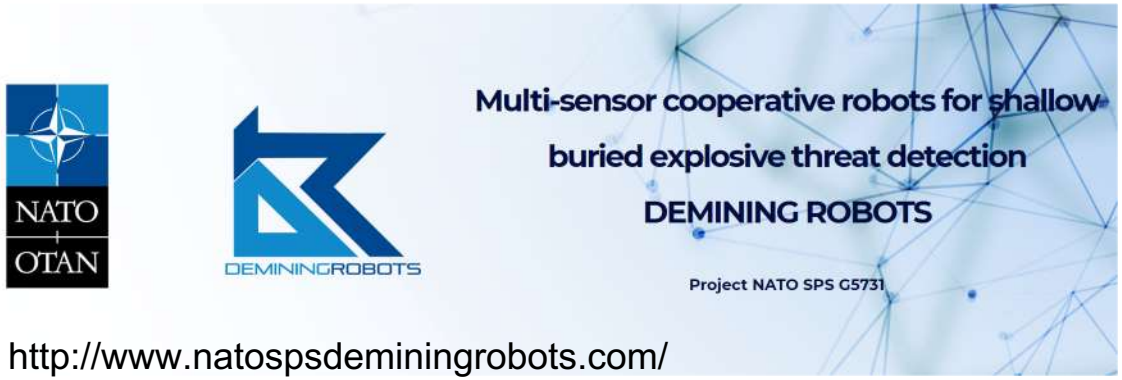


http://www.natospsdeminingrobots.com/

Water-filled testbed modeling, design, and fabrication for performance validation of a holographic subsurface RADAR antenna

Luca Bossi[1], Pierluigi Falorni[1], Fronefield Crawford[3], Tim Bechtel[3], Vadym Plakhtii[2], Lorenzo Capineri[1]

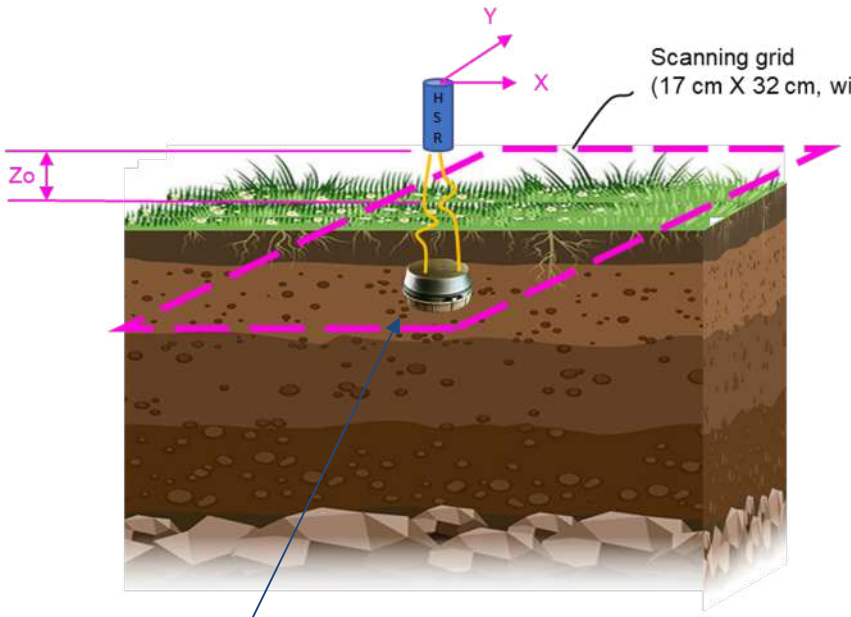
1. University of Florence - Department of Information Engineering - Italy
2. School of Radio Physics, Biomedical Electronics, and Computer Systems V.N. Karazin Kharkiv National University - Kharkiv, Ukraine
3. Department of Physics and Astronomy Franklin and Marshall College Lancaster, PA, USA

Outline

1. Microwave imaging RADAR for demining
2. Advantages of salt water filled testbed
3. Salt water modelling with Stogryn model
4. Testbed realization and experimentation
5. Conclusions

