UNIVERSITÀ DEGLI STUDI FIRENZE

Non-Destructive Testing applications of the microwave holographic radar

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OUTLINE

1. Presentation in brief of the University of Florence
2. The collaboration of Univ. of Florence and Tongji University
3. Operating principles of Holographic Radar for subsurface Investigations
4. Applications of the Holographic Radar.
    - 4.1 Civil engineering inspection of building and structures
    - 4.2 Cultural heritage preservation/conservation
    - 4.3 Non-Destructive Testing of engineering dielectric materials
    - 4.4 Unexploded Ordnance (UXO) detection
5. DEMINING 4.0 project for humanitarian demining
6. The University agreement framework

1.

Presentation in brief of the University of Florence

University of Florence

Origin from the ***Studium Generale*** established by the Florentine Republic on 1321

People

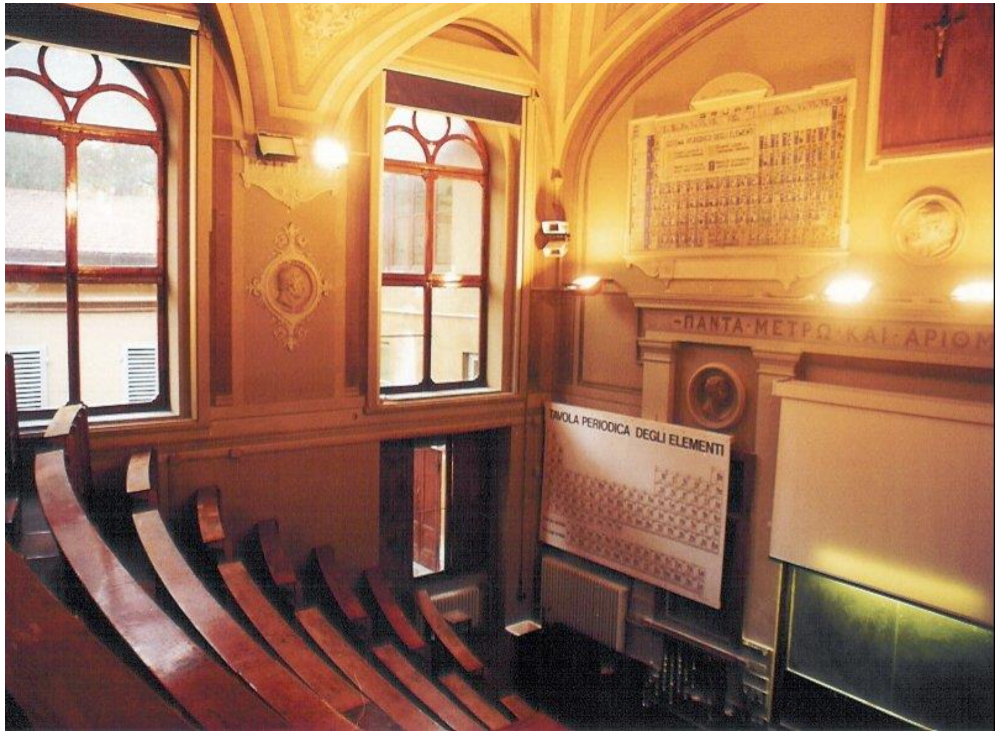
- 60.000 Students
- 2.300 Professors
- 1.400 PhD Students
- 750 Post Doc
- 100 Associate Researchers
- 1.700 Technicians and Administratives

Structures

- 4 Campus
- 6 Libraries
- 1 Cultural Centre for Foreigners
- 1 University Sports Centre (CUS)
- 15 University canteens
- 9 student housing & lodging
- 1 Museum of Natural History

Teaching (10 Schools)

- Agriculture
- Architecture
- Economics and Management
- Law
- Engineering
- Medicine and Surgery
- Psychology
- Education
- Mathematical, Physical and Natural Sciences
- Political Sciences



Research (24 Departments)

- 60 research structures
- 10 centers for research, knowledge transfer and higher education
- 15 joint workshops with enterprise
- 24 spin-off companies

www.unifi.it

School of Engineering

- ✓ Founded in 1970 in the former monastery of Santa Marta
- ✓ The building was acquired from the Vatican Church in 1980

- ✓ 1.200 new Students per year
- ✓ 6.000 Students
- ✓ 180 Professors
- ✓ 3 Departments
- ✓ 7 Undergraduate Degrees
- ✓ 11 Graduate Degrees
- ✓ 3 Ph.D. Degrees

https://www.ingegneria.unifi.it/vp-41-international.html

Dept. Of Information Engineering

- The Department of Information Engineering (DINFO) is the reference Department for ICT (Information and Communications Technology), where it carries out advanced research in control systems, computer science and engineering, electronics systems, electromagnetism, telecommunications, operation research, bioengineering and electrical engineering.
- DINFO employs a workforce of more than 210 units (including professors, researchers, technical and administrative people, post-doc fellows and PhD students)

Ultrasound and Non Destructive Testing Laboratory

Research Topics:

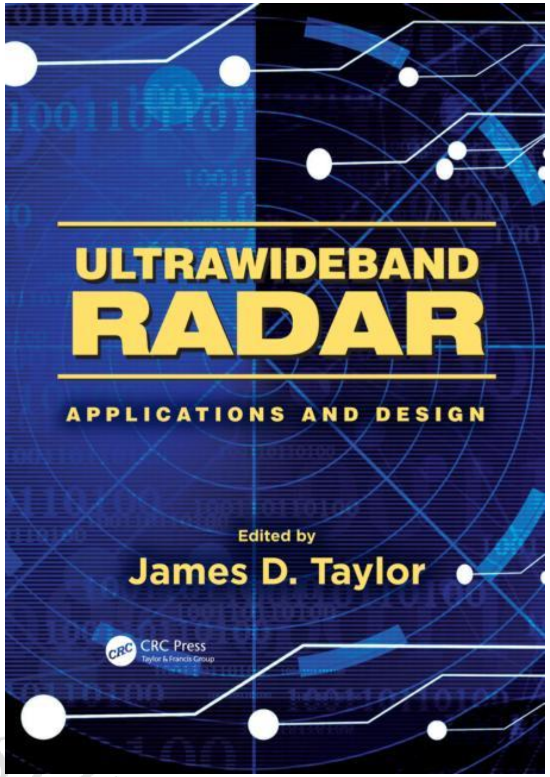
- Ground Penetrating Radar systems and applications
- Ultrasonic Sensors
- Analog Electronics Systems and sensors for non destructive testing

Research group:

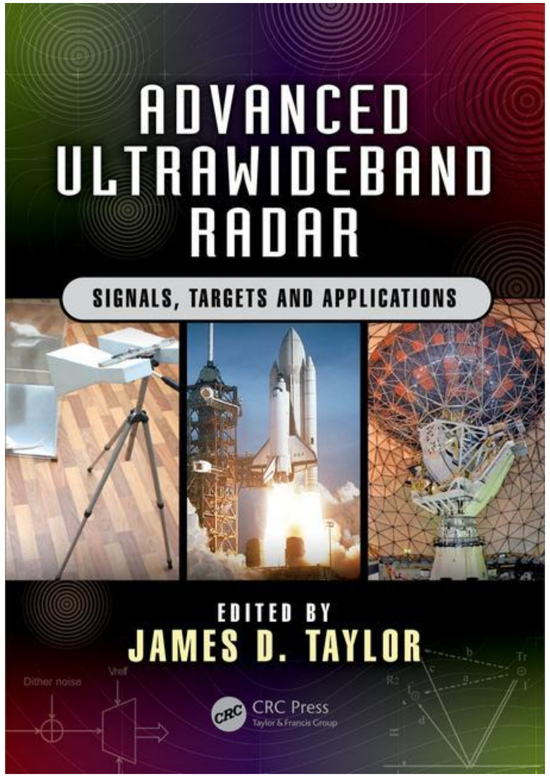
- Two associate professors
- Three research fellows
- Two doctorate students
- Two Technicians

https://www.dinfo.unifi.it/vp-303-electronics-for-analog-systems-and-sensors-for-non-destructive-testing.html

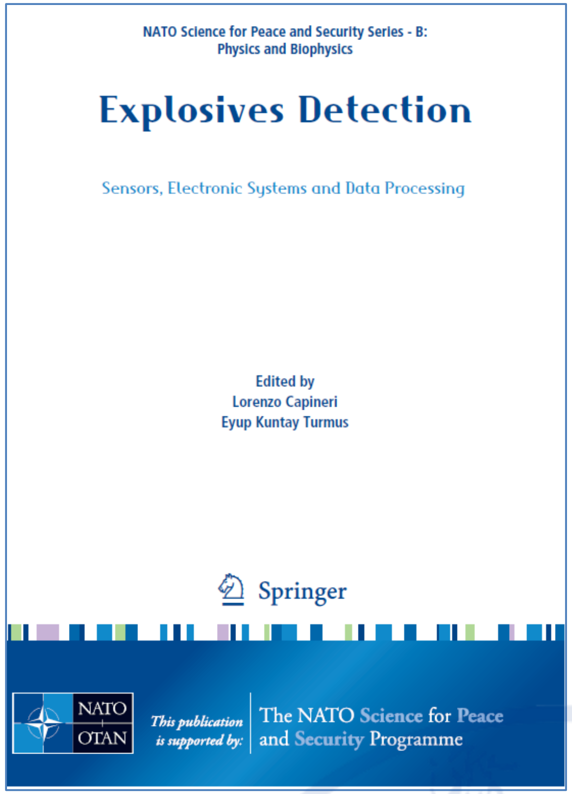
- 222 scientific publications in journals and peer-reviewed conference proceedings
- 7 patents
- 3 Books:



2012



2016



Editor - 2019 (in print)

Classes of Education

- **Information Engineering**
- **Industrial Engineering**
- **Civil and Environmental Engineering**

The Class of Degrees in **Information Engineering**

I level Degrees - 3 years / 180 ECTS

- Information Engineering
- Electronics and Telecommunications

II level Degrees - 2 years / 120 ECTS

- Electronics Engineering
- Telecommunications Engineering
- Computer Science Engineering
- Electrical and Automation Engineering
- Biomedical Engineering

https://www.dinfo.unifi.it/

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2.

The collaboration of Univ. of Florence and Tongji University

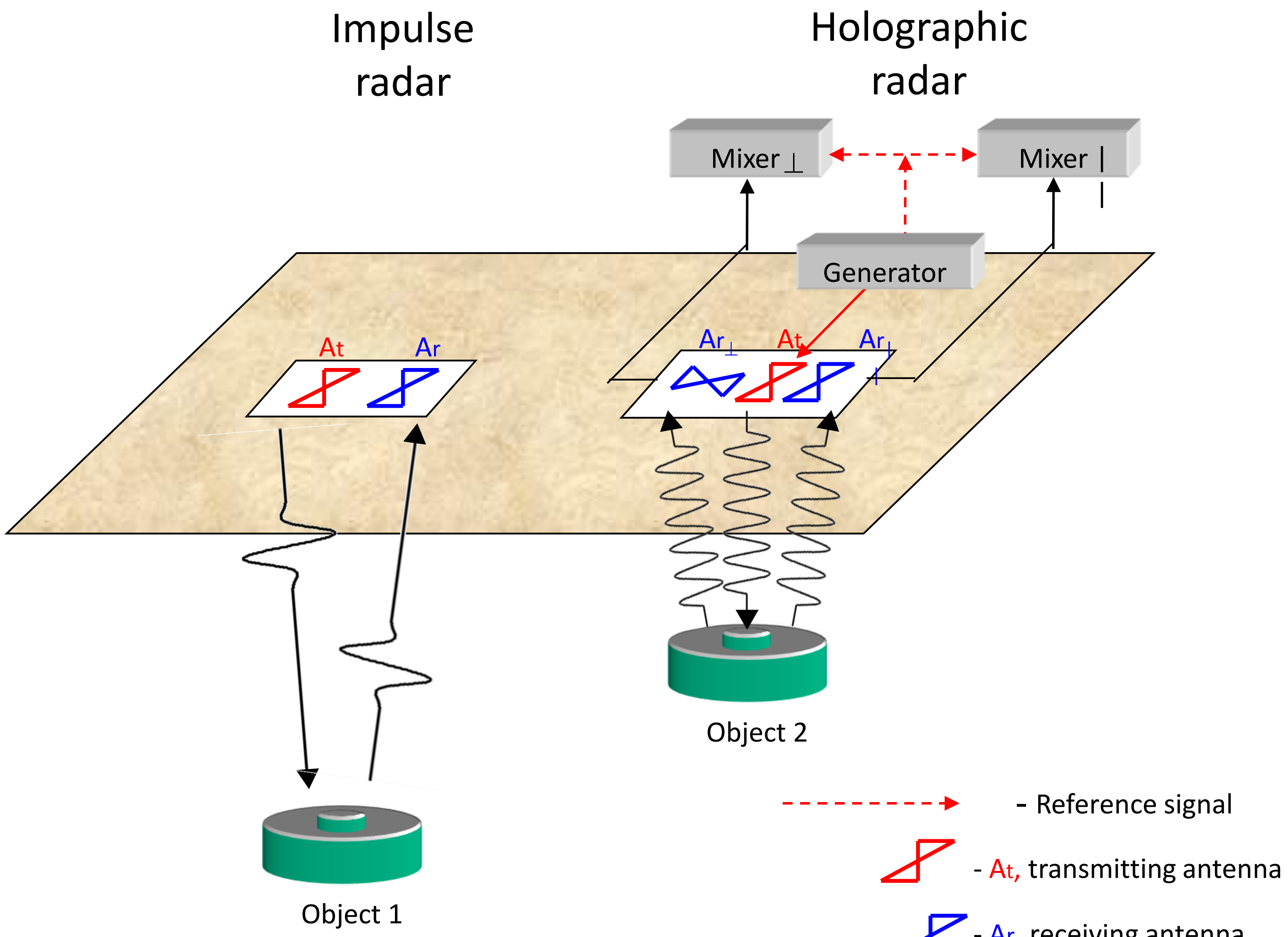
Joint papers/ meetings/ participated events

- PIERS 2008, 24-28 March 2008, Hangzhou, China, Invitation to special session on "Methods and Instruments for the Determination of Electromagnetic Properties of Soils and Materials"
- GPR 2012, 4-8 June 2012, Shanghai, China.
- Visiting Student at University of Florence Nov 2017- April 2018
- EGU General Assembly 2018 , «**The Integrated inversion interpretation of GPR and Rayleigh wave basedon Genetic Algorithm**» by Tan Qin, Yonghui Zhao, Shufan Hu, Cong An, Lorenzo Capineri, Shuangcheng Ge
- PIERS 2018 - Best Paper Award, «**Influence Analysis of Uneven Surface on Landmine Detection using Holographic Radar**", by Tan Qin, Pierluigi Falorni, Pietro Giannelli, Yonghui Zhao, Lorenzo Capineri

3.

Operating principles of Holographic Radar for subsurface Investigations

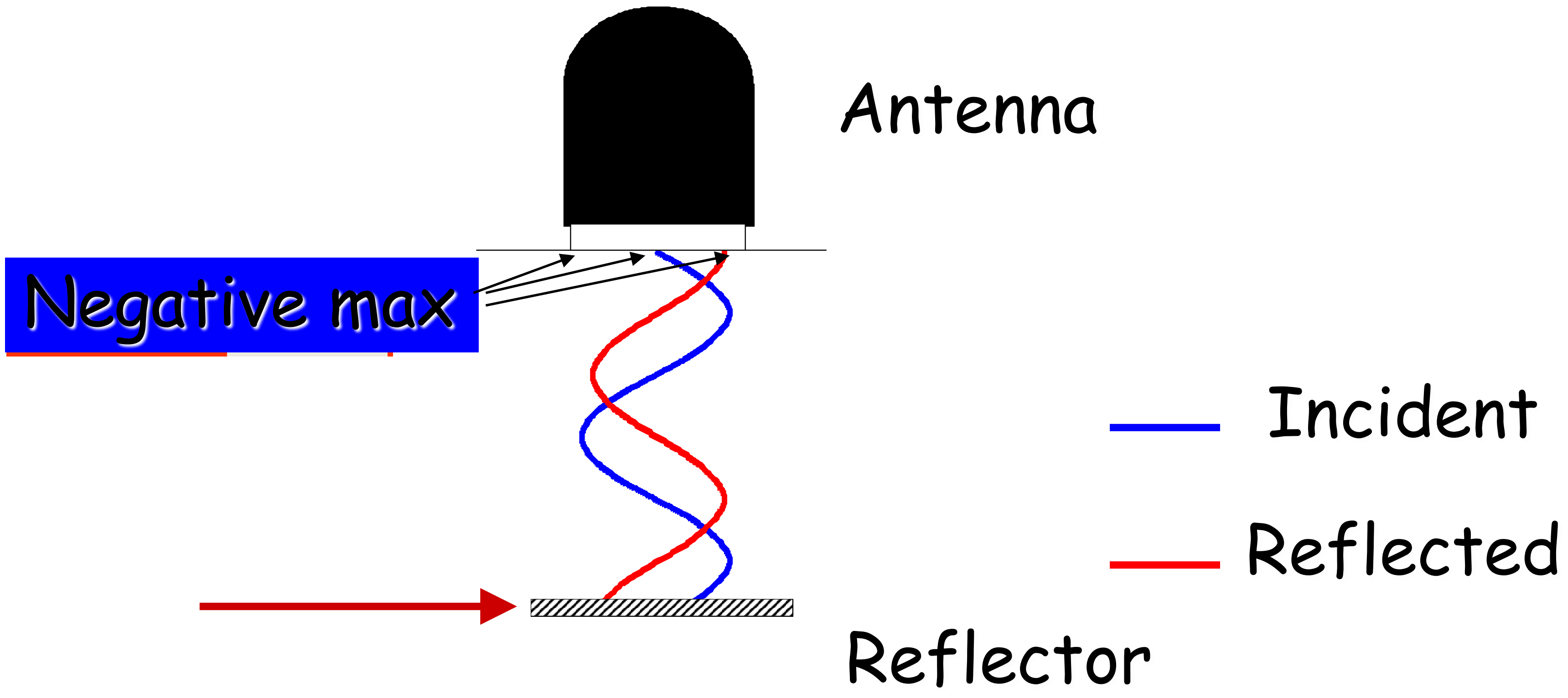
Comparison of Impulse and Holographic Radar



