ANNEX 3: FINAL REPORT

Marie Curie Actions – International Fellowships

Project n°: 269157

Project Acronym: AMISS

Project Full Name: Active and Passive MIcrowaves for Security and Subsurface imaging

AMISS

Active and Passive MIcrowaves for Security and Subsurface imaging

Marie Curie Actions

IRSES Final Report

Period covered: from 1/10/2011 to 30/09/2014

Project coordinator organisation name: Consiglio Nazionale delle Ricerche, Istituto per il Rilevamento Elettreomagnetico dell'Ambiente

1. FINAL PUBLISHABLE SUMMARY REPORT

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Active and passive MIcrowaves for Security and Subsurface imaging (AMISS)
AMISS was a knowledge exchange project to establish a collaborative network with international visibility to advance the theory and application of active and passive microwave imaging systems.
The project brought together seven partners from three EU and Associated countries and from three Third countries:

1. Consiglio Nazionale delle Ricerche (CNR), Italy (Coordinator) (EU Member);
2. Technische Universiteit Delft (TUDELFT), The Netherlands (EU Member);
3. Yildiz Technical University (YTU), Turkey (EU Associated Country);
4. Usikov Institute for Radio-physics and Electronics (IRE), Ukraine (Third Country);
5. State Research Centre of Superconductive Radioelectronics “Iceberg” (SRC), Ukraine (Third Country);
6. Bauman Moscow State Technical University (BMSTU), Russia (Third Country);
7. University of Sao Paulo, (USP), Brazil (Third Country).

AMISS’ objective
The overall objective of the project was to develop, characterize, and analyse the performance of new systems, sensors, and configurations for active and passive microwave imaging.
This was carried out in two research lines and the effectiveness of research results was tested in ground-penetrating radar (GPR) for subsurface sensing and infrastructure diagnostics and in security applications.

Work programme
AMISS was organized in four work packages. Work Package 1 dealt with Microwave and Millimetre wave imaging systems for security. In this package antenna arrays, through wall imaging systems, concealed weapon detection, and on body concealed object detection systems were designed. In work package 2 GPR technologies for subsurface sensing and critical infrastructure monitoring were developed. Antenna arrays and inpulse generators were developed, as well as systems for clutter reduction and holographic radar for shallow applications. GPR systems were applied in geophysical, archaeological, and non-destructive testing domains. Data processing was developed through linear and non-linear imaging and inversion methods and experimentally validated at the USP test site. Work package 3 investigated radar technologies for remote detection and registration of vital signs. In this package antennas and systems for biological radar scans were developed together with data processing techniques. These were experimentally tested under controlled conditions. Work package 4 was concerned with overall project management.

Achievements
The AMISS work packages have been executed through highly successful visits lasting between one week and 8 months. Visitors gave 8 research seminars, one graduate course, organized two session during international conferences, edited two special issues in international peer reviewed journals, contributed to 15 journal papers, one book chapter, and more than 30 proceedings, abstracts, and presentations in more than 10 international conferences.
The scientific achievements from the work packages are:

1. Work Package 1 developed full holographic radar for concealed objects detection, enhanced by data processing; development, implementation, and validation of a microwave tomographic data processing for a Through-Wall-Imaging system;

development, analysis, and realization of several new antennas for millimetre band applications.
2. Work Package 2 developed antennas and systems for novel GPR technology and associated data processing methods for tomography, imaging, and inversion.
3. Work Package 3 development and realization of bioradar prototypes with associated data processing methods; performance test analysis and defining measurement protocols for medical applications

Benefits and outgrowth
AMISS's visits, seminars, workshops, jointly organized conference sessions, and collaborative writing of abstracts, conference proceedings, and journal papers have created various new links and contacts between the researchers from the different institutes. Participants have been able to dedicate their knowledge and expertise to obtain command of the whole chain from equipment to application, developed dedicated products and software to improve existing technologies and creating new technologies. Knowledge exchange between EU/Associated countries and Third countries has proven crucially important and has led to continuing collaboration. AMISS knowledge exchange and networking resulted in a Memorandum of Understanding between CNR and IRE and between CNR and USP; it has resulted in CNR cooperating with a Chinese entity through mediation of SRC; it has allowed AMISS partners to participate in COST Action TU1208 and for CNR in COST Action TD1301; it has motivated BMSTU and CNR to pursue further collaboration through a bilateral agreement; it has resulted in a three-year project jointly carried out by TUDelft and USP financially supported through the Federal Brazilian Science without Borders programme; furthermore IRE and YTU have expressed the intention to further develop together a GPR system in Turkey based on the one developed by IRE in the AMISS project.

List of Keywords

Subsurface sensing; security; safety Ground Penetrating Radar; holographic radar; bioradar; passive radar:; microwaves; imaging; tomography; inversion.

Websites where additional information may be found

http://www.irea.cnr.it/index.php?option=com_k2&view=item&id=342:progetto-amiss&Itemid=167

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REPORT ON WORK PERFORMED AND RESULTS

1. Introduction

AMISS project had the main objective to establish and improve a collaborative network able to acquire international visibility, thanks to the achieved theoretical and applicative advancements in the field of the active and passive microwave imaging systems. The proposal involved three EU and Associate Countries members (Italy, The Netherlands, Turkey) and 4 partners from Third Countries (Russia, Ukraine, Brazil), as listed below:

1. Consiglio Nazionale delle Ricerche (CNR), Italy (Coordinator) (EU Member);
2. Technische Universiteit Delft (TUDELFT), The Netherlands (EU Member);
3. Yildiz Technical University (YTU), Turkey (EU Associated Country);
4. Usikov Institute for Radio-physics and Electronics (IRE), Ukraine (Third Country);
5. State Research Centre of Superconductive Radioelectronics “Iceberg” (SRC), Ukraine (Third Country);
6. Bauman Moscow State Technical University (BMSTU), Russia (Third Country);
7. University of Sao Paulo, (USP), Brazil (Third Country).

According to the workplan, the research macro-objectives of AMISS were:

1) Development/improvement and characterization of new sensors and systems for active and passive microwave imaging;
2) Set up, analysis and validation of state of art/novel data processing approaches for GPR in critical infrastructure and subsurface imaging;
3) Integration of state of art and novel imaging hardware and characterization approaches to tackle realistic situations in security, safety and subsurface prospecting applications;
4) Development and feasibility study of bioradar technology (system and data processing) for vital signs detection and detection/characterization.

The achievement of these objectives was pursued by setting up a workplan organization involving four work packages, three regarding the scientific/technical activities and the last one aimed to manage the project.

In the following, we summarise and describe AMISS activities according to the WPs and related tasks subdivision of the project.

WP1 Microwave and Millimetre wave imaging systems for security, coordinated by Prof. Ahmet Turk of YTU and with the involvement of YTU, CNR, IRE, SRC and BMSTU

WP2 Development of GPR technologies for subsurface sensing and critical infrastructure monitoring, coordinated by Prof. Evert Slob of TUDELFT and with the involvement of TUDELFT, CNR, YTU, IRE. BMSTU, USP

WP3 Radar technologies for remote detection and registration of vital signs, coordinated by Dr. Lorenzo Crocco of CNR and with the involvement of CNR, BMSTU, YTU

WP4 Project Management, coordinated by Dr. Francesco Soldovieri of CNR with the involvement of CNR, YTU and TUDELFT.

2. Scientific/Technical AMISS activities

In this Section, we report the successful activities of the scientific/technical WPs (WPs 1,2,3). The activities of WP4 are reported in the section regarding the Management.

WP1 Microwave and Millimetre wave imaging systems for security

Task 1.1: Horn, parabolic reflector and array antenna preliminary designs in microwave and MMwave bands.

YTU and IRE cooperated in carrying out the activities of this task. At the starting stage, the possibility of using dielectric loaded waveguide and horn antennas, also under an array configuration, was discussed in order to improve the performance of wideband microwave radar imaging and through-wall imaging systems, in terms of range resolution limits. In particular, YTU and IRE cooperated in the analysis of an UWB impulse radar design, with a focus on UWB horn and reflector antennas and impulse generator. In this framework, YTU developed a 2.5D ARM algorithm for fast and reliable analysis of parabolic reflector antennas of MM-wave systems.

The outcome of these activities are in

O. M. Yucedag, A.S. Turk, "Parametric Design of Open Ended Waveguide Array Feeder with Reflector Antenna for Switchable Cosecant-Squared Pattern", ACES JOURNAL, VOL. 27, NO. 8, pp. 668-675, AUGUST 2012

O.M. Yücedag, A.S. Türk, Design of horn fed offset parabolic reflector antennas with analytical regularization method", Journal of Electromagnetic Waves and Applications, 28(12*), 1502-1511., 2014 DOI:10.1080/09205071.2014.932056*

In addition, a journal paper *A.S.Turk et al. "Development of 2.5D Analytical Regularization Method for reflector antenna analysis" is in preparation for submission to IEEE Trans. Antennas and Propagation.*

A novel ultra-wide band Vivaldi shaped TEM fed dielectric loaded ridged horn design has been implemented by YTU, to be used as the antenna head for the Ground Penetrating Impulse Radar designed by IRE. The technological aim of this study was to achieve improved high antenna gain, narrow beam and low input reflection characteristics over an ultra-wide band for high-resolution impulse radar systems. Afterwards, the antenna has been integrated into the radar system designed by IRE and measurements have been carried out for this UWB antenna. Finally, the design of this antenna for GPR differential system has been tested in real conditions for road diagnostics and monitoring.

