EDITORIAL

Welcome to Issue 2, Volume 1 of *Ground Penetrating Radar*, the international, peer-refereed, open-access, academic journal designed to advance scientific knowledge and foster innovative engineering solutions in the field of Ground Penetrating Radar (GPR).

I wish to start this Editorial with many thanks to all colleagues who sent me warm messages and congratulations after the publication of the inaugural journal issue, in January of this year; also, I wish to express my deep gratitude to the Members of the Editorial Board and to all contributing Authors who believe in this newborn journal and have chosen *Ground Penetrating Radar* for the publication of their research works.

This issue comes later than expected, but with six interesting papers (see the Preface for an introduction to the papers) and a series of good news.

The first news item is that a journal section entitled 'News & Announcements' is inaugurated with this issue, dedicated to hosting the following content:

- Announcements regarding upcoming GPR-related academic activities, such as conferences and conference sessions, workshops, training schools, scientific contests and awards;
- Reviews of recent GPR-related books, submitted by their Authors and/or Publishers;
- Selected advertisements.

If you are interested in contributing to this section of the journal, please contact the editorial office at journal@gpradar.eu.

The second piece of news is that a Special Issue is being launched: the last issue of Volume 1 (to be published in December 2018) will be a collection of extended papers resuming contributions presented during the three days workshop 'Applications of Ground Penetrating Radar and related Science Management aspects' held in Split (Croatia), on 27-29 June 2018, in the framework of the 3rd International Conference on Smart and Sustainable Technologies (SpliTech 2018). This Special Issue is being edited by Prof. Dragan Poljak (University of Split, Croatia) and myself; submissions are open to scientists and experts who participated in the workshop and their co-Authors, only.

The third news is a scientific contest, open to Members of TU1208 GPR Association, only. Among all papers submitted to *Ground Penetrating Radar* from 1 September 2018 to 20 April 2019, whose Corresponding Author is a Member of TU1208 GPR Association at the time when the paper is submitted, the Editorial Board of the journal will select: (i) the Best Paper having an early-career investigator as

Corresponding Author, (ii) the Best Paper having a female scientist as Corresponding Author, (iii) the Best Paper having a scientist from an Inclusiveness Target Country as Corresponding Author. An early-career investigator is a scientist who received his PhD degree since no more than eight years at the time when the paper is submitted. Inclusiveness Target Countries currently are: Albania, Bosnia-Herzegovina, Bulgaria, Cyprus, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Luxembourg, Malta, Montenegro, Poland, Portugal, Romania, Slovenia, Slovakia, the former Yugoslav Republic of Macedonia, Republic of Serbia and Turkey. The Corresponding Authors of the awarded papers will receive award certificates and TU1208 GPR Association will support their participation in the 10th International Workshop on Advanced Ground Penetrating Radar (IWAGPR 2019, Rome, Italy, 3-5 July 2019) by reimbursing their conference registration fee. This contest is based on an idea proposed by Dr Pier Matteo Barone (American University of Rome, Italy).

All *Ground Penetrating Radar* papers are processed and published in true open access, free to both Authors and Readers, thanks to the generous support of TU1208 GPR Association and to the voluntary efforts of the journal Editorial Board. This issue is also supported by Adapis Georadar Teknik Ab (georadar.eu) and IDS Georadar s.r.l. (idsgeoradar.com): I would like to thank both companies personally, as well as on behalf of the journal Editorial Board, Authors and Readers.

Do you have suggestions to improve this journal? Would you like to leave a comment or ask a question? We are looking forward to hearing from our Readers! Send us a message at gpradar.eu/journal/contact.html or journal@gpradar.eu. Would you like to guest edit a Special Issue for *Ground Penetrating Radar*? Send us a proposal! If you wish to participate in the Editorial Board, please send us your motivation letter and curriculum vitae.

We hope to receive several interesting papers in the upcoming weeks!

The Editor-in-Chief
Lara Pajewski

PREFACE

I am delighted and honoured to introduce the second issue of the first volume of *Ground Penetrating Radar*, which includes six papers authored by scientists from 13 institutes in 11 countries (Belgium, Croatia, Czech Republic, France, Italy, Poland, Portugal, Serbia, Spain, Turkey, and United States of America).