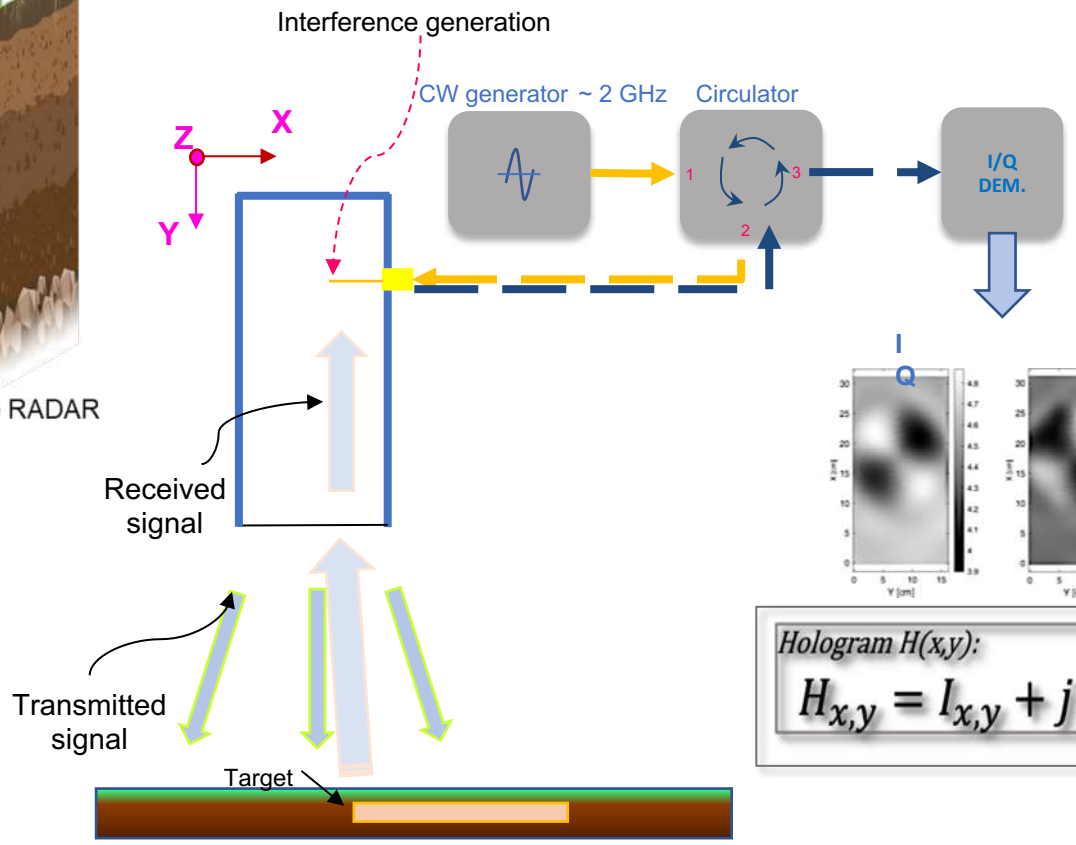
1

MICROWAVE IMAGING RADAR FOR DEMINING



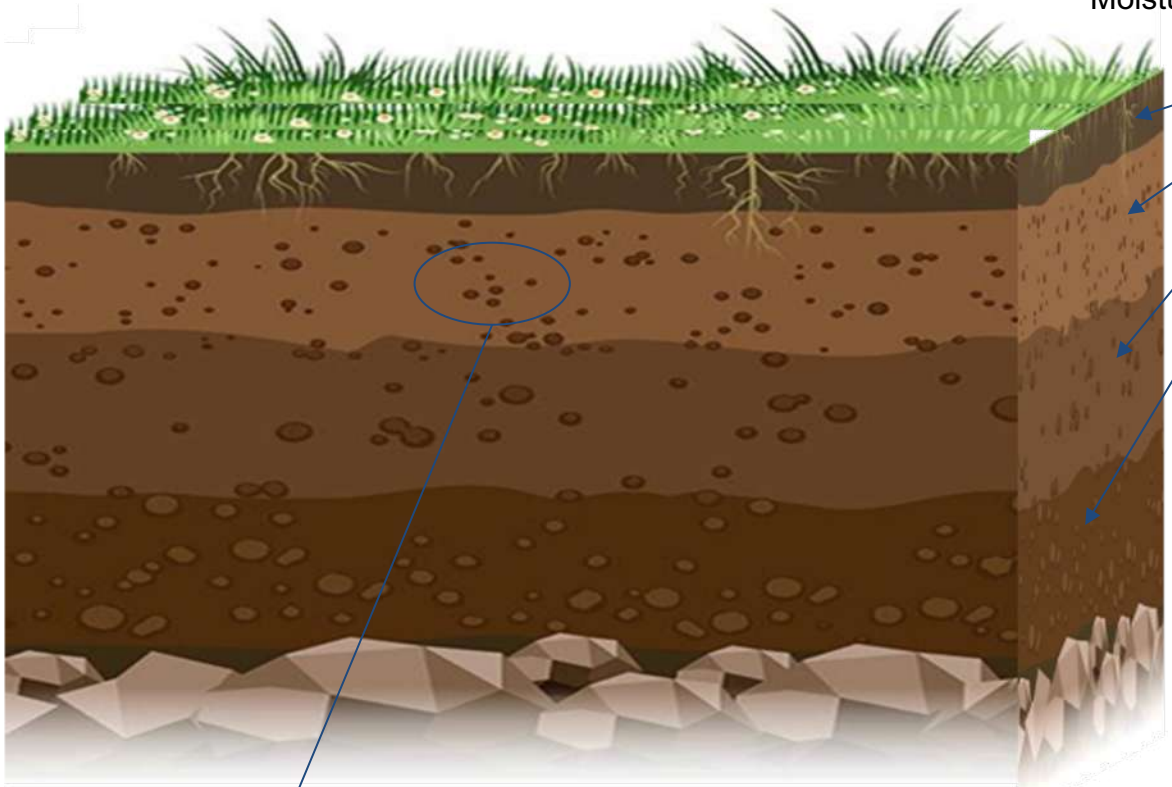
Schematic field operation of Holographic Subsurface RADAR

plastic landmine



MICROWAVE IMAGING RADAR SENSOR PRINCIPLE

Soil characteristics



Moisture content can vary between the soil layers

Changes the mineralogy and texture (e.g. clay, sand, gravel, etc.)

Inhomogeneous

Plastic landmine type PMN4

T. Bechtel *et al.*, "Characterization of Electromagnetic Properties of In Situ Soils for the Design of Landmine Detection Sensors: Application in Donbass, Ukraine," *REMOTE SENSING*, vol. 11, pp. 1232–1247, 2019, doi: 10.3390/rs11101232

