape is sufficiently accurate. We have confirmed the efficiency of SEABED even in inhomogeneous media.

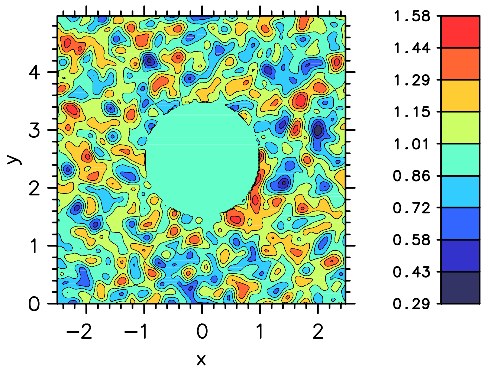


Figure 1: True target shape and $\varepsilon_r$ of media.

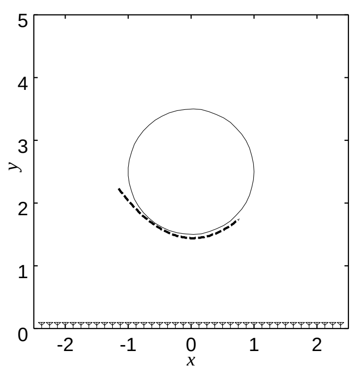


Figure 2: Estimated target shape.

## References

[1] T. Sakamoto and T. Sato, "A target shape estimation algorithm for pulse radar systems based on boundary scattering transform," IEICE Trans. Commun., May, 2004, (in press).