Franklin & Marshall College
PA, USA

Remote Sensing Laboratory
Bauman Moscow State Technical University

Florence University
Italy

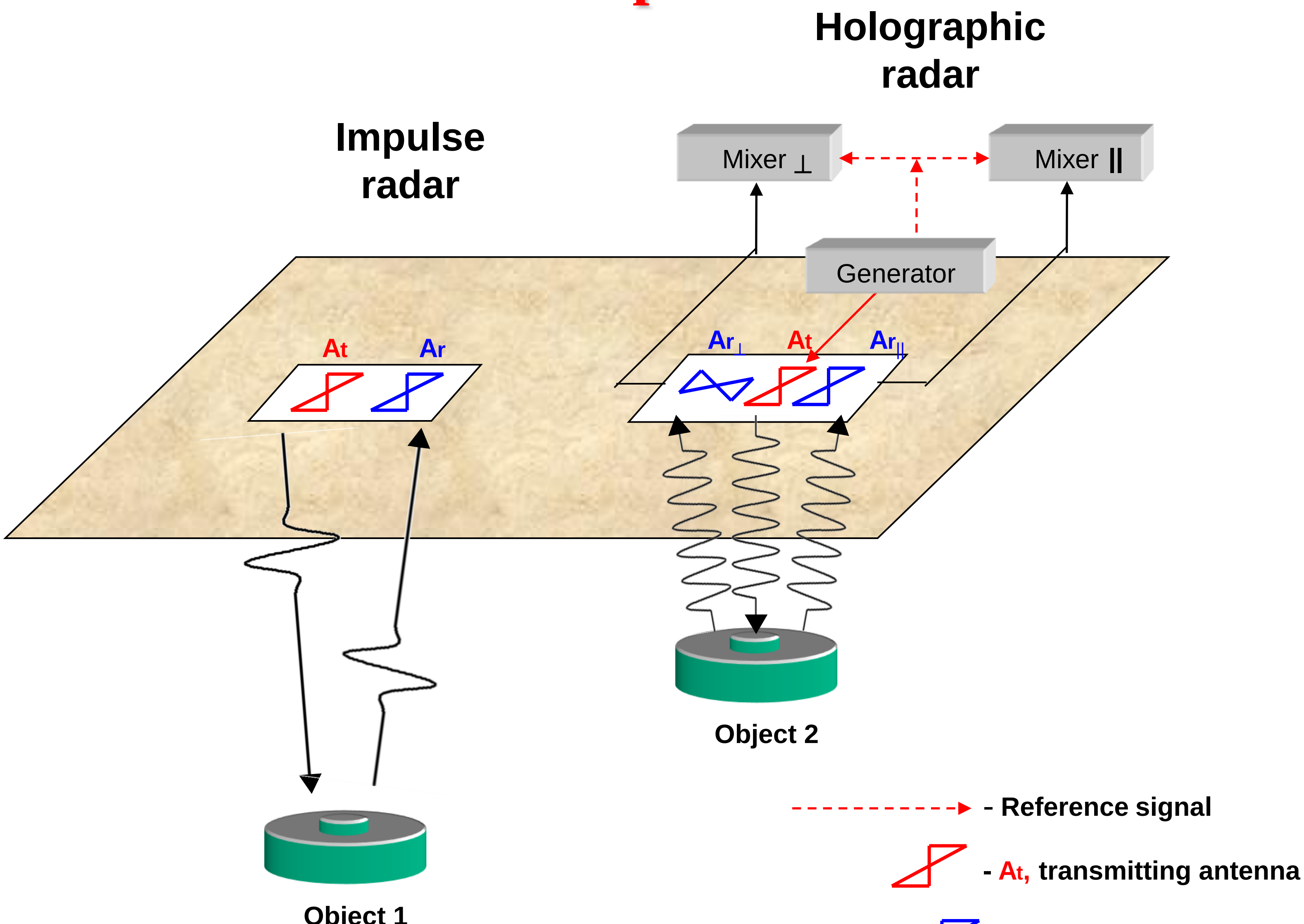
T.Bechtel, S.Ivashov, V.Razevig, V.Zhuravlev, L.Capineri, P.Falorni

USA Russia Italy

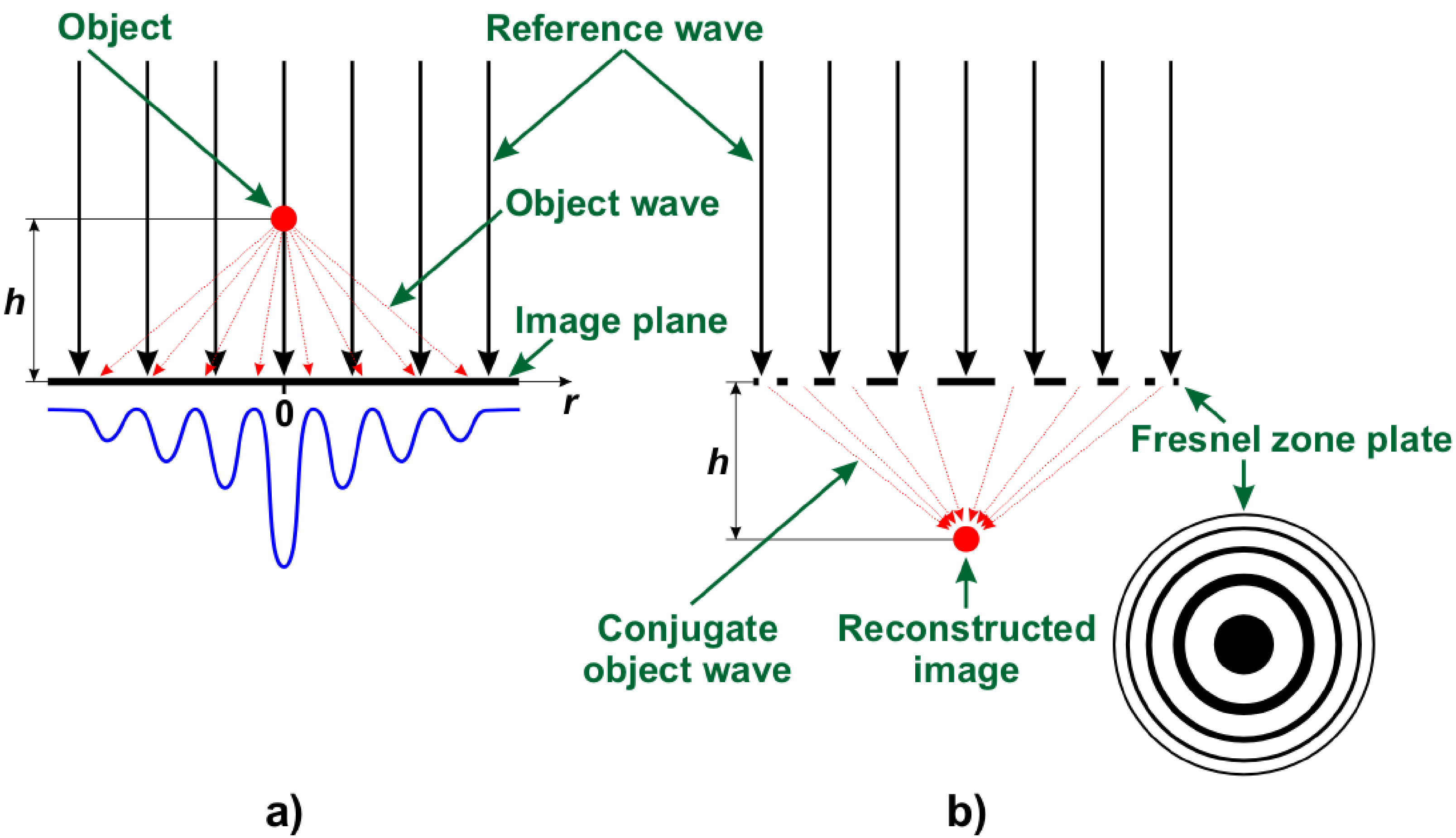
Using of holographic subsurface radar at the surveying and reconstruction of cultural heritage objects in Russia and Italy

