

Utilizzo del radar subsuperficiale di tipo olografico per l'indagine non distruttiva dei beni culturali e dei materiali per l'ingegneria

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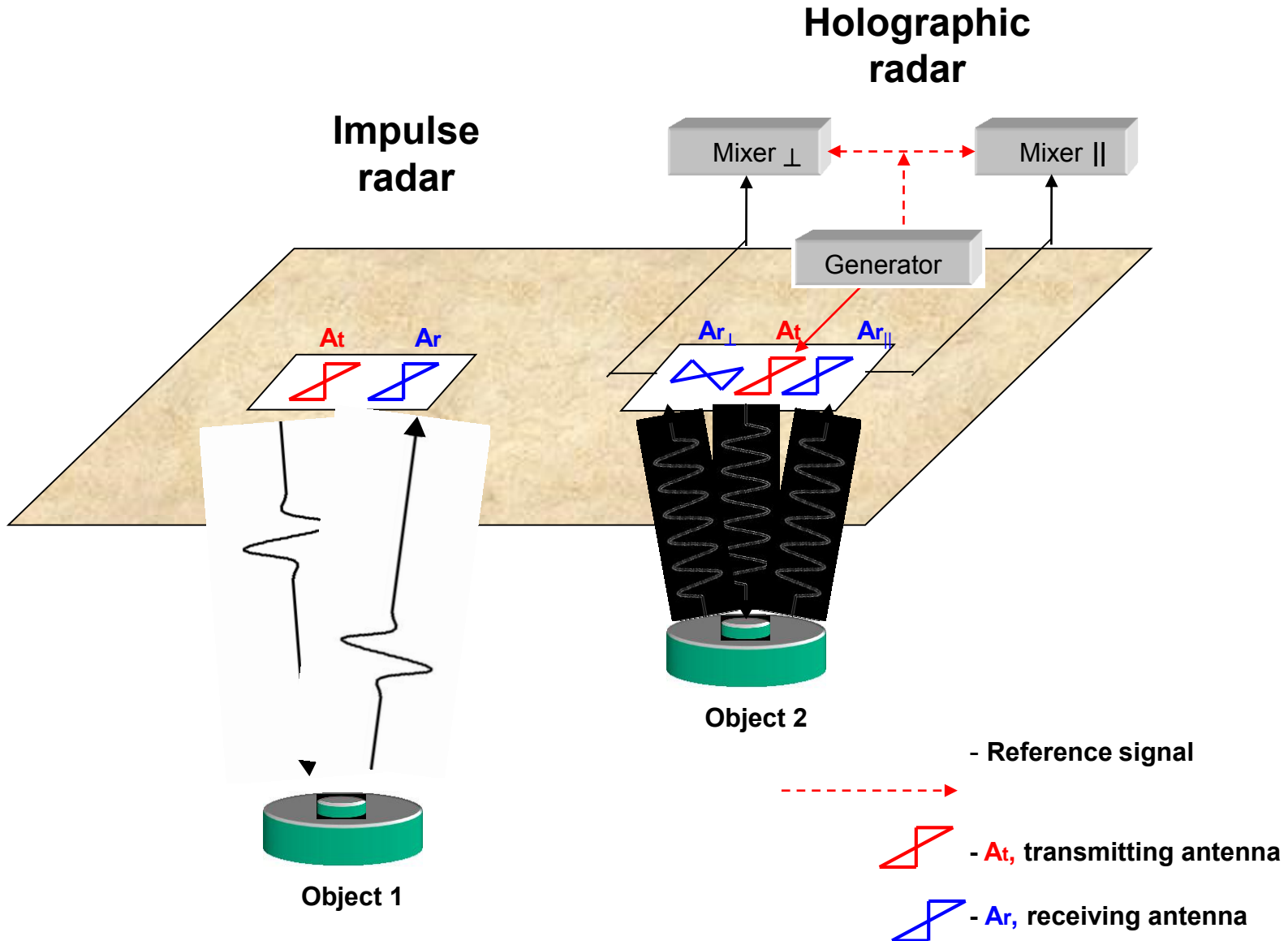
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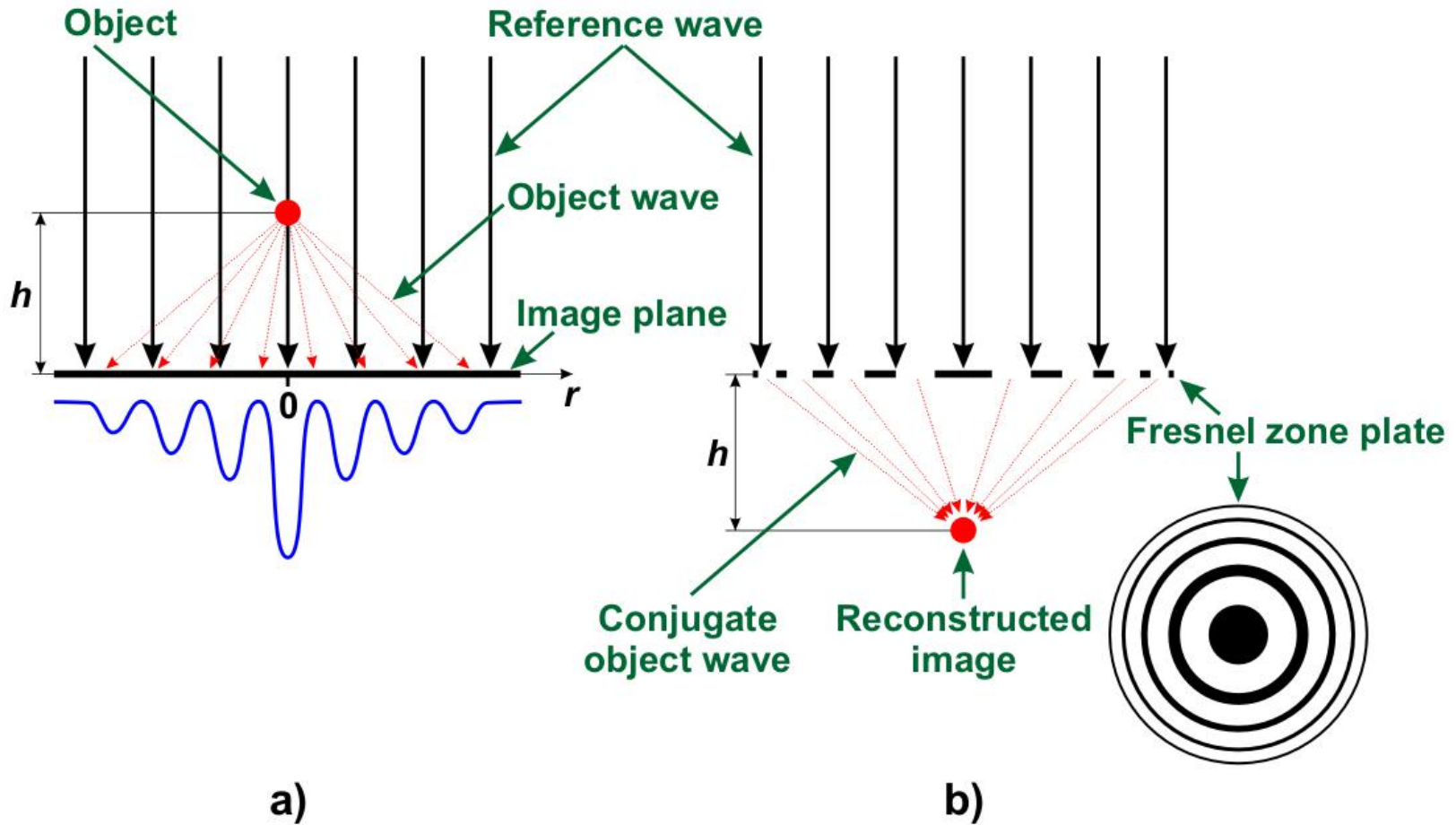
Outline