2

ADVANTAGES OF SALT WATER-FILLED TESTBED

Sandy testbed for Holographic RADARs

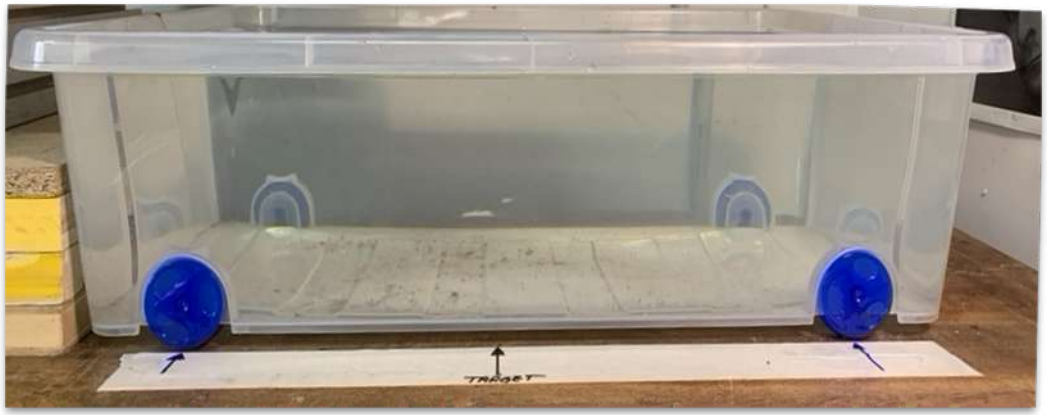
CONS

- Undesired reflections if the sizes and depth are small. Big sizes imply high weight.
- Difficult to control dielectric permittivity over the time due the evaporation
- Difficult to set (and modify) the dielectric permittivity to specific values

PROS

- Dielectric permittivity similar to terrain is easily obtainable
- Possible to shape the surface for considering the reflection of surface effects
- Doesn't require impermeability of the targets

Water-filled testbed for Holographic RADARs



CONS

- Dielectric permittivity of salt water change with temperature
- Targets must be impermeables

PROS

- Planarity of surface
- High contrast due the high dielectric permittivity difference between target and water
- High attenuation avoid reflection from sides and bottom of testbed
- Possibility to model the dielectric permittivity in relation to the frequency and easily modify it adding NaCl
- Easy positioning of the target inside the medium (water) and replicability of measurement.
- Easily transportable.

3

SALT WATER PERMITTIVITY MODELLING WITH STOGRYN MODEL

STOGRYN MODEL OF SALT WATER PERMITTIVITY*

Frequency of electromagnetic waves, Temperature of the water, Salinity

$$\epsilon = \epsilon_\infty + \frac{\epsilon_0 - \epsilon_\infty}{1 - j2\pi\tau f} + j\frac{\sigma}{2\pi\epsilon_o^* f}$$

Where:

ε_0, ε_∞ respectively, the static and high-frequency dielectric permittivity of distilled water (modified by the concentration of Sodium Chloride or NaCl);

τ Water Relaxation Time;

ε_0^* Dielectric permittivity of a vacuum (8.854 10-12 F/m);

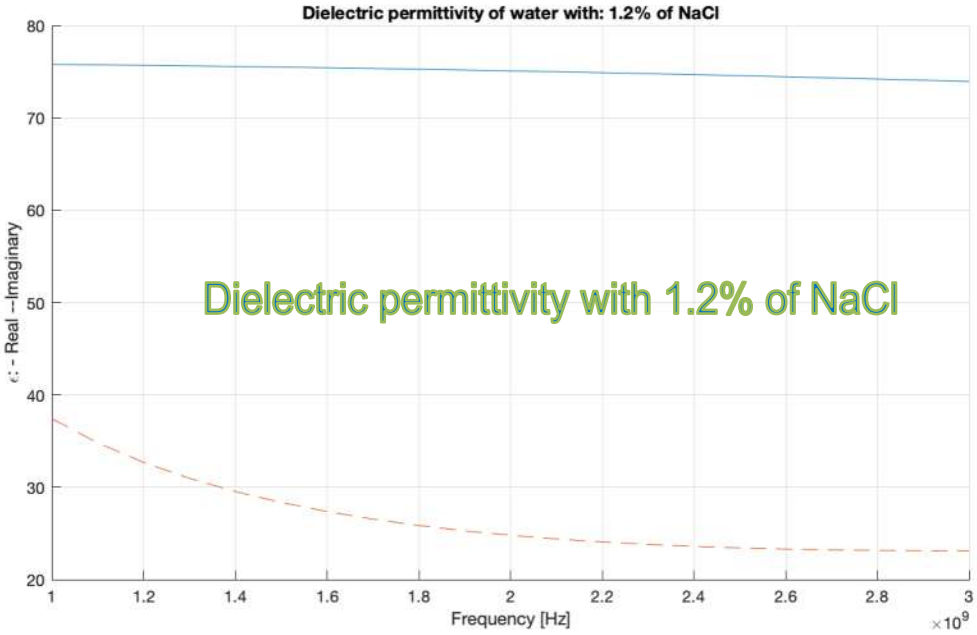
σ Ionic conductivity of the salt water in mho/m;

