T&A SURVEY

TISA®

2D Borehole Radar

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TISA 2D Borehole Radar

TISA 2D Borehole Radar (BHR) is the geophysicist's choice for a simple, safe and clear way to receive data about the subsurface.

What makes TISA 2D unique is its reflection mode of operation where both antennas are located in a single tool inside the same borehole. The transmitted pulses are reflected by a nearby object and detected by the receiver antenna. The depth of the antenna system and the measured pulse two-way travel time defines the 2D position of the detected object.

The TISA 2D tool can be used in various shallow and deep underground applications where traditional surface radar cannot penetrate and is beyond their range. Dense urban environments present different challenges than open unobstructed areas where ground penetrating radar (GPR) is most often used. What if the buried object is under a concrete slab or under a building? TISA 2D BHR has the ability to aid the search and the recovery of such targets. When there is a contrast of electromagnetic properties between the target and its surrounding, it is possible to isolate and precisely observe where the buried object is located.

The TISA 2D tool has been successfully used in a wide range of projects from sinkhole detection, locating concrete walls and unexploded ordnance (UXO). TISA 2D is most often used in Europe in identifying and aiding in the recovery of WWII aerial bombs. UXO detection is limited in North America, but it does demonstrate the tool's ability to find metal objects like underground storage tanks (UST) or buried steel drums.

Transillumination mode measurements, with transmitting and receiving antennas in two different boreholes, extends the area of application. Please contact our sales team to learn more about this option.

Collected data is displayed, processed and interpreted using T&A's property software TISAMap, providing unsurpassed accuracy and clarity of the results.

Is TISA 2D the Right Instrument for Your Application?

TISA 2D is a borehole radar system and as such belongs to the category of the ground penetrating radar (GPR) systems. Radar is a geophysical method which is used in situations when complementary information from an independent method is required or where other techniques are simply inadequate. GPR can be deployed in conjunction with other geophysical methods such as magnetics, electromagnetics, seismic and electrical resistivity. To decide on which circumstances to use GPR, it is essential to understand its working principals and its advantages in specific situations.

GPR systems use a transmitter antenna to send electromagnetic (EM) pulses into the subsurface and a receiver antenna to acquire the signal that is reflected from the ground. The reflected EM wave contains information about the electromagnetic properties of the penetrated medium, such as electrical conductivity and permittivity. Stated differently, GPR reacts in soil layers or with objects which have a significant contrast in electromagnetic properties. Fortunately many materials such as water, air, metals and most non-metals differ in their electromagnetic properties from the materials where they are embedded and are therefore potentially detectable with GPR.

Like all geophysical methods, radar has its limitations. The main concerns for GPR measurements are soil conditions with high conductivity. In these situations, radar signals are strongly attenuated and the so called "penetration depth" decreases.

Advantages of GPR

Every geophysical method has its range of applications and specific projects where it works more or less optimal. In general it is important to note that the following advantages are characteristic of GPR measurements in comparison with other methods.

- **High Resolution** – GPR is the geophysical measuring method, which provides the highest resolution. Often resolutions within a few decimeters are obtained.
- **Fast Data Acquisition** – Compared to other geophysical methods the data acquisition time of GPR is very short. This allows for an efficient and cost reducing measuring campaign.
- **Precise Localization of Objects** – The combination of the high resolution nature of GPR together with the accurate depth control of the TISA 2D probe gives a high precision in the location of any buried object. The localization precision is often superior when compared to other geophysical methods.
- **Sensitive to Object Dimensions** – GPR is an EM wave based method and as such it is sensitive to the surface area of an object perpendicular to the wave propagation direction. This allows in many situations to relate the measured data directly to the dimensions of an object in the subsurface.

The TISA Difference

TISA 2D differs from traditional surface GPR systems as it is deployed inside a borehole directly in the medium of investigation. This distinct setup allows for data acquisition from much greater depth as its measuring depth is essentially limited only by the borehole depth. The second advantage comes from the fact that TISA 2D is probing the subsurface in a perpendicular plane to the borehole direction. A vertical borehole results in a horizontal plane of investigation, which allows the study of the subsurface directly below surface constructions such as buildings. With classical surface GPR systems these areas cannot be measured and would have to be disregarded by a geotechnical survey.

TISA Applications

Given the working principle of GPR with its advantages and limitations, the most common applications of TISA 2D are listed below. This list is far from complete and any situation where subsurface structures exist with different electromagnetic properties to their surroundings pose a potential opportunity for the use of TISA 2D.