1. Operational principles of holographic radar for subsurface scans
2. Application examples with the manual scanning method (floors, pavements, wood)
3. Automatic scanner for engineering materials (foam, plastic, composites)
4. Semi-autonomous scanning systems based on robotized platforms

Comparison of Impulse and Holographic Radar Principle Circuits



Recording a Point Source in Optical Holography and its Hologram Reconstruction



- a) Hologram registration
- b) Hologram reconstruction

RASCAN-Series Radars



RASCAN-5/4000, 4 GHz
RASCAN-5/7000, 7 GHz

RASCAN-4/2000
2 GHz



Comparative Table of RASCAN-Series Radars

		RASCAN-4/2000	RASCAN-5/4000	RASCAN-5/7000
Frequency band, GHz		1.6 – 2.0	3.6 – 4.0	6.4 – 6.8
Number of frequencies		5		
RF output, W		$6 \cdot 10^{-3}$ (*)		
Sensitivity, W		10^{-9}		
Resolution in the plane of sounding at shallow depths, cm		4	2	1.5
Maximum sounding depth (depends on medium properties), cm		35	20	15
Dimensions, mm	Antenna	160 × 310 × 210 handle length – 1030	95 × 148 × 119	
	Control unit	157 × 63 × 200		
	In package	570 × 230 × 390	380 × 460 × 130	
Weight, kg	Antenna	w/o handle – 2.0 with handle – 2.5	0.6	
	Control unit	0.7		
	In package	9	5.5	

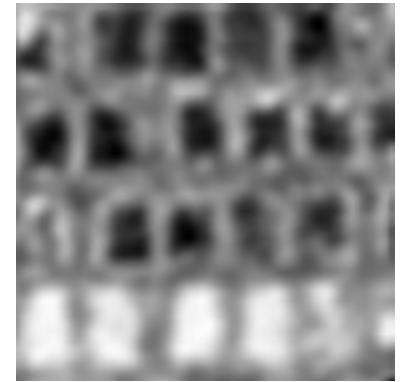
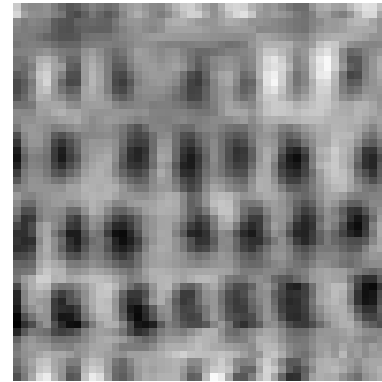
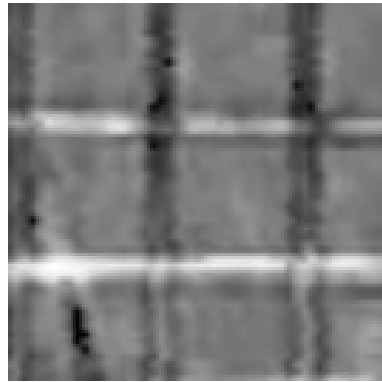
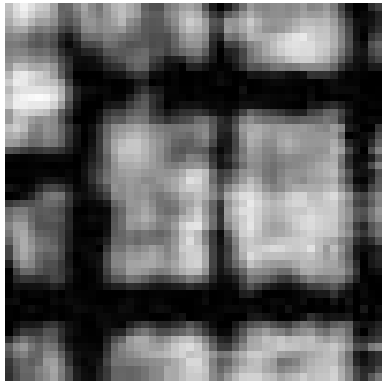
(*) - Low emitting power guarantees full safety for personnel while using RASCAN radars (two orders less than a mobile phone has), Russian sanitary certificate # 77.01.09.650.II.041358.10.05.

Detail View of RASCAN-5/4000 Radar



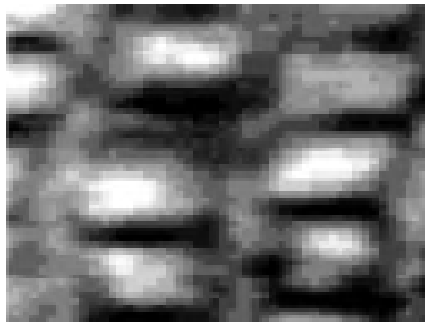
The Laboratory's staff members had been rewarded with Russian Federation government's prize in the field of science and technology for creation of the RASCAN radar technology.

Examples of RASCAN Diagnostics

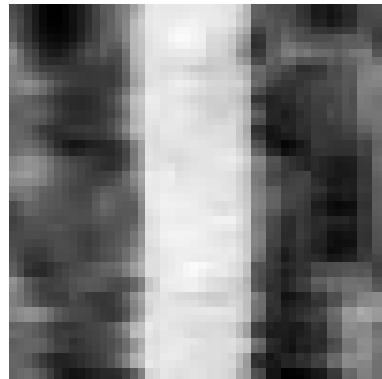


Radar images of the ferroconcrete walls

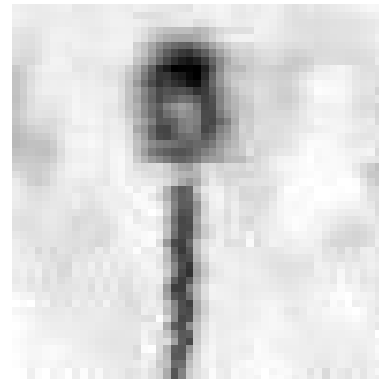
Radar images of the cinder concrete bricks walls.
Black spots are voids in the bricks.



Stone wall under plaster



A ventilation channel
in concrete wall



An electrical socket and
wire in concrete wall



A hand under table



For the first time for 350 years history of the London Royal Society, the Russian scientists participated in an exposition of the anniversary Society's Summer Scientific Exhibition. Within the frame of the joint international project related to humanitarian demining, the holographic subsurface radar RASCAN-4 designed in Remote Sensing Laboratory has been presented.

Our stand was included in the VIP short-list. Queen of England Elizabeth II visited the laboratory's stand to familiarize herself with this Russian technology.