Comparison of characteristics: Impulse Radar *vs* Holographic Radar

Parameter	Impulse Radar	Holographic Radar	Remarks
Frequency spectrum	continuous	discrete	
Penetration depth	Up to 10 λ	1-2 λ	λ – wave length in air
Resolution at shallow depths in plan of surveying	> λ	~ 0.25 λ	λ – wave length in air
Surveying over metal substrate	Impossible	Possible	
Possibility of object’s depth measurement	Directly from recorded signal	N.A.	The task for holographic radar doesn’t have proper decision now
Adaptation to the FCC norms	Difficult	Easier	Frequency spectrum of holographic radar could be selected in advance. Impulse radar has UWB spectrum that can’t be change arbitrarily.
Radar cost, USD	15,000-45,000	~ 5,000	

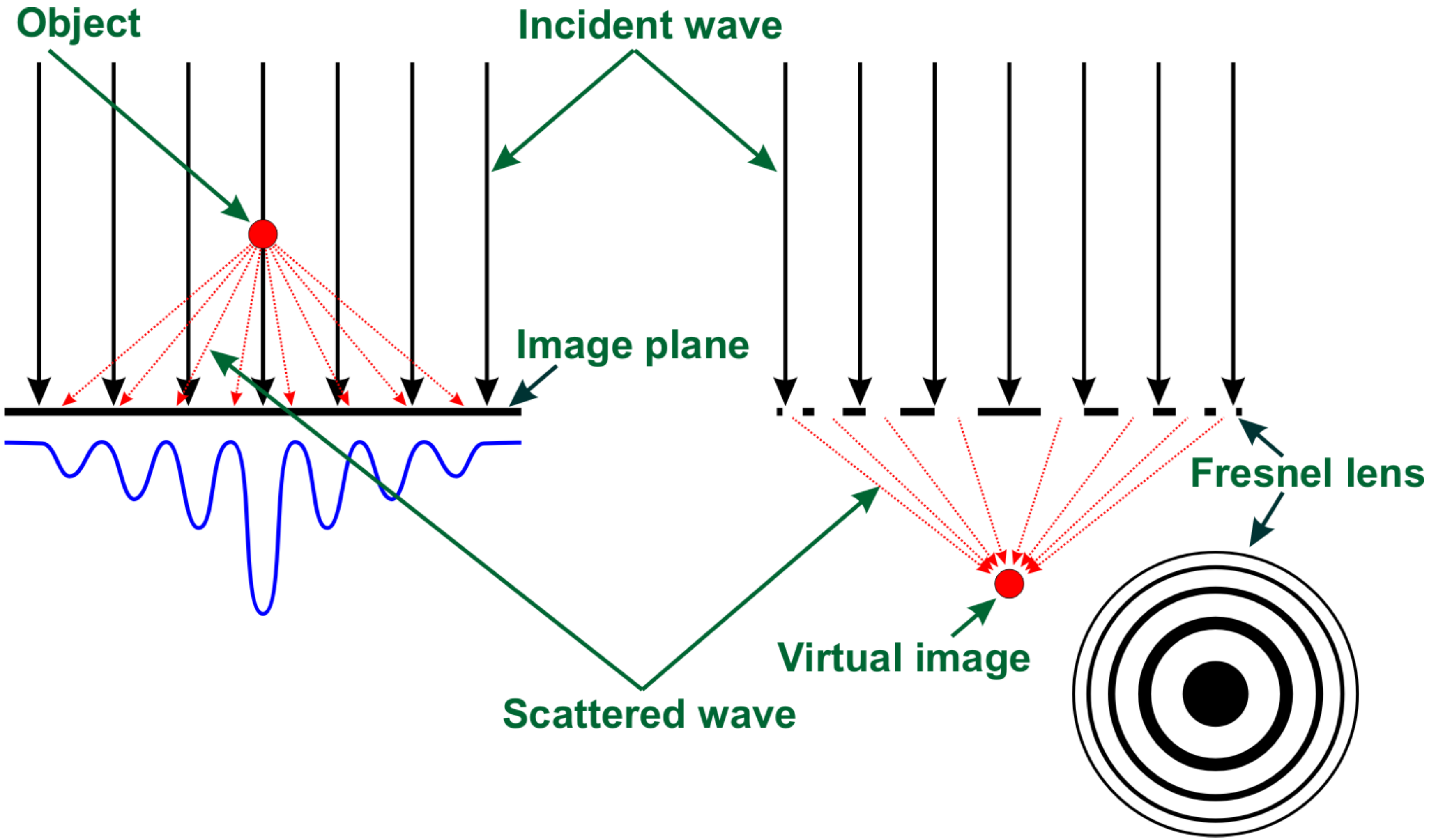
Principle of Holographic radar



Aperture scan with an holograhic radar

Principle of Simplest Optical Holography

Dennis Gabor is the Nobel Prize winner in Physics 1971



Recording a Point Source Optical Holographic Interference Pattern (left). Hologram Reconstruction (right)

Rascan Equipment

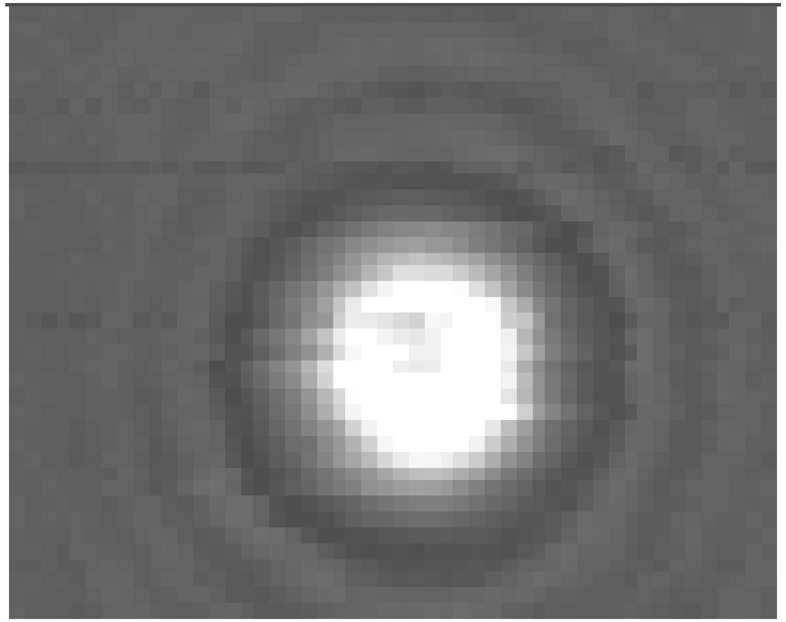
f= 2 GHz Holographic Radar

f= 4 GHz Holographic Radar

λ = c / f = 15 cm (in air)

λ = c / f = 7,5 cm   (in air)

3. Interference patterns : “Zebra” shift effect



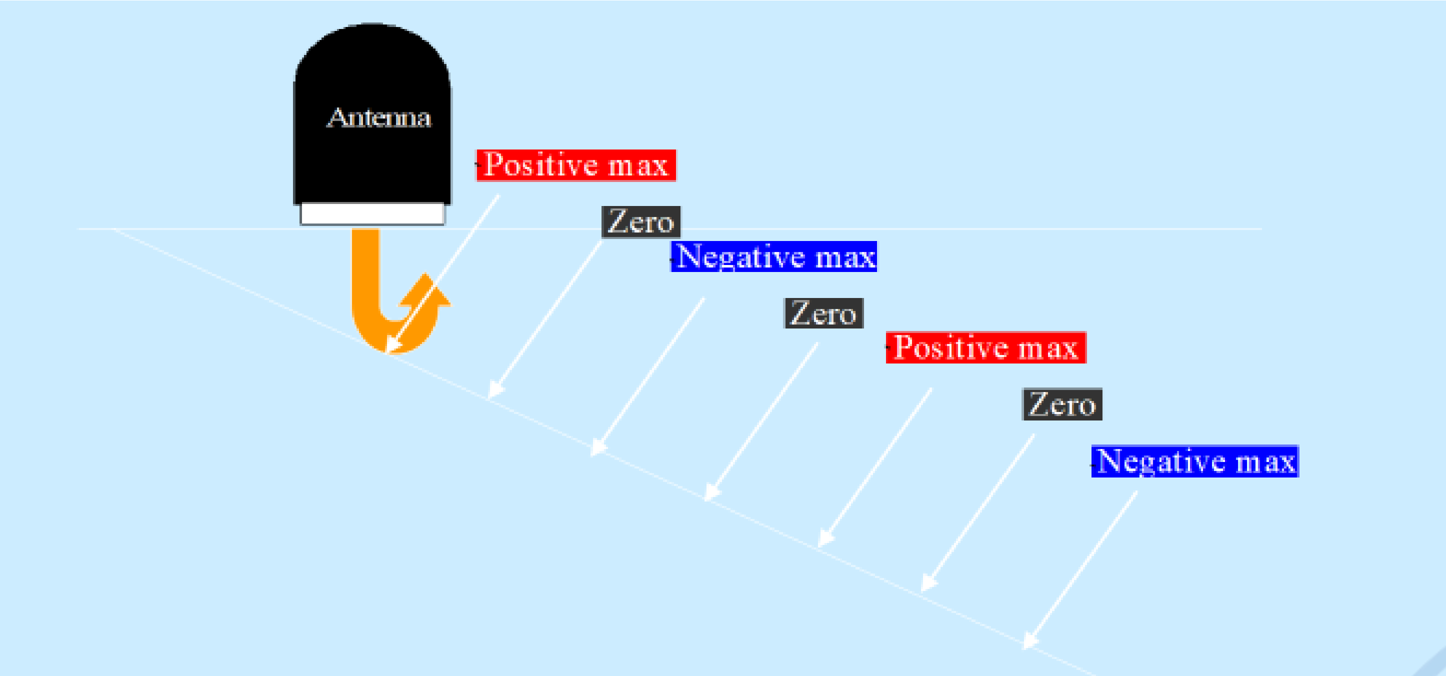
A scan in air at 5 frequencies close to 4 GHz (λ= 7.5 cm) of a metal Japanese wok (日本の中華なべ) with concavity up.

As frequency increases

Shrinks inwards

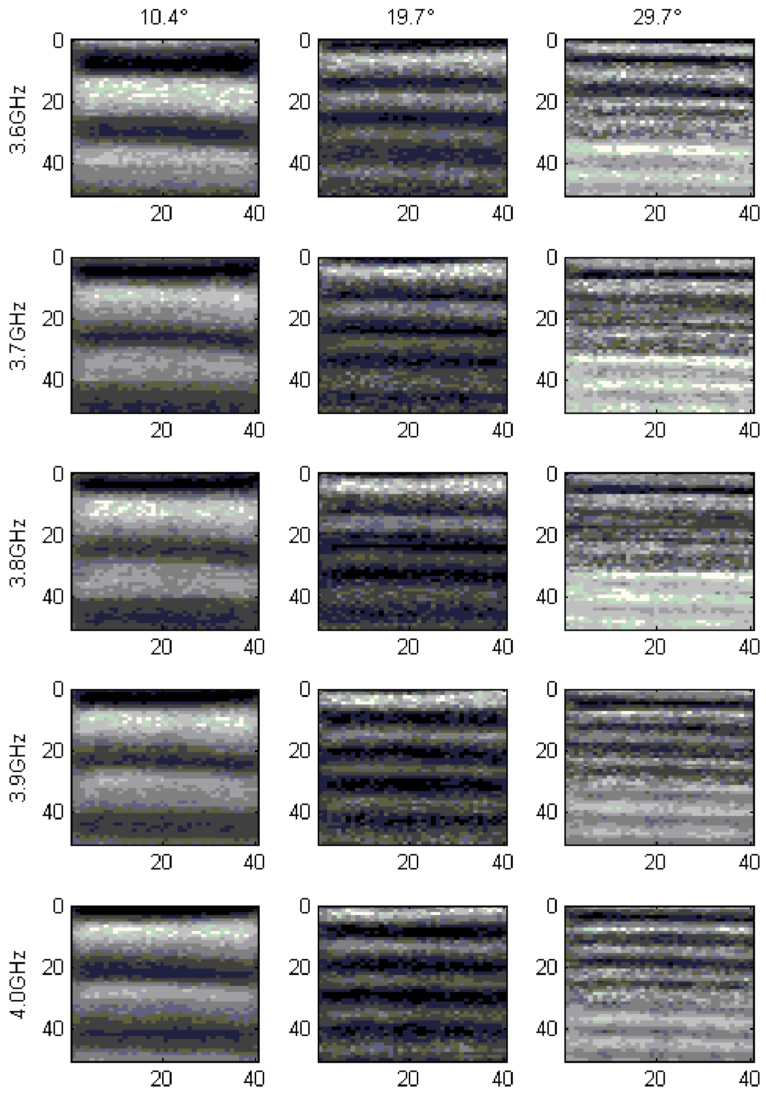
3. Interference patterns : “Zebra” shift effect

- Holographic radar of RASCAN type provides an output signal that is amplitude-modulated by the phase variation between the reference and received signals.
- RASCAN radar response is compared with a model by several experiments performed in air with a 4GHz probe scanning a planar metallic reflector inclined at different angles.
- The radar response shows a series of dark and light stripes with spacing dependent on signal frequency and velocity, and reflector inclination angle. The model is used to interpret the amplitude variations as a function of probe position.



https://ieeexplore.ieee.org/document/5550129

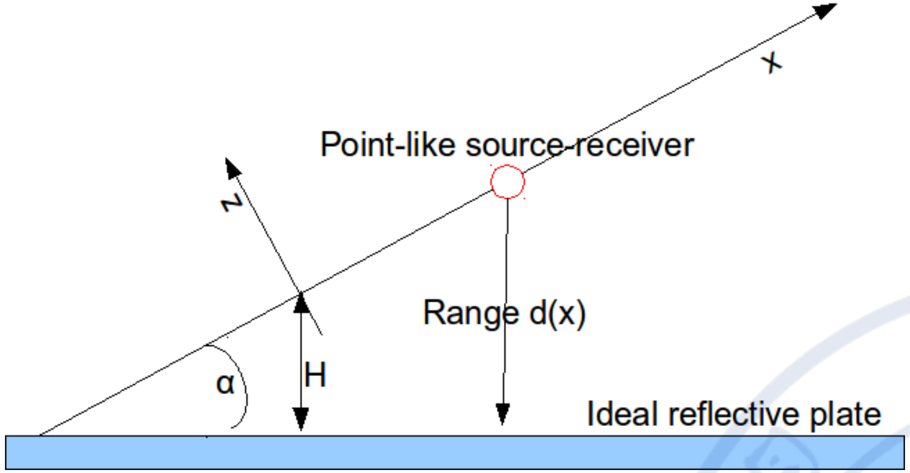
3. Interference patterns : “Zebra” shift effect



A series of contrast images at different angles α (9°, 18°, 27°) and frequency (3.6,3.7,3.8,3.9,4.0 GHz) show the “zebra effect” with different apparent wavelength λ’

$$\lambda' = \frac{\lambda}{2\sin(\alpha)}$$

α [°]	λ' [m]
9	0.240
18	0.121
27	0.082



4. Applications of Holographic Radar

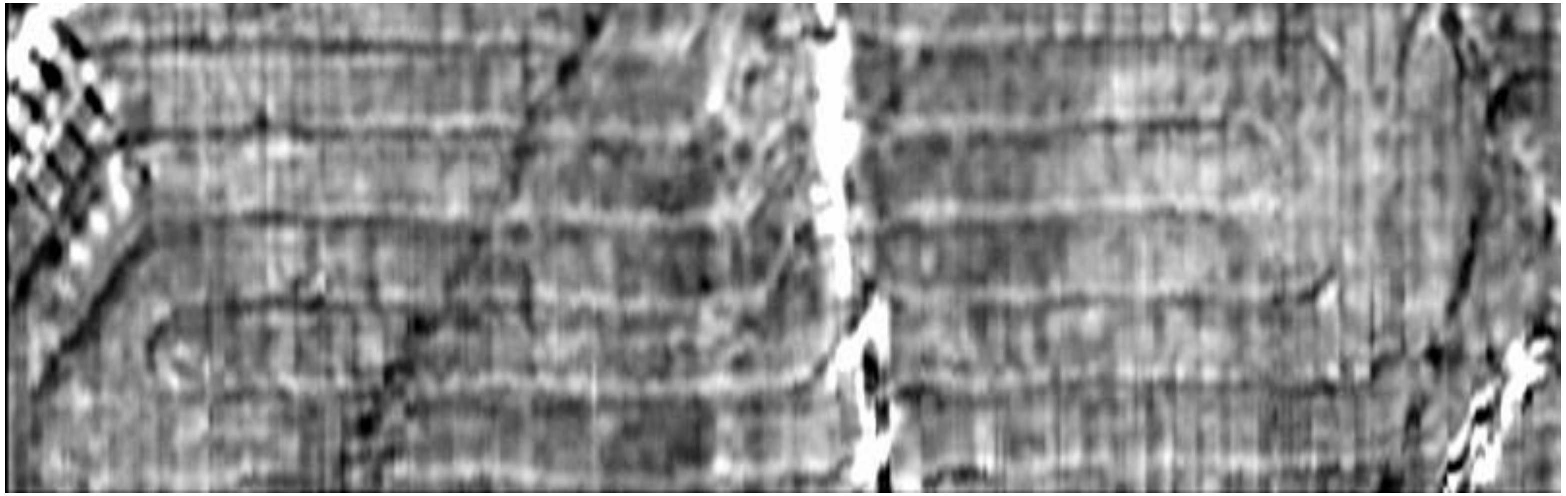
4.1 Civil engineering inspection of building and structures