The issue is opened with a paper entitled "**GPR system performance compliance according to COST Action TU1208 guidelines**," authored by myself, Milan Vrtunski, Željko Bugarinović, Aleksandar Ristić, Miro Govedarica, Audrey van der Wielen, Colette Grégoire, Carl Van Geem, Xavier Dérobert, Vladislav Borecky, Salih Serkan Artagan, Simona Fontul, Vânia Marecos, and Sébastien Lambot. Four tests are proposed, which can be carried out to evaluate the signal-to-noise ratio, short-term stability, linearity in the time axis, and long-term stability of the Ground Penetrating Radar (GPR) signal. The paper includes a thorough introduction to the topic, a full description of the tests, as well as results obtained by executing the tests on five pulsed control units and nine antennas with central frequencies from 400 MHz to 1.8 GHz. The performed measurements are not representative enough to establish absolute thresholds for the tests; nonetheless, they provide useful indications about values that one may obtain when testing GPR equipment, if the equipment is working reasonably well. Also, by periodically repeating the tests on the same equipment, it is possible to detect any significant shift from previously obtained values, which may imply that the GPR unit or antenna under test is not working in a normal or satisfactory manner. The Authors welcome any comments and suggestions to improve the tests. Moreover, we hope that the tests will be executed by other research teams, manufacturers and private end-users in the near future, on a wider variety of control units and antennas, on both brand new and older equipment; by sharing information about the obtained results, the GPR community can jointly establish reasonable thresholds for the tests, which can help to distinguish between equipment working properly and flawed equipment.

The second paper is entitled "**Frequency domain deterministic-stochastic analysis of the transient current induced along a ground penetrating radar dipole antenna over a lossy half-space**" and is authored by Anna Šušnjara, Dragan Poljak, Vicko Dorić, Sébastien Lalléchère, Khalil El Khamlichi Drissi, Pierre Bonnet, and Françoise Paladian. This paper presents a stochastic analysis of the transient current induced along a dipole antenna over a lossy half-space. The electromagnetic formulation of the problem is based on the Pocklington's integro-differential equation in the frequency domain, which is solved by means of the Galerkin-Bubnov indirect boundary element method; the transient solution is obtained by using the inverse fast

Fourier transform. By exploiting the Stochastic Collocation technique, the Authors investigate the variability of the current as a function of the soil permittivity, soil conductivity, and dipole distance from the half-space. Beyond the specific simulation case considered by the Authors, this paper represents a successful and valuable example of application of the Stochastic Collocation method in the GPR field, which may inspire other researchers to employ a similar approach in their simulations. Indeed, in GPR electromagnetic modelling problems there often is uncertainty on the input parameters, because some geometrical and/or physical properties of the scenario may be partly or entirely unknown. In such cases, the simple but robust Stochastic Collocation method can be effectively used to determine relevant statistics about the GPR responses and to assess confidence intervals in the numerical results.

Still concerning GPR antennas and full-wave methods for the solution of electromagnetic radiation and forward-scattering problems, the third paper is entitled "**Electromagnetic modelling and simulation of a high-frequency Ground Penetrating Radar antenna over a concrete cell with steel rods**;" it is authored by Alessio Ventura and myself. In this work, a high-frequency GPR antenna placed over a reinforced concrete cell is simulated by using the commercial software CST Microwave Studio, which implements the Finite-Integration technique. This study was mostly carried out during the Master thesis in Electronic Engineering of the first Author, under my supervision. Geometrical and physical information about the antenna was taken from the PhD thesis of Dr Craig Warren, where the same device was experimentally characterized and numerically modelled by using the Finite-Difference Time-Domain software GprMax3D; the reinforced concrete cell, instead, is one of the reference simulation scenarios of COST (European Cooperation in Science and Technology) Action TU1208 "Civil engineering applications of Ground Penetrating Radar." The paper comprises an explanation of how the CST model was built, followed by results calculated with the antenna above the concrete structure; comparisons with a simplified model, where the physical structure of the antenna is not taken into account, are also presented. The significant differences between the results of the realistic model and those of the simplified model confirm the importance of including accurate models of the actual antennas in GPR simulations. The results presented in the paper are available for download as 'Supplementary materials;' this gives me the opportunity to remind Readers that *Ground Penetrating Radar* encourages scientists to publish methods and results in as much detail as possible, as well as to enclose supplementary materials to their papers (e.g., data, software, videos, presentations, and any other useful electronic files).