The scientific outcomes of this activity are presented in

G.P. Pochanin, V.P. Ruban, P.V. Kholod, A.A. Shuba, A.G. Pochanin, A.A Orlenko "Enlarging of power budget of ultrawideband radar" (Proc. of the 6th International Conference on "Recent Advances in Space Technologies-RAST2013", pp. 213-216, June 12 14, 2013. Istanbul (Turkey).

Pochanin G.P., Ruban V.P., Batrakova A.G., Urdzik S.N., Batrakov D.O. "Measuring of thickness of asphalt pavement with use of GPR", 15th International radar symposium

proceedings, pp. 452-455. Gdansk, Poland, June 16-18, 2014. ISBN 978-83-931525-3-7.

Pochanin G.P., Ruban V.P., Kholod P.V., Shuba O.A., Pochanina I.Ye., Batrakova A.G., Urdzik S.N., Batrakov D.O., Golovin D.V. "Advances in Ground Penetrating Radars for Road Surveying", Proceedings of 7th International Conference on Ultra Wideband and Ultra Short Impulse Signals (UWBUSIS), pp. 13-18. September 15-19, 2014, Kharkiv, Ukraine.

Task 1.2: Active microwave tomographic system design for through wall imaging.

The first activity (CNR-BMSTU) of this task was concerned with the development and the improvement of a microwave tomographic approach, based on a linear inverse scattering approach, for Through-Wall-Imaging. The TWI tomographic approach has been tested in real conditions, by processing measurements collected with a time domain GPR system. The results of this activity are summarized in the report "Feasibility study and performances evaluation of a through-wall imaging approach via experimental validation".

A second activity regarded the design of a dielectric loaded compact ridged horn antenna by YTU for ultra-wide band (UWB) microwave through-wall imaging system. This has the aim to provide adaptive ranging and better resolution performance for the TWI RASCAN system developed by BMSTU group.

In addition, an adaptive UWB SAR algorithm has been developed by YTU group and TWI SAR laboratory test measurements have been performed for human-like targets at the distance of 2-3 meters from the radar platform. *The results of this assessment have been presented at 15th International Radar Symposium, Gdansk, Poland, June 16-18, 2014.*

Task 1.3: Active Microwave holographic system design for detection of concealed objects under clothes on human body.

The microwave holographic system was designed and implemented by BMSTU. This system is a holographic radar system exploiting in-phase and quadrature channels and works in a frequency band around 7 GHz. The data were provided by BMSTU to CNR. This allowed a comparison between the microwave tomographic approach developed at CNR with the data processing developed by BMSTU. In particular, the comparison was performed by focusing on the interpretability and the achievable resolution of the images. The results, which demonstrate the effectiveness of the system and data processing, are presented in

Zhuravlev, A.V., S.I. Ivashov, V.V. Razevig, I.A. Vasiliev, A.S. Bugaev (2013b), Holographic Subsurface Radar RASCAN-5, Proceedings of the International workshop on Advanced Ground Penetrating Radar (IWAGPR2013),pp. 289-294, Nantes, France, July 2-5, 2013.

Further studies have been performed between YTU and BMSTU to improve the holographic GPR system developed at BMSTU. As not expected outcome of the project, the fully holographic system has been characterised also for buried targets detection.

Zhuravlev, A.V., S.I. Ivashov, V.V. Razevig, I.A. Vasiliev, A.S. Türk, and A. Kizilay, "Holographic Microwave Imaging Radar for Applications In Civil Engineering", Proceedings of the IET International Radar Conference, paper A0065. 14-16 April 2013, Xi'an, China.

Ivashov, S.I., A.S. Bugaev, A.S. Turk, A.V. Zhuravlev (2013), "An Algorithm for Detection of Hidden Objects by Passive/Active Radiometer", paper D0121, Proceedings of the IET International Radar Conference, 14-16 April 2013, Xi'an, China.

Task 1.4: Radiometric passive imaging for concealed weapon detection.

YTU has designed waveguide and horn array fed parabolic reflector antennas for the radiometric passive millimetre wave imaging system developed by SRC. In particular, a 3-Dimensional Analytical Regularization Method (ARM) has been developed by YTU to perform fast and accurate design and analysis of waveguide array feeder of the parabolic reflector. The general aim of this activity was to obtain desired radiation characteristics for air and coastal microwave surveillance radars and radiometric passive millimeter wave imaging.

A knowledge transfer occurred from SRC to YTU regarding the 35 GHz passive radiometric imaging system and its sub-modules (i.e., antennas, receiver and image processing). As a future step, it is expected to realize a laboratory prototype of this system at YTU laboratory.

The performance of the two radiometric passive imaging systems developed at SRC (33 GHz and 94 GHz) have been enhanced thanks to the data processing tools developed at CNR. Radiometric images have been provided by SRC to CNR with the aim to develop and implement signal processing approaches able to improve radiometric images in terms of robustness with respect to noise and interpretability by the user. The activity was very important from two point of views; first, researchers of CNR had the possibility to investigate and deepen the analysis of the performance of these passive radiometric systems; secondly, CNR researchers developed tailored signal processing strategies to improve the interpretability of the radiometric images. The scientific aims of the developed data processing tools were the mitigation of clutter and the improvement of spatial resolution of radiometric images. The data processing approach performances have been appraised with the data collected by the two systems at 33 and 94 GHz.
The scientific outcomes of this activity are collected in

F. Soldovieri, A. Natale, V. Gorishnyak, A. Pavluchenko, A. Denisov, and L. Chen, "Radiometric Imaging for Monitoring and Surveillance Issues," International Journal of Antennas and Propagation, vol. 2013, Article ID 272561, 8 pages, 2013. doi:10.1155/2013/272561

F. Soldovieri, A. Denisov, V. Speziale, "A novel solution for car traffic control based on radiometric microwave devices", Vol. 16, EGU2014-13903, 2014 EGU General Assembly 2014.

As an unexpected result of the project, an activity has been started between SRC and CNR, regarding the study of a novel single-block UWB device, operating in the TeraHertz band. The system combines a super-wide band frequency-meter with a sensitive super-wide band panoramic receiver. The outcome of this scientific activity will be presented in the conference paper

A.Denisov, F.Soldovieri, J.Qiu, "Best candidate for the receiving and frequency measuring in the future analogue of "Agilent" in Terahertz band is Josephson junction", submitted to IEEE International Microwave Symposium, USA, May 2015.

WP2 Development of GPR technologies for subsurface sensing and critical

infrastructure monitoring

Task 2.1: Ultra-wide band (UWB) planar, TEM horn and array antenna designs for GPR systems.

It is worth noting that the activities of the tasks 1.1, 2.1 and 2.2 were strictly related to each other, so that they should be seen under a unified frame.

This task has been performed thanks to the cooperation between YTU an IRE.

The first activity was concerned with the design and implementation of an Ultra Wide Band TEM horn antenna suitable for Ground Penetrating Impulse Radar. This activity has regarded different layouts of TEM horn antennas such as, dielectric loaded, Vivaldi shaped and array versions with a focus on UWB GPR systems.
After, YTU and IRE have integrated the designed dielectric loaded compact ridged horn antenna, the reflector antenna and the prototype of the GPR available at IRE. The validation of such an integrated GPR system has been performed under a Forward Looking GPR configuration, aiming at detecting buried metal and dielectric objects in the area ahead the vehicle. The study yielded positive results. Experimental results were published in the proceedings of the conference UWBUSIS 2014:

Turk, A.S., A.K. Keskin, M. Dagcan Senturk, A. Magat, M.B. Ozakin, S. Aksoy,"Ultra wide band TEM horn and reflector antenna designs for down and forward looking ground penetrating radars", Proceedings of the International Workshop on Advanced Ground Penetrating Radar (IWAGPR2013), Nantes, France, July 2-5, 2013.

Ruban V.P., Shuba O.O., Pochanin O.G., Pochanin G.P., Turk A.S., Keskin A.K., Dagcan S.M., Caliskan A.T., "Analog Signal Processing for UWB Sounding", Proc. Of 7th International Conference on Ultra Wideband and Ultra Short Impulse Signals (UWBUSIS), pp. 55-58. September 15-19, 2014, Kharkiv, Ukraine.

The design of a new digital delay line with low jitter and extended range of delay was discussed during a visit of YTU at IRE. The prototype of the delay line was manufactured and tested during 2 visits to the YTU.

Task 2.2: Wide band impulse generator designs for multi-band GPR.

After an initial technical cooperation between IRE and YTU regarding the study of signal generators of impulse GPR able to work on a Ultra Wide Band, a 3 GHz impulse generator based on RF switch-transistor has been designed and realized by YTU group, in cooperation with IRE. Tests and measurements have been done successfully at YTU Microwave Laboratory.

Low cost high voltage impulse generators have been designed and realized for GPR transmitters. In particular, two short pulse generators have been designed by 2N2222 with its avalanche mode. The first one has been realized with a single stage, whereas the second one has been realized under a cascade modality, by using a cascaded multi-stage solution to achieve higher voltage. Measurements have shown the effectiveness of the proposed solution for the two generators.

The outcomes of this activity are presented in:

A.K. Keskin, M. D. Senturk, A. A. Orlenko, G.P. Pochanin, and A.S. Turk, "Low Cost High Voltage Impulse Generator for GPR", Proc. of 30th Annual Review of Progress in Applied Computational Electromagnetics, ACES 2014 Conference, March 23-27, 2014, Jacksonville, USA.