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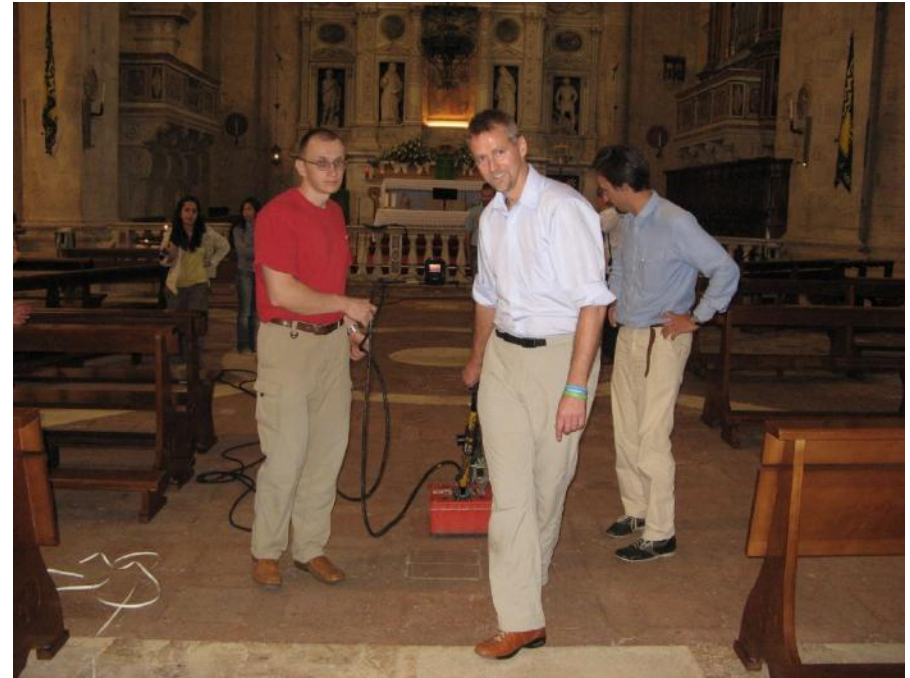
Inspection of the Church of San Biagio near Siena, Italy



The Church of S. Biagio was built near the city of Siena by Antonio da Sangallo during the 15th century.

The international team of Italian, American, and Russian scientists conducted an inspection of the floor in the Church of S. Biagio.

Aim of this experiment was to search for hidden cavities underneath the floor by using commercial GPRs – RASCAN and GSSI radars.



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A marble medallion on the floor



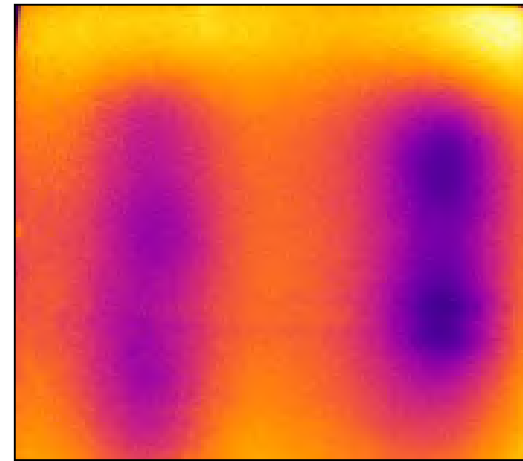
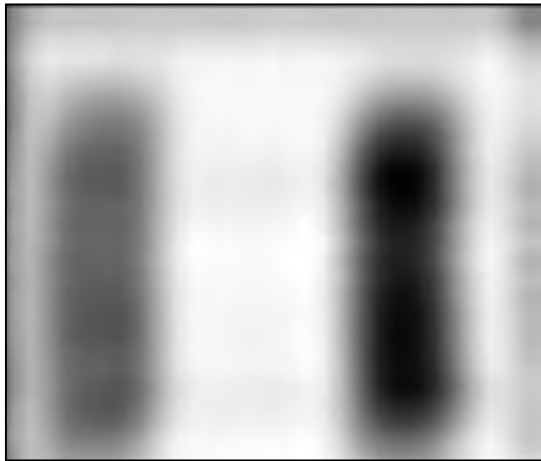
Radioimages of the medallion in two polarizations

Searching in archives results that ancient burial of XVI century has place under medallion.

Laboratory Model of the Medallion

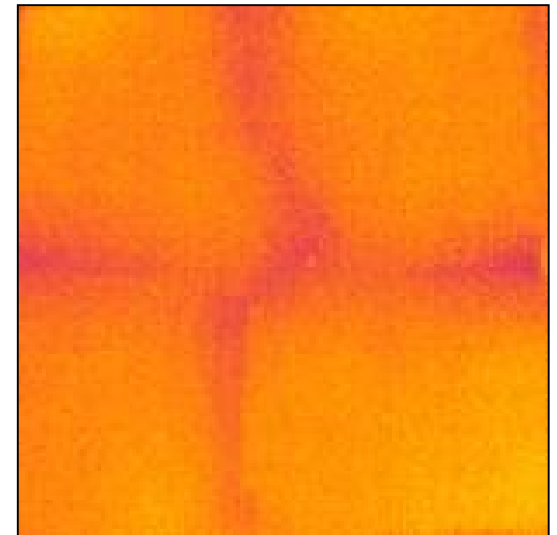
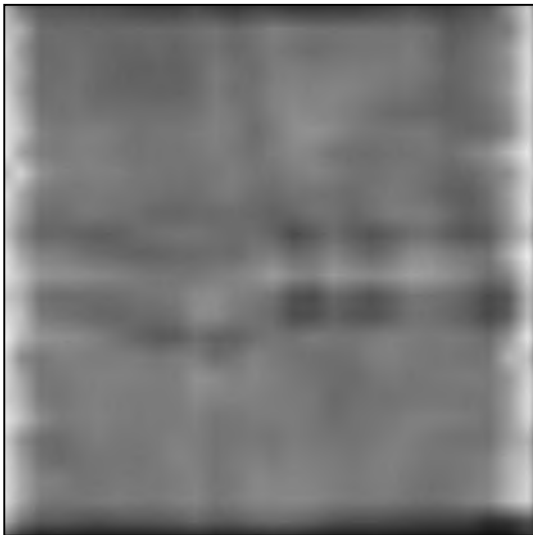


Laboratory model of the medallion supports



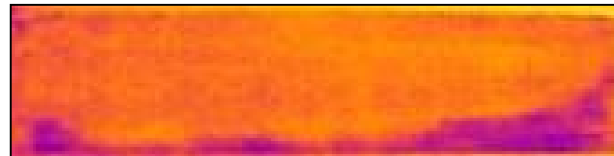
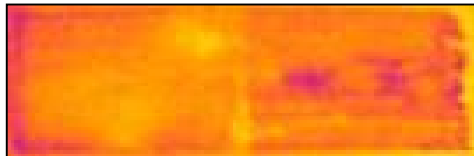
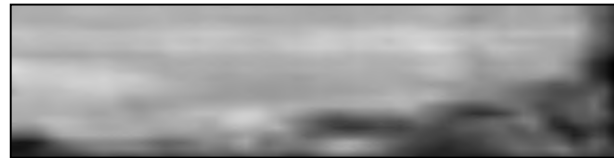
RASCAN (left) and IRT (RIGHT) images of bricks beneath a stone slab. The thermal anomaly is created by the bricks resting on a cool concrete slab. Images are 30cm by 30cm. IRT image spans 2.6°C.