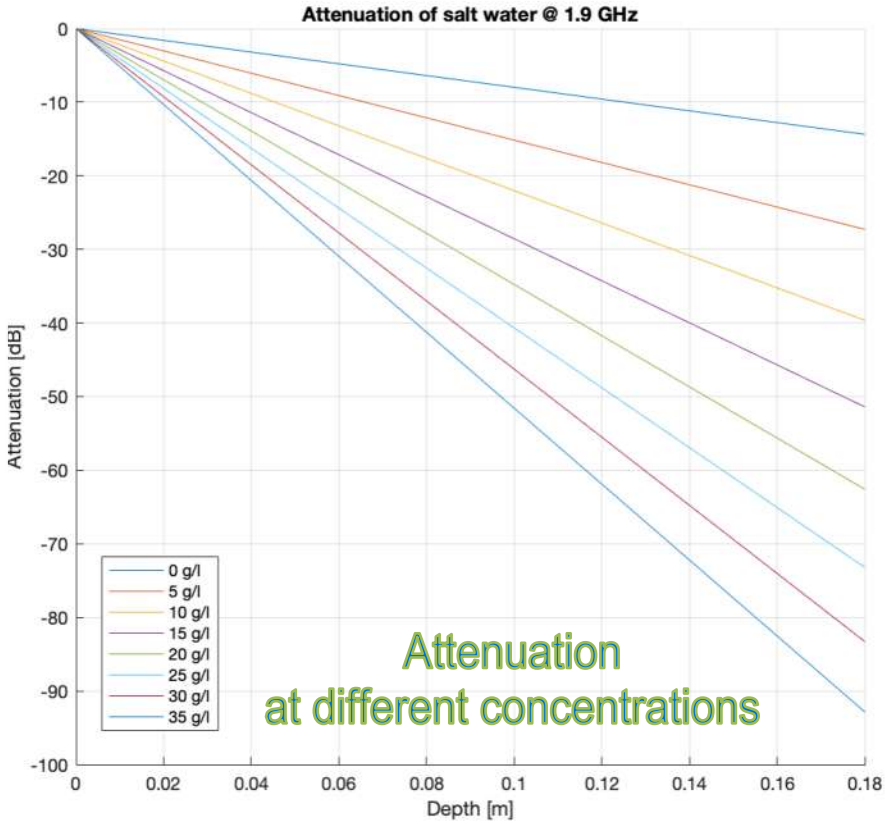
f Frequency of the electromagnetic wave.