Ruban V.P., Shuba O.O., Pochanin O.G., Pochanin G.P., Turk A.S., Keskin, A.K., Dagcan S.M., Caliskan A.T., "Analog Signal Processing for UWB Sounding", Proc. of 7th International Conference on Ultra Wideband and Ultra Short Impulse Signals (UWBUSIS), pp. 55-58, September 15-19, 2014, Kharkiv, Ukraine.

Task 2.3: Novel GPR system based on differential configuration for clutter mitigation

YTU has cooperated with IRE on the hardware development of the novel differential GPR system of IRE. In the first phase, YTU and IRE have designed a novel ultra-wide band TEM horn antenna suitable for the differential GPR system already available at IRE. At present, the differential system of IRE exploits printed bow-tie antennas and the activity of this task aims at investigating the possibility to use horn antennas for the IRE system. The differential GPR system is able to erase the direct coupling between receiving and transmitting antennas, so that it is suitable to detect and characterize weak scattering targets. After, YTU has developed novel ultra-wide band TEM horn antenna pair, which has been connected to the GPR system designed by IRE. The results of experimentation of the integrated GPR systems in controlled conditions have been presented in part in the conference paper:

Ruban V.P., Shuba O.O., Pochanin O.G., Pochanin G.P., Turk A.S., Keskin, A.K., Dagcan S.M., Caliskan A.T., "Analog Signal Processing for UWB Sounding", Proc. of 7th International Conference on Ultra Wideband and Ultra Short Impulse Signals (UWBUSIS), pp. 55-58, September 15-19, 2014, Kharkiv, Ukraine.

Large attention was given to the development of the advanced and specifically devoted data processing for the differential configuration, which is a non-conventional configuration for GPR surveys. The development of the data processing and its integration in the GPR system of IRE was made possible by the cooperation between CNR and IRE. A detailed description of the radar image reconstruction based on differential GPR data and tomographic inversion approaches are going to be presented in the journal paper under submission:

Persico R., Pochanin G., Ruban V., Orlenko A., Catapano I., and Soldovieri F., "High decoupled antenna and microwave tomography in GPR" under submission.

The above paper summarizes the results of the activity detailed below. First, a tomographic reconstruction approach was developed in the 2D geometry, both for the free space and half-space (buried targets) scenarios. The GPR system in combination with tomographic radar data processing permits to retrieve the shape of the objects from radar measurements. The effectiveness of the proposed inversion scheme has been tested by processing synthetic and experimental data and main scientific outcomes are in

Persico, R.; Soldovieri, F.; Catapano, I.; Pochanin, G.; Ruban, V.; Orlenko, O., "Experimental results of a microwave tomography approach applied to a differential measurement configuration", Proceedings of the International Workshop on Advanced Ground Penetrating

Radar, (IWAGPR2013), 2-5 July 2013,Nantes, France.

After, the more general case of a 3D scenario was considered and theoretical investigations were performed on three differential antenna systems, also thanks to several experiments clarifying the characteristics of these differential antenna configurations. The activity dealt with the comparison of three antenna systems, where receiving antennas are symmetrically displaced with respect to the transmitting antenna along three orthogonal directions for 3D imaging of targets in free-space. To this end, synthetic radargrams were generated by a finite-difference time-domain forward solver (developed at IRE), for each measurement set-up. After, a microwave tomographic approach was developed and applied to process the scattered field differential data and obtain the images for the comparison among the three configurations. The scientific outcomes of these investigations have been published in

Varianytsia-Roshchupkina L.A., Gennarelli G., Soldovieri F., Pochanin G.P., "Comparative Analysis of Three RTR-Differential GPR Systems for Subsurface Object Imaging" Radiophysics and Electronics. 2014, vol. 4, (in press).

Varianytsia-Roshchupkina L.A., Soldovieri F., Pochanin G.P., Gennarelli G.,"Full 3D Imaging by Differential GPR Systems", Proc. of 7th International Conference on Ultra Wideband and Ultra Short Impulse Signals (UWBUSIS), pp. 120-123. September 15-19, 2014, Kharkiv, Ukraine.

Varianytsia-Roshchupkina L.A., Gennarelli G., Soldovieri F., "Comparison of Two Differential GPR Systems for Imaging Objects under a Reflection Configuration", proc. of 15th International Radar Symposium, Gdansk, Poland, June 16-18, 2014.

Task 2.4: Holographic radar for shallower subsurface imaging

CNR, in cooperation with BSMTU, has developed a linear inversion approach able to deal with the data provided by holographic radar systems, with the aim to improve performances in terms of spatial resolution and focusing, for an easier interpretation of the reconstructed images. Results of the inversion approach have been achieved at CNR in controlled conditions, thanks to the data provided by the RASCAN.4/4000 holographic radar developed at BMSTU.
CNR and BMSTU have completed the work of the integration of the novel data processing algorithm to localize and geometrically qualify subsurface scattering objects via holographic radar. The main outcomes of this activity are in

I. Catapano, L. Crocco, A. Affinito, G. Gennarelli, V. Razevig, I. A. Vasiliev, S. I. Ivashov, F. Soldovieri, "On the holographic radar as a tool for structural monitoring", Proc. of 33rd EARSeL Symposium, Matera, 6-7 June 2013.

Catapano I., L. Crocco, A. Affinito, G. Gennarelli, F. Soldovieri, "Monitoring by holographic radar systems" Proc. of EGU General Assembly, Vienna, 7-12 April 2013.

Task 2.5: Application of GPR systems to several domains: geophysical, archeology, NDT applications.

This task had the aim of validating the use of GPR systems in different application fields, ranging from geophysics, to archaeology, non-destructive testing and monitoring. This task together with all the following ones (especially task 2.9) of WP should be seen under a unified frame. In particular, in this task, the approaches based on a linear model of the electromagnetic

scattering have been validated in several application domains and we list several publications where such an activity has been reported. The other main activity of validation of the developed reconstruction approaches is in task 2.9, with a specific focus to the datasets collected at USP facilities. In this task, a microwave tomographic approach developed by CNR has been also validated in real conditions for archaeological prospecting in two cases, regarding the inspection of a prehistoric site in a cave of the Southern Italy and the surveys for delimiting the geometry of a Roman villa in UK, respectively.

F. Soldovieri, E. Utsi, R. Persico, and A.M: Alani "Imaging of Scarce Archaeological Remains using Microwave Tomographic Depictions of Ground Penetrating Radar Data", International Journal of Antennas and Propagation, Volume 2012, Article ID 580454, 8 pages, doi:10.1155/2012/580454

Catapano I, Loperte A., Satriani A., Larocca F., Affinito A., Soldovieri F., Amato M., "Three-dimensional ground penetrating radar surveys at Grotte dell'Angelo, Pertosa, (SA), Southern Italy", Rendiconti Online Societa' Geologica Italiana, 2013

Catapano I, Affinito A., Gennarelli G., di Maio F., Loperte A., Soldovieri F., "Full three-dimensional imaging via ground penetrating radar: assessment in controlled conditions and on field for archaeological prospecting", Applied Physics A, vol. 115, pp. 1415-1422, 2014

Task 2.6: Electromagnetic modeling of subsurface wave propagation and scattering from sub-layers and buried objects.

The inversion methods of Task 2.8 required the proper modeling of the subsurface wave propagation; accordingly, numerical tools able to handle the so-called forward simulation were developed by TUDELFT in cooperation with USP. The forward modeling approaches were able to tackle, without approximation, 1D and 2D propagation of a wave (and its interaction with an obstacle) in a layered medium.
An approach has been developed, which is able to model a horizontally layered earth response for vertical transverse isotropic layers. The fields can be generated by electric or magnetic dipole sources and the magnetic and electric field responses can be computed. Sources and receivers can be located anywhere in the layered model; this allows to compute surface reflection measurements, as well as surface to borehole and cross borehole measurements.
As second activity, a fast time domain finite difference code was developed to model 2D TE-mode GPR data by TUDELFT, which was used by USP to model several scenarios necessary for achieving Task 2.9. A novel modeling method, based on electromagnetic reciprocity and scattering formulation, was developed. This method transforms measured reflection data into new data, which correspond to a virtual measurements in which the sources are in the same location as those of the actual measurements, but the user can place the receivers at any desired depth level thereby creating a vertical radar profile data set. The resulting data contain true amplitude information and includes all propagation and scattering of the actual subsurface situation. It forms the basis for a game changer in terms of full waveform inversion strategies. Results can be found in:

Slob E. and K. Wapenaar, "GPR wave field decomposition, synthesis, and imaging for lossless layered vertically transverse isotropic media", Proceedings of the International Workshop on Advanced Ground-Penetrating Radar (IWAGPR2013), pp. 21-26. Nantes, France, July 2-5, 2013.

Slob, E. and K. Wapenaar, "Coupled Marchenko equations for electromagnetic Green's function retrieval and imaging", Proc. of SEG 83rd Annual Meeting, pp. 1863-1867. Houston, USA, September 2013.

Slob, E., J. Hünziker, J. Thorbecke, and K. Wapenaar, "Creating virtual vertical radar profiles from surface reflection Ground Penetrating Radar data", Proceedings of the 15th International Conference on GPR2014, Bruxelles, Belgium, June 2014.

Task 2.7 Fast single and multi component linear inversion algorithms using the imaging principle.