Cracks Detection in marble plates



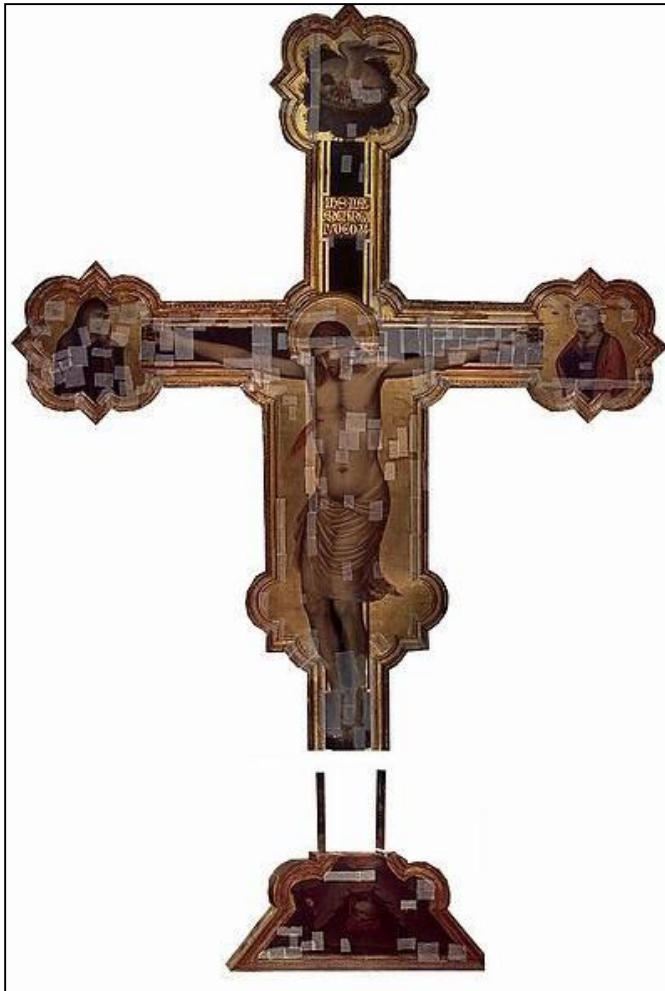
A 30cm by 30cm piece of marble contains two nearly invisible, hairline cracks; one vertical and one horizontal. At left is a RASCAN-4/4000 image of the slab with the cracks barely dampened using a fine paint brush, and right shows an IRT image of the same. In both cases, the moisture highlights the cracks. IRT image spans 1.8°C.

Inspecting Wooden Structures



Three dry pine boards with internal termite damage inferred from visible tunnels on edges. RASCAN (middle) and IRT (bottom) anomalies show remarkable coincidence, and confirm that the damage visible on edges extends into planks. Planks and images are 25cm wide, variable length. IRT images span 3.9°C.

The investigation on the Croce di San Marco with Rascan 4/4000



Description of the cross

The Cross of San Marco dates back to the mid-fourteenth century and is attributed to Puccio di Simone.

The work can be considered one of the greatest of Florentine painting: it reaches a total height of 6.30 meters. The plank is made up of a vertical part, the upright of a cross, and a horizontal part, the arm, which are joined together by a joint between wood.

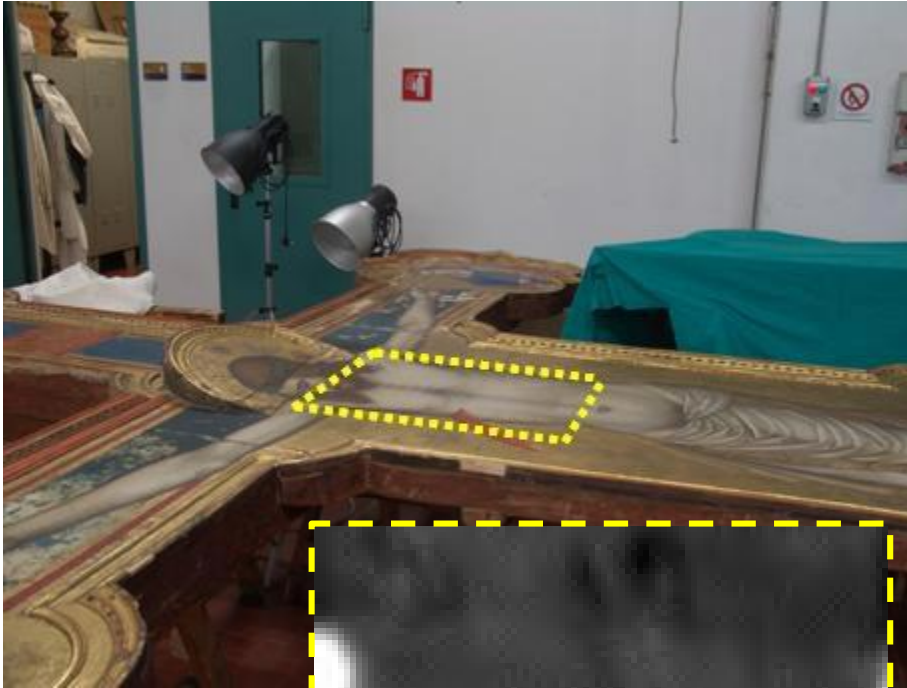
The thickness of the poplar planks is 7 cm and the entire support, including the crosspieces, reaches a thickness of about 25 cm for a total weight estimated at around 500 kg.

Scans

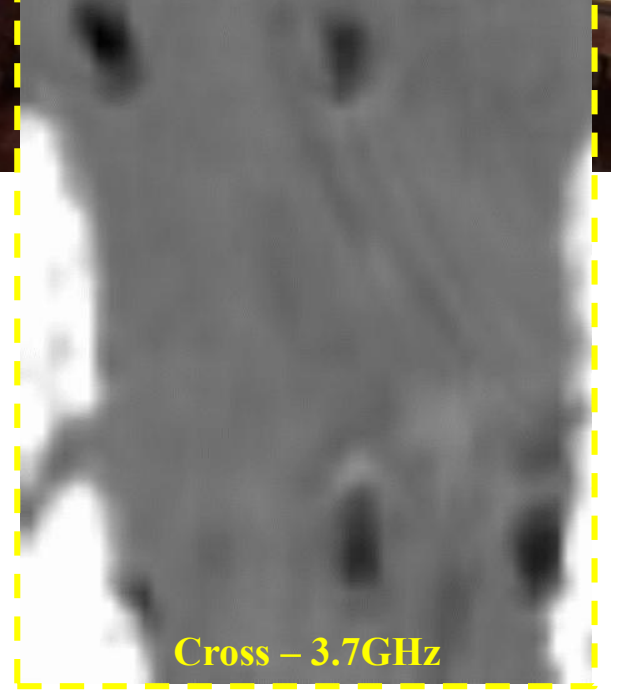
For this first phase of measurements it was decided to scan three areas that cover the areas of the supporting infrastructure and the area of the relief insert for the aureole.

The work was protected with a green cloth supporting a plexiglass sheet provided with numbered scan lines. If necessary, the plexiglass plate was blocked by pressing it with a wooden vice.