Second International Workshop, “Analyzing Art: New Technologies - New Applications”
Saint Petersburg, July 25-27, 2018

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	

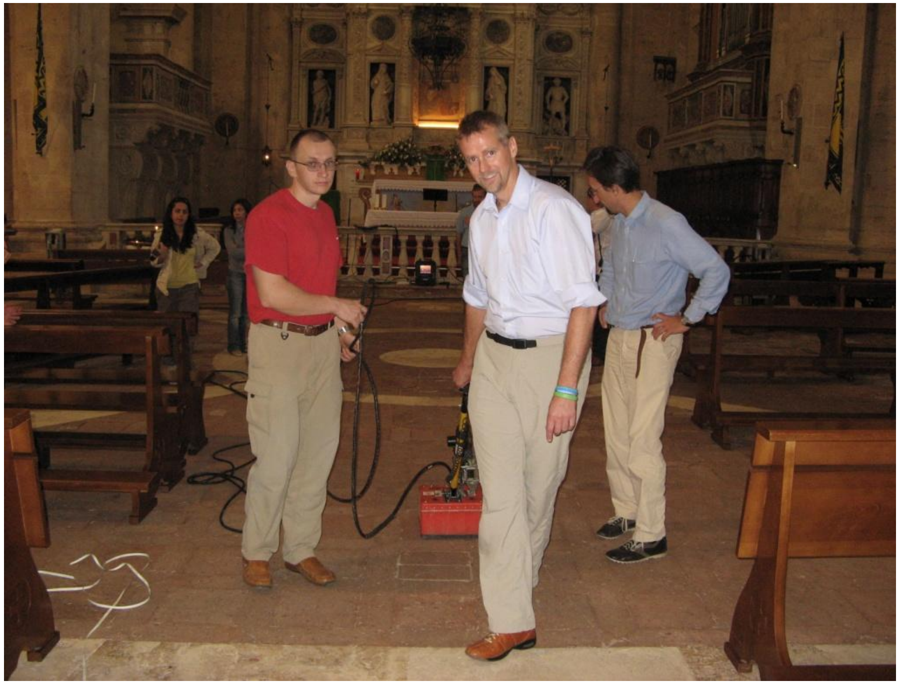
(*) - Low emitting power guarantees full safety for personnel while using RASCAN radars (two orders less than a mobile phone has), Russian sanitary certificate # 77.01.09.650.П.041358.10.05.

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.

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.



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

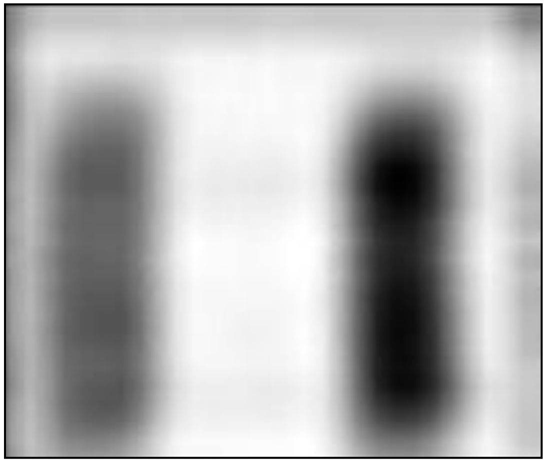
A marble medallion on the floor

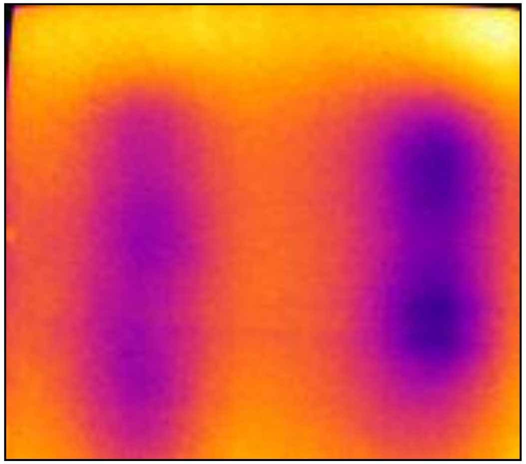
Radioimages of the medallion in two polarizations

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

Laboratory Model of the Medallion

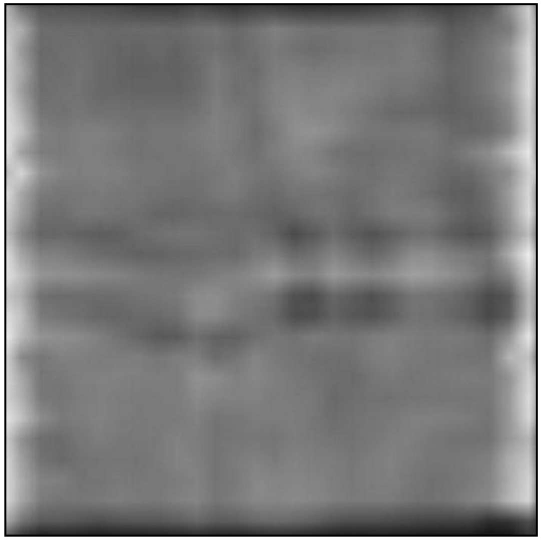
Laboratory model of the medallion supports

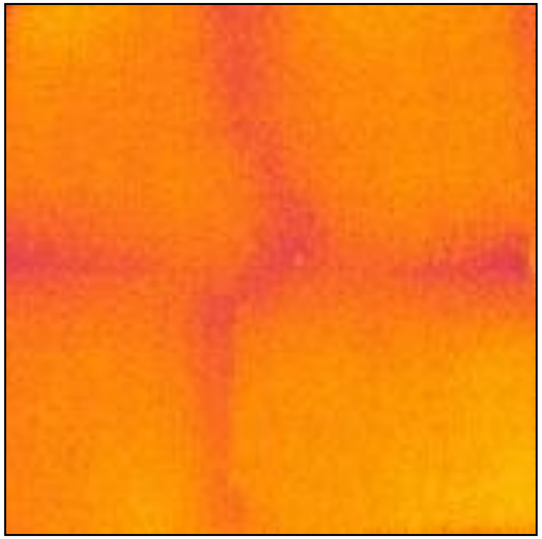




RASCAN (left) and IRT (RIGHT) images of bricks beneath a stone slab.
The thermal anomaly is created by the bricks resting on a cool concrete slab.
Images are 30cm by 30cm. IRT image spans 2.6ºC.

Cracks Detection





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^{o}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.

First scanning area

The first scanning area is positioned vertically along the trunk of the image of Christ.

In the images relating to the three intermediate frequencies of the CROSS polarization the metal nails are clearly visible, which are used to hold the structural parts of the wooden cross together.

Always in CROSS polarization the image relative to the frequency of 3.7GHz shows in a particularly clear way the contrast between the area laminated in gold and the area painted on wood. In this image is clearly visible a puff placed at the blood sketch on the side.

Second scanning area

The second scan area was placed horizontally, at the top of the cross just below the halo.