ε_0, ε_∞, τ also depends on the normality of solution and temperature °C

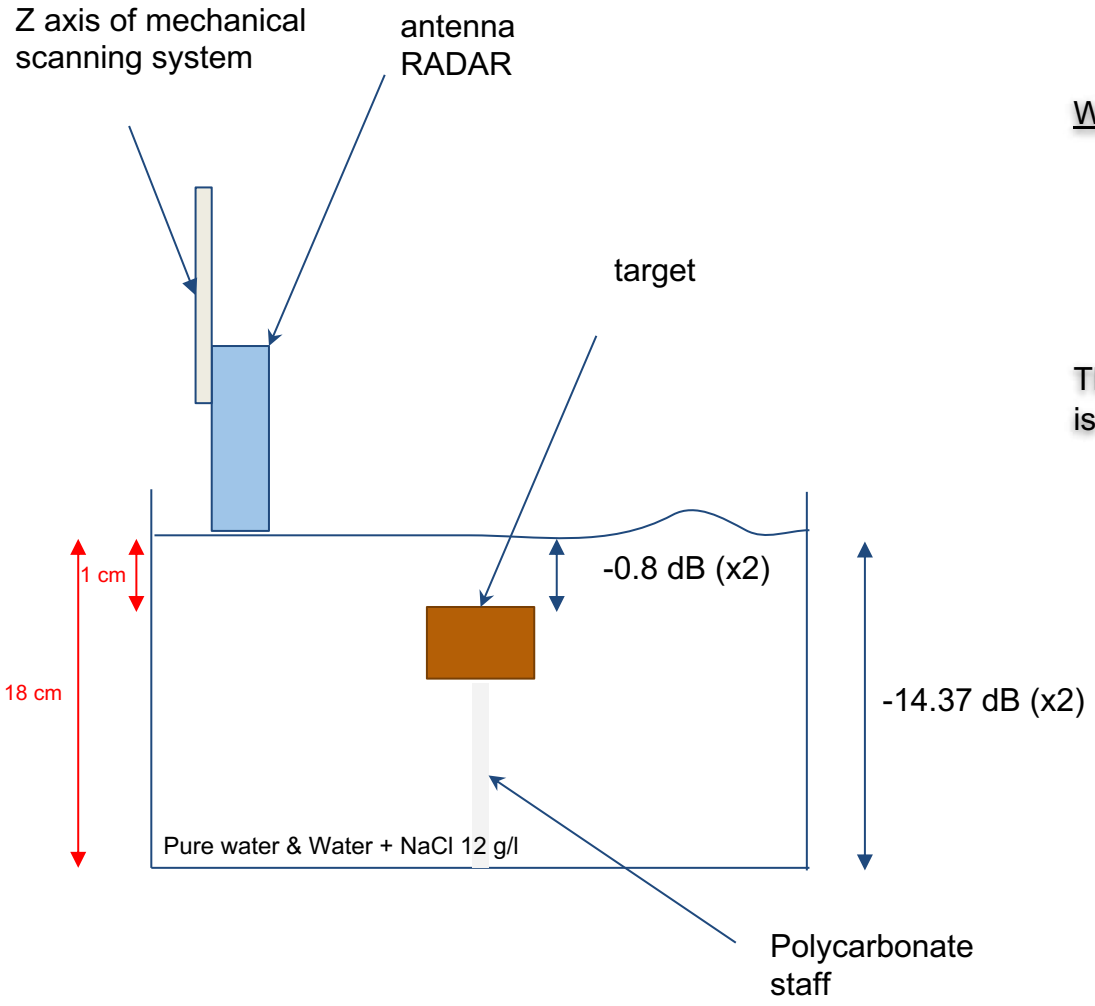
*A. Stogryn, "Equations for Calculating the Dielectric Constant of Saline Water (Correspondence)," IEEE Transactions on Microwave Theory and Techniques, vol. 19, no. 8, pp. 733–736, Aug. 1971, doi: 10.1109/TMTT.1971.1127617.

STOGRYN MODEL OF SALT WATER PERMITTIVITY SIMULATION





STOGRYN MODEL OF SALT WATER PERMITTIVITY



With NaCl

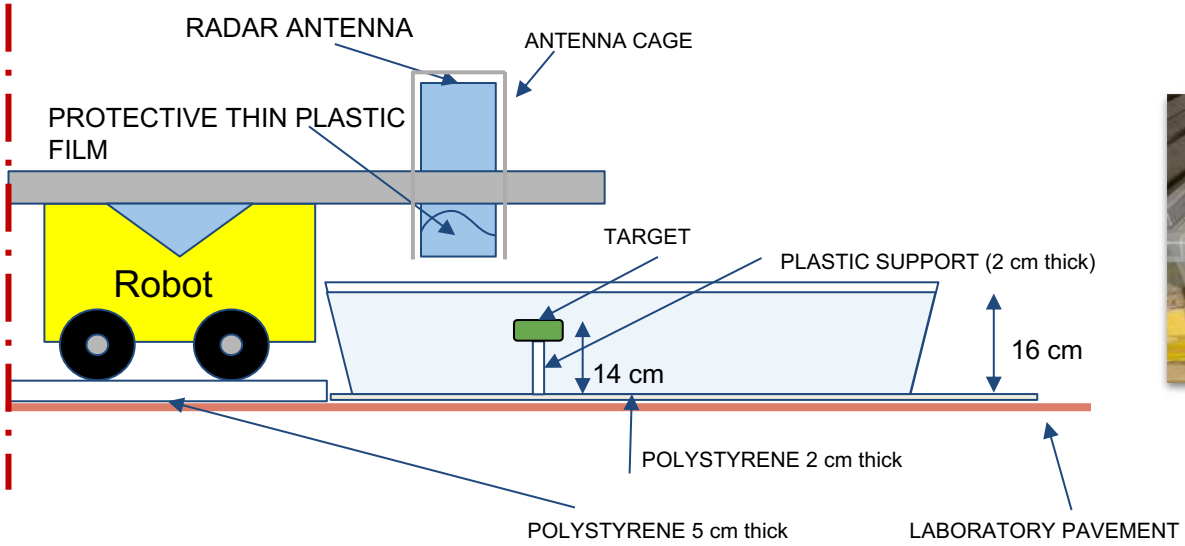
- Reflection index of water surface: ~ 9
- Reflection coefficient of water: ((1-9)/(1+9))^2≅0.64
- Wavelength in water: 2 cm