Investigation on the Croce di S. Marco



Parallel – 3.6GHz



Cross – 3.7GHz

Survey of the Senate Building in St. Petersburg



In St. Petersburg, the famous Senate building, which was built by Italian architect Carlo di Giovanni Rossi in 1829–1834, had been under reconstruction and parquet had to be laid. Heating pipes, electricity and communication wires were laid under floor of the building. Their location was not documented. According to the technology, before the laying of the parquet on the concrete floor, plywood sheets should be nailed to its surface. But this could not be done because of fear to damage the pipes and other communications. Our laboratory was asked to search location of the pipes and communications.

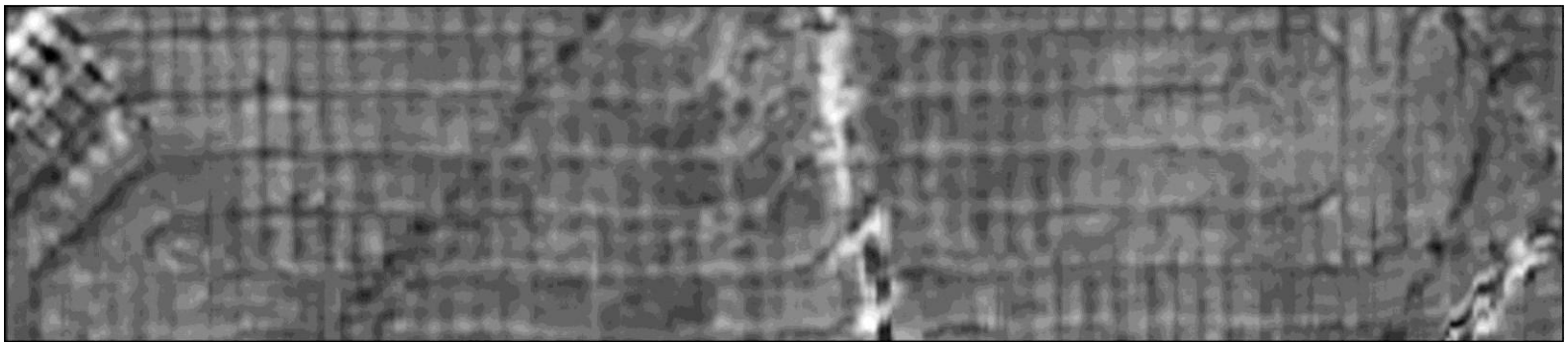
Survey performed by holographic subsurface radar RASCAN-4/2000



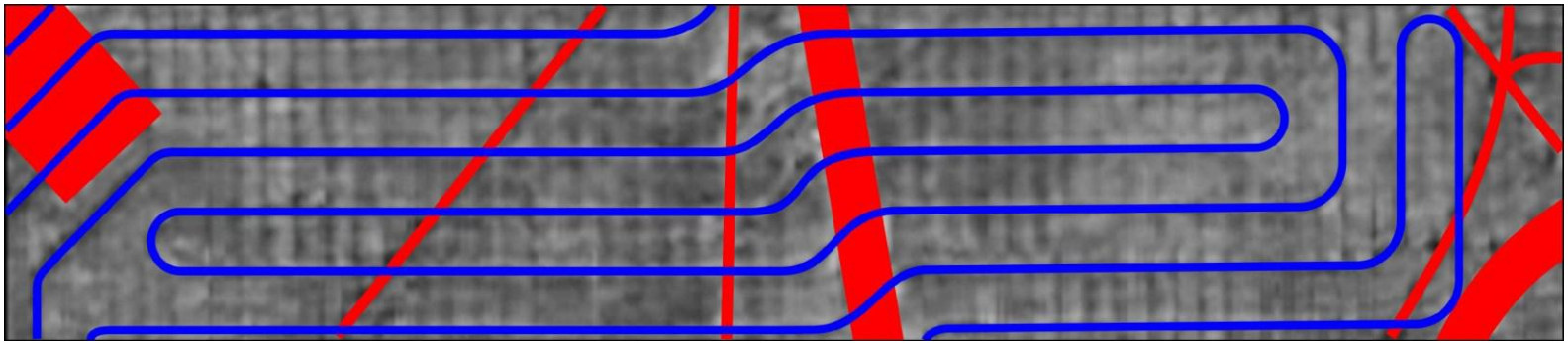
Holographic subsurface radar RASCAN-4/2000in work.



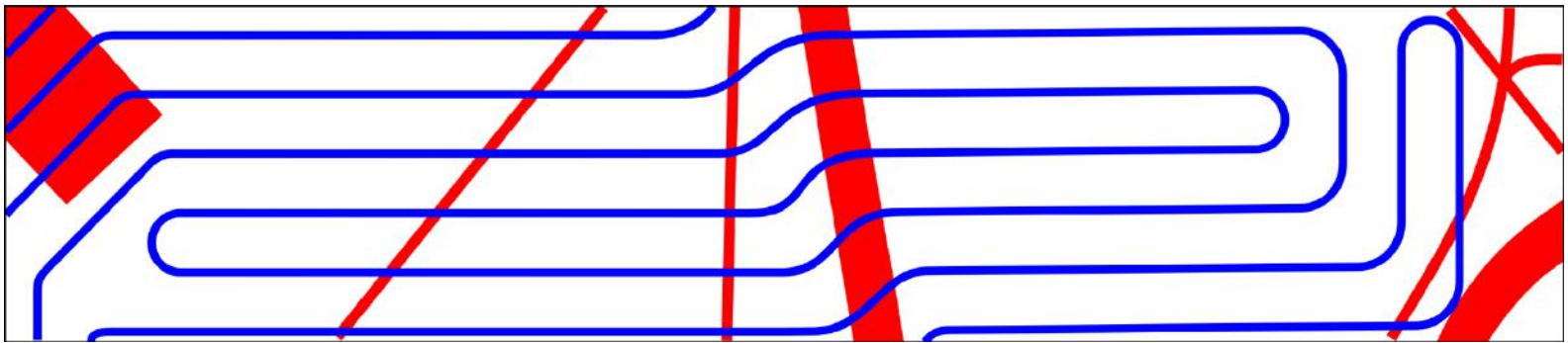
Wells with cables in the concrete floor.



a)



б)