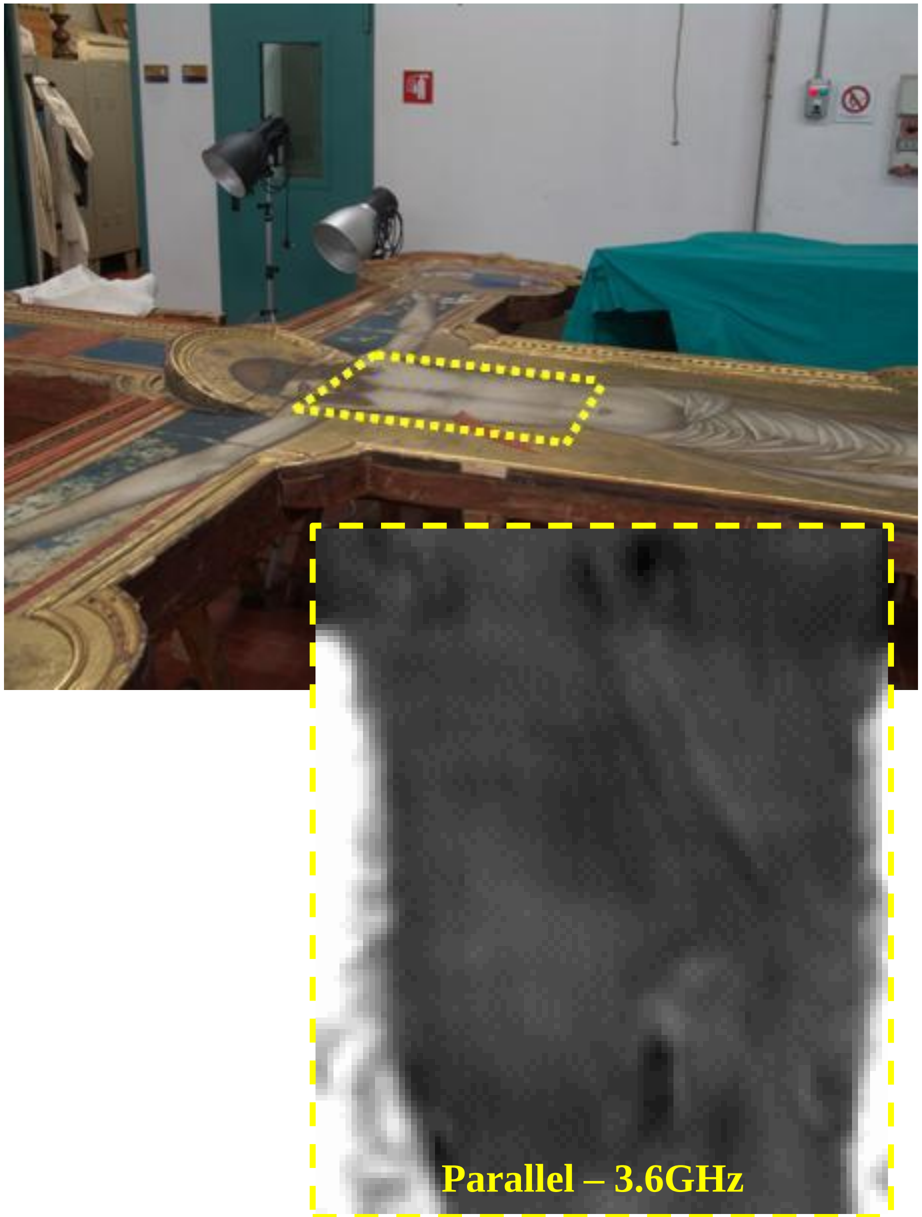
Also in this scan the images of the fixing nails are confirmed, this time better visible in the images related to the PARALLEL polarization. Note that this scan is done in an orthogonal direction with respect to the previous one.

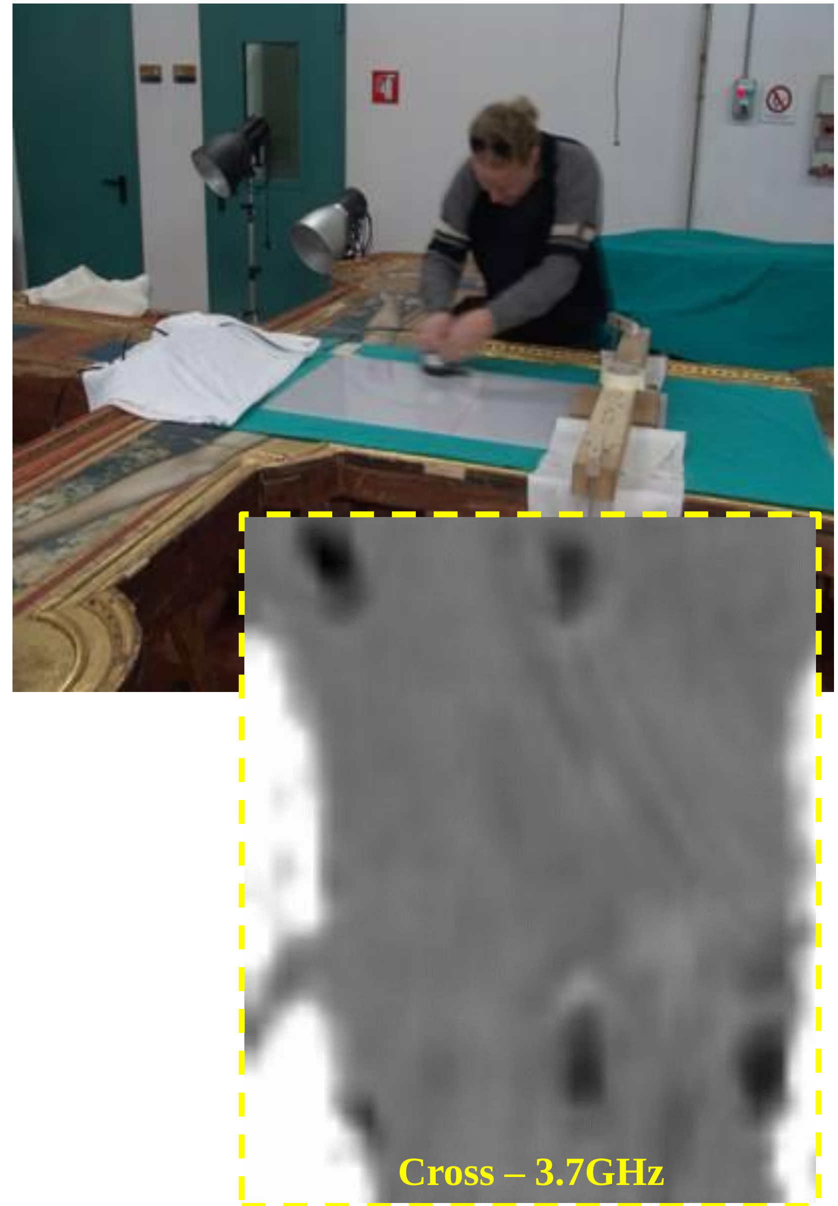
At the three higher frequencies, both in CROSS polarization and in PARALLEL polarization, numerous striations are visible, compatible with the flaming of the underlying wood.

Third scanning area

The third scan area is still positioned vertically but narrower than the first area to rise above the halo area.