The three papers introduced above stem from COST Action TU1208 "Civil engineering applications of Ground Penetrating Radar." COST is the longest-running European framework supporting trans-national cooperation among

researchers, engineers and scholars. COST Actions are bottom-up science and technology networks where scientists, professionals and stakeholders can jointly develop their own ideas; they are active through a range of networking tools, such as workshops, conferences, training schools, short-term scientific missions, and dissemination activities. COST Action TU1208 was running from 4 April 2013 to 3 October 2017; its main objective was to exchange and increase scientific-technical knowledge and experience of GPR techniques in civil engineering, whilst promoting a wider and more effective use of this safe and non-destructive method in the monitoring of structures.

The journal issue continues with the paper entitled "**GPR research in Wojanów railway tunnel, Sudetes mts., Poland**," authored by Adam Szynkiewicz. This is an interesting and detailled case study, where a commercial GPR equipped with three different antennas was used in the context of a geotechnical research carried out for the purposes of designing the renovation of Wojanów railway tunnel, in Poland. GPR measurements were performed above and inside the tunnel, namely along the ceiling of the tunnel, along the tunnel walls, and all along the tunnel floor (on the railway tracks, as well as close to the tunnel walls). The central frequencies of the three antennas were 100 MHz, 250 MHz, and 800 MHz. Most data were analysed in a two-dimensional system; a preliminary analysis in a three-dimensional system was attempted, too. The Author describes how the survey was carried out, how data were processed and interpreted, and how the various antennas were able to provide different kinds of information; the paper provides practical advice and useful recommendations. We are very pleased to host this contribution on *Ground Penetrating Radar*, because case studies dealing with the use of GPR in tunnels are not common in the scientific literature (this is realistically due to the fact that GPR tunnel inspections present considerable practical difficulties) and because of the longstanding experience of the Author in the GPR field, which reflects in the paper.

The journal issue is concluded with two papers coming from an excellent research team, where innovative solutions for suppressing clutter and reducing the corresponding false alarms in Forward-Looking GPR (FLGPR) are presented and validated on experimental data. The main focus is on the use of vehicle mounted FLGPR, equipped with dual band array antennas, for the detection of buried explosive threats, such as mines and improvised explosive devices.

The first paper of this pair is entitled "**Model-based clutter reduction method for forward looking Ground Penetrating Radar imaging**" and is authored by Yukinori Fuse, Borja Gonzalez-Valdes, Jose A. Martinez-Lorenzo, and Carey M. Rappaport. A model-based clutter suppression image processing method, which uses a mask to reduce clutter from the rough ground surface and from objects above the ground, is described and tested. The proposed approach is able to clean the L-Band Synthetic

Aperture Radar (SAR) image obtained by the FLGPR by employing a mixed binary mask, which is produced from L-Band and X-band data; this mask covers only the surface scatterer signals and excludes the signals generated by buried targets within the masked covering area. A new simulated SAR image is created, by exploiting the masked L-Band SAR image; the simulated image, due to the primary clutter objects, is subtracted from the original image, thus providing a clutter-suppressed SAR image without affecting the buried target signals. The performed tests show that the application of the proposed method significantly reduces the false alarm rate.

The subsequent paper, which is the last contribution included in this journal issue, is entitled "**False alarm reduction by target tracking for Forward Looking Ground Penetrating Radar**" and is authored by Yukinori Fuse, Masoud Rostami, Borja Gonzalez-Valdes, and Carey M. Rappaport. In this contribution, a target tracking process is proposed, which can be applied to multiple clutter suppressed SAR images to further reduce the false alarm rate. It is observed that underground objects tend to scatter similarly for most stand-off distances and yield a consistent image, independent of the platform position. Such image consistency from the buried targets is a feature that is exploited to distinguish them from clutter objects. If the position of the FLGPR antennas is accurately measured by Global Positioning System units, while the radar system is moving, the position of the signals on the SAR image can be compared in a selection of frames and the signals that remain at a given position, which are indicative of stationary targets, can be identified, while the clutter signals can be eliminated. Tests performed by the Authors show that false alarms are further reduced by this approach and the detection performance of the radar is improved.

I wish to warmly thank all Authors of these six papers for choosing *Ground Penetrating Radar*. I hope that their scientific efforts and their trust in this journal will be returned back with an effective spreading of their researches. Many thanks also to all researchers and experts involved into the revision process of the papers, for their voluntary efforts.

I am grateful to TU1208 GPR Association (gpradar.eu/tu1208), Adapis Georadar Teknik Ab (georadar.eu), and IDS Georadar s.r.l. (idsgeoradar.com), for supporting the publication of this issue, and to COST (cost.eu) for having funded and supported the Action TU1208 (gpradar.eu).

The Editor-in-Chief
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