Construction Engineering

- Foundation detection
- Underground storage tank (UST) detection
- Deep buried metal and non-metal object detection
- Inspection of concrete shafts
- Sinkhole detection
- Cavities and voids detection
- Karst/Fracture detection
- Jetgrout column diameter determination

Mining

- Early detection of hazardous rock formations
- Water pocket detection
- Fracture network detection
- Ore body delineation and reserve estimations

Military

- Unexploded ordnance (UXO) detection
- Military tunnel and bunker detection

Configuration

TISA 2D BHR comes complete with:

1. Downhole Receiver Antenna
2. Downhole Transmitter Unit Including Pulse Generator, Battery and Transmitter Antenna
3. Uphole Console + Battery
4. Uphole Receiver Electronics
5. Cabling to/from Downhole Transmitter Unit and Receiver Antenna

Specifications

Console Dimensions	9.4 x 7.9 x 3.5 in (24 x 20 x 9 cm)
Console Weight	5.3 lbs (2.4 kg)
Probe Diameter	2.4 in (6 cm)
Probe Length	6.9 ft (2.1 m)
Probe Weight	20.1 lbs (9.1 kg)
Cable Weight	0.22 lbs/ft (0.32 kg/m)
Antenna Center Frequency	200 MHz*
Maximum Depth of Survey	100 ft (30.5 m) Below Surface*
Temperature Range	-10 to +40 °C
Power Consumption	Full Day Survey with one Standard Battery Set
Required Borehole Diameter	3.2 in (8 cm) or Larger. Non-Metal Casing Required in Non-Consolidated Formations

*Please contact our sales team to learn more about the possibilities of using different antenna frequencies as well as to extend the maximum measurement depth.

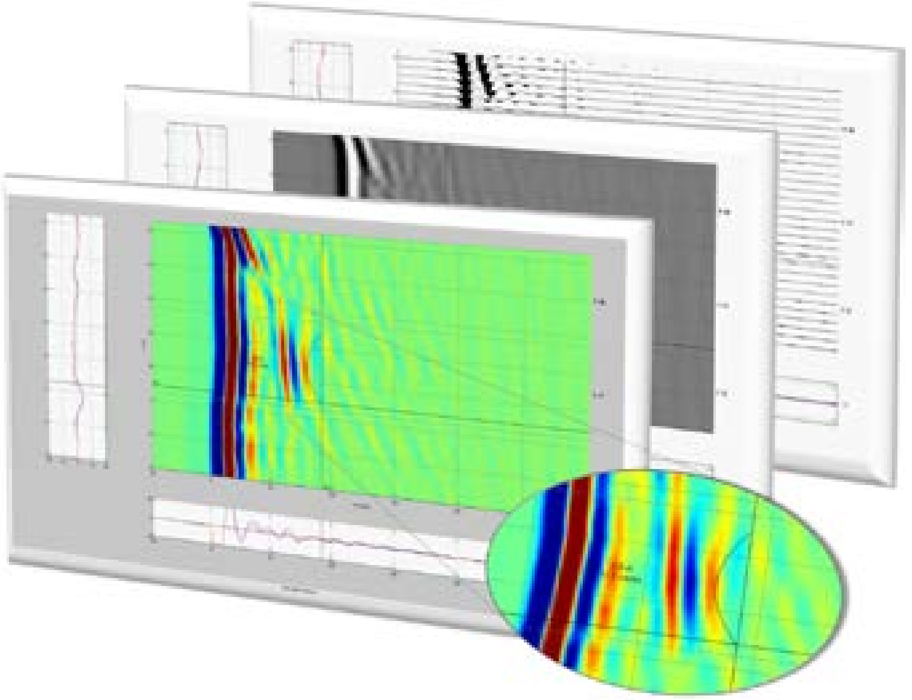
Set-up

The total set-up procedure (hardware and software) takes approximately 15-20 minutes. From the System Setup Menu in the console, the operator sets the GPR parameters such as antenna frequency, recording time window and imaging mode. The Survey Menu allows insertion of the survey parameters such as the start depth, measuring intervals and the format of the units. In the Acquisition Control the different possible recording modes such as trigger based, recording delay or GPS input are set. After finishing the parameter set-up, the data acquisition is started in the Run Menu.

TISAMap Software

TISAMap is the specifically designed software package to display, process and interpret radar data recorded with TISA 2D. Besides standard processing steps such as Dewow and AGC gain application, TISAMap allows to subdivide the recorded depth interval into user defined horizontal layers. This feature is especially useful for vertically recorded radar profiles which are often affected by changing soil conditions with depth. By insertion of several layers the user has the ability to apply individual processing parameters to the different soil layers (e.g. clayish vs. sandy layers).