Investigation on the Croce di S. Marco

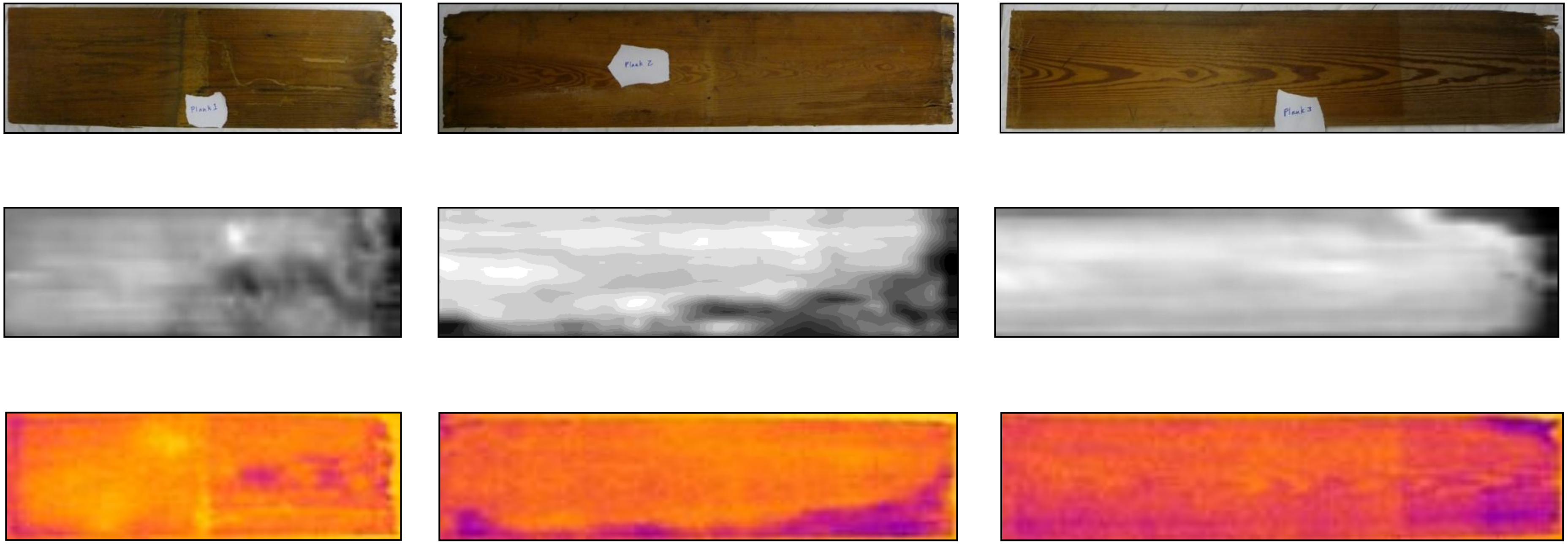




Spurt of blood.

One of the peculiarities that emerged during the survey is the presence in the radar images of a shape that follows the sketch of blood coming from the wound on the rib.
The presence of this trace was unexpected on the area painted on the golden plate. In fact, it is not plausible that a dielectric layer with a thickness of less than one tenth of a millimeter can modify the module or phase of the reflected wave.
To corroborate this hypothesis, a specimen has been made with gold foil partially covered by a layer of minio. In this case, as expected, the measurement carried out above the minio layer is not distinguishable from that made above the gold foil without minio.
The hypothesis that seems to be more plausible is that the paint used for the san-gue sketch contains metallic elements, and therefore can be assimilated to a non-perfect conductor. In this case, the electric field would be only partially canceled, thus resulting in a variation of phase different from 180 °, from which the image above.
This second hypothesis is confirmed by the analyzes carried out previously by the Opificio delle Pietre Dure of Florence, which highlight the significant presence of lead in the paint of the blood sketch.
Lead was used at the time of processing to make the color white, here used to represent water mixed with blood that comes from the side of Christ.

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^{o}C.

Wall mosaic "Dedication of the Church to the Virgin" investigation by RASCAN radar of the University of Padua (Italy).

The church of Santa Maria dell'Ammiraglio (La Martorana) in Palermo, Sicily.

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.

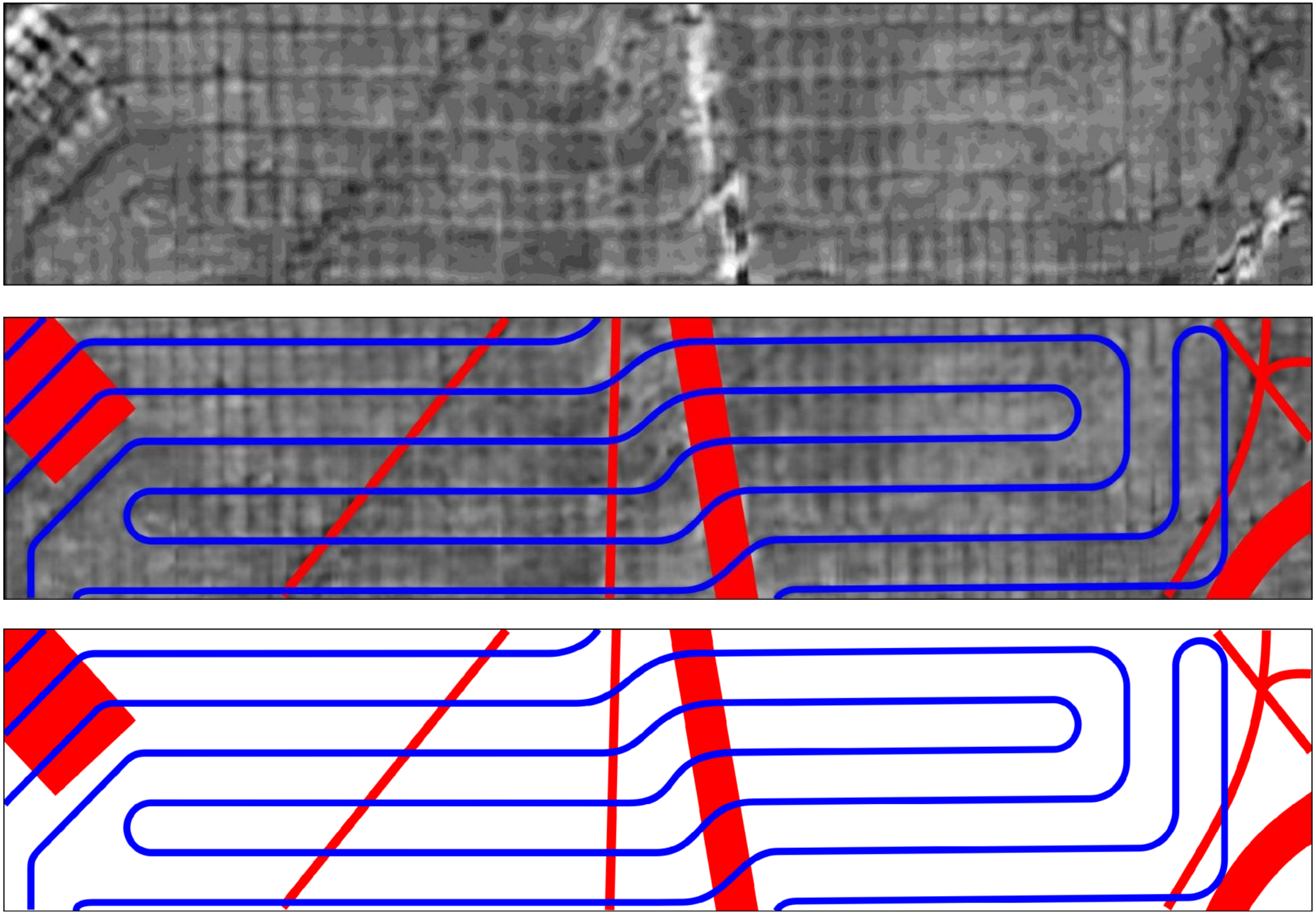
The survey was performed by holographic subsurface radar RASCAN-4/2000



Holographic subsurface radar RASCAN-4/2000in work.



Wells with cables in the concrete floor.