4.2 Cultural heritage preservation/conservation

4.3 Non destructive testing of engineering dielectric materials

4.4 Unexploded Ordnance (UXO) detection for humanitarian demining

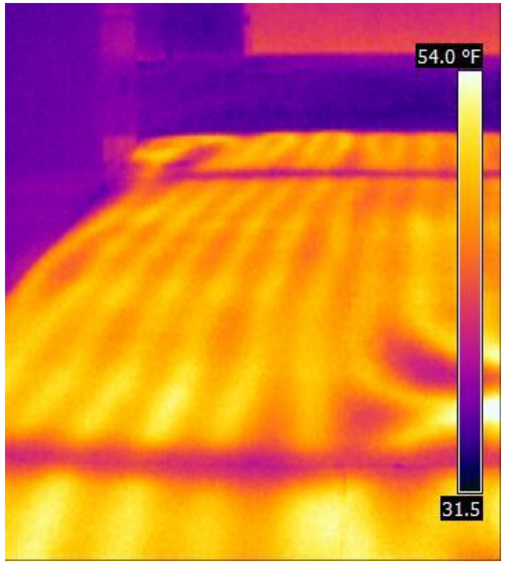
Comparison of imaging : Radar vs infrared (IR)

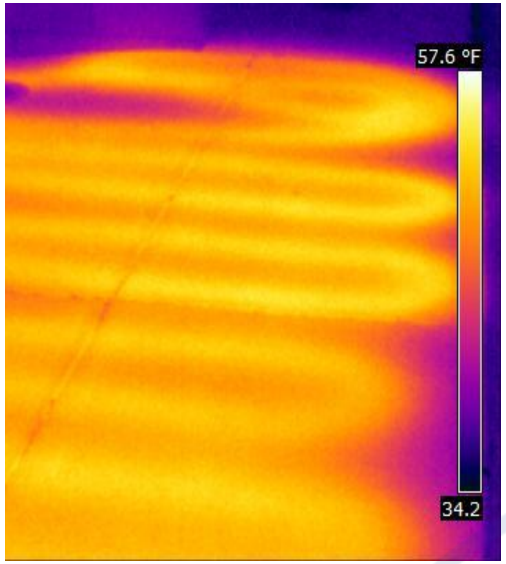


Radar image at 2GHz of unknown pipes in old concrete floor of the Russian Senate Building, Saint Petersburg

Thermal Images
(warm air in tubes on a cold day)

FLIR i60





Alternative NDT methods: Xray and IR imaging

	Radiography (X-Ray)	IRT
Required Access	both sides	one side only
Radiation Hazard	high	none
Licences or Permits	yes	none
Set-Up Time	long	long (?)
Data Collection	slow	rapid
Real-Time Results	none	complete
Data Storage	film	digital
X-Y Target Location	highly accurate	highly accurate
Z Target Location	poor to none	highly accurate
Target Discrimination	poor to none	excellent
Live Line Detection	none	none
100% Guaranteed	no	no

Holographic Radar method with high resolution imaging is competitive for selected applications

The investigation on the *Croce di San Marco*

6.30 m

Description of the cross
The Cross of San Marco dates back to the mid-fourteenth century and is attributed to Puccio di Simone.
Height of 6.30 meters.
Thickness of the poplar planks is 7 cm
total weight estimated at around 500 kg.

The plank is made up of a vertical part, the upright of a cross, and a horizontal part, the arm, which are joined together.

How are where are joined together?

X-Ray investigation was complex and expensive.

http://www.opificiodellepietredure.it/index.php?it/1074/puccio-di-simone-attr-croce-dipinta-firenze-san-marco-disinfestazione

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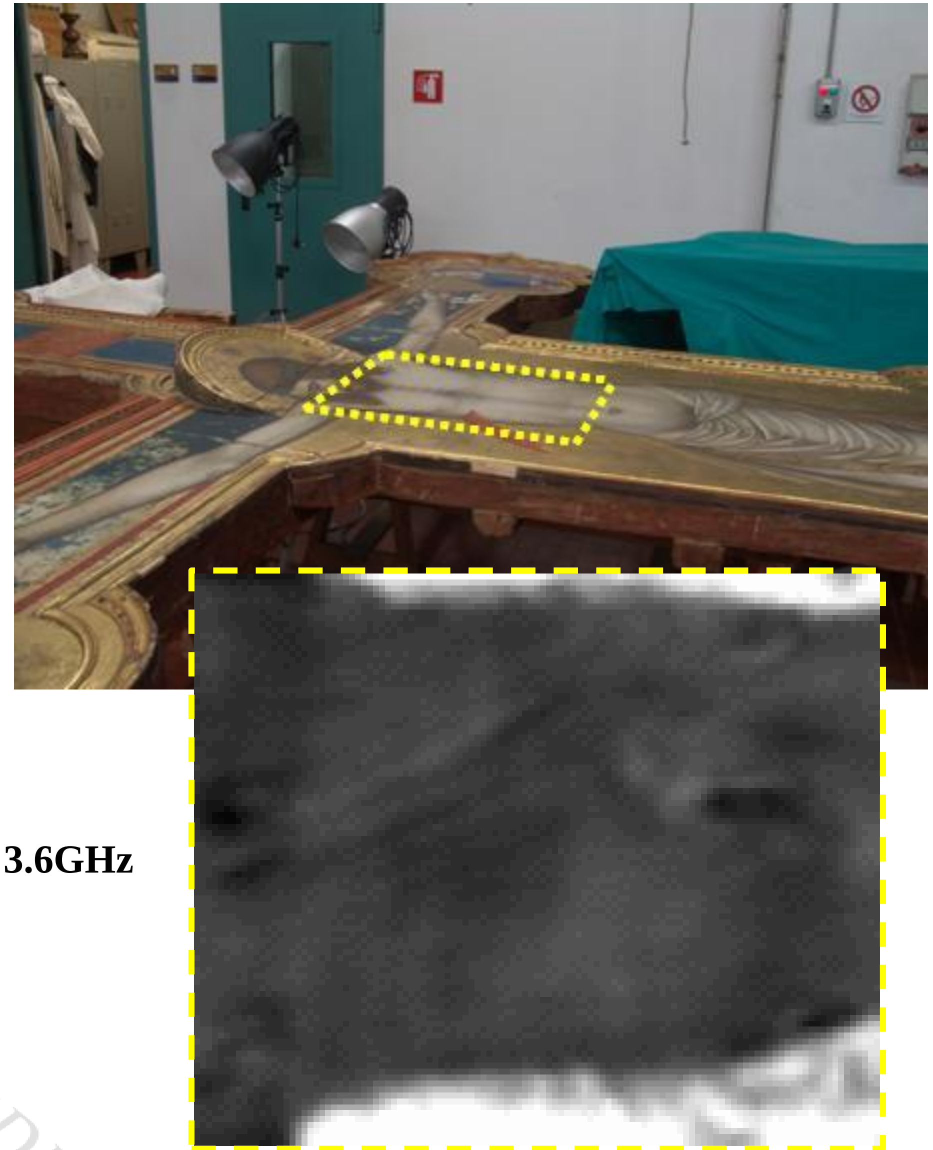
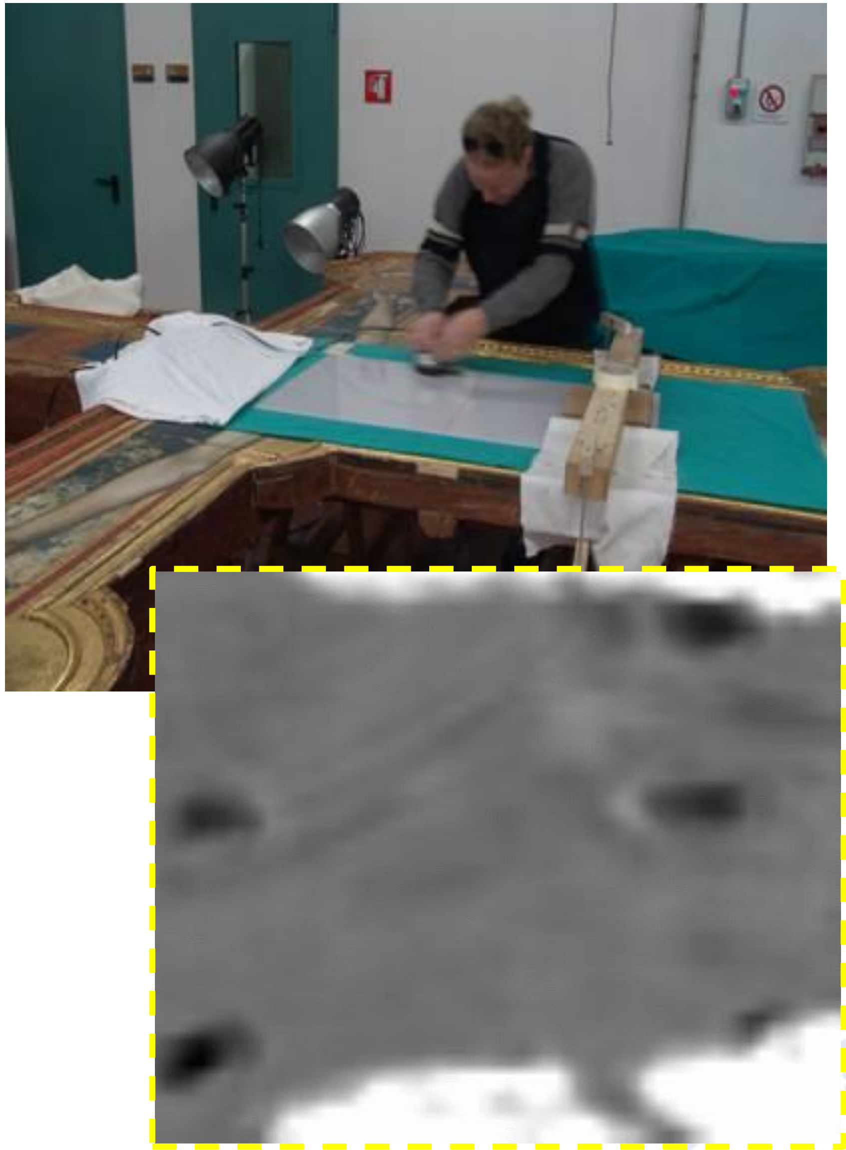
Investigation of inner structure of the *Croce di San Marco*

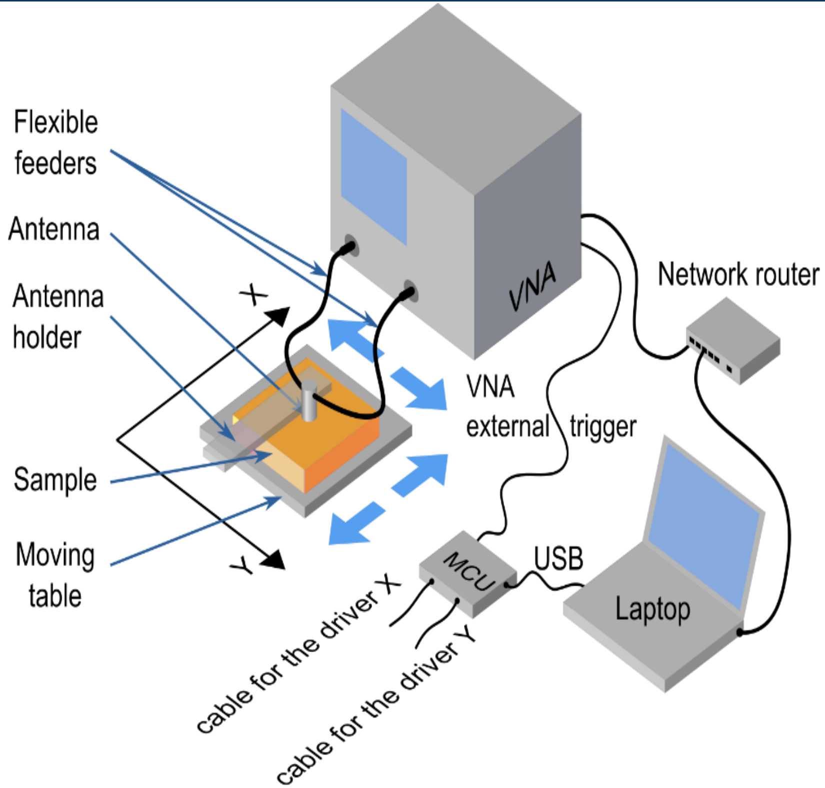


Parallel – 3.6GHz



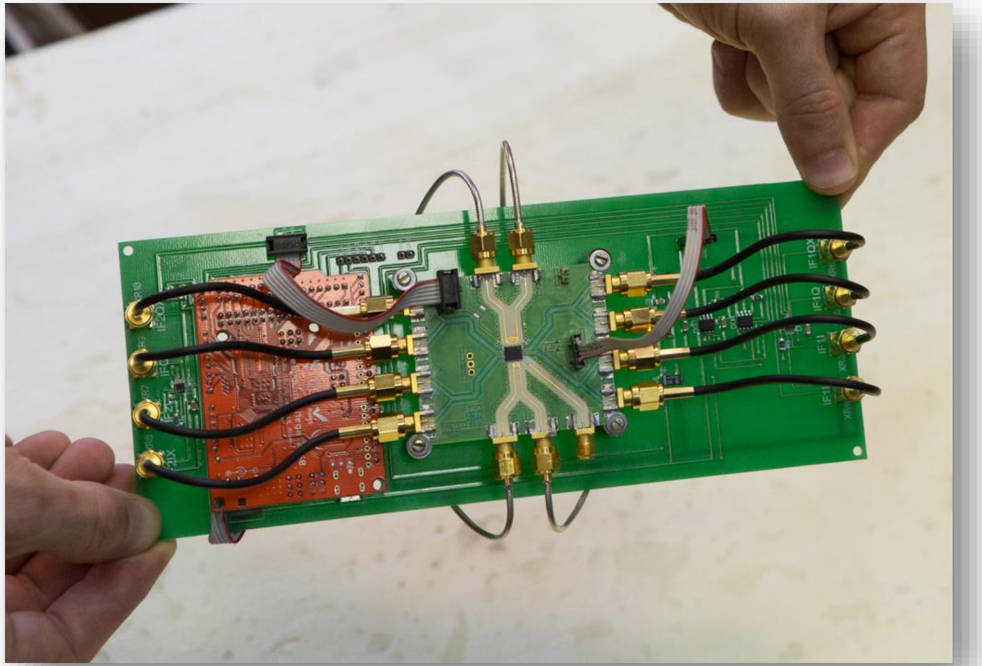
Cross – 3.7GHz

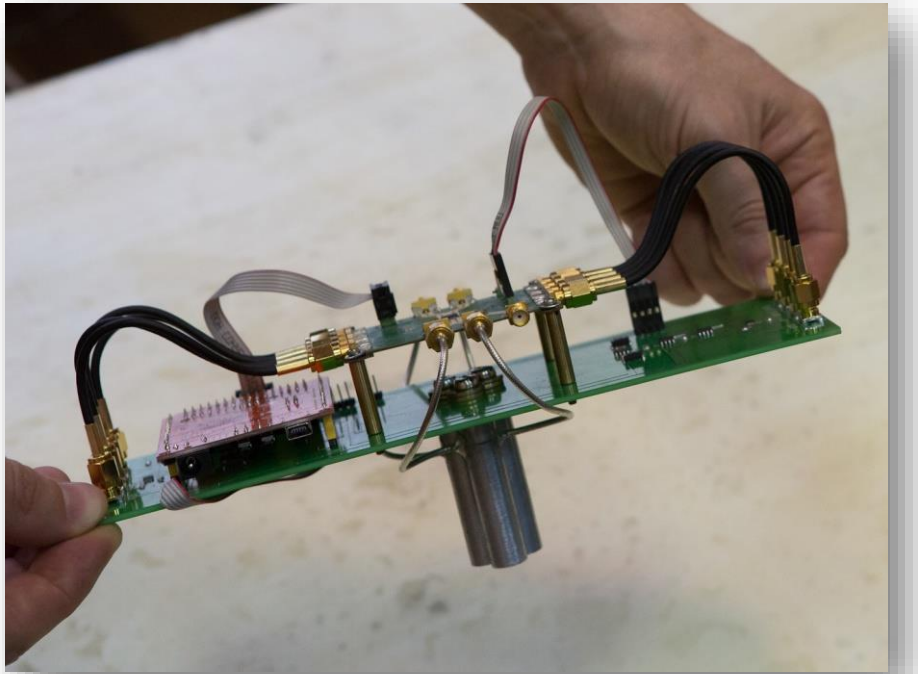
High Frequency hologram reconstruction



- Reconstruction of the MW holograms by back-propagation technique was applied, based on 2D Fast Fourier Transform.
- A high frequency (22GHz) laboratory setup was applied to increase the spatial resolution and accuracy
- Electronics is designed to provide In Phase and Quadrature signals (I/Q).

