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Contactless Multiview and Multistatic Microwave Subsurface Imaging

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This contribution deals with a sub-surface imaging approach able to focus multi-transmitter and multi-receiver ground penetrating radar data collected with a contactless measurement configuration. The imaging task is conveyed as a linearized inverse scattering problem, which is formulated by considering the Born approximation and a 2-D ray-based propagation model. The Interface Reflection Point (IRP) model, previously described in [1] and [2], is here exploited to model the scattering phenomenon for case of Multiple Input Multiple Output (MIMO) data. Figure 1 represents the 2D geometry of the imaging problem where transmitters and receivers are spatially separated and located at a non-negligible height (in terms of wavelength) above the air-soil interface. According to the IRPmodel, the data to unknown relationship to be inverted can be written as follows:

$$E_s(\boldsymbol{r}_q, \boldsymbol{r}_p, \omega) = \frac{-j\omega\sqrt{\epsilon_s}}{2\pi c} \iint_{\mathrm{D}} \frac{T_{12}T_{21}}{\sqrt{(R_1+R_2)(R_3+R_4)}} \exp\left\{-\frac{j\omega}{c}\left((R_1+R_4)+\sqrt{\epsilon_s}(R_3+R_4)\right)\right\} \chi(\boldsymbol{r}) d\boldsymbol{r} \qquad (1)$$

$E_s(\boldsymbol{r}_q, \boldsymbol{r}_p, \omega)$ being the scattered field (data) at the angular frequency ω when the antenna at $\boldsymbol{r}_p = (x_p, -h)$ acts as transmitter and the antenna at $\boldsymbol{r}_q = (x_q, -h)$ acts as receiver, and $\chi(\boldsymbol{r}) = \frac{\epsilon_t}{\epsilon_s} - 1$ is the contrast function (unknown) describing the presence of targets at any point $\boldsymbol{r}(x, z)$ within the investigation domain D. In eq. (1), $c \approx$ 3e+8 m/s is the electromagnetic wave speed in air, ϵ_s the relative permittivity of the soil, T_{12} and T_{21} denote the air-soil and soil-air Fresnel's transmission coefficients, and R_1, R_2, R_3, R_4 the length of the ray path, see Fig. 1.

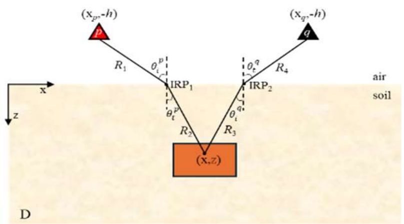

Figure 1. Geometry of the radar imaging problem

The IRP approach has been recently proposed and exploited to process data collected by an array of transmitting and receiving antennas located at a fixed spatial position [2]. In this contribution, the IRP approach is extended to the case of multistatic data, collected by moving transmitting and receiving antennas on the investigated subsurface domain. Differently from [2], in this contribution, to speed up the imaging performance and improve the computational efficiency, the adjoint inversion scheme is adopted to produce a tomographic reconstruction. The performance of the Multistatic-IRP (MIRP) imaging approach will be discussed by considering experimental data provided by the Georgia Institute of Technology [3]. Mathematical details and the imaging results regarding the experimental dataset will be presented at the conference.

References

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[2] I. Catapano et al., "Contactless Microwave Tomography via MIMO GPR," in IEEE Geoscience and Remote Sensing Letters, vol. 20, pp. 1-5, 2023, Art no. 3502505, doi: 10.1109/LGRS.2023.3257540.

[3] T. Counts, A. Gurbuz, W. R. Scott, J. H. McClellan, & K. Kim, "Multistatic Ground-Penetrating Radar Experiments" IEEE Transactions on Geoscience and Remote Sensing, 45(8), 2007, pp. 2544-2553.