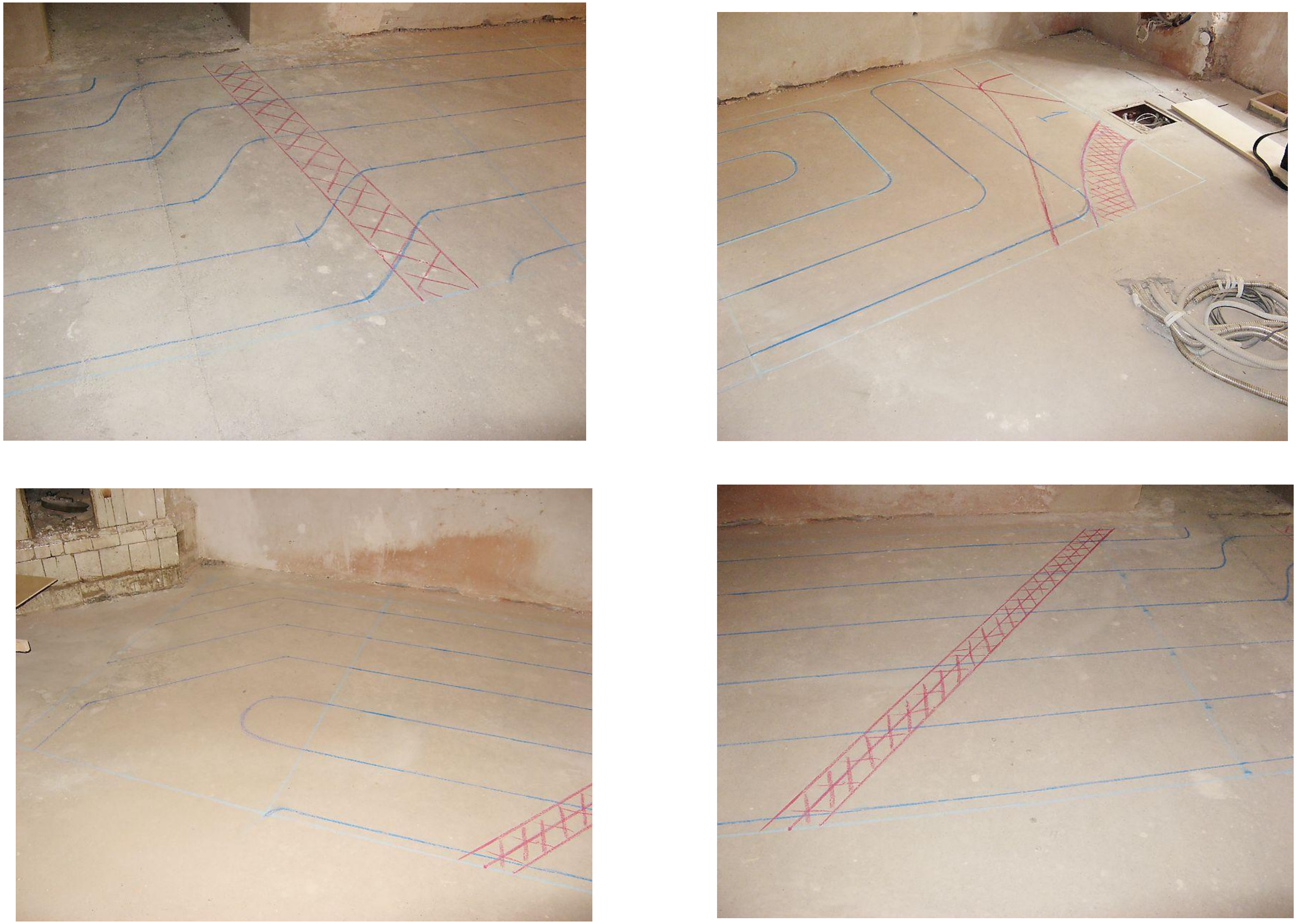


а)

б)

в)

Result of the survey:
а) 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.