Holographic radar (22-26 GHz) for high resolution imaging





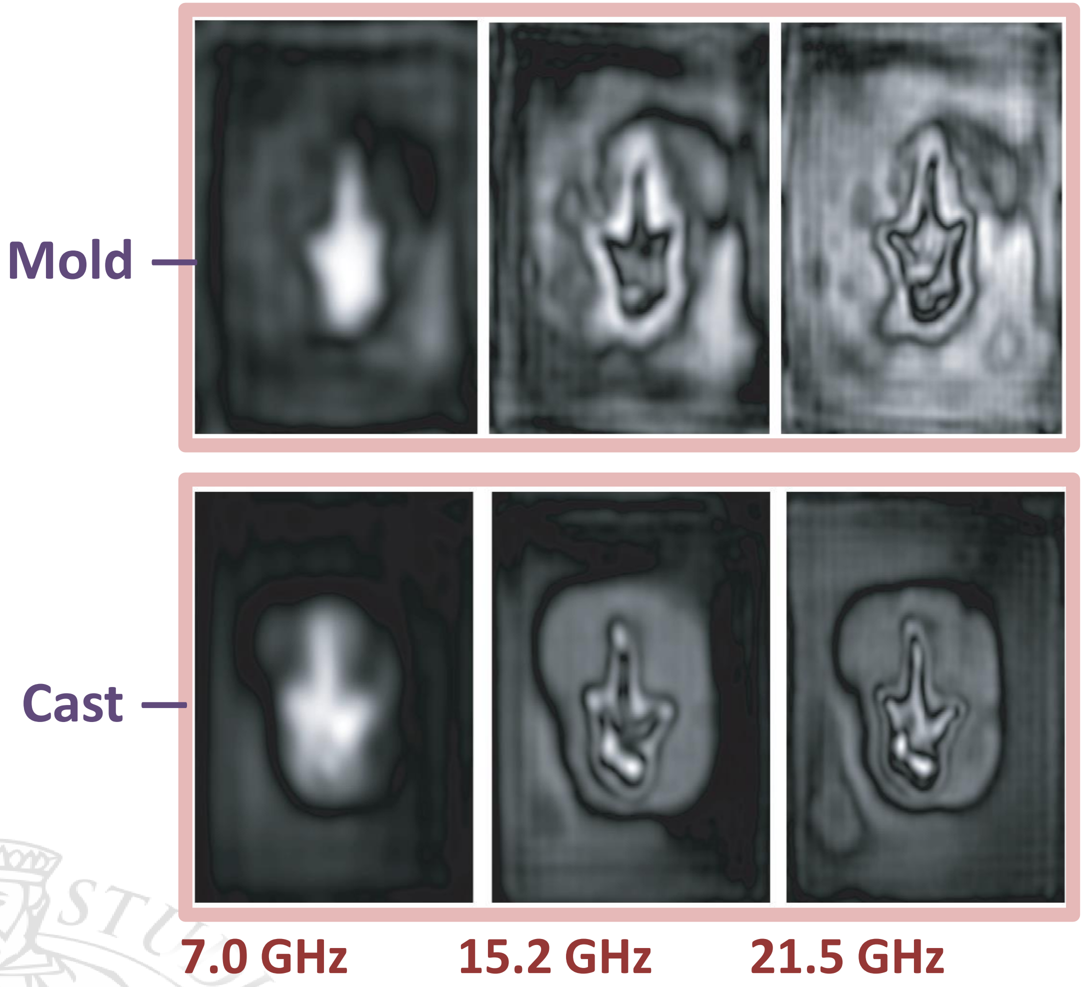
Dinosaur's Track Sample

- A model mold-and-cast dinosaur track was created by making a gypsum plaster cast of an actual dinosaur track (var. *Anamoepus* from Dinosaur State Park in Connecticut, USA) and reproducing the tightly-fitting mold from this cast

- Mold: area of 255×225 mm, height of 27 mm
- Cast: same area, height of 22 mm
- The track: in the middle of the samples, 11 cm long by 7.5 cm wide

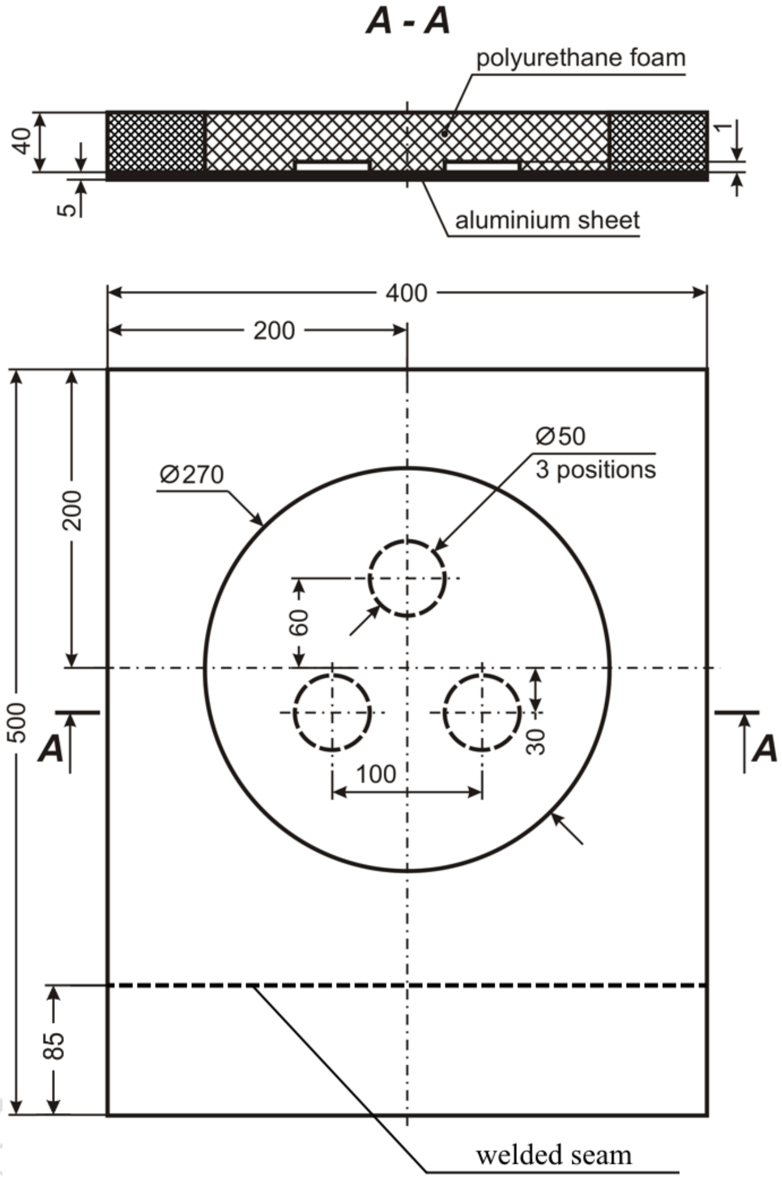
Experimental Results

- The experiments were conducted in three MW frequency ranges: 6.4-7.0, 12.8-15.2 and 18.0-21.5 GHz.
- The scanned area — 250×220 mm, the sampling step — 3 mm, the distance to the sample surface — 25 mm.

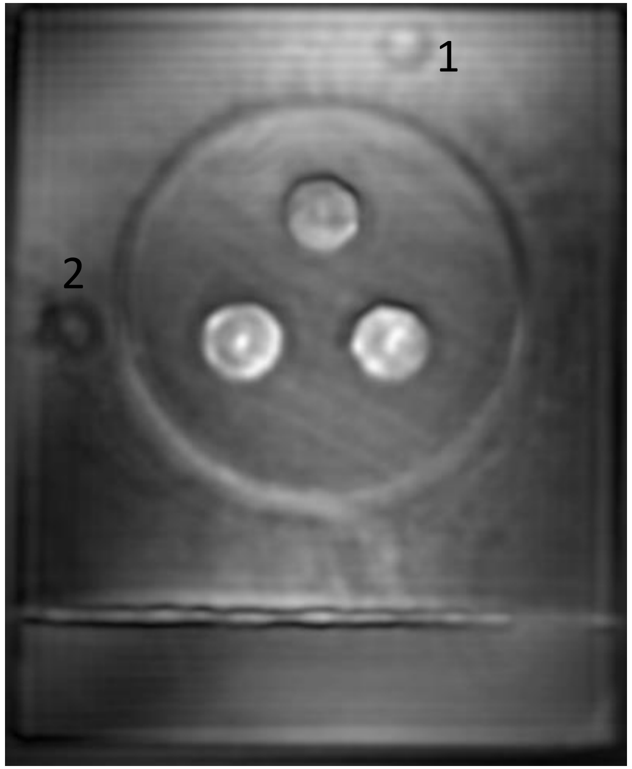


→ the feasibility of Microave W holographic subsurface radar technology for non-contact imaging and recording of tracks where they are exposed (some track surfaces are fragile)

Diagnostics of Composite Dielectric Materials for Aerospace



Microwave hologram
22.5 GHz ($\lambda \cong 1.3$ cm)



Note: defects 1 and 2 are not expected

General overview of landmines detection

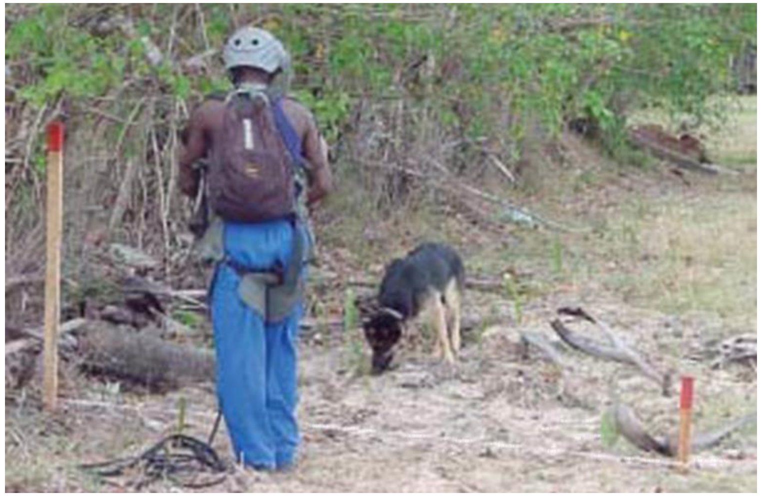
Landmines /UXO detection in figures: actual mine clearance in Cambodia 2000-2008.

Type of Item	Total Number of Items Found	Time to Confirm (hours)	Time to Dig (hours)	Time to Neutralize (hours)	Total Time	Percentage of Total Time
Antitank Mines	961	80	80	80	240	0.00074%
Antipersonnel Mines	89,327	7,400	7,400	7,400	22,000	0.068%
UXO	452,770	38,000	38,000	38,000	110,000	0.34%
Scrap clutter	191,737,707	16,000,000	16,000,000	0	32,000,000	**99.6%**

Advances – particularly in GPR (Minehound, ALIS, HSTAMIDS) - have “improved” this to 70%-80%

Macdonald, Jacqueline et al. (2003) Alternatives for Landmine Detection, Rand Corporation, Santa Monica, CA

THE UNITED NATIONS APPROVED METHODS



Images courtesy from, ICRC, Halo Trust, PM/HDP

These approaches combine human with hand-held electromagnetic sensors or human-animal interaction. Operators are always close to threats during detection and buried target removal, increasing the risk of casualties.

A first big question: distinguishing mines from clutter?

Ruler is 300 mm

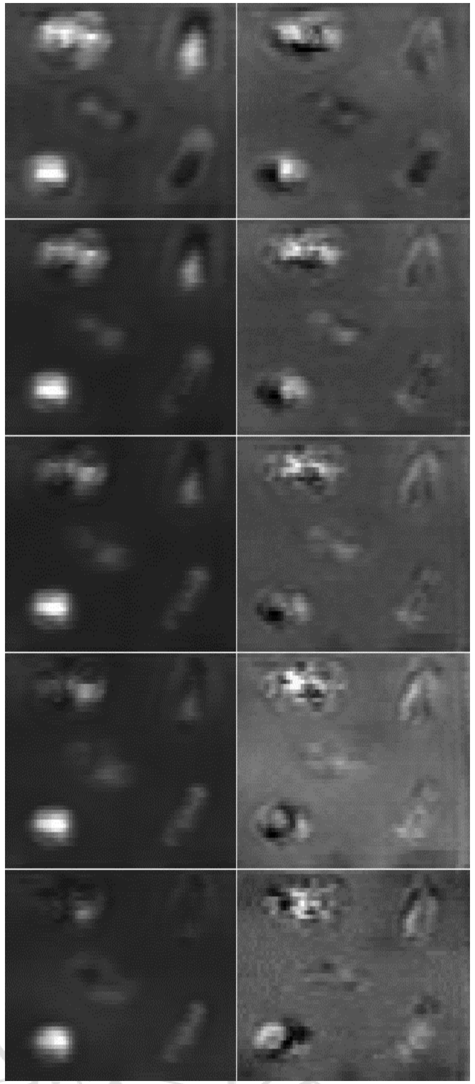
The simulated mine at the bottom left (a plastic sweet box filled with sugar) is compared in these experiments in a sand box with typical battlefield clutter objects:

- a squashed can
- an unexploded shell
- a large stone, and
- some barbed wire

Experiments done at F&M.

Targets shape and dimension evaluation

Parallel Perpendicular



3.6

3.7

3.8

3.9

4.0 GHz

The Rascan system uses 5 frequencies from 3.6 to 4.0 GHz and measures both parallel and perpendicular polarisations. Each image is different in detail.

For image analysis a single display image is formed from summing the background corrected absolute values over all images.

Windsor et al, "*Single displays for RASCAN 5-frequency 2-polarisation holographic radar scans*" PIERS ONLINE, VOL. 5, NO. 5, page 496, 2009:

Test bed outdoor with sandy soil

A first experiment of augumented reality:
the projection of the holographic image on the scanned surface in real time.

Scanning at F&M and
at Enviroscan in Lancaster , USA

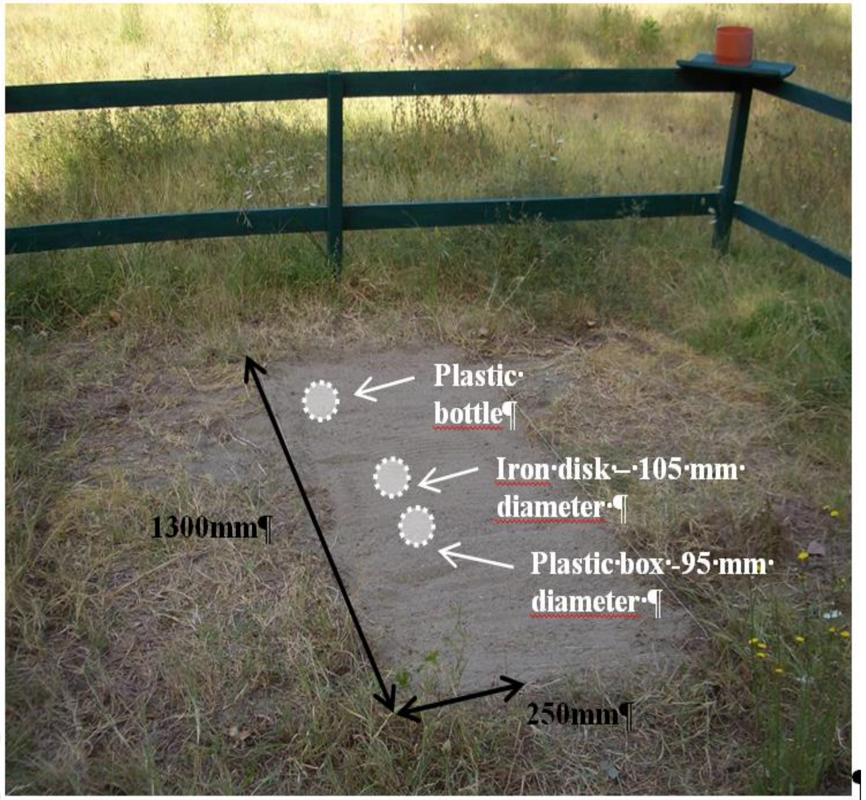
First public exhibition at Royal Society, London, 2010

Looking for buried land-mines with holographic radar

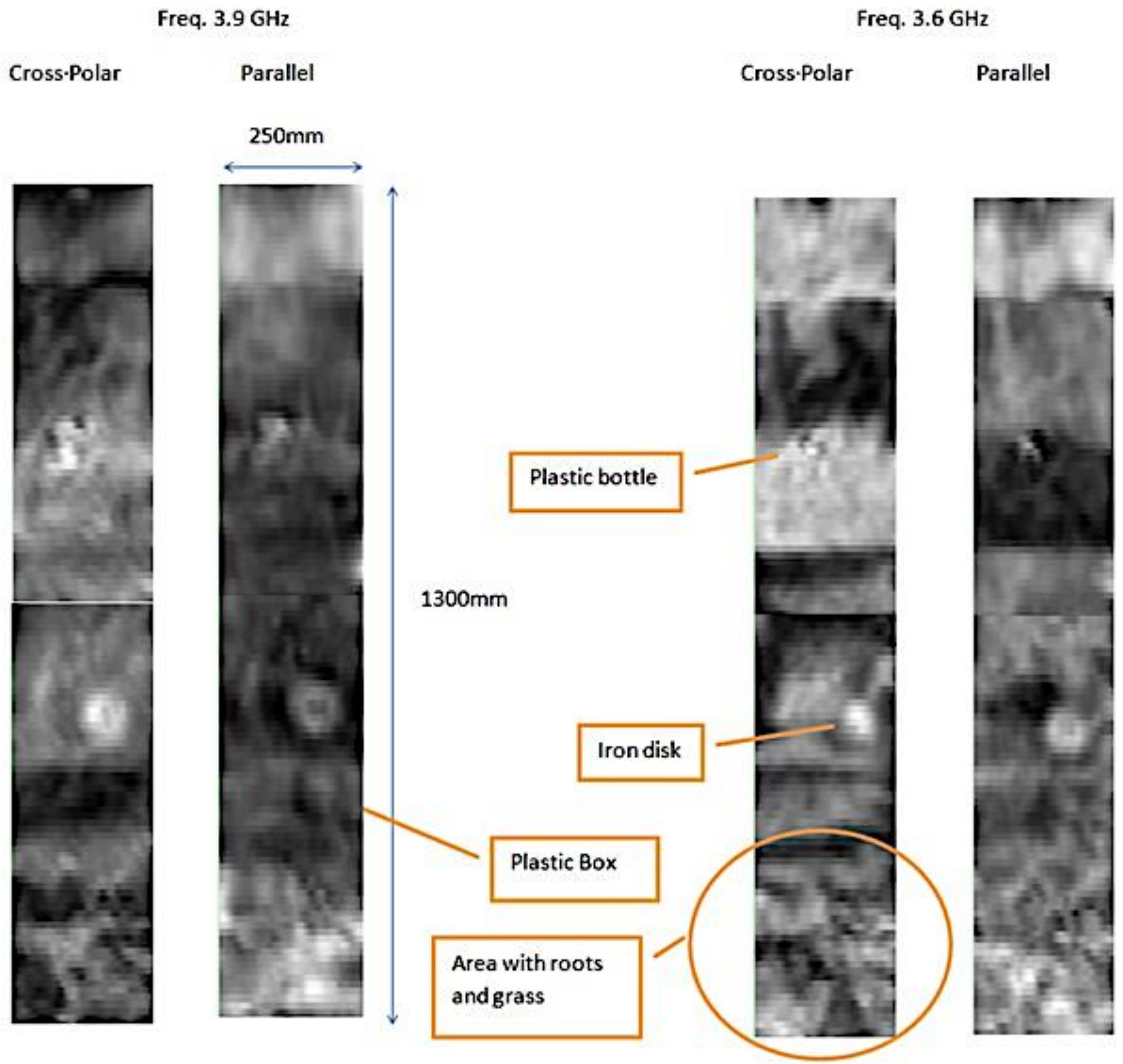
An exhibit selected for the Royal Society Summer Exhibition, London, 23-26 June 2010

Test bed with natural soil

A second big question: how natural soil influence the detection?



