URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

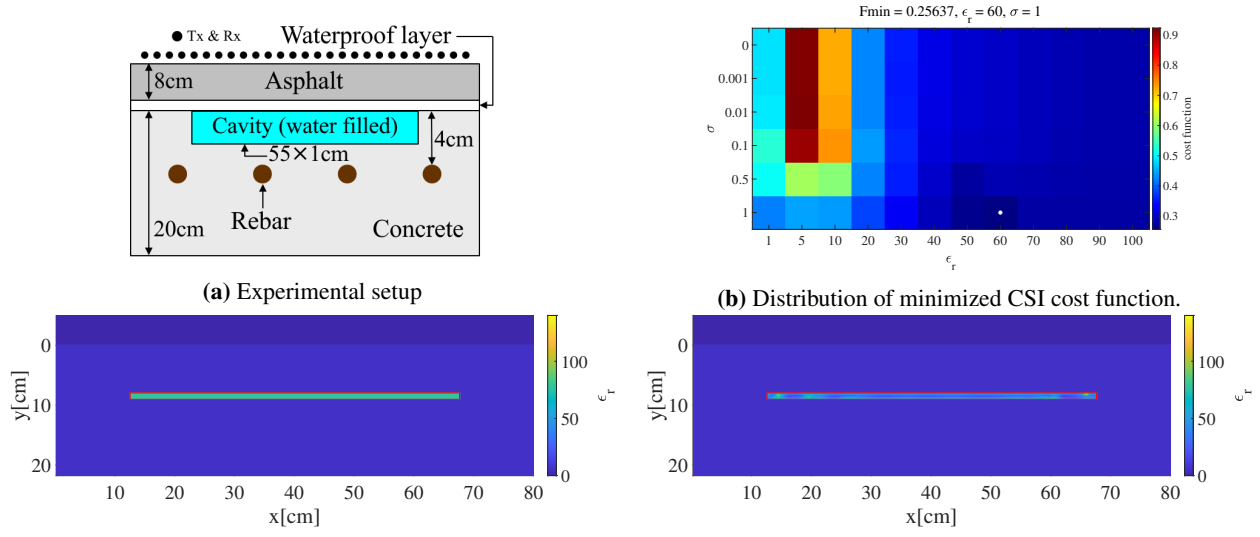
Experimental Study on Contrast Source Inversion Based Complex Permittivity Reconstruction for Microwave Nondestructive Road Evaluation

Katsuyoshi Suzuki(1) and Shouhei Kidera(1)
(1) Graduate School of Informatics and Engineering, University of Electro-Communications, Tokyo, Japan

There is an emergent demand to monitor an aging infrastructure, such as road, bridges and tunnels, to avoid a catastrophic collapse or subsidence. Microwave ultra wideband (UWB) radar is one of the most attractive options to achieve an effective non-destructive evaluation (NDE), which can provide a deep penetration depth into concrete material. Many researches demonstrated that complex permittivities of anomaly objects, *e.g.*, cavities, water, corroded steel bars, are significantly varied, and has a distinct contrast from that of concrete medium [1], and thus, it is one of the most useful parameters to characterize a material of buried object. However, the traditional radar imaging method cannot quantitatively retrieve complex permittivity of buried object. Conversely, the tomography approach, *i.e.,* inverse scattering (IS) analysis, can reconstruct a dielectric profile of object by solving the domain integral equation. However, the traditional IS approach, *e.g.*, contrast source inversion (CSI) [2], generally suffers from inaccuracy due to non-linearity or ill-posed condition, especially in the NDE observation model, because an illumination angle is severely limited, and then, the reconstruction accuracy largely depends on the initial estimate.

To address with the above mentioned problem, this paper introduces an accurate initial estimation approach by minimizing the CSI cost function. Assuming that a buried object has a homogeneous profile, *e.g.* air or water-filled cavity, our method initially determines the combination of its constant permittivity and conductivity, where only the variables of total field are optimized in the CSI iteration process.

The experimental validations, using realistic road test-site with water filled cavity between asphalt and floor board, is described as follows. Figure 1 (a) and (b) shows the experimental setup and the residual map of the CSI cost function, respectively, and the optimal combination is determined around the actual dielectric parameters of water. The final reconstruction profile is shown in Fig. 1 (d), and it also demonstrates that the post-CSI reconstruction with the optimal initial estimate retains a high reconstruction accuracy even in such severe ill-posed condition case.



(a) Experimental setup

(b) Distribution of minimized CSI cost function.

(c) Ground truth profile

(d) Reconstruction profile

Figure 1. Experimental overview and reconstruction results for relative permittivity.

References

[1] R. Zoughi, "Microwave non-destructive testing and evaluation principles," vol. 4. *Springer Science & Business Media*, 2000.

[2] P. M. van den Berg and R. E. Kleinman, "A contrast source inversion method," *Inv. Probl.*, vol. 13, pp. 1607-1620, Jul. 1997.