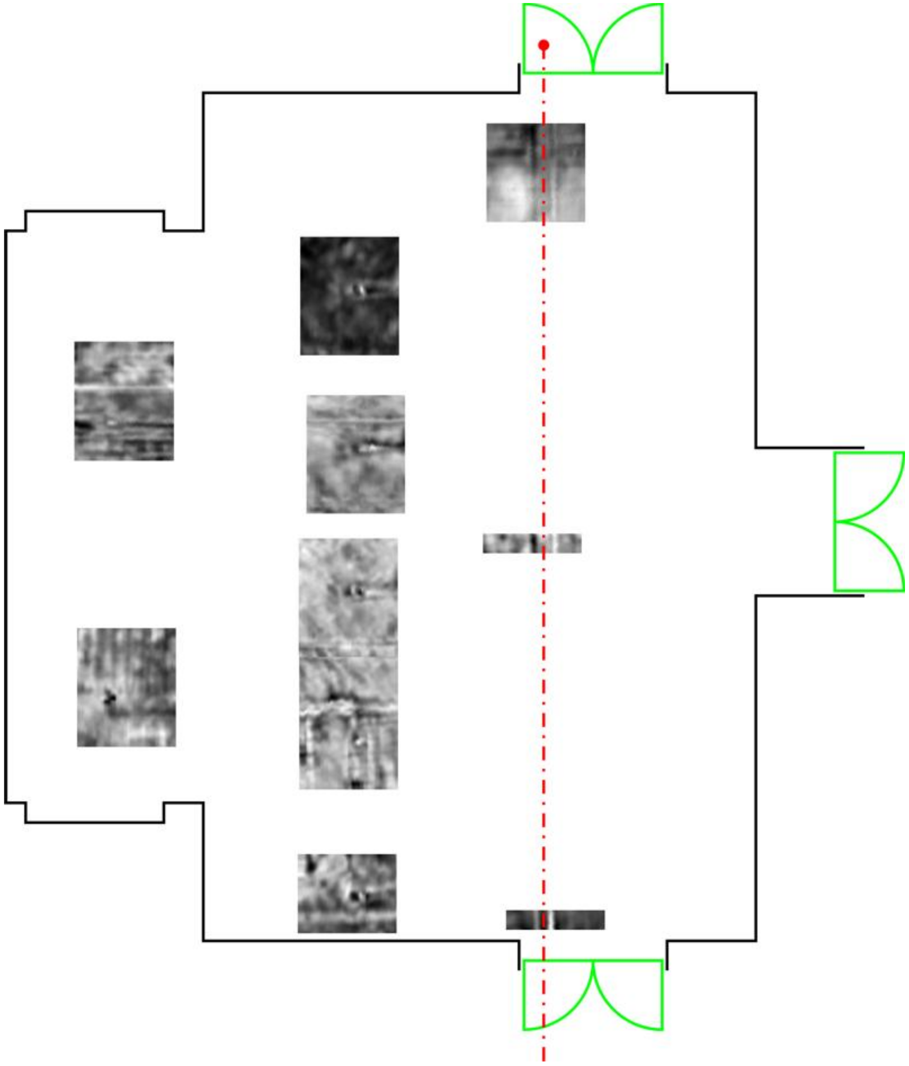


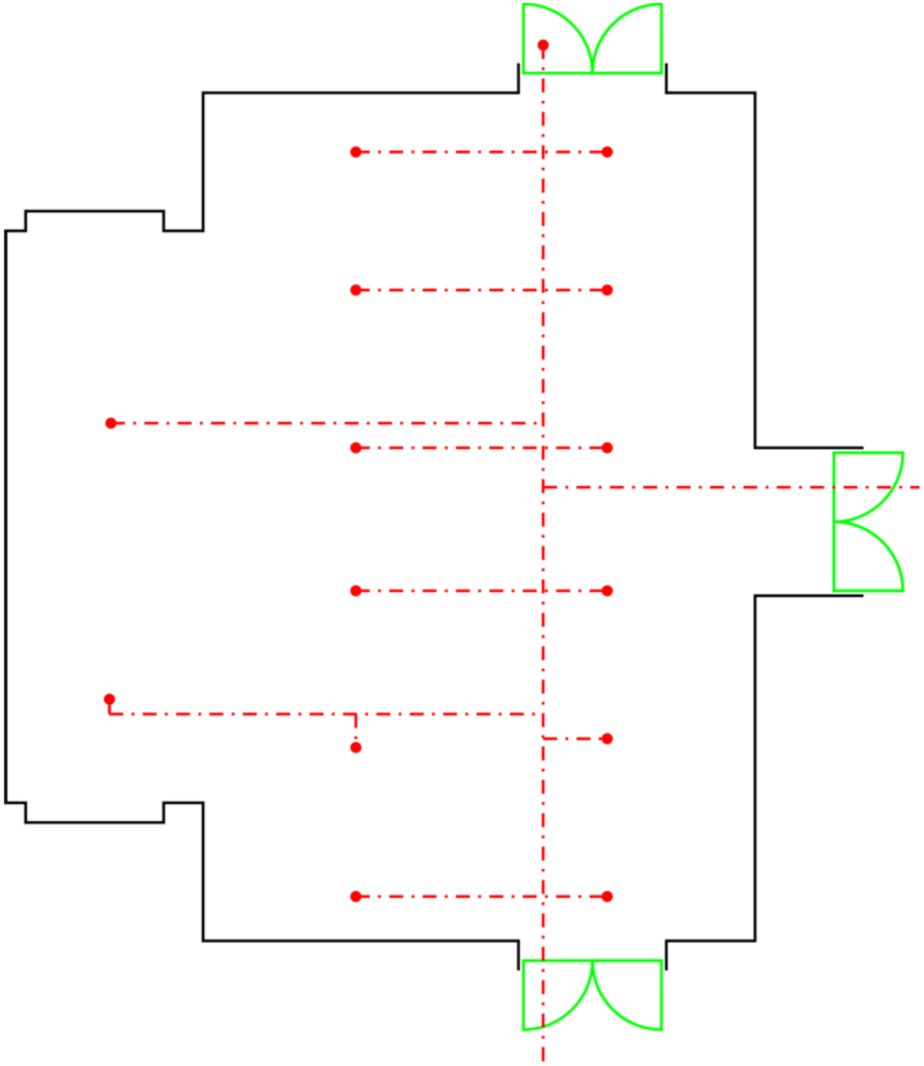
The result of surveying was drawn on the floor surface by chalk.

An Example 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

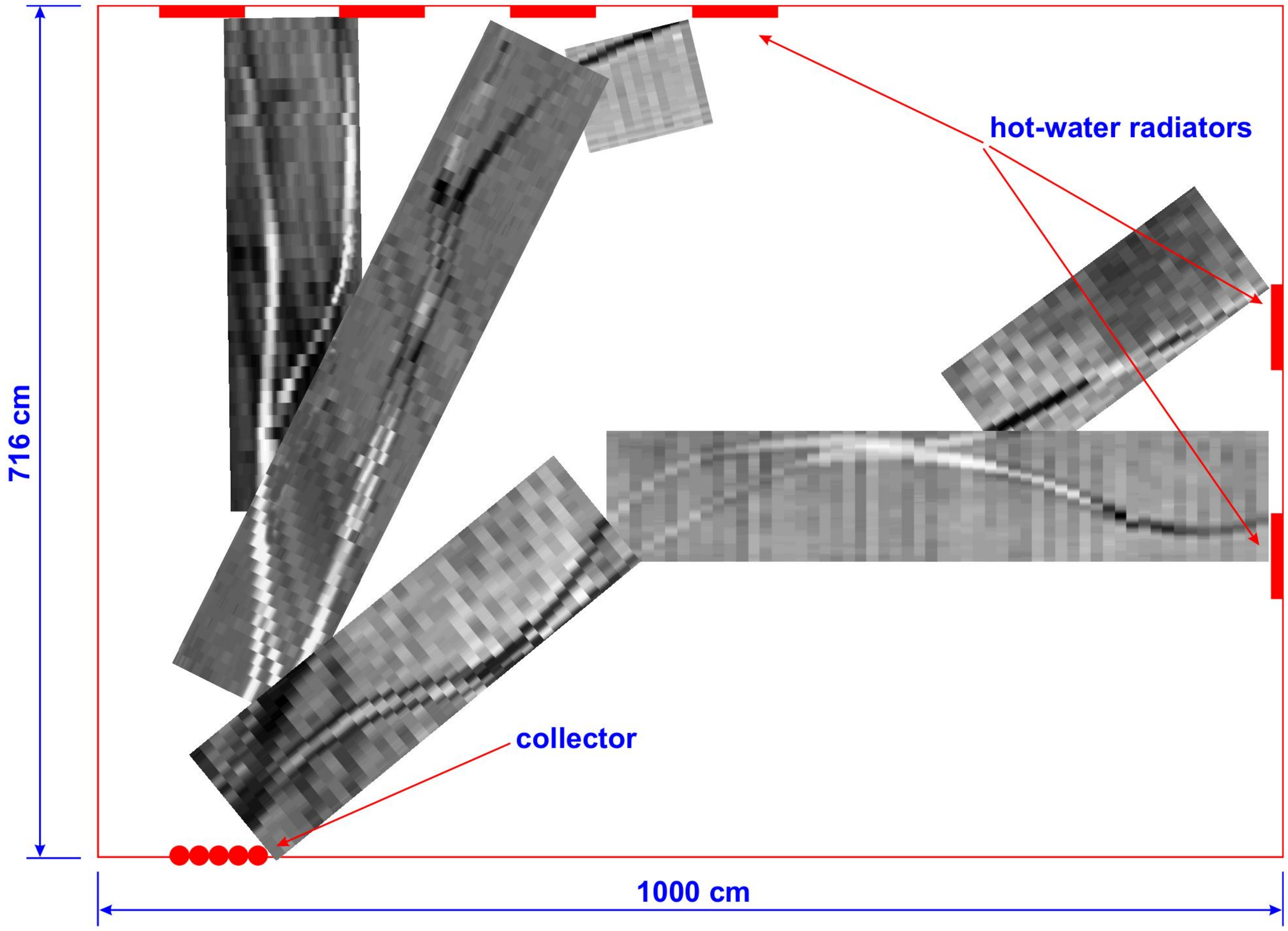




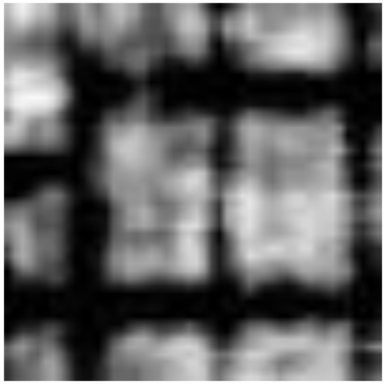
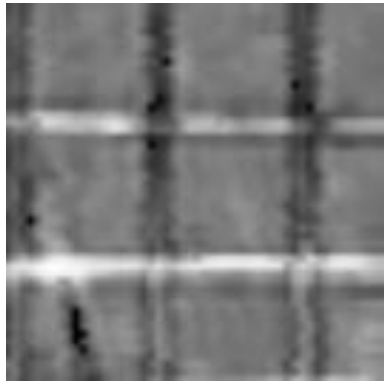
Surveying of a Concrete Floor