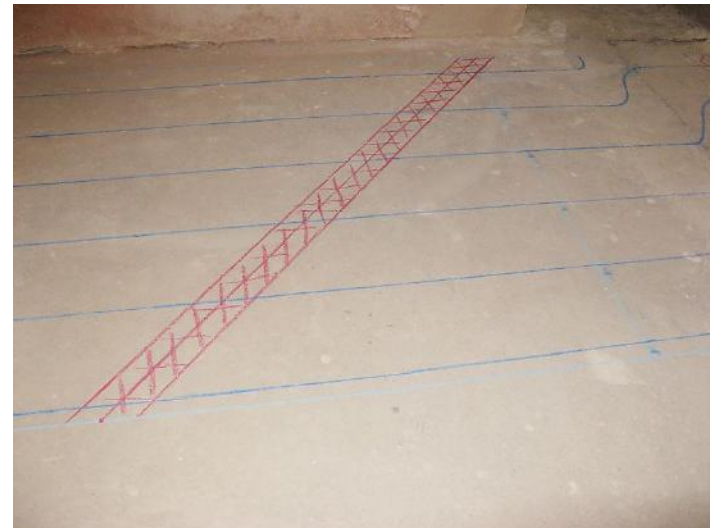
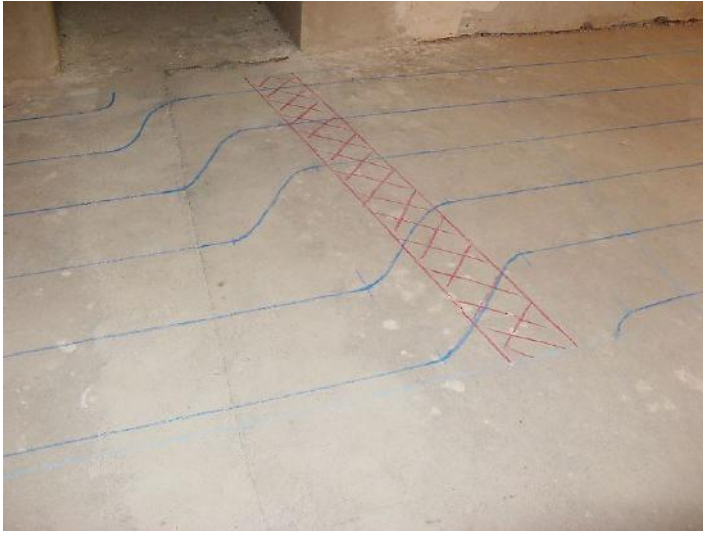
в)

Result of the survey:

a) radar image of a floor part

б) position of pipes and cables on the radar image

в) drawing of the internal structure of the floor.



The result of surveying was drawn on the floor surface by chalk.

A zoom of Holographic Subsurface Radar Image



In this image, it is possible to see how the heater pipes are bending over the cable.

