URSI-B EMTS 2025, Bologna, 23–27 June

Quantitative subsurface imaging via linear microwave tomography and U-NET

G. Esposito(1), F. Soldovieri(1), I. Catapano*(1), G. Gennarelli(1)
(1) Institute for Electromagnetic Sensing of the Environment – National Research Council of Italy, Napoli, Italy
e-mail: {esposito.g, soldovieri.f, catapano.i, gennarelli.g}@irea.cnr.it

Quantitative imaging involving the estimation of both the signal propagation velocity, i.e. the relative permittivity, into the probed medium and the reconstruction of the relative permittivity of the detected targets is an open challenge in Ground Penetrating Radar (GPR) literature. This contribution focuses on the second issue and proposes an approach combining linear microwave tomography (MWT) with deep learning. Specifically, GPR data are firstly processed by standard time-domain (TD) procedures and then via a MWT approach. This last models the scattering phenomenon according to the Born Approximation and solves the inverse problem in a regularized way with Truncated Singular Value Decomposition [1]. After, the qualitative MWT image (i.e. its real and imaginary parts) is given as input to the popular convolutional neural network (U-NET) [2], which is trained on a synthetic dataset to provide the permittivity map of the investigated scenario. The adopted approach has been recently proposed in [3] and is herein thoroughly assessed using full-wave synthetic data and experimental measurements gathered in controlled laboratory conditions. Furthermore, the reconstruction capabilities of the approach are compared with those achieved when U-NET takes in input TD radargrams instead of MWT images. An example of the achievable results is shown in Fig. 1. The test case refers to a water filled pipe buried in a soil having relative permittivity equal to 5. The image shows the filtered radargram, the real and imaginary parts of the MWT image, the ground truth, and the U-NET predictions achieved with the two different training schemes, i.e. by using the MWT images and TD processed radargrams as input. More details about the imaging approach and further results will be presented at the conference.

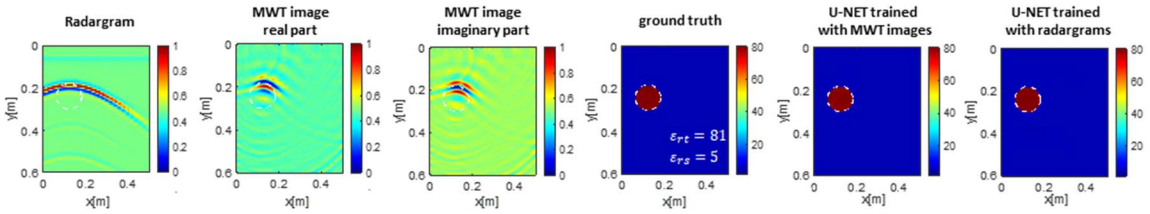

Figure 1. Simulation results in the case of a water pipe. The dashed circle in each image indicates the contour of the pipe.

References

[1] Webster, J.G., Catapano, I., Gennarelli, G., Ludeno, G., Soldovieri, F. and Persico, R. (2019). Ground-Penetrating Radar: Operation Principle and Data Processing. In Wiley Encyclopedia of Electrical and Electronics Engineering, J.G. Webster (Ed.). https://doi.org/10.1002/047134608X.W8383.

[2] O. Ronneberger, P. Fischer, and T. Brox, "U-Net: Convolutional networks for biomedical image segmentation," in Proc. 18th Int. Conf. Med. Image Comput. Comput.-Assist. Intervent., vol. 9351. Cham, Switzerland: Springer, 2015, pp. 234–241.

[3] G. Esposito, I. Catapano, F. Soldovieri and G. Gennarelli, "Quantitative GPR Imaging via U-NET," 2024 IEEE International Symposium on Antennas and Propagation and INC/USNC - URSI Radio Science Meeting (AP-S/INC-USNC-URSI), Firenze, Italy, 2024, pp. 901-902, doi: 10.1109/AP-S/INC-USNC-URSI52054.2024.10687135