TUDELFT has developed and implemented a new method for imaging GPR reflection data collected in multi-offset mode. The method can work with a minimum of required information about the subsurface and is capable to remove internal multiples. First, the one-dimensional version has been demonstrated to work, then extensions to two- and three-dimensions were implemented. The output of this imaging algorithm is the input for full-waveform non-linear inversion, which is the main objective of Task 2.8. In particular, the method has been extended to 3D and multicomponent multi-offset electromagnetic reflection and data can be used to create an electromagnetic wave field, which focuses inside a 3D heterogeneous lossless earth at an arbitrary chosen location. This focusing wave-field can be obtained simultaneously in its up-going and down-going components. The focusing wave-fields allow constructing a virtual vertical ground penetrating radar (VRP) data set, with a virtual source at the focus point and receivers at the receiver locations of the measurements. The up- and down-going VRP data can then be used to create a subsurface image at the focus point by multidimensional deconvolution. This method eliminates all internal multiple effects on the final image and recovers the true reflection amplitude at the image location. This feature allows for using this image in a local inversion scheme for full waveform inversion.

CNR and USP have first cooperated to improve the linear inversion approaches already available at CNR, with the aim to adapt them to forensics archaeology applications. These approaches have been then used in real conditions thanks to the processing of data collected at an experimental site at USP. This latter activity is presented in task 2.9, with the related scientific outcomes.

Another activity has regarded the development of an advanced scattering model capable of accounting for the 3D and vectorial nature of the scattering phenomenon used to design a novel imaging approach capable of providing full 3D images of buried targets. This approach has been validated experimentally thanks to the activities in Tasks 2.5 and 2.9

Catapano I., Affinito A., Crocco L., Gennarell, G., Soldovieri, F., "Full 3-D electromagnetic subsurface imaging using ground penetrating radar," Proc. of Workshop on Advanced Ground Penetrating Radar (IWAGPR2013), 2-5 July 2013, Nantes, France.

As an unexpected result of the project, a new approach was developed and analysed, where the reconstruction capabilities of the microwave data processing are improved in term of achievable resolution, by using a periodic lattice between the antenna system and the targets, This activity has led to the following publication on a very prestigious Journal

Gianluca Gennarelli, Raffaele Persico, and Francesco Soldovieri. "Effective imaging systems based on periodic lattices." Applied Physics Letters, vol. 104.19 (2014): 194103.

Task 2.8: Full waveform non-linear inversion

This task was devoted to develop and analyse inverse scattering approaches able to perform a quantitative description of the targets in terms of electromagnetic properties (dielectric permittivity, electrical conductivity and magnetic permeability). These approaches are characterized by further mathematical difficulties as compared to the ones presented in Task 2.7 (based on linear inverse scattering model and approaches). In fact, in this case, we are concerned with the non-linearity of the relationships between the scattered/reflected field data and the unknown electromagnetic properties of the targets, so that a problem of reliability of the achieved solutions arises (false solution existence).
Different geometries and background scenarios have been considered.

For the 1D geometry, an inverse modelling has been developed with the aim to carry out a quantitative analysis regarding the estimation of the electromagnetic properties of a layered medium starting from a GPR trace (A scan). The problem has been tackled by using the Ant Colony Optimization, as a global random search method to minimize a cost function representing the distance between the measurements and model data. The quantitative analysis was performed over a simple 1D model, in order to better evaluate the performance of the proposed methodology with respect to the reliability and the accuracy of the results. The study was focussed on this canonical case starting from data acquired in a fixed-offset, off-ground configuration, with the aim to retrieve the properties of a slab in free space. After several statistical analyses, necessary to select the tuning parameters of the reconstruction scheme, the optimization was able to provide very accurate results, in terms of estimation of dielectric permittivity, conductivity and thickness of the slab. An experimental validation of the approach was performed with real data acquired at CNR-IREA laboratory by using two kinds of antenna systems as a 2 GHz GPR antenna working in time domain and a laboratory system using two ridged horn antennas working in frequency domain. This quantitative analysis was possible thanks to the cooperation between USP and CNR and is the subject of a journal paper to be soon submitted.

As another activity, a study has been carried out about the performance of a full waveform inversion of a layered electromagnetic medium through a two-step linear problem according to the scheme below. Sources are located above the receivers and the receivers are located on a plane. Horizontal electric and magnetic field components are measured at the receiver plane and both the fields are properly sampled. Then, the recently developed coupled Marchenko-type equations are exploited to create an upgoing and downgoing wave-fields, which are generated by a virtual source at a chosen location in the subsurface, without any knowledge of the layered medium. This constructed wave-field is used to retrieve the correct reflection amplitude of the interface at the focus point as a function of offset in space domain, or incidence angle in the plane wave domain. From the reflection coefficient as a function of the incidence angle, the dielectric permittivity and magnetic permeability can be computed by direct matrix inversion. As stated above, both the steps of the inversion scheme concern with linear operations. The successive steps have regarded the inclusion of 3D heterogeneities in the inversion scheme and accounting for the losses in the model, by assuming non-zero conductivity.

A potential breakthrough in full waveform inversion was achieved by TUD rendering the full-waveform inversion a linear problem unlike what is commonly assumed. The developed scheme carries out a full waveform inversion in three linear steps. The first step reorganized

the measured reflection data such that receivers are placed from the original measurement surface to any user-desired depth level. In this step, surface reflection data are transformed into a virtual vertical radar profile where the sources remain at their original locations while the receivers are placed in the subsurface. This step is a linear filter step that requires as input the emitted source time signature and the time of first arrival from all sources to the subsurface receiver location. A smooth subsurface model suffices to achieve this step and such model can be obtained through velocity analysis carried out on the measured data. After this first step, the upgoing and downgoing wave-fields are known separately at the receiver level. The second step carries out a multidimensional deconvolution, effectively placing the sources at the receiver depth level, and obtains the local reflection response at the receiver depth level. The reflection response is true-amplitude and forms the data on which Amplitude Versus Angle AVA analysis can be carried out. This analysis forms the actual inversion and is the third step in the method. Theoretical development and numerical results can be found in:

Slob, E., "Non-destructive monitoring of layered infrastructure using GPR data", Proc. of EGU General Assembly, Vienna, 7-12 April 2013.

Slob E. and K. Wapenaar, "GPR wave field decomposition, synthesis, and imaging for lossless layered vertically transverse isotropic media", Proceedings of the International Workshop on Advanced Ground-Penetrating Radar (IWAGPR2013), pp. 21-26. Nantes, France, July 2-5, 2013.

Slob, E. and K. Wapenaar, "Data-driven inversion of GPR surface reflection data for lossless layered media", Proceedings of the 8th European Conference on Antennas and Propagation, April 2014.

Task 2.9: Experimental validation of the GPR systems at the USP geophysical test site.

This task was devoted to perform an experimental validation of the inversion approaches developed in the tasks above (mainly Tasks 2.7 and 2.8), by using data collected in experiments/measurements performed at a full scale, in different operative contexts, thanks to the USP facilities The different datasets were made available to all the partners to make a performance analysis of the reconstruction/imaging approaches.

During the secondment of CNR researchers to USP (first reporting period), a good information exchange was performed about the features of the USP geophysical tests, as well as about the working principles of the CNR imaging approaches. This knowledge sharing was performed with the aim to define the experiments to be carried out at USP test site and facilities, in order to obtain an experimental validation of model based data processing strategies developed at CNR.

First case (USP-TUDELFT)

GPR data were acquired at the IAG Controlled Site of Shallow Geophysics. GPR pseudo-3D profiles (2D parallel profiles), by employing 200, 270 and 400MHz antennas for mapping interferences (pipelines, metallic and plastic drums).
During the secondment of Prado (USP) at TUDELFT, GPR data collected on April/May and July 2013 at the field sites Campos de Jordão and São José dos Campos (Sao Paulo State – Brazil) have been processed for monitoring geotechnical and climatic variables, as support to

early warning systems for landslides in São Paulo. Numerical modelling has been performed to make the interpretation of the processed data simpler. The field data allow imaging the main characteristic of the study area in terms of seismic and electromagnetic waves (interfaces and velocity profiles). The geotechnical data (saturation and particles size distribution) also support the model to generate the synthetic radargrams, for different water content conditions. Coda Wave Interferometry (CWI) is the method used for cross-correlating short time-windows of the data and plotting the time lag versus the window central time. From these results, we found that applying the CWI method can be used to monitor small velocity changes, which can be related to slight moisture content variations. These results will be presented in:

Prado, R.L., E. Slob and R.M. Mendes, "Geophysical support for the assessment/monitoring of partially saturated soils on land susceptible to shallow landslides", accepted for the presentation at the 1st SEG/SBGf Workshop on Near Surface Geophysics, Salvador, Brazil, 3-4 December 2014.

As a spin-off from these activities, USP submitted a research project proposal for financial support by the Federal Brazilian Science without Borders program in which TUDELFT and USP collaborate. The proposal entitled *Seismic and electromagnetic data inversion to enhance near surface characterization* was granted in 2014 and will run for three years. The project involves four scientists and three PhD students from USP and two scientists and two PhD students from TUDELFT, and several mutual visits are planned.

Second case (USP-CNR)

The second case regarded the use of microwave tomographic approaches jointly developed by CNR and USP for forensics surveys. The experiment was concerned with the monitoring of the decomposition of a buried organic target (a pig taken as a human simulant) buried on December 18th, 2012 at the USP campus in Pirassununga (USP). This campus was chosen for the experiment because there was already an area available to bury an animal, avoiding the bureaucracy for environmental care needed to develop this same experiment in the USP campus in São Paulo (SP).
GPR data were exploited to evaluate the application of the qualitative inversion (microwave tomography) to monitor the decomposition process of a human being simulant. For this experiment, a pig (*Sus scrofa*) with mass comparable to that of an average human (about 70 to 80 kg) was buried. The animal was chosen due to similarities in its decomposition process of a human being, according to biochemical analyses.
Several GPR measurement surveys at different periods were performed and the microwave data processing allowed to detect and estimate the shape/extent of the grave and the buried pig. Microwave tomographic processing also allowed locating the grave itself, due to an improvement on the visualization of the clutter caused by soil disturbances.
The scientific outcomes of these investigations have been published in

E. R. Almeida, E.R., I. Catapano, J.L. Porsani, F. Sodovieri, "Ground Penetrating Radar and microwave tomography for forensic imaging", International Workshop on Forensic Science and Archaeology 2013. November 22-23, 2013, Rome, Italy.