Surveying of the Leningradskaya hotel, Moscow



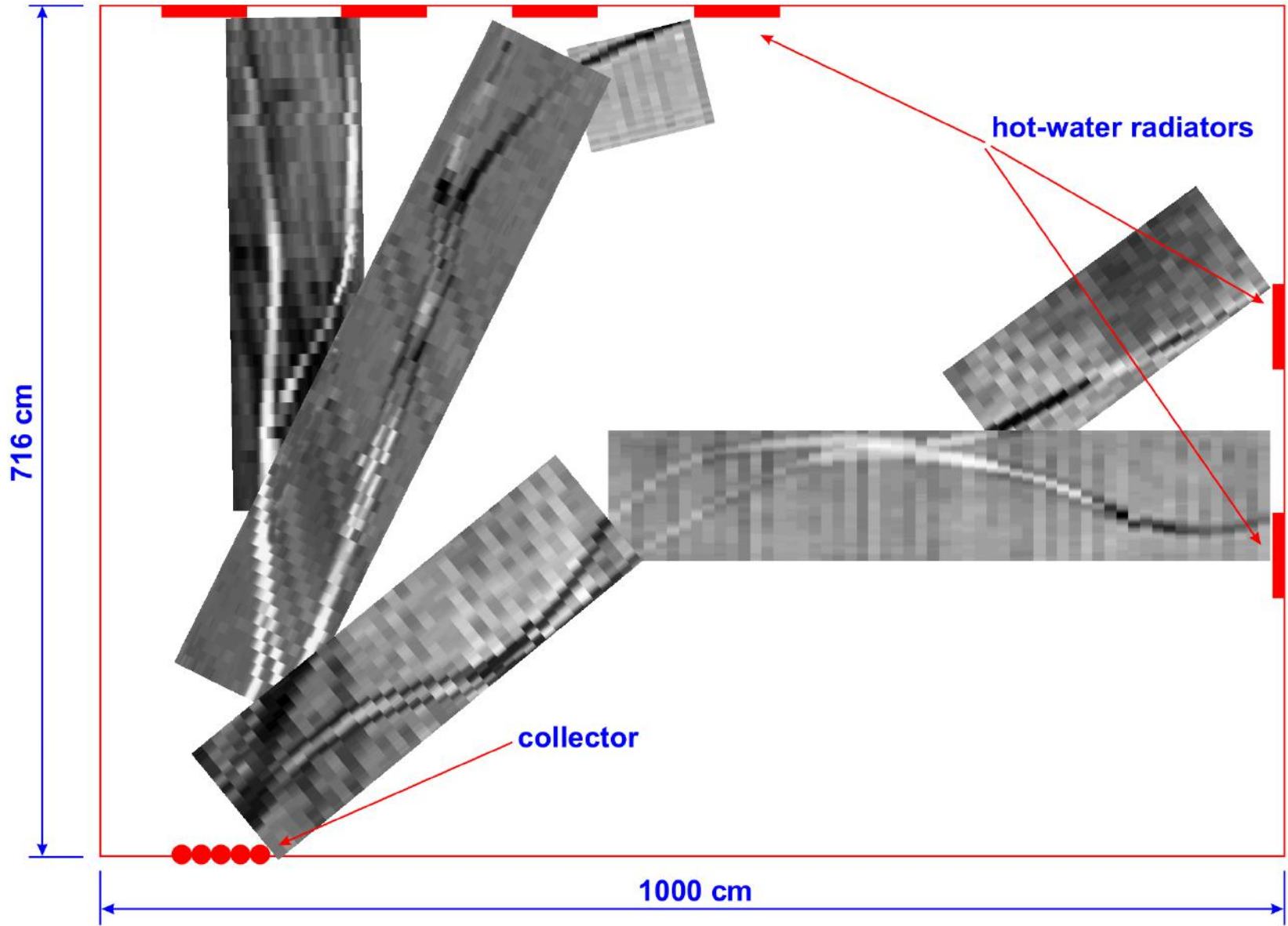
Surveying of a Concrete Floor



Concrete floor inspection



Heating plastic pipe



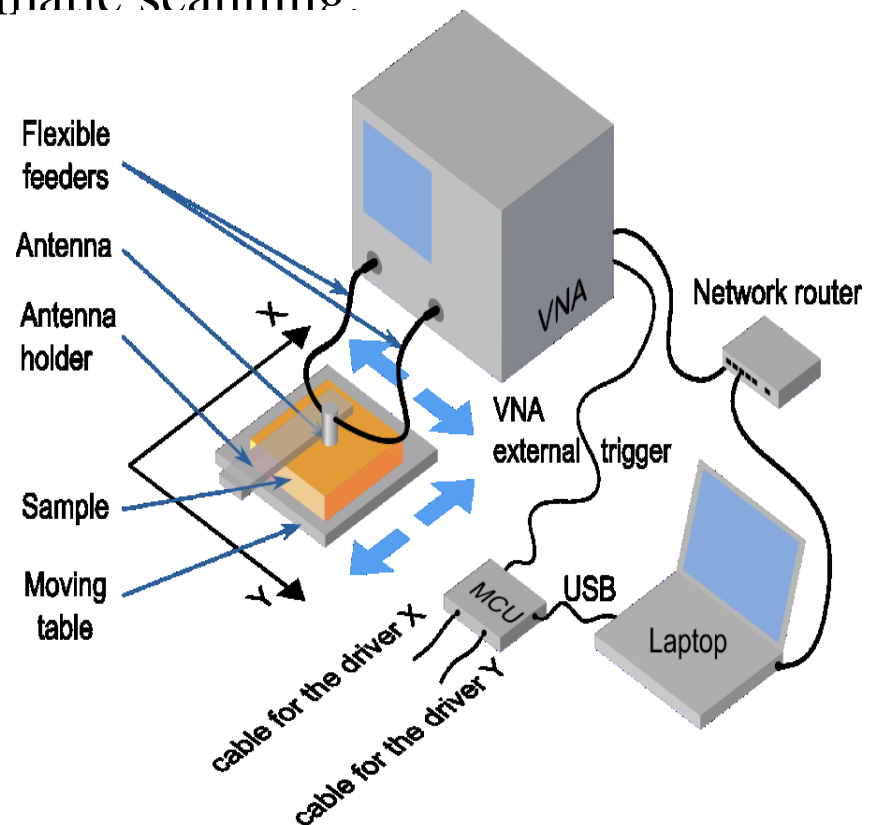
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Experimental Setup

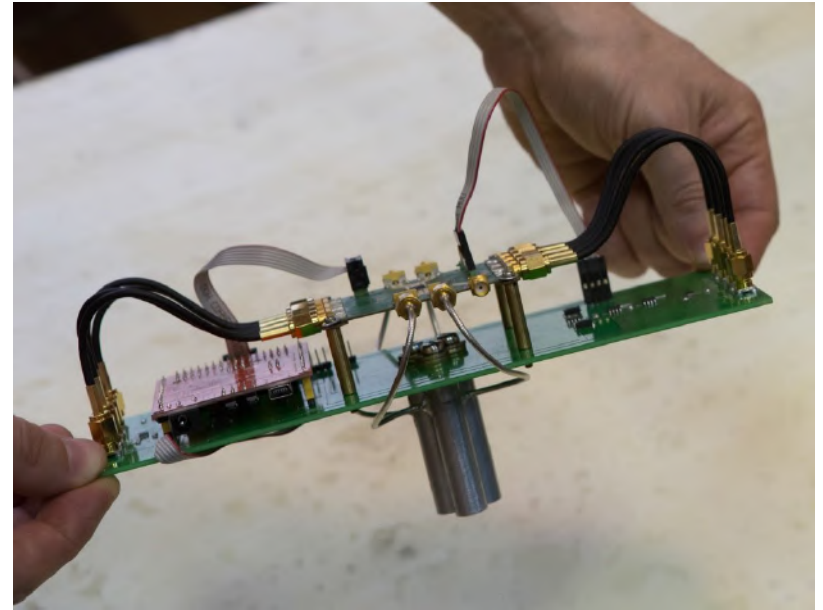
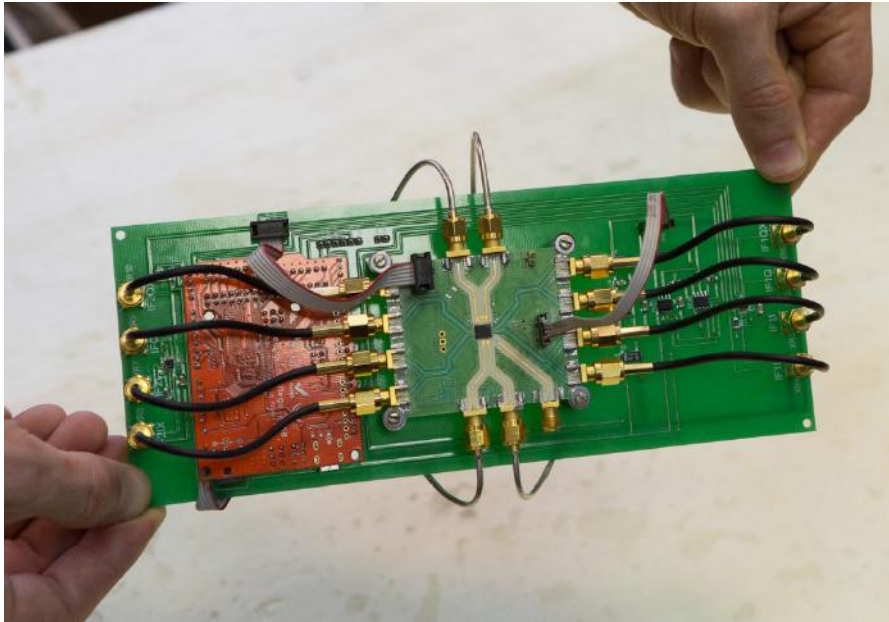


- A special experimental setup designed for subsurface radar imaging was applied, it allows sampling at arbitrary programmable points, testing various scanning and sounding parameters.
- The data acquisition is accomplished by automatic scanning.



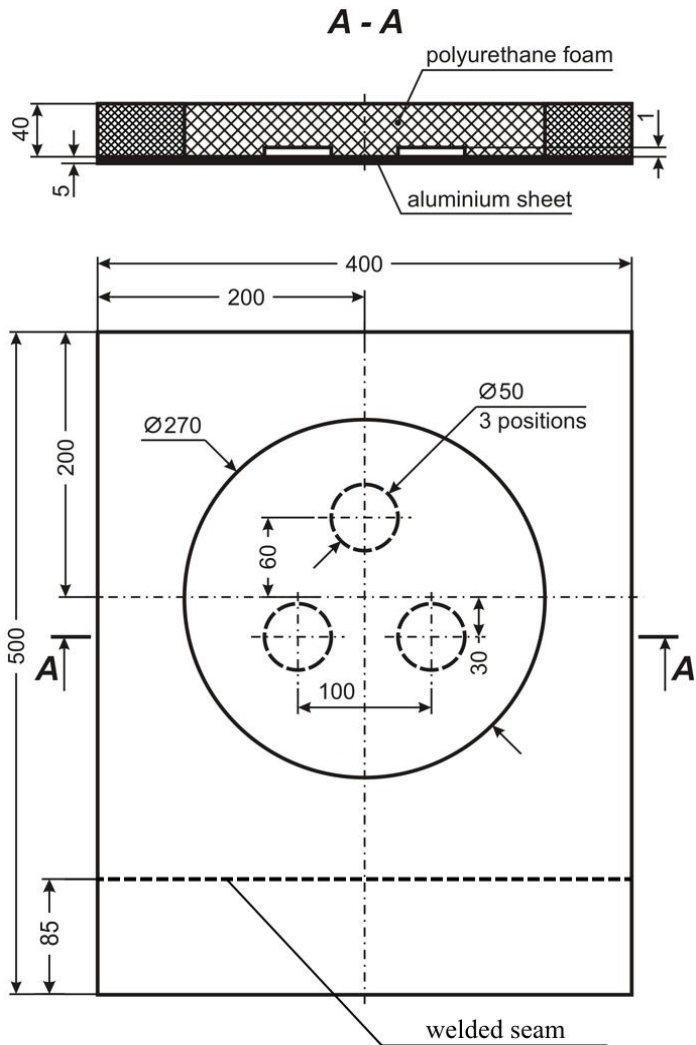
- For the reconstruction of the MW holograms back-propagation technique was applied, based on the Fast Fourier Transform.