The water content is 30 l, the salt weight is 360 g.

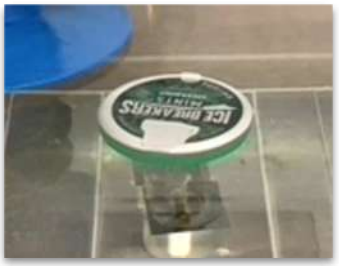
Landmine plastic simulant

4

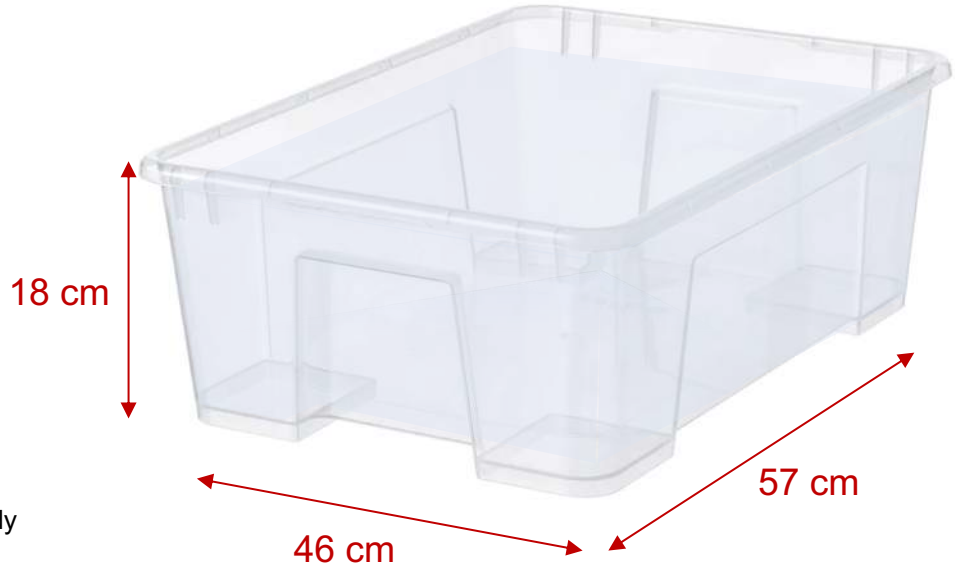
TESTBED PRACTICAL REALIZATION



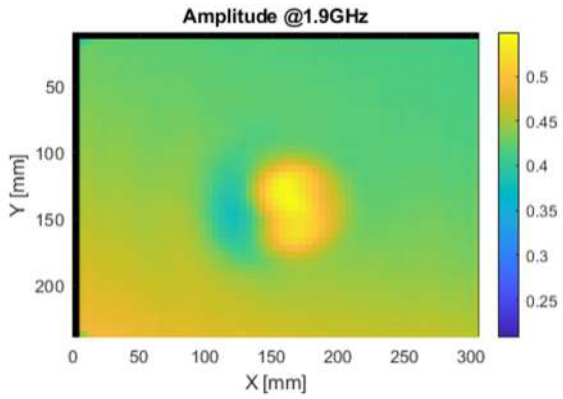
From top left, clockwise: setup of experiment, testbed fabricated and filled with water, plastic box sizes