E. R. Almeida, J. Porsani, I. Catapano, G. Gennarelli, and F. Soldovieri, "GPR data analysis enhanced by microwave tomography for forensic archaeology," Proc. of 15th International Conference on Ground Penetrating Radar GPR 2014, June 30-July 4, 2014.

A scientific paper will be submitted in the first days of December 2014 in which a

comprehensive performance analysis of the microwave tomography applied to the data acquired over a decomposing organic target is described.

Third case (USP-CNR)

A novel strategy based on the linear inversion (microwave tomography) approach has been implemented to process GPR data collected in controlled conditions at USP laboratories for studies concerning the possibility to detect and monitor subsurface oil spills. The scientific outcomes have been published in the journal papers

Bertolla, L., Porsani, J.L., Soldovieri, F., Catapano, I., "GPR-4D monitoring a controlled LNAPL spill in a masonry tank at USP, Brazil", Journal of Applied Geophysics, vol.103, pp .237 – 244, 2014.

Catapano, I., Affinito, A., Bertolla, L., Porsani, J.L.,Soldovieri, F., "Oil spill monitoring via microwave tomography enhanced GPR surveys", Journal of Applied Geophysics, vol.108, pp. 95-103, 2014.

Catapano I., Bertolla L., Porsani J.L., Soldovieri F, "Pipelines Monitoring Via Microwave Tomography Enhanced GPR Surveys", solicited for the oral presentation at Seventeenth International Water Technology Conference (IWTC- XVII), 5-7 November 2013, Istanbul, Turkey.

WP3 Radar technologies for remote detection and registration of vital signs

Task 3.1: Analysis of bio-radar technology, achievements, and possible application areas; Design of transmitters, receivers and antennae of the BioRascan radars that operate in the maximum range of 4-15 GHz; Elaboration and adjustment of the radar design in laboratory conditions.

After an extensive review of the relevant literature, the involved institutions have tackled the issues of bioradar systems design in the frequency band of interest. This activity has been the subject of the secondment of Prof. Turk from YTU at BMSTU. The technical details of this activity and its outcomes are collected in deliverable D3.1 "Report on prototypes of designed bio-radars that operate in different part of the overall frequency band 4-15 GHz".

Different prototypes of the bioradar systems have been designed and realized at BMSTU and CNR. In particular, as an unexpected result a simple radar system based on the holographic principle has been designed and realized a CNR, by using two flared horn antennas working in the frequency band around 2.5 GHz. An experimental activity involving this simple system has been carried out to investigate the possibility of detecting vital signs from a subject located behind an obstacle exploiting the 1-4GHz frequency band.
The scientific outcomes of this task are described in the papers

F. Soldovieri, I. Catapano, L. Crocco, L. N. Anishchenko, S.I. Ivashov, "A feasibility study for Life Signs monitoring via a continuous wave radar", International Journal of Antennas and Propagation, Volume 2012, Article ID 420178, 5 pages, doi:10.1155/2012/420178

L. Anishchenko, S. Ivashov , I. Catapano. L. Crocco, G. Gennarelli, F. Soldovieri, "Radar for vital signs characterization: a comparison between two different frequency band systems",

Proc. Of 7th International Workshop on Advanced Ground Penetrating Radar Conference, Nantes, France, July 2013.

Task 3.2: Development of approaches for bio-radar data processing and their integration in the system.

In the starting period of the project, two different processing methodologies, independently developed by CNR and BMSTU, have been applied and compared in a laboratory controlled experiment carried out at BMSTU using a bioradar system developed by BMTSU. After, the processing methodologies, independently developed by CNR and BMSTU during the first term, have been further applied to process laboratory controlled data independently collected, with different devices, at both BMSTU and CNR-IREA. The observed results have demonstrated that the two independent processing tools developed during the project are suitable for integration, as they provide comparable information, which are however achieved through different elaborations, thus enabling a cross-validation processing framework.
Scientific outcomes of the activity have been the subject of the papers

L. Anishchenko, S. Ivashov , I. Catapano. L. Crocco, G. Gennarelli, F. Soldovieri, "Radar for vital signs characterization: a comparison between two different frequency band systems", Proc. Of 7th International Workshop on Advanced Ground Penetrating Radar Conference, Nantes, France, July 2013.

Task 3.3: Experiments with the designed radar in controlled conditions for detection of human's vital signs and his reaction to different stress factors.

Task 3.3 was concerned with the full assessment of the designed radar systems in controlled and real conditions and benefited of the outcomes of Task 3.1 and Task 3.2. In this framework, one important step has been the work carried out during the secondment of two researchers from BMSTU at CNR-IREA. During this secondment, an extensive measurement analysis was performed thanks to the bioradar prototype developed at CNR-IREA (in cooperation with BMSTU), regarding the characterization of vital signs for biomedical applications. In particular, the study of bioradar as tool for sleep syndromes analysis has been investigated. During this study, the results of the two processing methodologies developed at BMSTU and CNR were compared, by processing collected data collected under different observation modalities.
As another activity carried out in this task, the effect of possible differences in the measurement protocols adopted at BMSTU and CNR-IREA has been considered. This study has been preliminary to the adoption of the bioradar systems designed in AMISS for fully operative conditions.

Scientific outcomes of this task are reported in the following papers.

L. Anishchenko, M. Alekhin, A. Tataraidze, S. Ivashov, A. Bugaev, F. Soldovieri, "Application of step-frequency radars in medicine," Proc. of SPIE 9077, Radar Sensor Technology XVIII, 90771N (May 29, 2014); doi:10.1117/12.2049523..

M.D. Alekhin, L.N. Anishchenko, A.V. Zhuravlev, S.I. Ivashov, L.S. Korostovtseva, Y.V Sviryaev, "Evaluation of sleep disordered breathing using non-contact remote bio-radiolocation method", Sleep Medicine. 2013. Vol. 14, Suppl. 1. pp. e58. http://www.sleep-journal.com/article/S1389-9457(13)01320-8/pdf

M.D. Alekhin, L.N. Anishchenko, A. Tataraidze, et al., "A Novel Method for Recognition of Bioradiolocation Signal Breathing Patterns for Noncontact Screening of Sleep Apnea Syndrome," International Journal of Antennas and Propagation, vol. 2013, Article ID 969603, 8 pages, 2013. doi:10.1155/2013/969603, http://www.hindawi.com/journals/ijap/2013/969603/

Tataraidze A., L. Anishchenko, M. Alekhin, L. Korostovtseva, Y. Sviryaev, "Estimation of respiratory rhythm during night sleep using a bio-radar," Proc. of SPIE 9077, Radar Sensor Technology XVIII, 90770Z (May 29, 2014); doi:10.1117/12.2049519.

M.D. Alekhin, L.N. Anishchenko, A. Tataraidze, S. Ivashov, V. Parashin, A. Dyachenko, "Comparison of Bioradiolocation and Respiratory Plethysmography Signals in Time and Frequency Domains on the Base of Cross-Correlation and Spectral Analysis," International Journal of Antennas and Propagation, vol. 2013, Article ID 410692, 6 pages, 2013, doi:10.1155/2013/410692, http://www.hindawi.com/journals/ijap/2013/410692/

3. Main scientific highlights and research achievements.

WP1 Microwave and Millimetre wave imaging systems for security

- Knowledge sharing and exchange between YTU and BMSTU regarding the design of wideband holographic radar module, to achieve higher range and resolution for practically useful radar system development.
- Design of a waveguide array to feed a parabolic reflector (YTU-SRC). The main aim of this design is to obtain desired radiation characteristics for air and coastal microwave surveillance radars and radiometric passive millimeter wave imaging system.
- Understanding of passive radiometric imaging system and its sub-modules, such as antennas, receiver and image processing, as cooperation between SRC and YTU.
- Development of a full holographic radar at BMSTU for concealed objects detection, enhanced by data processing developed at CNR.
- Development, implementation and validation of a microwave tomographic approach by CNR, for processing data gathered by means of a Through-Wall-Imaging system. This activity was supported by BMSTU.
- Development of data processing strategies by CNR, for the improvement of the interpretability of the passive radiometric images achieved with the passive radiometric systems available at SRC.
- Development and analysis performance analysis of a novel 2.5D ARM algorithm for fast and reliable analysis of parabolic reflector antennas of MM-wave systems. (YTU-SRC).
- Design, realization and validation of a novel ultra-wide band Vivaldi shaped TEM fed dielectric loaded ridged horn and integration as antenna head for Ground Penetrating Impulse Radar designed by IRE (YTU-IRE).
- Design of a novel compact UWB antenna called “partial dielectric loaded ridged horn” for ultra-wide band (UWB) microwave through-wall imaging system available at BMSTU (YTU-BMSTU).
- Development and performance analysis of an adaptive UWB SAR algorithm and TWI SAR laboratory test measurements for human-like targets at the distance of 2-3 meters from the radar platform (YTU-BMSTU).
- Design and realization of a fully holographic system (hardware + software) using two measurement channels to acquire in-phase and quadrature signal for concealed targets

detection. The system has been extended also to the case of buried target detection.