Diagnostics of Composite Materials



HF holographic radar (22-26 GHz) for composite materials diagnostics

Diagnostics of Composite Materials



Drawing of the sample



MW hologram reconstruction

Dinosaur's Track Sample

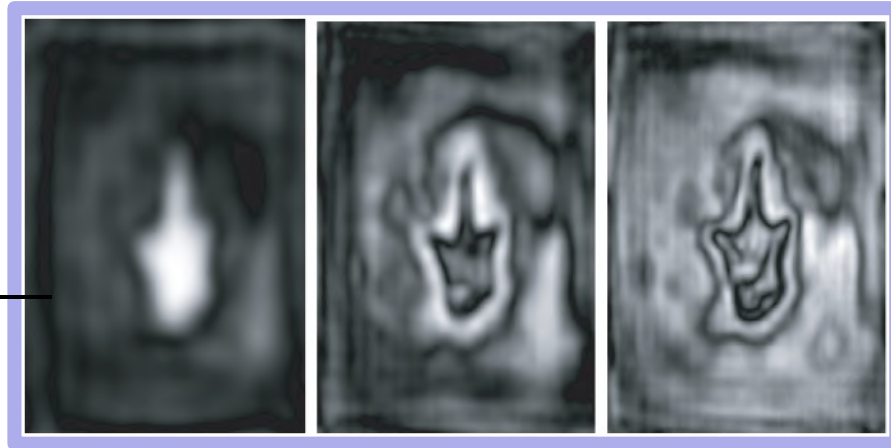
- A model mold-and-cast dinosaur track was created by making a gypsum plaster cast of an actual dinosaur track (var. *Anomoepus* from Dinosaur State Park in Connecticut, USA) and reproducing the tightly-fitting mold from this cast

- 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

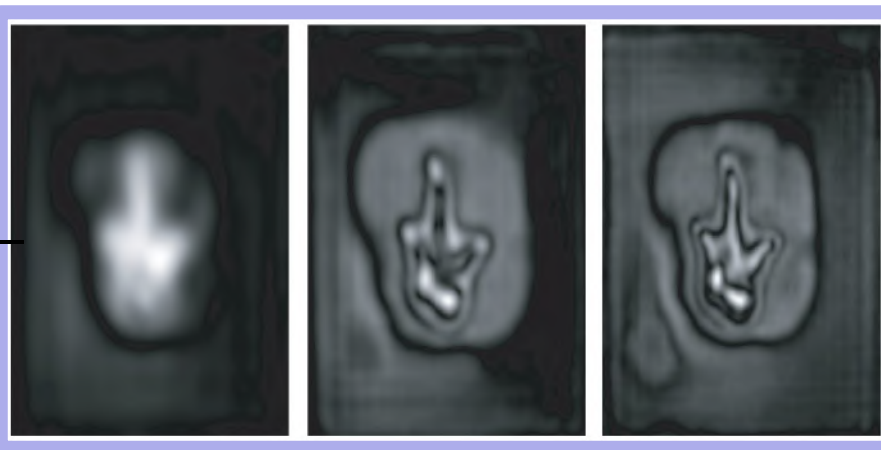


Experimental Results

- The experiments were conducted in three 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 MW holographic subsurface radar technology for non-contact imaging and recording of tracks where they are exposed (some track surfaces are fragile)



7.0 GHz

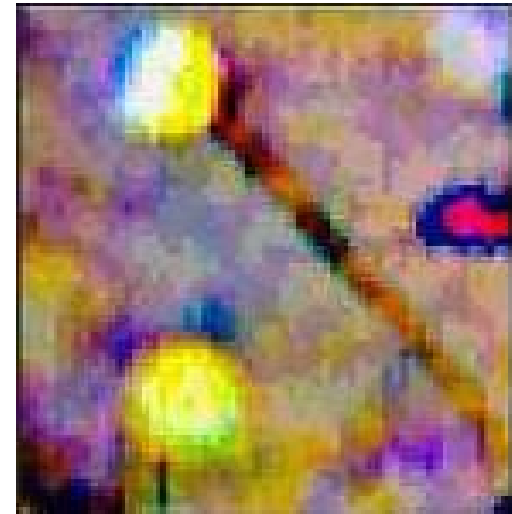
15.2 GHz

21.5 GHz

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Robotic scanner for real-time images to search for buried shallow objects



See video Radar Object Scanner at :

<http://www.youtube.com/watch?v=G6lM2-Qixyg&feature=youtu.be>

Holographic image

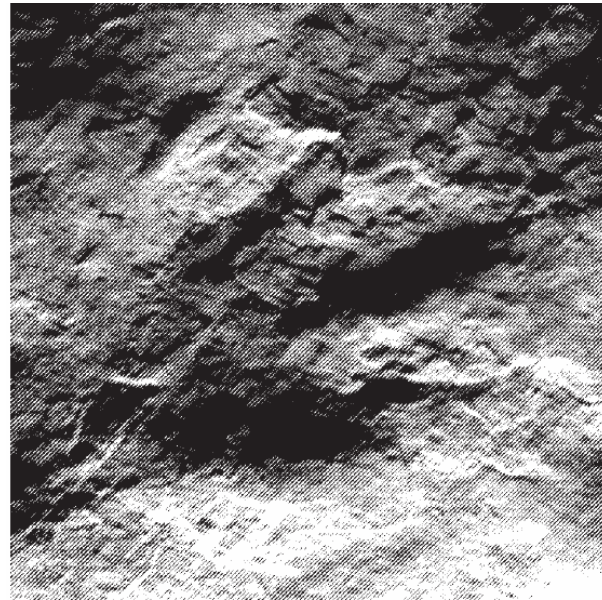
Experimentation with a robot scanner for research in the paleontological field at the Parco dei Lavini di Marco (MCR)



Preliminary experimentation on a tridactyl dinosaur's footprint at 4 GHz



Holographic image of a superficial footprint



Optical image of a superficial footprint

CONCLUSIONS

Holographic subsurface radar technology is not universal one. However in some cases it can be useful and unique.

It gives opportunity to record high resolution ($\lambda/4$) images of objects' internal structures at one-side access to them.

In this quality holographic radars differ from X-ray devices that need two-side access to the structure under consideration. Two-side access is impossible in most cases of interest for cultural heritage surveys.

Several materials (concrete, plaster, bricks, wood, rocks, natural soil) of interest for cultural heritage can be investigated but also (plastics, foams and composites) by selecting proper operating frequency.

Scanner and with different antennae (2GHz, 4GHz, 7 GHz, 18 GHz) have been built.

Mechanical scanners provide high spatial sampling resolution and can operate remotely by controlled robotic vehicles.

ACKNOWLEDGMENTS

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- Progetto RiMiDiA – «Riflettometria a Microonde per la Diagnostica di beni Artistici», Regione Toscana POR CREO

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