Experiment on a test bed in Firenze, Italy with 4 GHz radar



International collaboration – Scientific Diplomacy

Collaboration between engineers, physicists, geologists at international level is important to make significant progresses in science and technology for humanity.

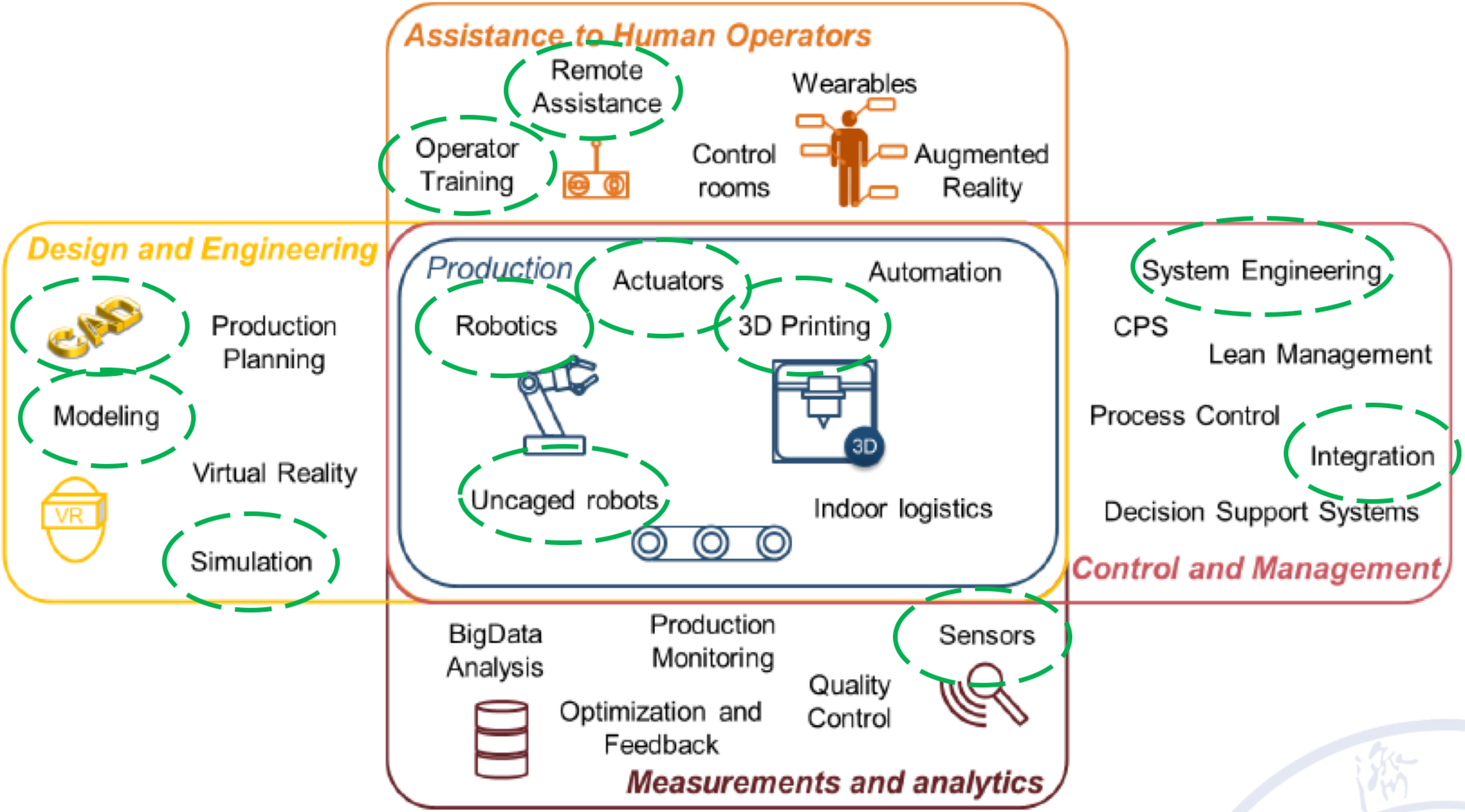
5.

DEMINING 4.0 project for humanitarian demining

The Industry 4.0 Paradigm has been adopted for a new design approach with the following advantages :

- The operator on the field can operate at safe distance from the robotic platform in a comfortable situation (less tiredness)
- The scanning is quicker and can be operated 24 hours a day (no day light and good weather conditions are required)
- Non contact radar antenna
- Spatially and time correlated data from radar, optical, IMU, and other sensors are archived on the robot and remotely accessible from team of experts or AI.

WHAT WE USED OF *INDUSTRY 4.0* ?



ANALYSIS OF SYSTEM DESIGN CHARACTERISTICS

- Four wheels robot
  - weight: 40 kg including batteries
  - According to the simulations of mechanical movement on a bumpy surface [1], it is shown that the robotic platform will work on most target minefields
  - Operation time: about 2.5 hours
- GPR detection speed: few meters per minute
- HSR scanning speed: 16cm x 32cm plan-view (5 mm step) in about 3 minutes
- Open Platform with ROS (Robotic Operating System)

[1] T. Bechtel, G. Pochanin, S. Truskavetsky, M. Dimitri, V. Ruban, O. Orlenko, T. Byndych, A. Sherstyuk, K. Viatkin, F. Crawford, P. Falorni, A. Bulletti, L. Capineri, "Terrain Analysis in Eastern Ukraine and the Design of a Robotic Platform Carrying GPR Sensors for Landmine Detection"

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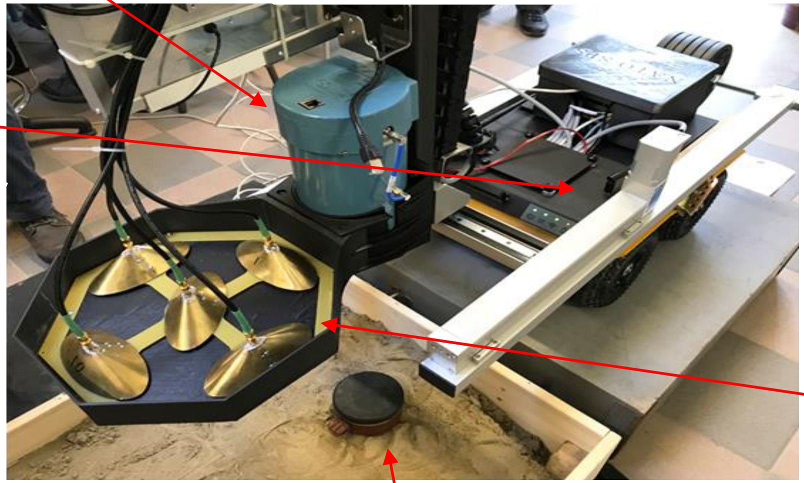
PROPOSED ROBOTIC SCANNER SYSTEM FOR LANDMINE DETECTION

Remote server

Wireless interface

The Internet connection

HSR
(Holographic Subsurface Radar)

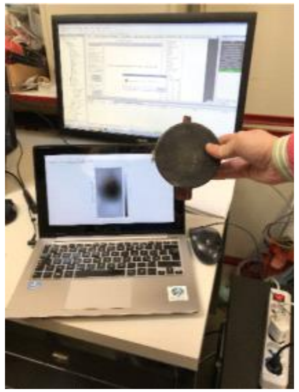


GPR
(impulse radar)

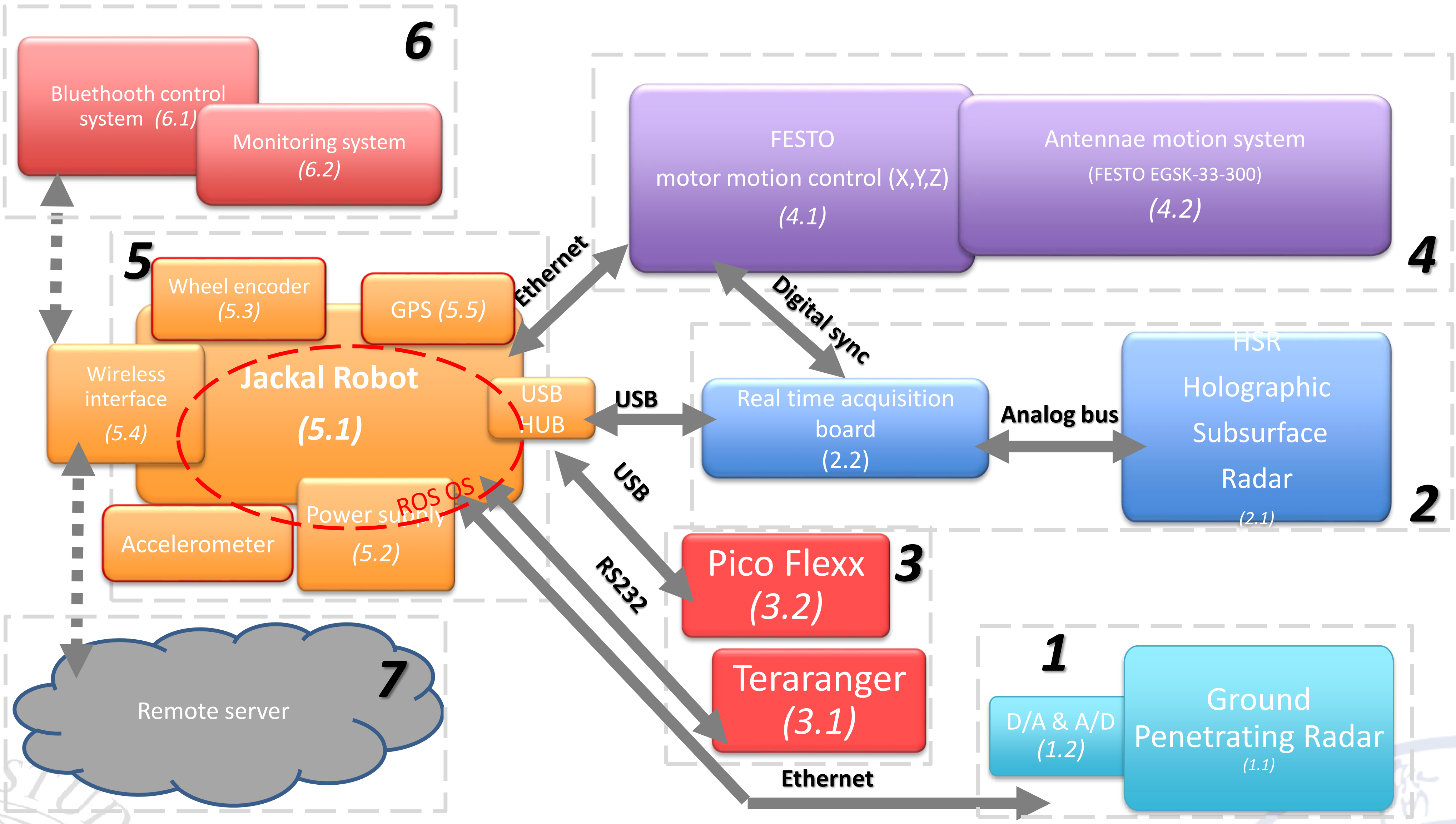
ROBOT SCANNER

PMN-1 landmine simulant

Local Monitoring system

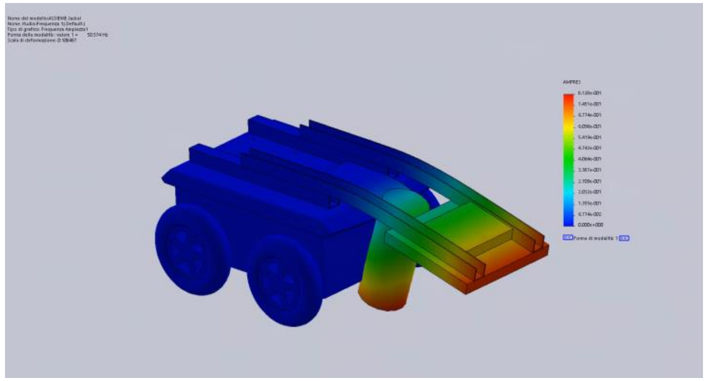


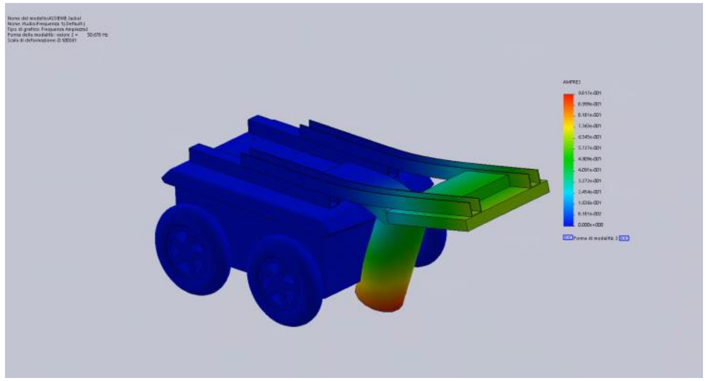
ROBOT SCANNER ARCHITECTURE



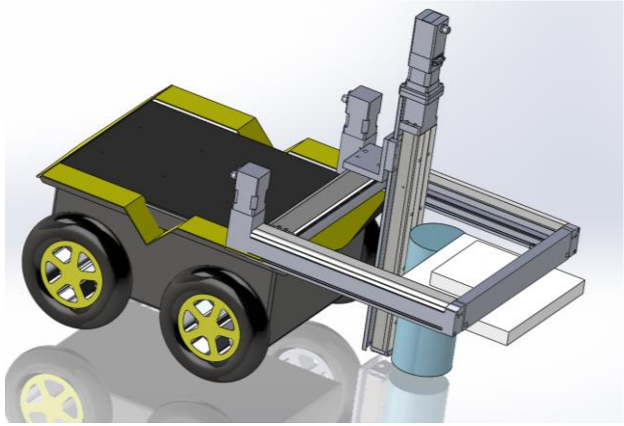
THE CAD MODELLING OF ROBOTIC SCANNER BASED ON THE COMMERCIAL OPEN ROBOT VEHICLE CLEARPATH© "JACKAL"

Vibrational modes

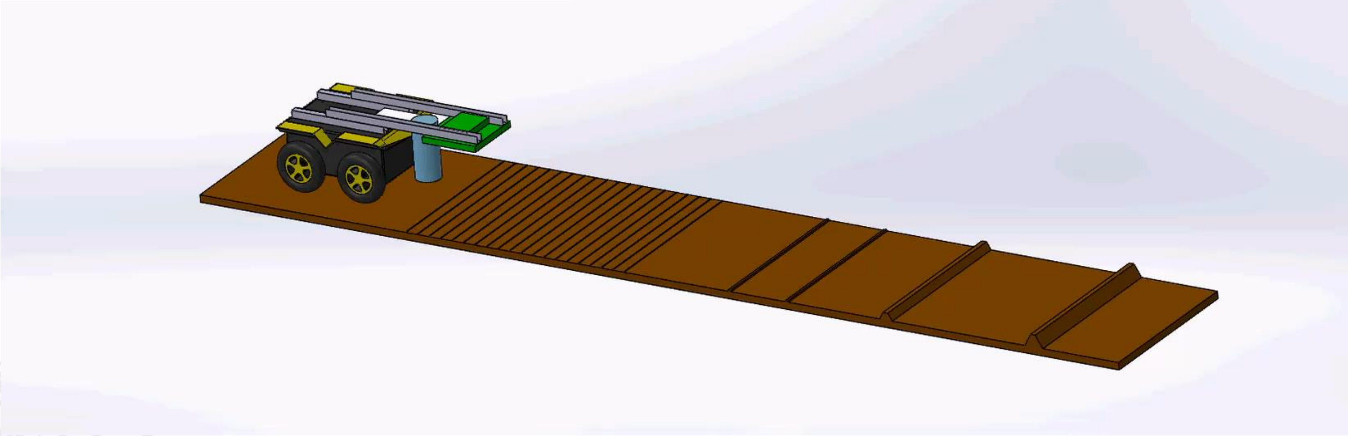




Robotic scanner



Simulations on uneven ground



3D PRINTING FOR ROBOT PARTS AND ACTUATORS

- The digital models of mechanical parts have been exchanged by project teams to refine the design and fabricated with high reproducibility in different countries with low cost.