- Development of a 3-Dimensional Analytical Regularization Method (ARM) to perform fast and accurate design and analysis of waveguide array feeder of the parabolic reflector for the radiometric passive millimetre wave imaging systems at SRC (YTU-SRC).
- System design knowledge of 35 GHz passive radiometric imaging system and its sub-modules (i.e., antennas, receiver and image processing) were transferred from SRC to YTU.
- Performance analysis of the two radiometric passive imaging at SRC (33 GHz and 94 GHz) exploiting data processing tools developed at CNR.

WP2 Development of GPR technologies for subsurface sensing and critical infrastructure monitoring

- Design and implementation of an Ultra Wide Band TEM horn antenna for Ground Penetrating Impulse Radar.
- Implementation of an improved version of the differential GPR system at IRE, also thanks to the cooperation with YTU.
- Integration of the designed dielectric loaded compact ridged horn antenna, reflector antenna in the GPR prototype available at IRE and successful validation of the integrated GPR system under a Forward Looking GPR configuration. (YTU-IRE).
- Design, manufacturing and testing of a new digital delay line, with low jitter and extended range. The stability performance of the system sampling has been improved (IRE-YTU).
- 3 GHz impulse generator based on RF switch-transistor (2N2222 model switch-transistor) has been designed and realized by YTU group in cooperation with IRE. Tests and measurements have been done successfully at YTU Microwave Laboratory (YTU-IRE).
- Design realization and preliminary testing of two low cost high voltage impulse generators for GPR (YTU-IRE).
- Improvement of the differential transmitting and receiving antenna system for GPR at IRE. The T/R antenna decoupling exceeds up to – 65 dB over the operating frequency band of 0.8÷1.6 GHz (IRE-YTU).
- Development and implementation of a novel method for retrieving virtual surface to borehole data from surface reflection data (TUDELFT).
- Development and implementation of a new imaging scheme for GPR reflection data collected in multi-offset mode for a layered earth and in multicomponent multi-offset mode for general three-dimensional heterogeneous earth (TUDELFT).
- Development and implementation of a full waveform inversion scheme to obtain electric permittivity and magnetic permeability from reflection GPR data for a layered earth (TUDELFT).
- Development and implementation of a numerical code for modelling GPR data for any acquisition configuration in a layered vertical transverse isotropic medium (TUDELFT-USP).
- Development, performance analysis and validation of microwave tomographic approach for GPR data processing under the differential configuration in 2D and 3D geometry. The experimental validation of the approach has been carried out thanks to data provided by the differential GPR system designed and assembled by IRE (CNR-IRE).
- Development and implementation of a full 3D microwave tomographic approach equipped with a GUI interface for hidden target detection and characterization (CNR).

- Development and implementation of a linear inversion approach able to process data provided by holographic radar systems; the approach has been validated in controlled conditions, thanks to data provided by the RASCAN.4/4000 holographic radar developed by BMSTU (CNR-BMSTU).
- Improvement of 2D linear inverse scattering approaches in view of their application in real situations (CNR).
- Development of a novel approach based on the use of a periodic lattice to improve the performances of a microwave tomographic approach in terms of resolution limits (CNR).
- Development, performance analysis and validation of full inverse scattering approach in 1D geometry for quantitative estimation from GPR traces (USP-CNR).
- Development and performance analysis of a full waveform inversion scheme based on three linear steps (TUDELFT).
- Validation of linear and non-linear inversion approaches thanks to experimental data collected in controlled and real situations (USP-CNR-TUDELFT).

WP3 Radar technologies for remote detection and registration of vital signs

- Design and realization of three bioradar prototypes. In particular, two systems have been realised at BMSTU, which work in two different frequency bands, centred at 4 and 15 GHz, respectively. The third system has been realized at CNR and operates in a lower frequency band as compared to the ones of BMSTU, i.e., at about 2 GHz (CNR-BMSTU-YTU).
- Development of specific data processing developed at BMSTU and CNR. The different data processing codes have been compared by means of the validation via experimental data collected at the two institutions. The path for their integration has been traced, as they provide different, and complementary ways, to process the radar traces to achieve information on vital signs of the inspected subject.
- Extensive analysis of the performance of the bioradar systems, in the specific field of the medicine, by focussing on monitoring of patients for sleep syndromes analysis.
- Definition of measurement protocols and processing strategies for medical applications.

Secondments activity

1 Date 11/01/2012 - 25/01/2012, Prof. Ahmet Serdar Turk (ER, YTU) at IRE. Prof. Turk visited IRE institute gain information about laboratory infrastructure, research topics and design capabilities on GPR system.

2 Date 06/07/2012 - 20/07/2012, Prof. Ahmet Serdar Turk (ER, YTU) at IRE. Prof. Turk visited IRE institute to discuss about the cooperation activities regarding a custom-design long-range UWB GPR system.

3 Date 21/10/2012 27/10/2012, Prof. Sergey Ivashov (ER, BMSTU) at CNR. Training given by Dr. Ivashov on radar systems for safety and security. Seminar “”A Review of the Remote Sensing Laboratory’s Techniques for Humanitarian Demining”. Planning of the cooperation between BMSTU and CNR.

4 Date 21/10/2012 27/10/2012, Dr. Lesya Anishchenko (ER, BMSTU) at CNR. Training on bioradiolocation as remote or non-contact measurement of movement, breathing and pulse parameters of biological objects. Seminar on ”Bioradiolocation and Its

Applications". Planning of the bioradar activities.

5 Date 18/11/2012 - 30/11/2012, Mustafa Dagcan Senturk (ESR, YTU) at IRE. Dr. Senturk visited IRE group to be trained on the expertise of IRE about GPR transmitter unit, including the differential planar T/R antennas and impulse generator design techniques.

6 Date 26/01/2013 07/02/2013, Dr. Francesco Soldovieri (ER, CNR) at USP. Dr. Soldovieri gave XV Summer School of Geophysics 2013 for PhD students, which was carried out from 28 January to 1 February, with a course entitled "Modeling and inversion of GPR data". Training given by Dr. Soldovieri on data processing for radar imaging to USP PhD students. Planning of the visit of PhD student Dr. Emerson Almeida at CNR.

7 Date 26/01/2013 07/02/2013, Dr. Ilaria Catapano (ER, CNR) at USP. Dr. Catapano gave XV Summer School of Geophysics 2013 for PhD students, which has been carried out from 28 January to 1 February, with a course entitled "Modeling and inversion of GPR data". Training given by Dr. Catapano on inverse scattering approaches. Planning of the activities USP-CNR.

8 Date 08/02/2013 - 19/02/2013, Prof. Ahmet Serdar Turk (ER, YTU) at IRE. Prof. Turk visited IRE institute to discuss about novel GPR antennas with high gain-bandwidth characteristics and new GPR receiver unit with extended delay-line for long-range target detection scenarios.

9 Date 11/6/2013- 22/6/2013 Prof. Gennadiy Pochanin (ER, IRE) at YTU. Prof. Pochanin visited the microwave and antenna laboratory of YTU with the main aim to perform trial tests of the short range impulse GPR (prototype 1) designed by IRE equipped with the UWB horn antennas designed by YTU group.

10 Date 11/6/2013- 22/6/2013 Dr. Vadim Ruban (ER, IRE) at YTU. Dr Ruban visited the microwave and antenna laboratory of YTU and cooperated in the trial tests of the short range impulse GPR (prototype 1) designed by IRE equipped with the UWB horn antennas designed by YTU group.

11 Date 11/07/2013 -22/07/2013, Prof. Jorge Luis Porsani (ER, USP) at CNR. Training on geophysical techniques. Presentation of the USP activities and facilities for AMISS exploitation. Planning of the activities between USP and CNR. Official establishment of a scientific collaboration through a MOU.

12 Date 4/8/2013 – 14/4/2014. Prof. Renato Prado (ER, USP) at TUDELFT. Prof. Prado cooperated in the development and validation of forward models for GPR data.

13 Date 28/8/2013-30/03/2014 Dr. Emerson Rodrigo Almeida (ESR, USP) at CNR. Training on microwave tomographic approaches for GPR data inversion. Training on quantitative methods for estimation of soil electromagnetic properties. GPR data processing via microwave tomography for forensics applications. Measurements in controlled conditions for soil em properties estimations.

14 Date 29/8/2013- 8/9/2013 Prof. Ahmet Serdar Turk (ER, YTU) at SRC. Prof. Turk visited SRC to be trained on 35 GHz and 94 GHz passive millimeter wave imaging systems designed by SRC. Discussions were carried out to design a novel reflector antenna as proposed by Prof. Turk.

15 Date 23/10/2013-23/11/2013 Dr. Aleksandr Tataraidze (ESR, BMSTU) at CNR. Training on the data processing for microwave imaging systems and bioradar systems.

Experimental activity about the vital signs characterization for sleep control.

16 Date 23/10/2013-23/11/2013 Dr. Maxim Alekhin (ESR, BMSTU) at CNR. Training on the data processing for microwave imaging systems and bioradar systems. Experimental activity about the vital signs characterization for sleep control.

17 Date 15/11/2013- 1/12/2013 Mustafa Dagcan Senturk (ESR, YTU) at IRE. Senturk visited IRE with the aim to support the design of impulse generator and UWB antenna units of a GPR system

18 Date 25/11/2013- 09/12/2013 Liudmyla A.Varianytsia Roshchupkina (..IRE)at CNR. Training on microwave tomographic techniques for GPR data processing. Implementation of a 2D code for tomographic approach to the differential GPR data processing.