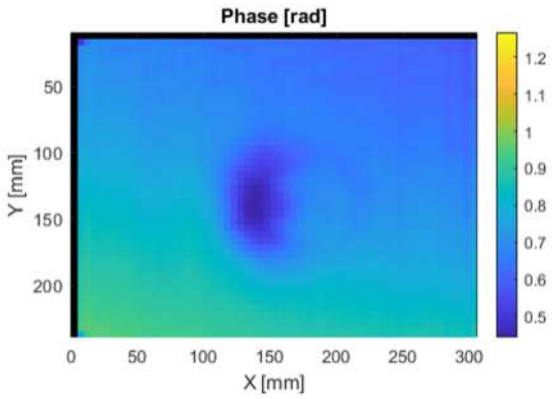
A reference target (plastic void candy box) of 7.5 cm diameter.



Acquisition in distilled water @ 20 °C



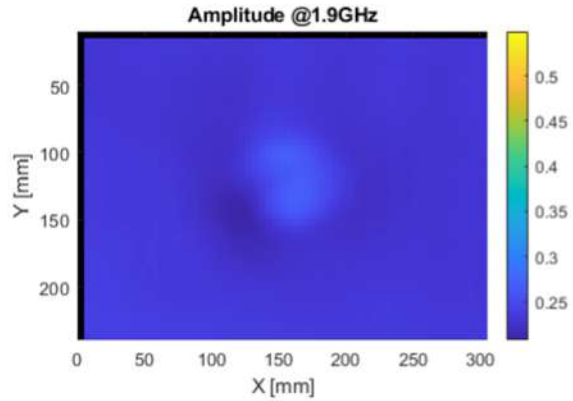
Dynamic: 0.16927[V]
Mean: 0.43934 [V]
Standard Dev.: 24.1535 [mV]



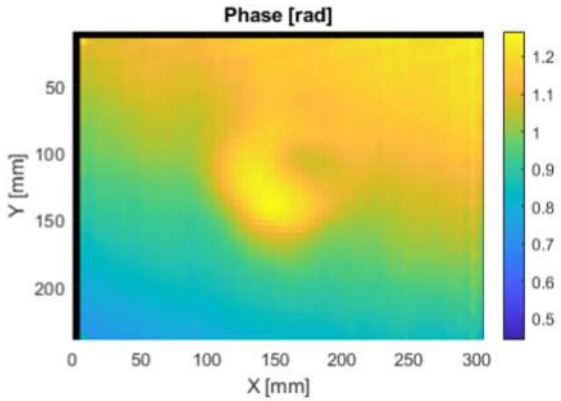
Dynamic: 0.51376 [RAD]
Mean: 0.73156 [RAD]
Variance: 0.098734 [RAD]

Reference image

Acquisition in salt water (12 g/l) @ 20 °C



Dynamic: 0.063809[V]
Mean: 0.23124 [V]
Standard Dev.: 7.3607 [mV]



Dynamic: 0.54963 [RAD]
Mean: 1.0269 [RAD]
Variance: 0.128 [RAD]

Reference image

5

CONCLUSIONS

- We have demonstrated the design of a testbed for validation of a holographic RADAR system based on a plastic box filled with water.
- Water filled testbed is easy to fabricate, versatile in terms of the dielectric permittivity and conductivity.
- The measurement conditions are repeatable.

These first experiments confirm what is expected from the simulation. In the future we will conduct measurements to assess whether the measured values are consistent with the values obtained with modeling. The data thus obtained will also be useful for validating the holographic inversion algorithms.

THANK YOU FOR ATTENTION

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PhD. Student Luca Bossi – XXXIV Cycle

DNFO – Department of Information Engineering
USCND Laboratory
University of Florence – Florence, Italy

Mail: l.bossi@unifi.it