A robotic arm for manipulating different tools for landmine removal

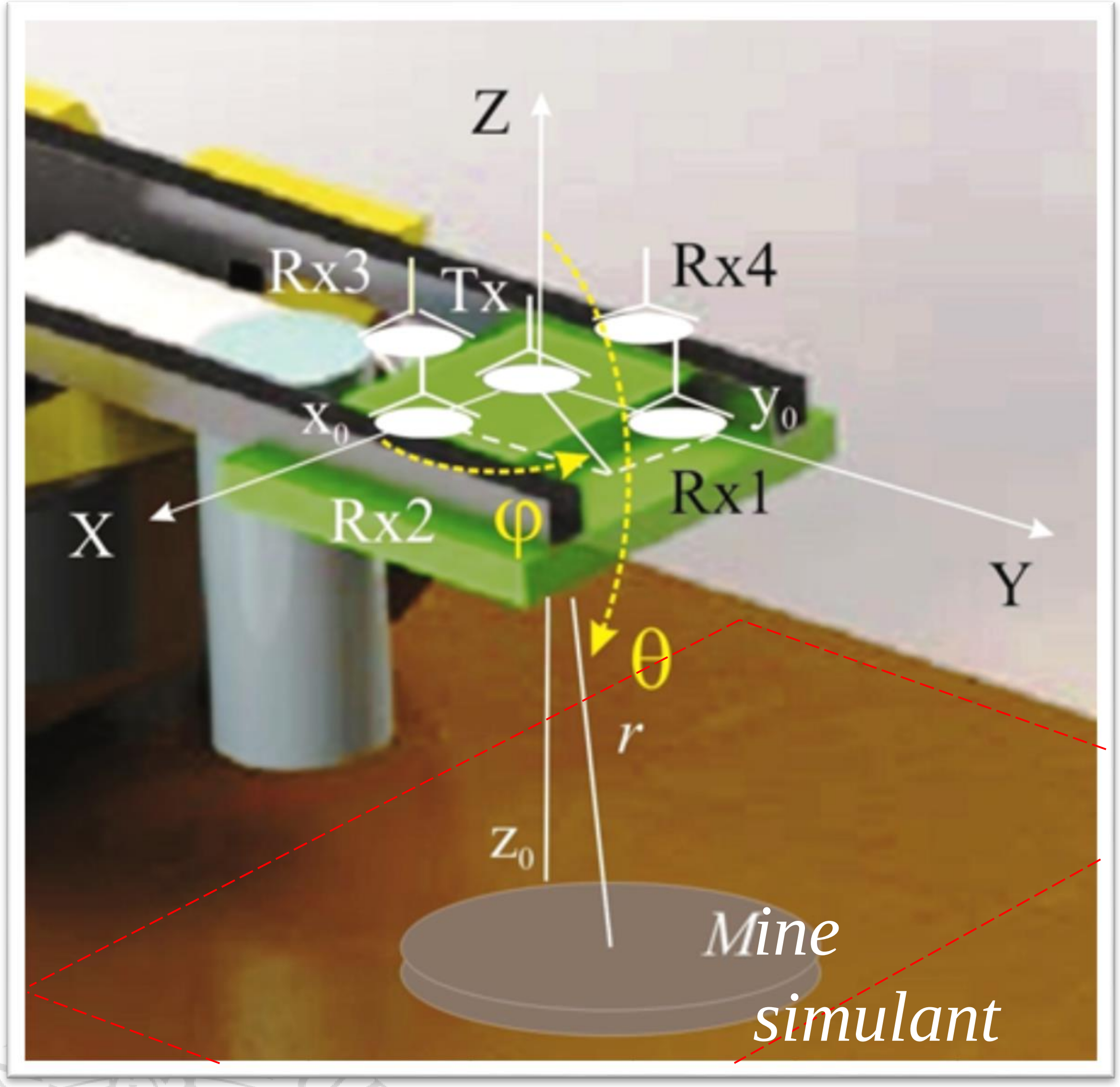
1Tx+4Rx antenna system for the impulse GPR is shown in the octagonal 3-D printed case..

ROBOTIC SCANNER SENSORS INTEGRATION

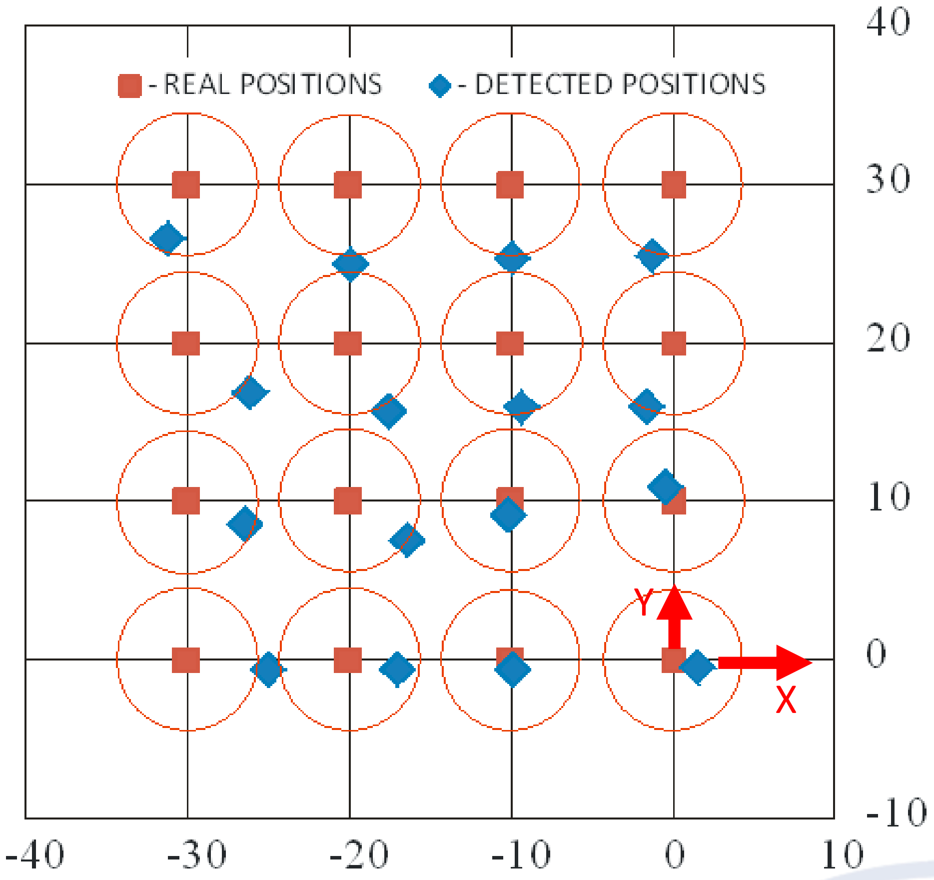
A. Impulse radar (1Tx-4Rx) for rapid target detection and location (2 GHz center frequency, 2GHz bandwidth@-6dB)
B. Holographic radar for target imaging with programmable (1.7 – 2.0 GHz) continuous wave operating frequency
C. 3D camera scanner with PMD technology for measuring the antenna-soil distance useful for radar scan data interpretation.

[3] G. Pochanin et al, “Field Measurement of Permittivity, Electrical Conductivity, Magnetic Susceptibility, and Topographic Relief of Soils in Donbass, Ukraine for Robotic, Multi-Sensor, Humanitarian Demining System Design”, URSI 2017, Montreal Canada

A. GPR ARRAY (1TX – 4RX) FOR TARGET FAST DETECTION

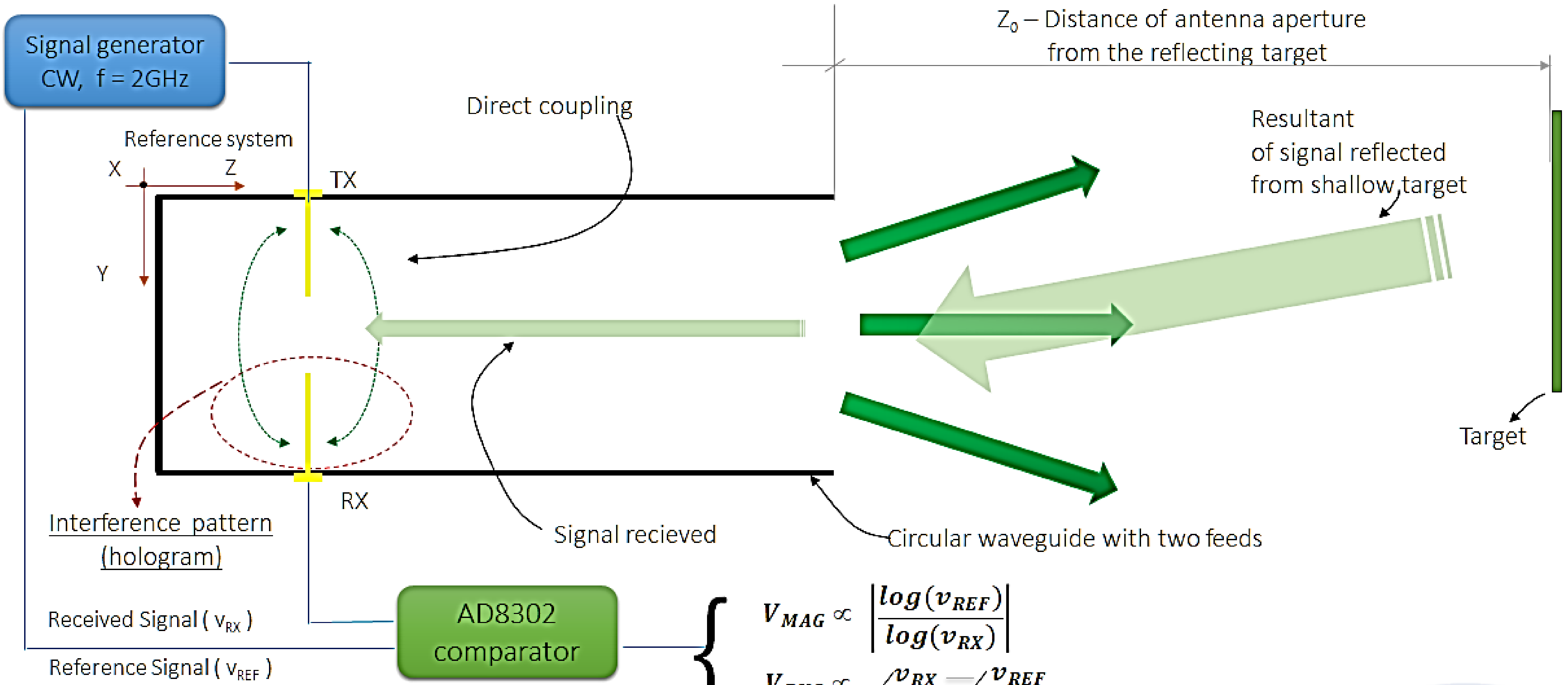


Real time position estimation of a plastic PMN mine simulant on a flat surface [4] in laboratory conditions.



[4] O. Pochanin et al "Estimation of Lane Width for Object Detection Using Impulse GPR with "1Tx and 4Rx" Antenna System", GPR 2018, Rapperswil (CH) June 2018

B. HOLOGRAPHIC RADAR (1.7-2.0 GHz) FOR TARGET IMAGING

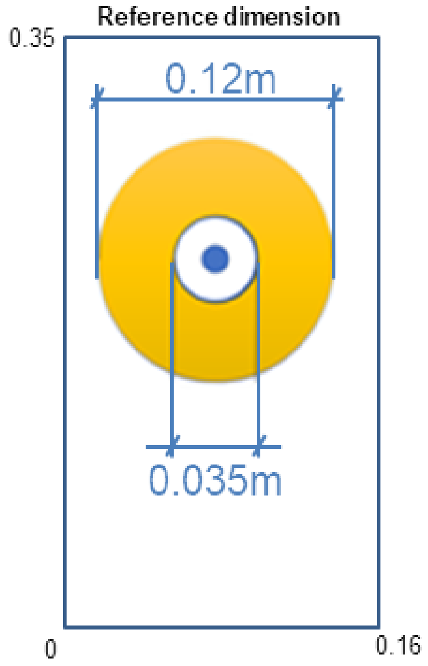


$$\begin{cases} V_{MAG} \propto \left|\dfrac{log(v_{REF})}{log(v_{RX})}\right| \\ V_{PHS} \propto \angle v_{RX} - \angle v_{REF} \end{cases}$$

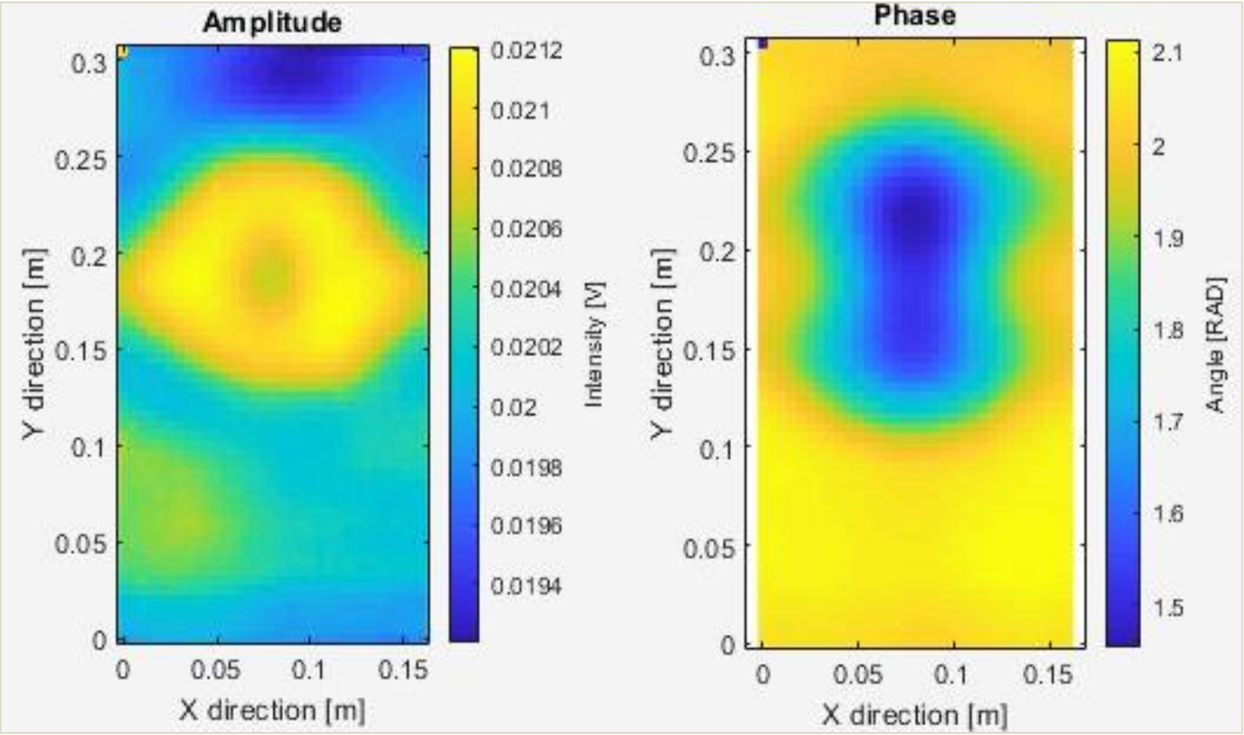
[5] G. Borgioli, Hologram reconstruction algorithm for landmine recognition and classification based on microwave holographic radar data" , PIERS 2018 Toyama Japan