19 Date 08/2/2014-15/2/2014 Prof. Ahmet Serdar Turk (ER, YTU) at IRE. Prof. Turk visited IRE institute to have information about the impulse GPR system designed by IRE. The time-range extension of GPR receiver was discussed for long range forward looking scenarios.

20 Date 24/4/2014 – 24/8/2014. Prof. Evert Slob (ER, TUDELFT) at USP. Prof. Slob had several meetings with professors and graduate students to discuss the research and doctoral projects underway; work field in Campos do Jordão (area of studies); collaboration with Prof. Prado regarding processing of real data and generation of synthetic data; teaching in graduate course "Imaging and inversion of GPR data"; participation with a lecture and taking part of "round table" in an event that discussed the geophysical graduate courses in Brasil; lecture in the seminars of the Department.

21 Date 4/7/2014- 18/7/2014 Dr. Vadim Ruban (ER, IRE) at YTU. Dr Ruban visited the microwave and antenna laboratory of YTU to perform demonstration experiments regarding the long range impulse GPR (prototype 2) receiver designed by IRE.

22 Date 4/7/2014- 17/07/2014 Liudmyla A.Varianytsia Roshchupkina (ER, IRE)at CNR. Training on microwave tomographic techniques for 3D GPR data processing. Implementation of a 3D code for tomographic approach to the differential GPR data processing.

23 Date 12/07/2014-23/07/2014 Dr. Gennadiy Pochanin (ER, IRE) at CNR. Seminar on “Recent advances on radar systems at Institute for Radiophysics of the National Academy of Science of Ukraine”. Training given by Dr. Pochanin on hardware solutions for differential GPR. Planning of the activities between CNR and IRE. Preparation of an official MOU between IREA-CNR and IRE.

24 Date 22/08/2014- 3/9/2014 Dr. Mustafa Dagcan Senturk (ESR, YTU) at SRC. Senturk visited SRC institute and was trained on millimeter wave imaging systems. Senturk discussed the design and numerical analysis of a novel switchable reflector antennas

25 Date 22/08/2014- 3/9/2014 Ahmet Kenan Keskin (ESR, YTU) at SRC. Keskin visited SRC institute and was trained on millimeter wave imaging systems.

26 Date 22/08/2014- 3/9/2014 Dr. Alper Caliskan (ESR, YTU) at SRC. Caliskan visited SRC institute and was trained on millimeter wave imaging systems. Dr. Caliskan discussed the fast 2.5D numerical EM analysis algorithms developed at YTU.

27 Date 31/08/2014- 15/09/2014 Liudmyla A.Varianytsia Roshchupkina (.ER, IRE) at YTU. Training and discussion on efficient electromagnetic numerical methods for forward

looking UWB GPR scenarios.

28 Date 31/8/2014- 15/9/2014 Prof. Gennadiy Pochanin (ER, IRE) at YTU. Prof. Pochanin visited the microwave and antenna laboratory of YTU to perform the field tests of the long range impulse GPR (prototype 2) designed by IRE.

29 Date 05/09/2014- 15/9/2014 Dr. Vadim Ruban (ER, IRE) at YTU. Dr. Ruban visited the microwave and antenna laboratory of YTU for the experimentation of UWB reflector antennas designed by YTU connected to the GPR system for subsurface target detection and through-wall imaging.

30 Date 2/9/2014- 11/9/2014 Dr. Ilaria Catapano (ER, CNR) at BMSTU. Discussion on the developed bioradar systems and draft of a project proposal to carry on the research activities developed during the AMISS project and in order to move towards the real applicability of BioRadars in clinical practices. Training given by Dr. Catapano on data processing for microwave imaging. Seminar on “Microwave tomography for radar imaging”

31 Date 2/9/2014- 11/9/2014 Dr. Rosa Scapaticci (ESR, CNR) at BMSTU. Training on bioradar systems. Discussion on the developed bioradar systems and draft of a project proposal to further carry on the research cooperation developed during the AMISS project and in order to move towards the real applicability of BioRadars in clinical practice. Seminar on “New methodologies and applications for microwave imaging in biomedical field”.

32 Date 6/9/2014-17/09/2014 Prof. Oleksandr Denisov (ER, SRC) at CNR. Seminar on “Radiometric systems for security and surveillance”. Training given by Porf. Denisov on the active and passive radiometric systems.

33 Date 6/9/2014-17/09/2014 Dr. Valentyna Denisova (TECH, SRC) at CNR. Training given by Dr.Denisova on the hardware solutions for active and passive radiometric systems.

Enhancement of AMISS cooperation and opening of new collaborations

The effectiveness of the cooperation under AMISS framework is testified by the Memorandum of Understanding and Cooperation setup between the Institute for Electromagnetic Sensing of the Environment of CNR separately with USIKOV INSTITUTE FOR RADIOPHYSICS AND ELECTRONICS (IRE) and Instituto de Astronomia, Geofísica e Ciências Atmosféricas of University of Sao Paulo.

The cooperation between CNR and SRC has activated, thanks to the cooperation of SRC with Chinese entities, a cooperation of CNR with Department of Microwave Engineering in Harbin Institute of Technology and the company SWIEE – South West Institute of Electronic Equipment (a leader company for aerospace and security in China).

We want to stress the fact that several of the partners involved in AMISS are also partners of the COST Action TU1208 “Civil Engineering Applications of Ground Penetrating Radar”. This represents a good opportunity to continue the cooperation beyond AMISS’s life. In addition, the assessed cooperation among AMISS partners can be important in view of project opportunities arising in Horizon 2020.

CNR researchers are also actively involved in COST action TD1301 “MiMed”. Such a trans-

domain action is specifically aimed to accelerate the development of diagnostics devices exploiting microwave frequencies. As mentioned above, this is a topic relevant to the activities in WP3, namely the bioradar systems for vital signs detection and monitoring. Accordingly, in the framework of the second meeting of TD3101 cost action, held in Prague (CZ) on 11-13 September 2014, Lorenzo Crocco has organized a special workshop devoted to bio-radiolocation in which Prof. Ivashov and Dr. Anishchenko have been invited as guest speakers, to present their activities and results, also achieved in the framework of AMISS WP3. Following this meeting, Russian colleagues have started the formal procedures to enrol Russia as an IPC country for the Action.

Furthermore, the promising results obtained and the huge relevance covered by vital signs monitoring in the field of health care and medical applications, motivated CNR and BMSTU researchers to pursue their cooperation on this topic beyond the AMISS project. Accordingly, during the visit of Dr. Catapano and Dr. Scapaticci at RSLab, an application for a new project in the frame of the bilateral agreement between CNR and Russian research centers has been prepared and submitted. The proposal takes its move from the work done in the AMISS project and it is entitled 'Bioradar Systems for life signs monitoring in medicine: prototypes development and feasibility assessment in controlled and real conditions'. This proposal is devoted to address the scientific challenges that have to be faced to move towards the real applicability of BioRadars in the clinical practice.

The promising results obtained between TUD and USP has resulted in a new three-year research project entitled "Seismic and electromagnetic data inversion to enhance near surface characterization" and is financed by the Brazilian Science without Borders program. In this project, Slob is a special visiting researcher and a PhD student from USP will visit TUD to perform laboratory experiments and analyse the data.

At the end of the AMISS project, IRE and YTU have expressed intention to continue cooperation to develop in Turkey a GPR system based on the one made at IRE.

MANAGEMENT REPORT

As first activity, the Kick-off meeting held on November 3, 2011, was organized by CNR via Skype conference; the meeting was focused on the definition of the main guidelines for the start-up of the project.
Several items have been pointed out within the meeting, namely: the objectives of the project, the activity of each work package, the secondments. Also, the rules for the participating and for the access to the distribution of funds were recalled and explained.
Subsequently, the Partnership approved the appointment of the roles proposed by the Coordinator:
- Francesco Soldovieri, as scientific responsible of the overall project;
- Francesca Di Matteo, as Project Administrator, in order to support the activity of the Coordinator and the PMT;
and the following work-package managers:
- Ahmet Serdar Turk – YTU, WP1 Microwave and Millimetre wave imaging systems for security:
- Evert Slob – TUDELFT, WP2 Development of GPR technologies for subsurface sensing and critical infrastructure monitoring;
- Lorenzo Crocco – CNR, WP3 Radar technologies for remote detection and registration of vital

signs.
- Francesca di Matteo, for the administrative aspects and Ilaria Catapano (CNR) for the support to the scientific aspects of the management. WP4 Project Management.
Finally, the Partnership approved the following Project Management Team members:
- Francesco Soldovieri – CNR
- Evert Slob – TUDELFT
- Ahmet Serdar Turk – YTU
- Gennadiy P.Pochanin – IRE
- Alexander Denisov - SRC
- Renato Prado - USP
- Sergey Ivashov – BMSTU

The pre-financing, with the exception of a percentage of 3% that has been retained by the Coordinator for management budget, as decided in the Partnership Agreement and re-defined in the KOM, has been distributed by CNR, early after it was received by EC, among CNR, TUDELFT and YTU, the three UE member or associated countries of the AMISS project.

A continuous flow of information has been activated between the AMISS management and the Project Officer, with the main aim to have clear information about mobility modalities in response to the issues raised by the partners.

All the partners provided the administrative support in order to facilitate the feasibility of the secondments, with reference to the VISAs, the invitation procedure, the staying of the seconded persons.

Very frequent communications between the Coordinator and the partners were exchanged aimed at a constant monitoring of the project activities.

As further activity of MGT, the continuous updating of the website has been ensured according to the information provided by all the partners.