Concrete floor inspection

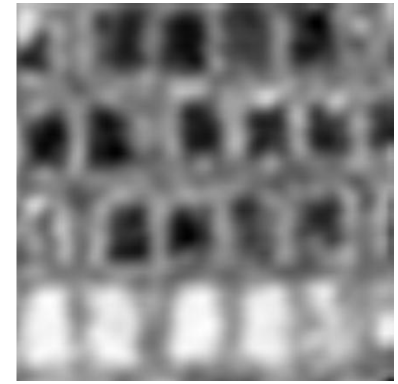
Heating plastic pipe


hot-water radiators
collector
716 cm
1000 cm

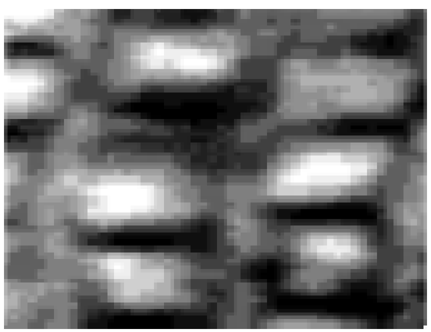
Examples of RASCAN Diagnostics

Radar images of the ferroconcrete walls

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



Stone wall under plaster

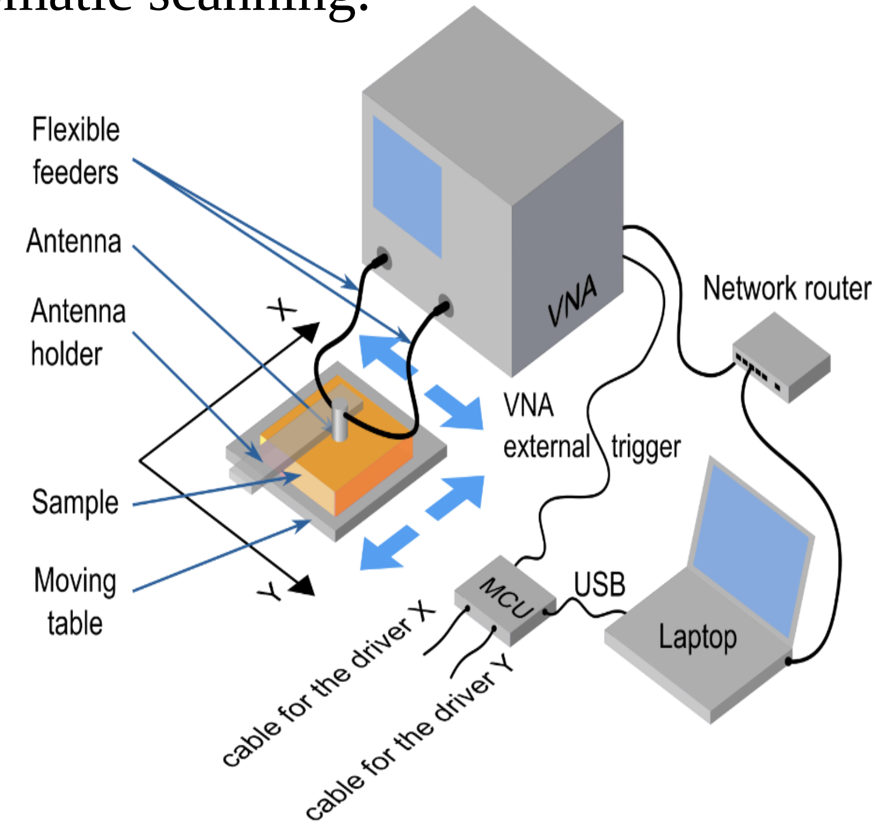
A ventilation channel
in concrete wall

An electrical socket and
wire in concrete wall

A hand under table

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.

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

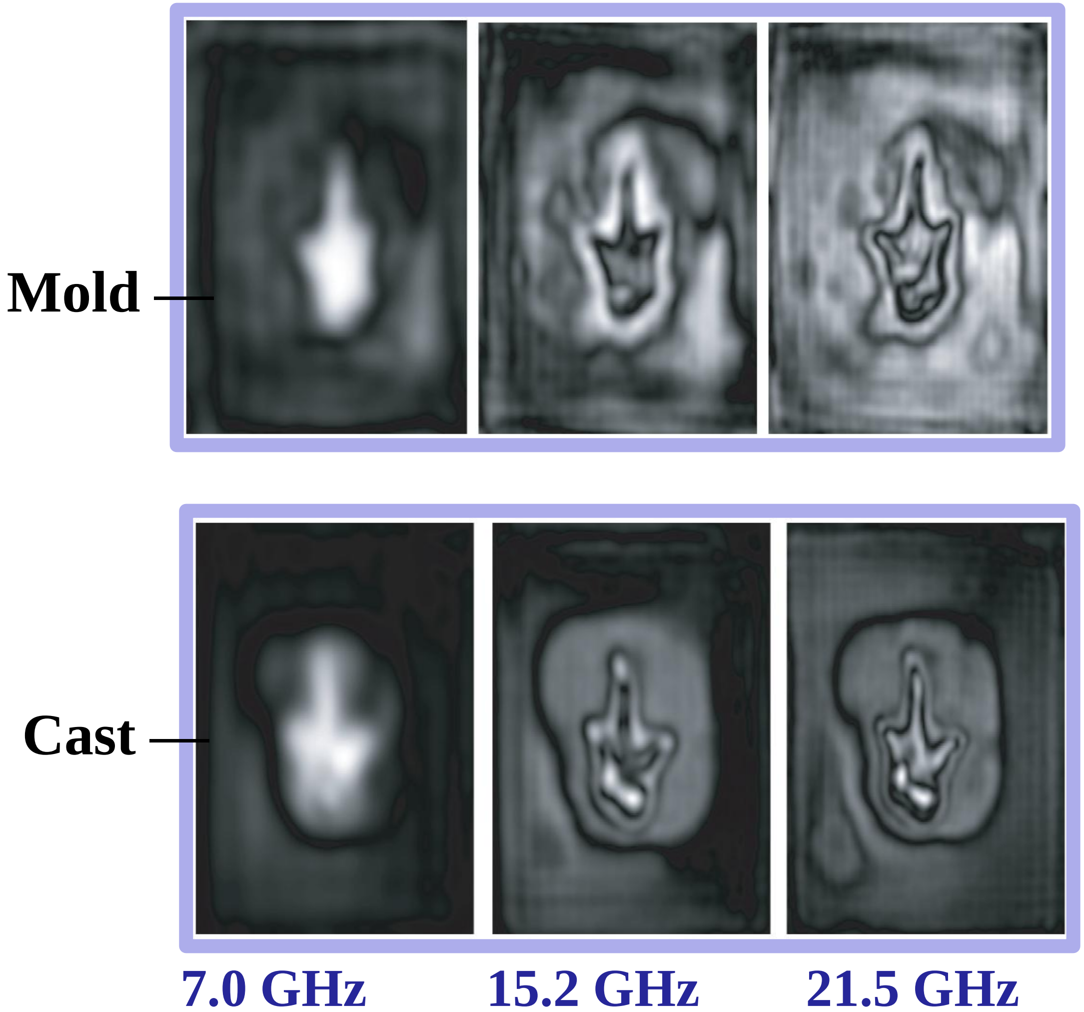
- Mold: area of 255×225 mm, height of 27 mm

- 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 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.