B. HOLOGRAPHIC DATA (AMPLITUDE AND PHASE) VISUALIZATION

Compact Disk sizes

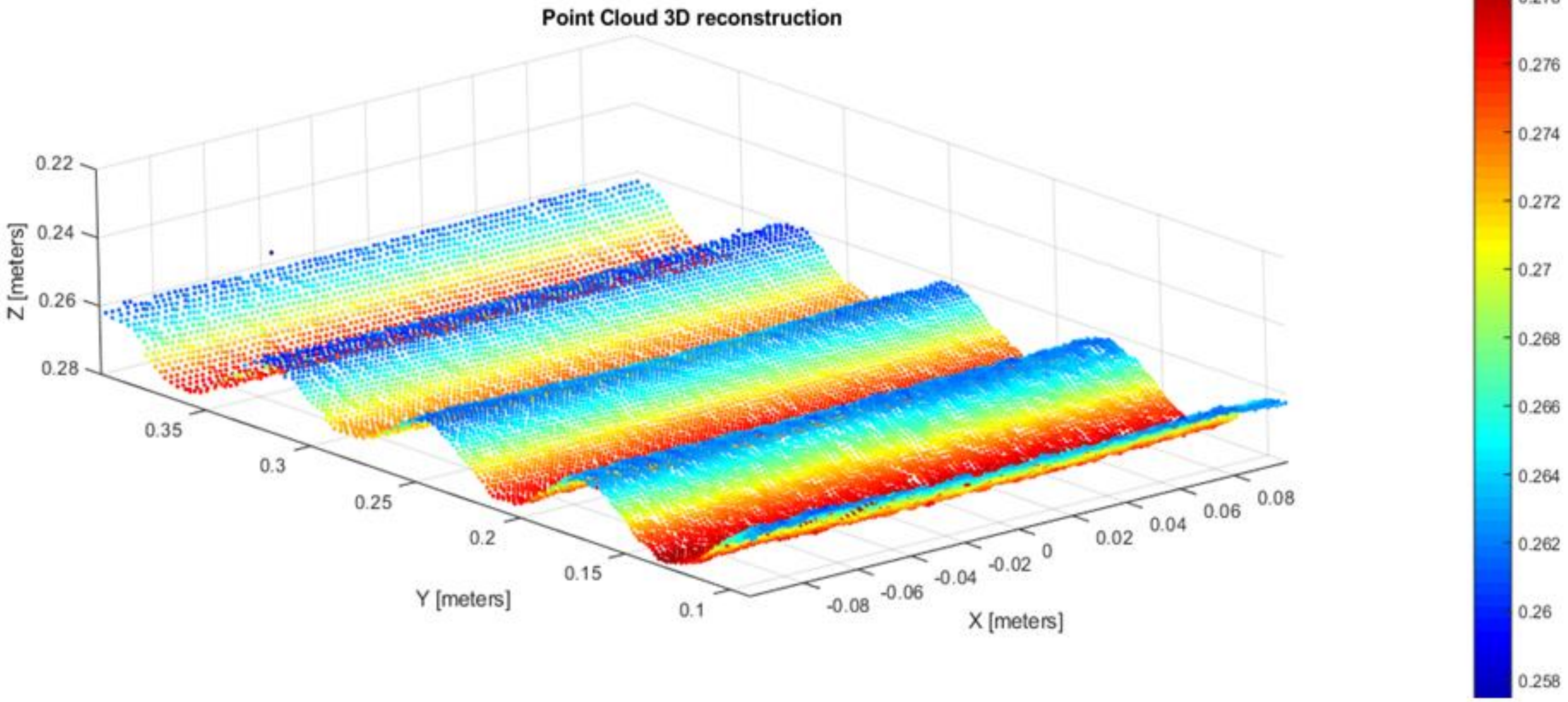


Hologram components



C. SOIL SURFACE DIGITAL EVALUATION MODEL

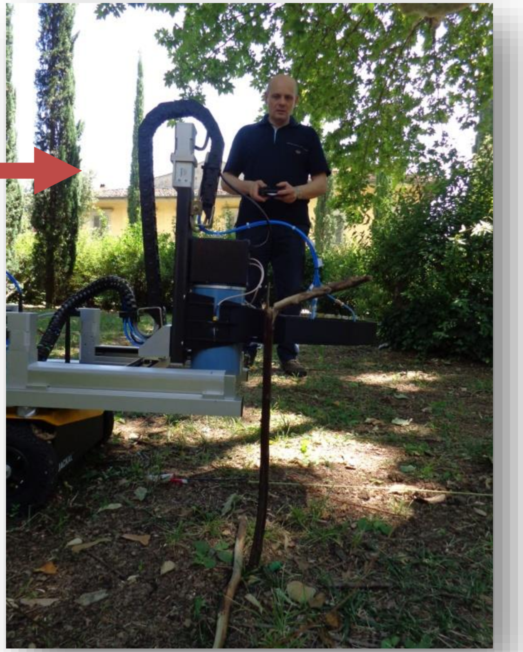
Point cloud



PRELIMINARY RESULTS FROM TEST FIELD

Decentralized Experiment

- Robotic scan (2.5min/0.4m^2) in Firenze, (IT)
- Supervising team in Rapperswil, (CH, GPR2018)
- Controlled by iPad in Kharkiv (UA)
- Scan monitored by laptop in Pennsylvania (USA)



Data Archiving and shared processing

- Data downloaded and image elaborated in Pennsylvania (USA): 4 minutes
- Images uploaded back to Robot in Firenze and then to controller in Kharkiv (UA): 1 minute

FIELD TEST WITH BURIED PMN-1 PLASTIC LANDMINE SIMULANT

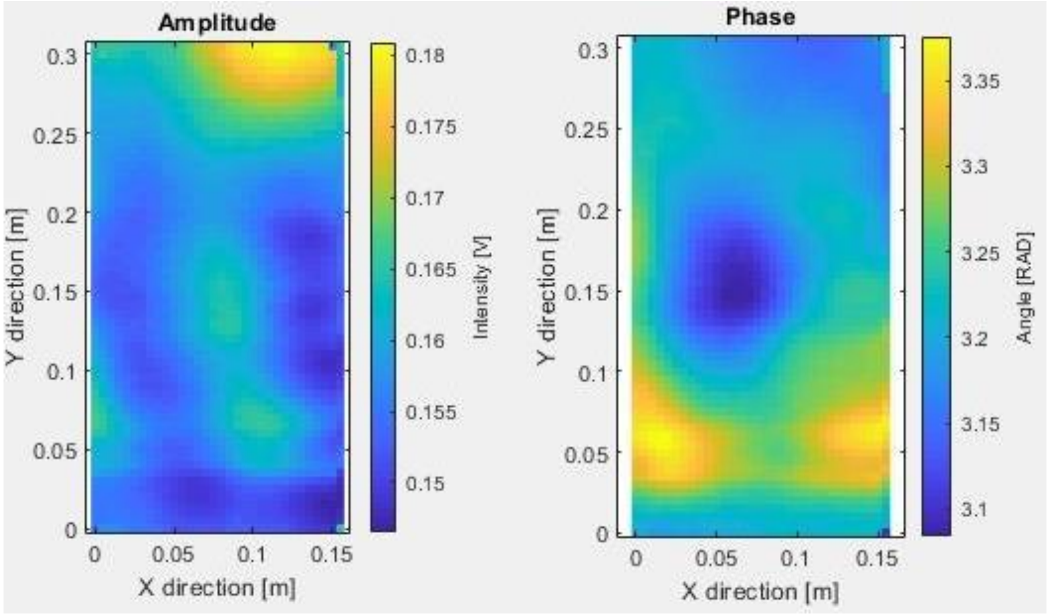
Optical reference image during deployment ***in the ground at about 3cm depth*** (top) and after 20 days in dry season (bottom).

Specification
- **Height**: 5.7 cm
- **Diameter**: 11.2 cm
- **Main charge weight:** 240 g TNT
- **Total weight**: 0.6 kg

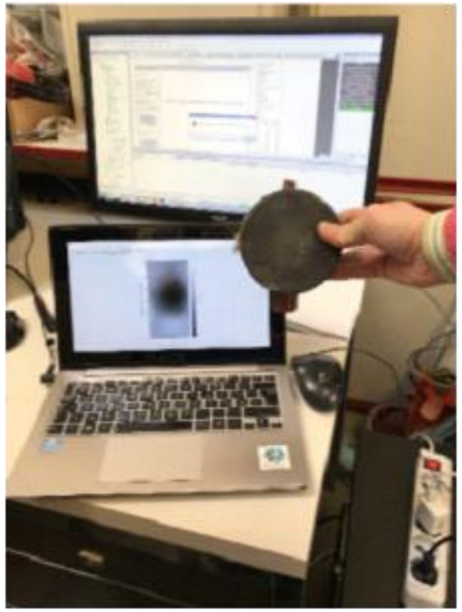
PMN1 provided by Phoenix UK ltd

HOLOGRAM IMAGES OF A BURIED PMN-1 PLASTIC LANDMINE

RAW DATA FROM HOLOGRAPHIC RADAR SCANNER

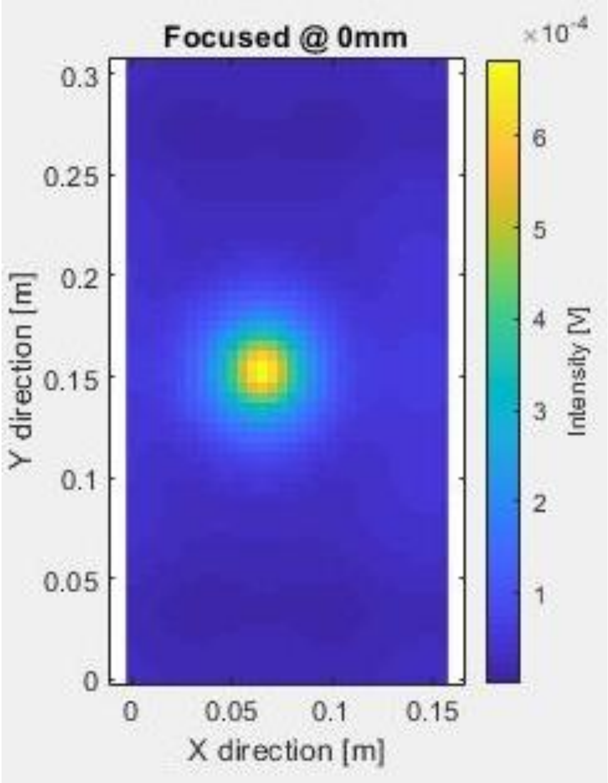


PROCESSING



Focussing and deconvolutions [5] performed on one of the remote terminals

RESULTS SHARED ON WEB PLATFORM

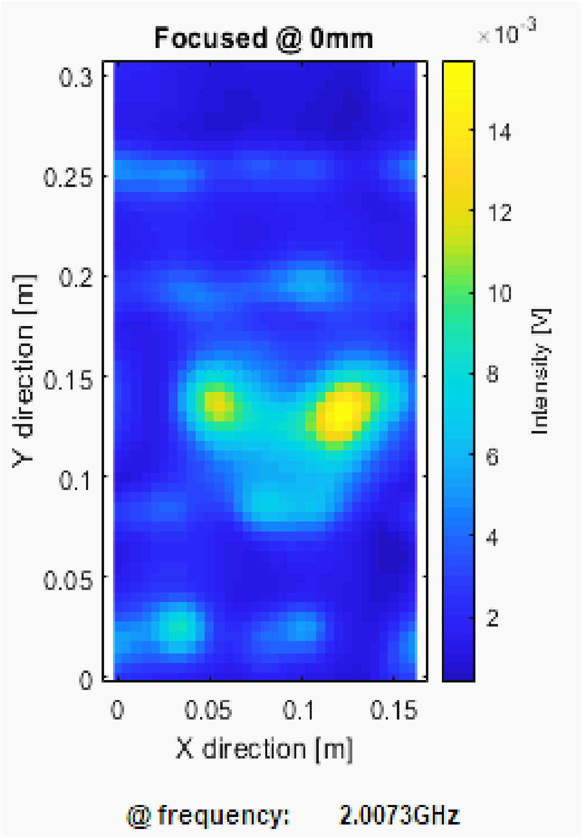


G. Borgioli, et al "Hologram reconstruction algorithm for landmine recognition and classification based on microwave holographic radar data" , PIERS 2018 Toyama Japan

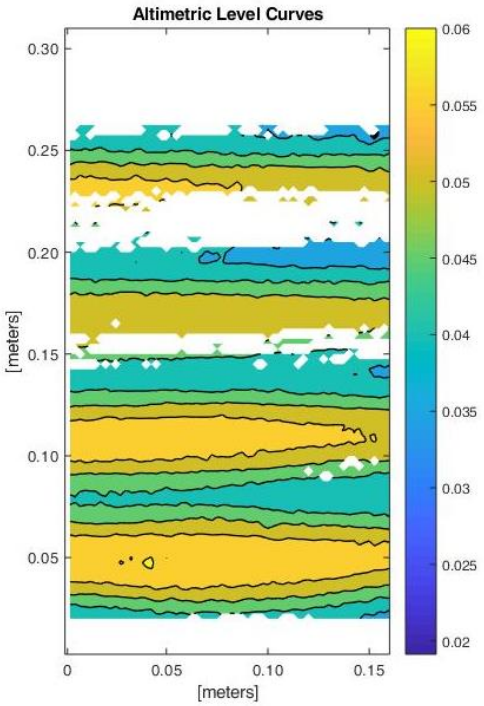
POST PROCESSING OF HOLOGRAMS AND OPTICAL 3D CAMERA

Optical reference

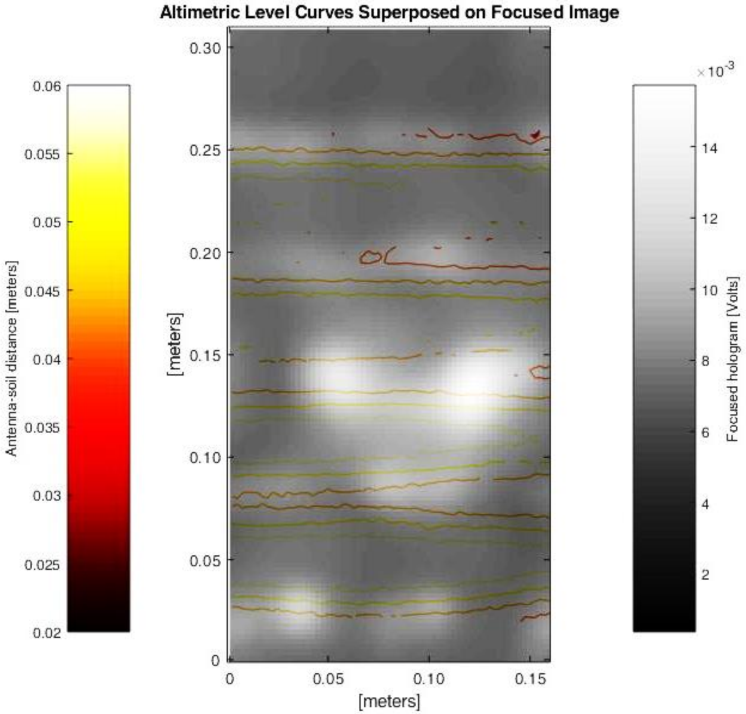
Reconstructed image



Level curves



Level curves superposed on Reconstructed image



The three teams in collaboration

ADVANCED RESEARCH WORKSHOP ON EXPLOSIVES DETECTION Florence 17-18 october 2018

After the completion of the *NATO Project G5014 "Holographic and Impulse Subsurface Radar for Landmine and IED Detection"*

http://www.nato-sfps-landmines.eu/

A new project **"DEMINING 4.0"** for the development of a collaborative team of robots has been submitted in 2019 to NATO Science for Peace and Security Programme.

6. The University agreement framework

The University agreement framework

Univ of Florence Departments participating to the agreement with Tongji University

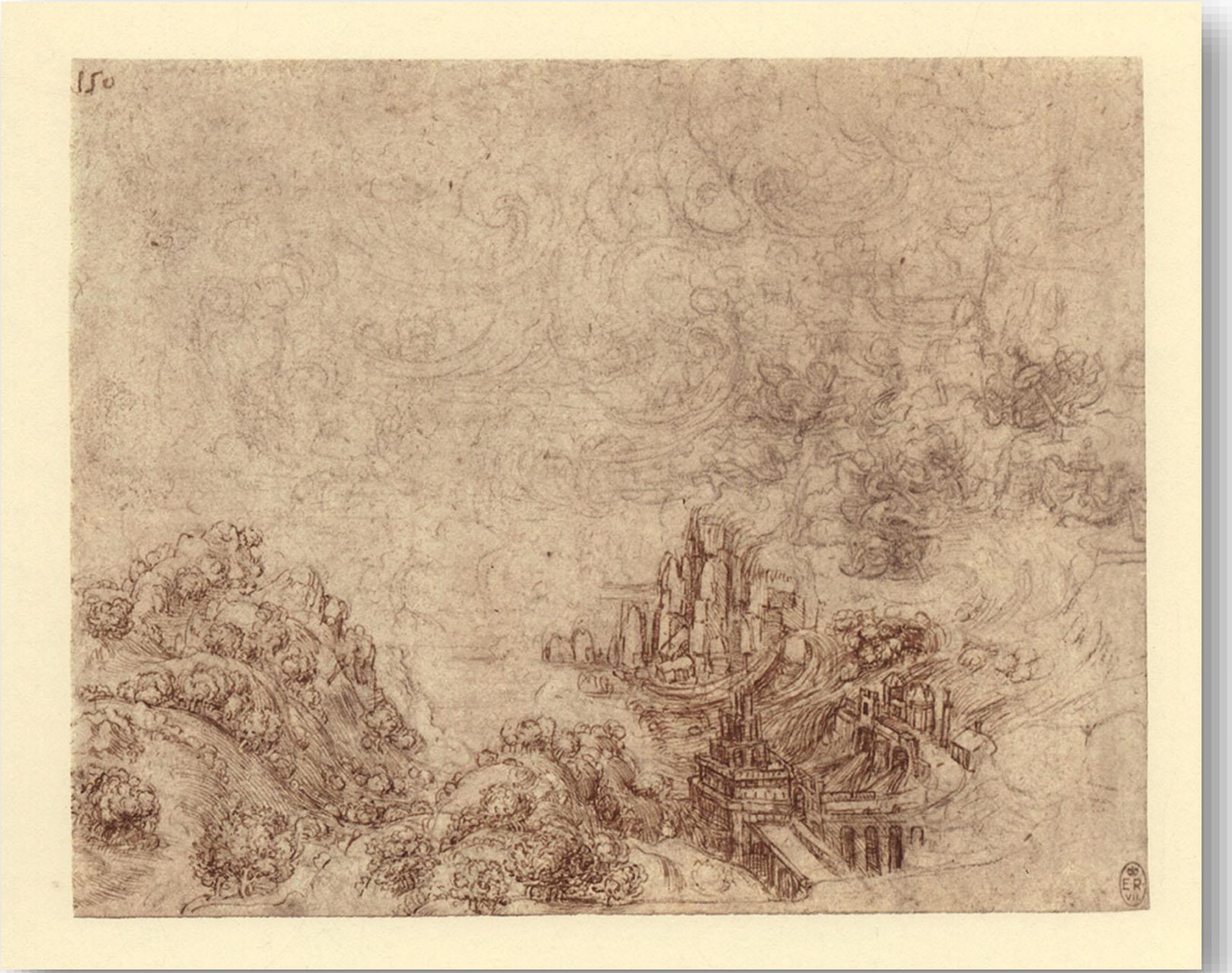
Area 04: Scienze della Terra **(Earth Science)**
Area 07: Scienze agrarie e veterinarie
Area 08: Ingegneria civile ed Architettura **(Double Degree)**
Area 09: Ingegneria industriale e dell'informazione **(Industrial and Information Engineering)**
Area 10: Scienze dell'antichità, filologico-letterarie e storico-artistiche
Area 11: Scienze storiche, filosofiche, pedagogiche e psicologiche
Area 12: Scienze giuridiche
Area 13: Scienze economiche e statistiche
Area 14: Scienze politiche e sociali **(Double Degree)**