About the first reporting period, the financial reporting was submitted on time by the Coordinator to the REA on EC Participant Portal in complying with the FP7 reporting rules. The paper C forms were collected and promptly provided to the REA. The first periodic report was submitted on time by the Coordinator on EC Participant Portal in complying with the FP7 reporting rules. The financial reporting was submitted on time by the Coordinator to the REA on EC Participant Portal in complying with the FP7 reporting rules

In the first period of the project, the number of secondments has been smaller as compared to the expected ones. This has required a rearrangement of the secondment plan, with a twofold aim: improving the original secondment plan and catching the new cooperation opportunities arising for the knowledge/information exchange of the first period. On the basis of the rearrangement of the secondment plan, which is a dynamic process, always driven by the agreement of the PO, we have reached about a good percentage of the originally expected secondments. A new secondment plan has been agreed among the partners and submitted to and agreed by REA. The secondments have been then carried out according to this plan.

Project results have been disseminated through the project website and in several international conferences and workshops. Also, many results have been published in international peer reviewed journals.

The list of publications referred to the AMISS project has been uploaded on the EC participant portal. A continuous updating of the website is ensured according to the information provided by all the partners.

As last activity of the management, the second periodic and the final reports have been delivered by the Coordinator on EC Participant Portal in complying with the FP7 reporting rules REA. The financial reporting has been submitted by the Coordinator to the REA on EC Participant Portal in complying with the FP7 reporting rules and an adjustment has been provided for the first reporting period, as requested by REA.The paper C forms have been collected and promptly provided to REA.

2. USE AND DISSEMINATION OF FOREGROUND

- **Dissemination activities**

Maximum 2 pages

This section must include a list of planned dissemination activities (publications, conferences, workshops, web, press releases, flyers, etc) in free text format. Where Articles have been published in the popular press, please provide a list as well.

AMISS consortium has devoted a very large attention to the dissemination activities, which have carried out by means of different tools and practices.

The first activity has regarded the publication of 14 journal papers and one book chapter. Moreover further joint papers (at least three) are under preparation/submission.

We report below a selection of the more relevant paper published on ISI journals.

- F. Soldovieri, I. Catapano, L. Crocco, L. N. Anishchenko, S.I. Ivashov, “A feasibility study for Life Signs monitoring via a continuous wave radar”, International Journal of Antennas and Propagation, Volume 2012, Article ID 420178, 5 pages, doi:10.1155/2012/420178.
- O. M. Yucedag, A.S. Turk, “Parametric Design of Open Ended Waveguide Array Feeder with Reflector Antenna for Switchable Cosecant-Squared Pattern”, ACES JOURNAL, VOL. 27, NO. 8, pp. 668-675, AUGUST 2012.
- M.D. Alekhin, L.N. Anishchenko, A. Tataraidze, et al., "A Novel Method for Recognition of Bioradiolocation Signal Breathing Patterns for Noncontact Screening of Sleep Apnea Syndrome," International Journal of Antennas and Propagation, vol. 2013, Article ID 969603, 8 pages, 2013. doi:10.1155/2013/969603, http://www.hindawi.com/journals/ijap/2013/969603/
- M.D. Alekhin, L.N. Anishchenko, A. Tataraidze, S. Ivashov, V. Parashin, A. Dyachenko, "Comparison of Bioradiolocation and Respiratory Plethysmography Signals in Time and Frequency Domains on the Base of Cross-Correlation and Spectral Analysis," International Journal of Antennas and Propagation, vol. 2013, Article ID 410692, 6 pages, 2013, doi:10.1155/2013/410692, http://www.hindawi.com/journals/ijap/2013/410692/
- F. Soldovieri, A. Natale, V. Gorishnyak, A. Pavluchenko, A. Denisov, L. Chen, “Radiometric Imaging for Monitoring and Surveillance Issues,” International Journal of Antennas and Propagation, vol. 2013, Article ID 272561, 8 pages, 2013. doi:10.1155/2013/272561

- Catapano, A. Affinito, G. Gennarelli, F. di Maio, A. Loperte, F. Soldovieri, “Full three-dimensional imaging via ground penetrating radar: assessment in controlled conditions and on field for archaeological prospecting”, Applied Physics A, doi 10.1007/s00339-013-8053-0
- G. Gennarelli, R. Persico, F. Soldovieri. “Effective imaging systems based on periodic lattices.” Applied Physics Letters, vol. 104.19 (2014): 194103.
- Luciana Bertolla, Jorge Luís Porsani, Francesco Soldovieri, Ilaria Catapano, GPR-4D monitoring a controlled LNAPL spill in a masonry tank at USP, Brazil, Journal of Applied Geophysics, Vol.103, April 2014, Pages 237-244 ISSN 0926-9851, http://dx.doi.org/10.1016/j.jappgeo.2014.02.006.
- I. Catapano, A. Affinito, L. Bertolla, J.L. Porsani, F. Soldovieri, “Oil spill monitoring via microwave tomography enhanced GPR surveys,” Journal of Applied Geophysics, Vol.108, pp. 95-103. ISSN 0926-9851, http://dx.doi.org/10.1016/j.jappgeo.2014.06.017, Sept. 2014.
- M. Alekhin, L. Anishchenko, A.Tataraidze, S. Ivashov, L. Korostovtseva, Y. Sviryaev, and A. Bogomolov., “Selection of Wavelet Transform and Neural Network Parameters for Classification of Breathing Patterns of Bio-radiolocation Signals” Biomedical Informatics and Technology (T.D. Pham et al. (Eds.): ACBIT 2013, CCIS 404, pp. 175-178. Springer, Heidelberg (2013). http://link.springer.com/chapter/10.1007/978-3-642-54121-6_15

Strictly related to this activity was the participation and the presentation of works at International conferences. AMISS researchers presented and published in Proceedings more than 30 works at important international conferences, covering a large area of technological conferences as EGU, IWAGPR, GPR Conf., SPIE, IWTC, EARSEL, IEEE-UWBUSIS, IEEE-IRS, RAST, AGU, ACES. In this frame, AMISS consortium presented the activities of the project at CONFERENCE PROCEEDINGS PEOPLE 2012 Marie Sk#odowska-Curie Actions In Horizon 2020,hels at CYPRUS on November 2012.
As an outcome of the scientific technological results achieved, a paper concerned with the use of radar systems for demining and IED detection, was presented at the Resilient Threat Management 2013 Conf. organised by the European Defence Agency, March 2013, Brussels, Belgium.

The relevance of the AMISS activities is testified by three invited presentations reported below:

F. Soldovieri, “Microwave tomography for radar imaging: status and perspectives,” Plenary talk at 15th International Conference on Ground Penetrating Radar GPR 2014, June 30-July 4, 2014
Catapano I., Bertolla L., Porsani J.L., Soldovieri F, “Pipelines Monitoring Via Microwave Tomography Enhanced GPR Surveys”, invited for the oral presentation at Seventeenth International Water Technology Conference (IWTC-XVII), 5-7 November 2013, Istanbul, Turkey.
Pochanin G.P., Ruban V.P., Kholod P.V., Shuba O.A., Pochanina I.Ye., Batrakova A.G., Urdzik S.N., Batrakov D.O., Golovin D.V. “Advances in Ground Penetrating Radars for Road Surveying” 7th International Conference on “Ultra Wideband and Ultra Short Impulse Signals” September 15-19, 2014, Kharkiv, Ukraine .

In the framework of AMISS activities, Francesco Soldovieri (CNR) has organized and convened the following sessions at European Geophysical Union General Assembly 2013

From Artefact to Historical Site: Geoscience and Non-Invasive Methods for the Study and Conservation of Cultural Heritage, Conveners: Nicola Masini, Monica Alvarez de Buergo , Lev Eppelbaum, and Francesco Soldovieri.

Electromagnetic sensing techniques and geophysical methods for critical and transport infrastructures monitoring and diagnostics. Conveners: Jean Dumoulin, Francesco Soldovieri, Lorenzo Bigagli, Sven Nordebo.

In these two sessions, the presentations of several works related to AMISS activities were given.

F. Soldovieri has been Editor of two Special Issues on International Journal of Antennas and Propagation (http://www.hindawi.com/journals/ijap/), an open-access journal, regarding the thematics of AMISS and where several AMISS papers have been published.

- *R. Pierri, J.C: Bolomey, Q:H: Liu, and F. Soldovieri, "Inverse Scattering and Microwave Tomography in Safety, Security, and Health," International Journal of Antennas and Propagation, vol. 2013, Article ID 589598, 2 pages, 2013. doi:10.1155/2013/589598*
D. Erricolo, F. Soldovieri, and W.C. Chew, "Propagation Models and Inversion Approaches for Subsurface and Through-Wall Imaging," International Journal of Antennas and Propagation, vol. 2012, Article ID 821263, 2 pages, 2012. doi:10.1155/2012/821263

The AMISS project has been quoted in the article "Special report Microwaves in Europe: Winning ways" on Microwave Journal, vol. 55, no.9, pp. 86-102,September 2012.
The text is below reported.
"As its title suggests, the results of the Active and Passive Microwaves for Security and Subsurface imaging (AMISS) project will be two-fold – ground penetrating radar for subsurface sensing and critical infrastructure diagnostics and passive and active microwave imaging systems for security applications. The proposal is for two lines of research. The first is concerned with the development, characterization and performance evaluation of new systems, sensors and configurations able to mitigate the clutter, and increase information content and redundancy, for both passive and active microwave imaging, while the second considers the development, implementation and performance evaluation of processing tools."