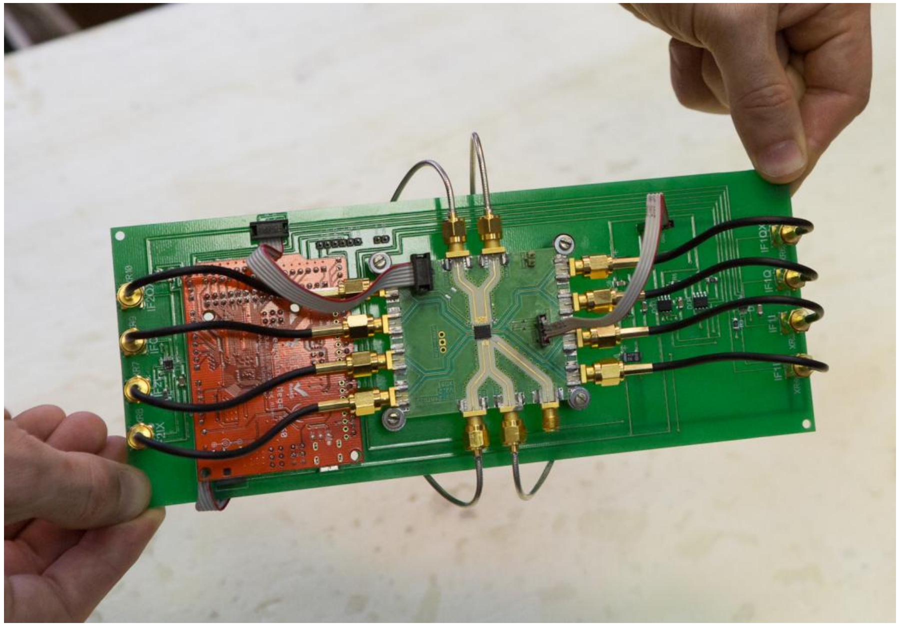
→ the feasibility of MW holographic subsurface radar technology for non-contact imaging and recording of tracks where they are exposed
(some track surfaces are fragile)

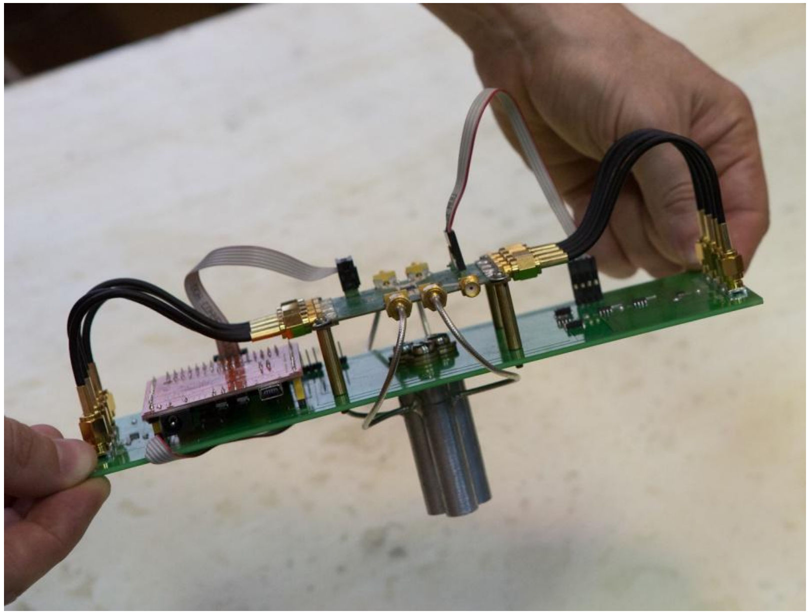
Columbia's Accident

Space Shuttle Columbia take off
on 16th of January 2003.

Columbia's remains after unfortunate landing on
1st of February 2003, *Flight International*, 29 April-5
May 2003, pp. 26-29.
Collected on the ground remains of Columbia were laid
out in a hangar by the NASA Investigation Board.

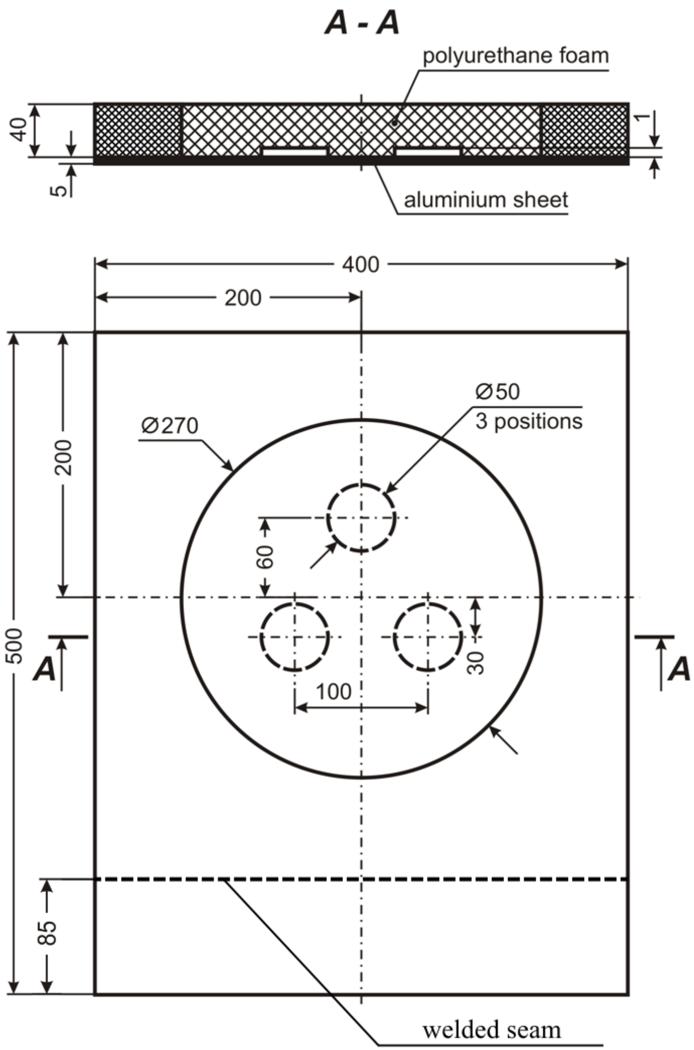
Diagnostics of Composite Materials





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

Diagnostics of Composite Materials



Drawing of the sample

MW hologram reconstruction

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.

CONCLUSION

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.

ACKNOWLEDGMENTS

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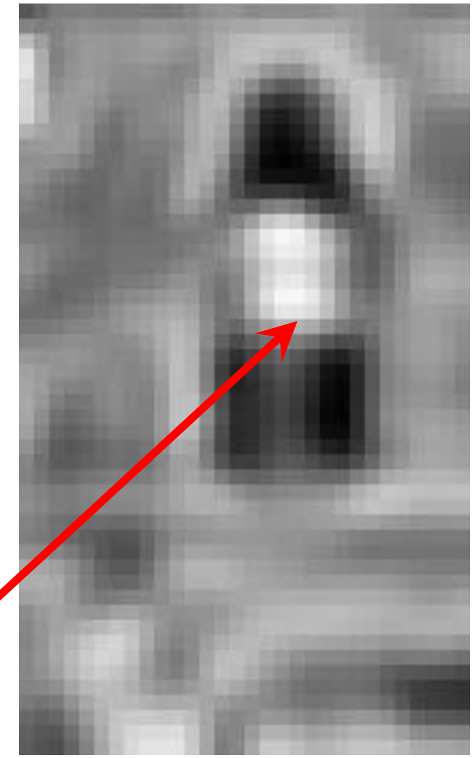
by the Russian Science Foundation under project #15-19-00126.

Authors express their gratitude
to Dr. Roberto Olmi, IFAC CNR – Italy,
for his help in investigation of the Croce di San Marco.

A Joke in the Final



The radar image of vodka bottle is obtained by RASCAN-4/4000 inside of cupboard

Vodka level