Type of Framework Bilateral Agreement

Cultural and Scientific collaborations
Exchange Program: Teaching – Research - Mobility – Joint projects

DURATION
Start : 15 June 2017
End : 14 June 2024

Vinci is the birthplace of Leonardo da Vinci



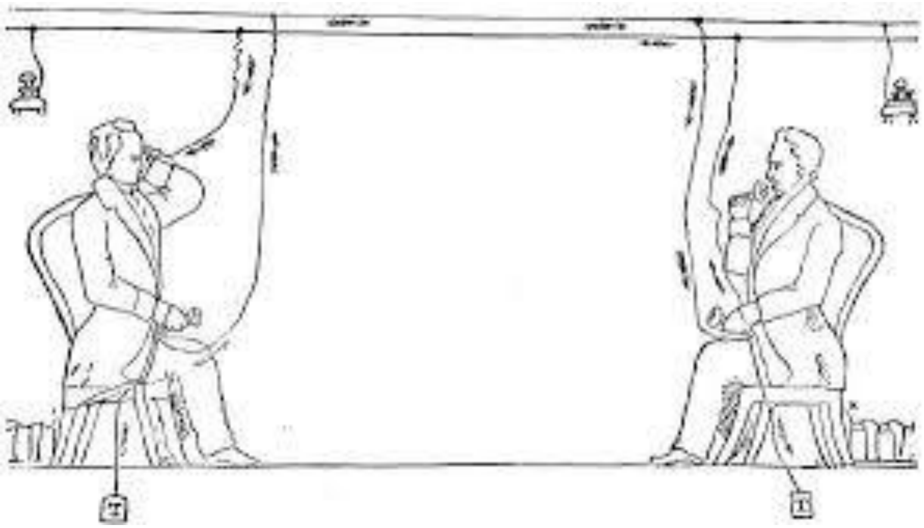
L'ACQUA "VETTURALE DELLA NATURA"

Firenze, Istituto e Museo di Storia della Scienza

Galileo's Telescope. The Instrument that Changed the World.

2009 Philadelphia, The Franklin Institute *"Galileo, the Medici & the Age of Astronomy"*

Firenze is the birthplace of Antonio Meucci invento of telephone

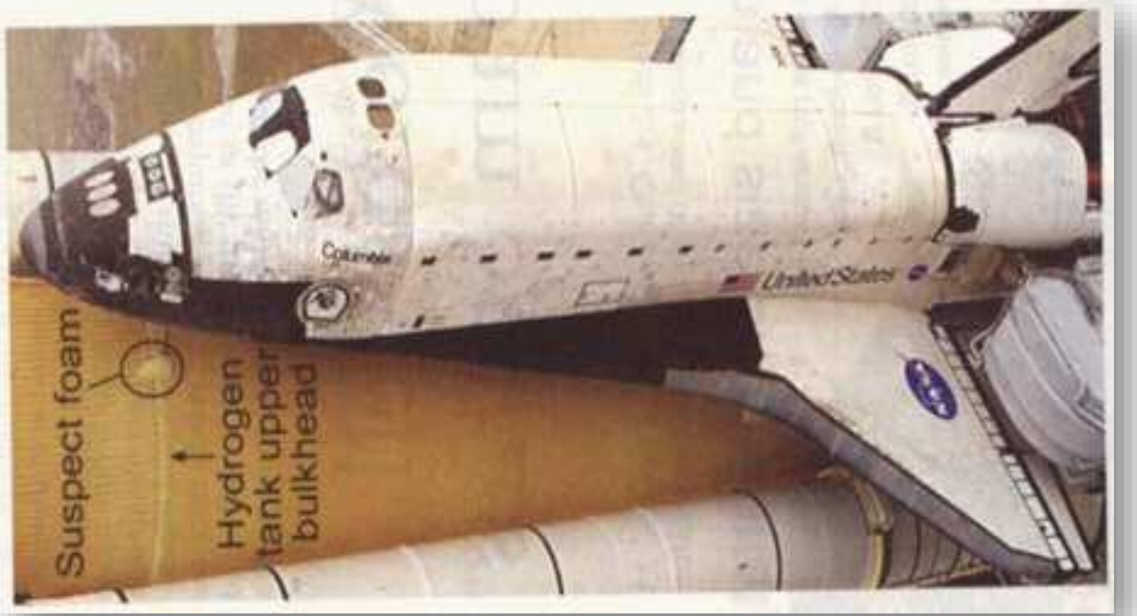


https://www.youtube.com/watch?v=L-SQvjNBP-Y

Looking forward to see you at University of Florence

https://www.unifi.it/changelang-eng.html

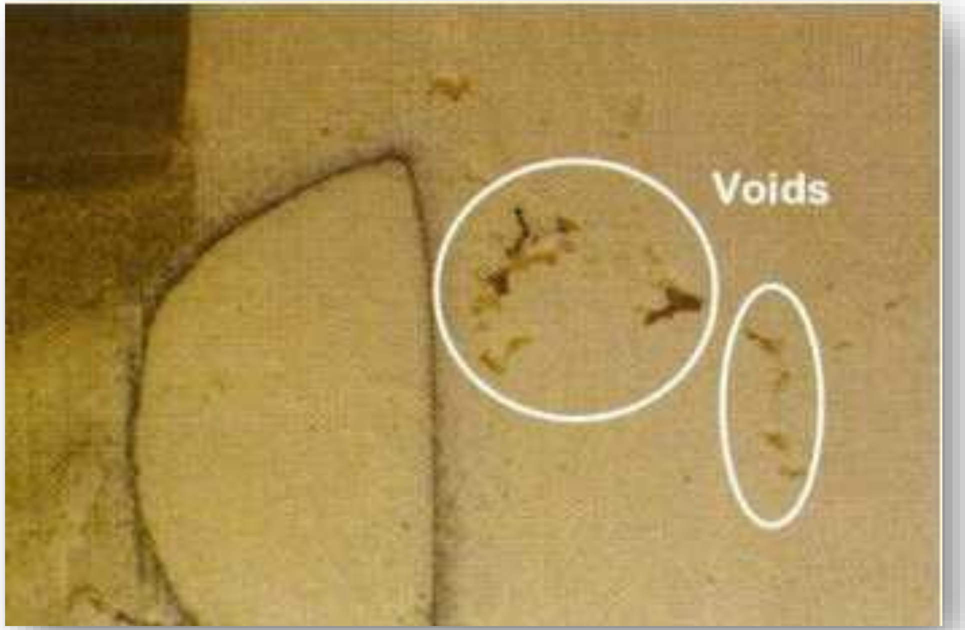
Moisture detection in dielectric materials



Space Shuttle Columbia at prelaunch.

Yellow parts of Shuttle construction are insulation foam of external fuel.

Aviation Week & Space Technology, February 17, 2003, pp. 27-30.



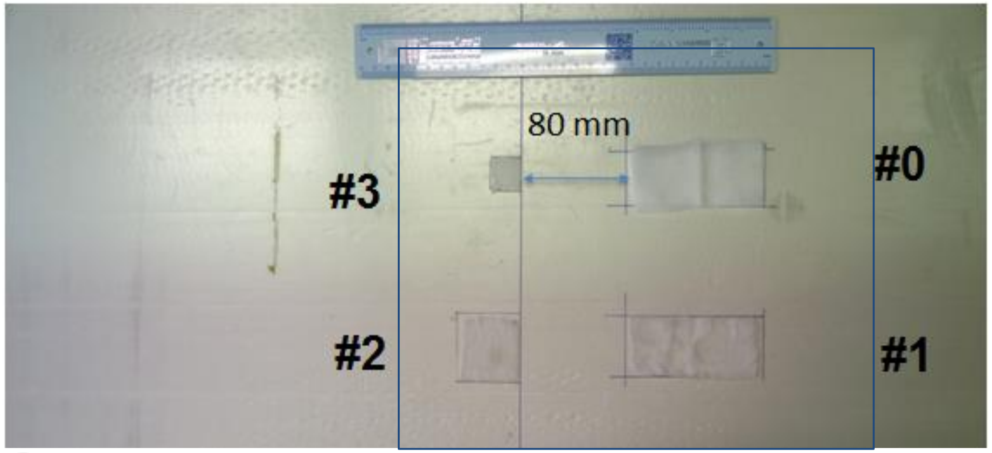
Voids in thermal protection coating of shuttle external tank.

Aviation Week & Space Technology, April 7, 2003, pp. 30, 31.

Moisture detection in dielectric materials

Thermal insulation panels:
ε_r=1.1 *(42 mm @6.7GHz)*

Target #	Largest Dimension [mm]	Estimated Dimension (-6dB) [mm]	Water content [grams]
0	95	Not detected	0 (dry)
1	95	64	1.2
2	45	32	0.4
3	22	20	0.2



(Holographic Image with I/Q signals @6.7GHz)

L. Capineri et al *Water detection in thermal insulating materials by high resolution imaging with holographic radar*. In: ISEMA 2016

Final assessment of the applications of Rascan radar

Technical

- Rascan type holographic radar can be designed to efficiently operate in contact or close proximity (cm) of the surface for producing high plane resolution imaging ($\lambda/4$).
- Selection of operating frequencies depends on the electromagnetic penetration depth of target materials and application.
- Radar heads working at (2, 4, 7, 22)GHz are available.
- Reconstruction of the MW holograms by back-propagation technique with In-phase and Quadrature signals.

Final assessment of the applications of Rascan radar

Operative / Applications

- Holographic subsurface radar technology is not universal one. However in some cases it can be useful and unique in obtained results.
- It gives opportunity to record images of objects' internal structures at one-side access to them.
- In this quality RASCAN radars differ from X-ray devices that need two-side access to the structure under consideration. Two-side access is impossible in the most cases.
- Concrete, wood, marble, ceramic, plastic, foams, dry homogeneous soil are suitable materials for holographic microwave subsurface imaging.

The radar radiates electromagnetic waves at a constant frequency ω whose amplitude and phase do not depend on time. The reflected wave has constant amplitude A_r, but the phase of the reflected wave φ_r depends on the range to the object *l*

$$\varphi_r = 2\sqrt{\varepsilon}\,\frac{l\omega}{c}$$

Then, the reflected signal is mixed with the radar reference signal in the mixer (with A_o and φ_o are the amplitude and phase of the reference signal respectively). The amplitude of signal in the mixer output at the difference frequency is given by

$$A_r A_o \sin(\varphi_o - \varphi_r)$$

A Review of 15 Years of Collaboration between Università di Firenze and F&M

In 2004 a collaboration began with the research group of Prof. Tim Becthel for the use of a new subsurface radar based on the principle of holography within an international project financed by the International Science and Technology Center. Since that time, the collaboration has progressively grown, studying the new applications for the holographic radar in the field of non-destructive investigations in the field of civil engineering, cultural heritage and subsequently for the detection of unexploded ordnance (UXO) for humanitarian demining. At the Laboratory of Ultrasound and Non-Destructive Testing of the University of Florence, electronic systems have been designed to obtain information on the characteristics of different dielectric materials, and optimization of the holographic radar has been carried out. These research projects, developed in collaboration with international research groups in the UK, Japan, Russian Federation, and Ukraine, are presented at the meeting to understand the innovative features of the holographic radar. The presentation concludes with the development of a multi-sensor robotic platform for the detection of explosive devices, in which the Industry 4.0 paradigm has been adopted to integrate other sensors with the holographic radar scan leading to a new project called Demining 4.0. The research group at F&M has expanded with the collaboration of Prof. Fronefield Crawford and various students, who have developed parts of the system for detecting wire traps near explosive devices. This intense research activity, carried out in close collaboration with the researchers and students of the University of Florence, has naturally led to the approval of an agreement between the two institutions signed during 2019.

Brief Biography Prof PhD NDT Lorenzo Capineri

Lorenzo Capineri (M’83–SM’07) was born in Florence, Italy, in 1962. He received a M.S. degree in electronic engineering, in 1988, a doctorate degree in nondestructive testing, in 1993, and postdoctorate in advanced processing method for ground penetrating radar systems from the University of Florence, in 1994. In 1995, he became an Associate Researcher and an Associate Professor of Electronics with the Department of Information Engineering (formerly Department of Electronics and Telecommunications) with the University of Florence, in 2004. In 2017 he received the National Scientific Qualification as Full Professor in Electronics. He has worked on several research projects in collaboration with national industries, the Italian Research Council (CNR), the Italian Space Agency (ASI), and the European Space Agency (ESA), AEA Technology and UKAEA, England, International Science and Technology Centre (ISTC), Moscow, Russia, Thales Alenia Space Italia (TASI), Texas Instruments, USA, Joint Research Centre (European Commission), and NATO. He has coauthored seven Italian patents, four book chapters, and about 250 scientific and technical papers. His research interests include the design of ultrasonic guided wave transducers, medical ultrasound systems, buried objects detection with seismo-acoustic methods, and non-destructive testing with ground penetrating and holographic radar.

Full Curriculum Vitae.

https://www.dinfo.unifi.it/upload/sub/laboratori/uscnd/lorenzo/LC2016_CV_full_1.6.pdf

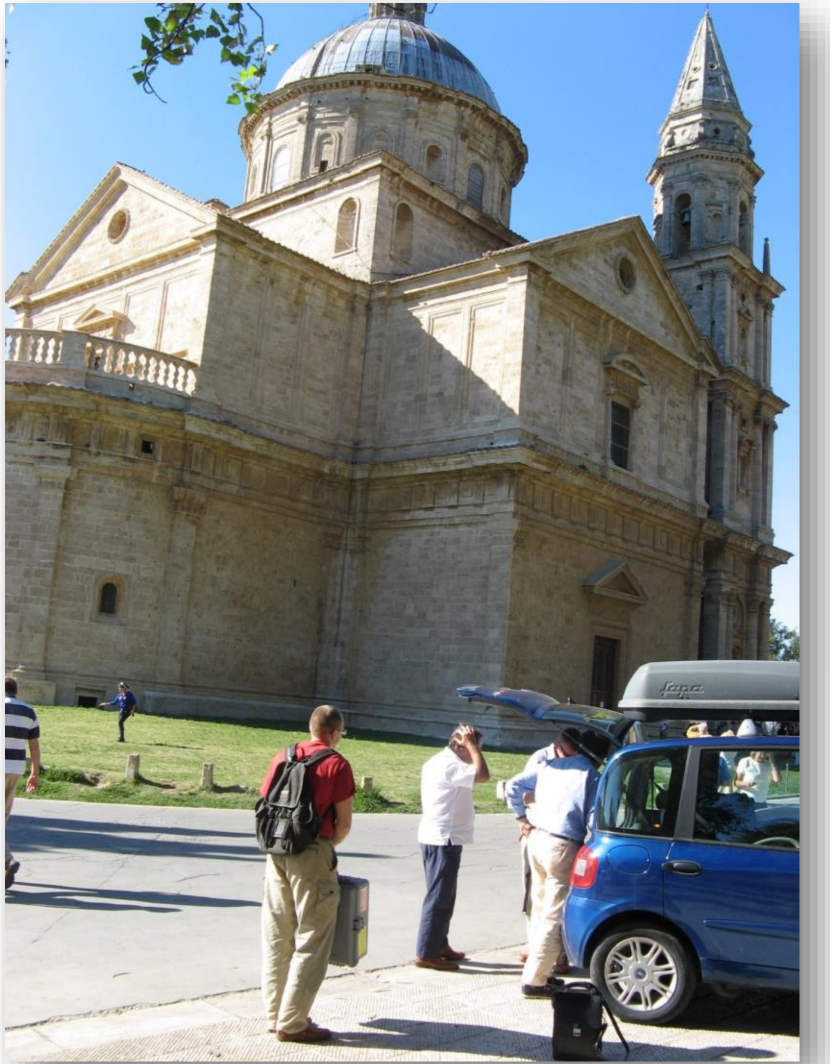
Russian Academy of Science, Moscow 2004

Landmines detection in the garden of University of Florence, Italy, Sept 2007

GPR 2010 Conference , Lecce , Italy

scanning at F&M Fackenthal Hall

Inspection of the Church of San Biagio (Montepulciano, Italy), Sept. 2007



US in Kharkiv and Donbass August 2016

Kharkiv (Ukraine) at IRE-NASU May 2017

ADVANCED RESEARCH WORKSHOP ON EXPLOSIVES DETECTION Florence 17-18 october 2018

F&M 2010