Interactive hyperbola fitting allows the estimation of the ground velocity and hence the permittivity for each layer. Subsequently, a time-distance conversion can be applied to locate a detected object in space. TISAMap allows for an efficient and state of the art processing, interpretation and display of all your recorded borehole data.



Display

- Grey-scale
- Color-scale
- Wiggle Plot
- Frequency Domain
- Interpolated Shading

Processing

- Dewow
- Background Subtraction
- Static Correction
- Various Gain Options
- Band Pass Filter
- Polarity Flip

Interpretation

- Survey Parameter Editing
- Interactive Velocity Analysis
- Time-Distance Conversion
- Data Export

Project: Sinkhole Detection

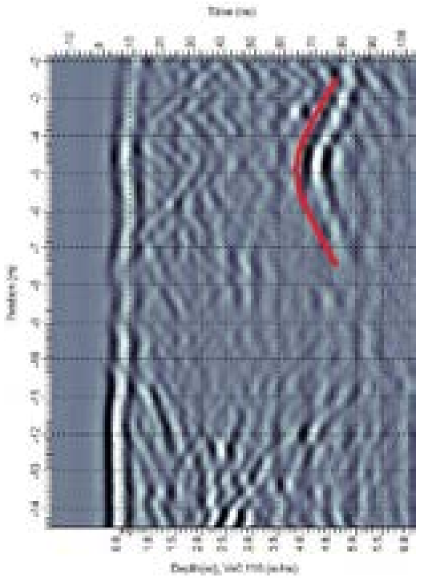
A sinkhole of unknown origin was initially detected at the exit of a parking lot adjacent to an office building. The sinkhole was filled and the parking lot resurfaced. Two months later the surface of the parking lot collapsed again. The second sinkhole was larger than the first, measuring 5 to 6 meters in depth. The parking garage has two levels and there was an immediate safety concern. There had never been any problems in the twenty year history at this business location. An immediate investigation to locate the origin of the sinkhole was conducted.

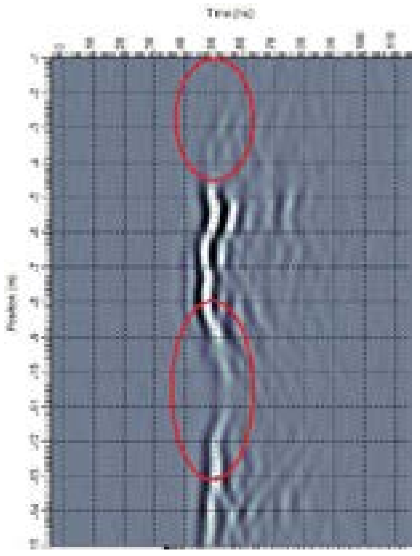
Process

The goal of the field investigation was to discover the cause of the subsidence in the research area using the TISA 2D geophysical measuring technique. It was suspected that either an old underground water basin or sewerage leak was the cause. Reflection measurements were made from boreholes A, B, and C, as well as three zero-offset cross-hole measurements between AB, AC and BC at a maximum depth of 15 meters below the surface.

Conclusion

The wave velocity in the medium was determined with a Tx-Rx variable direct wave measurement inside borehole C and was found to be 11.6 cm/ns. The two images below show data acquired in reflection and transillumination modes. In the reflection data (left graphic) an obstacle in 4-5 m depth was identified, which could be related to a 5 m deep pit dug close to the survey area. The transillumination data set (right graphic) shows two sections where the direct wave has a weaker amplitude. The higher one is a result of the same pit which is located between the two measuring boreholes and therefore reduces the amount of recorded energy in this depth range. The second reduction of energy is found in a depth interval of 9.5 to 11.8 meter below the surface. This reduction of amplitude is associated with a later arrival time of the direct wave. Such a later arrival time indicates the presence of a low velocity medium like a water filled void between boreholes A and B. This could explain the subsidence of the surface encountered at this location.





Project: Berlin UXO Detection

TISA 2D is an excellent alternative to magnetometers that are typically used in the detection of World War II UXO's. There are two main advantages of TISA 2D over traditional magnetometer measurements:

1. Larger detection range from the borehole which means fewer boreholes are required.

1. TISA 2D enables to search underneath obstacles at the surface, such as buildings or metallic structures which would disturb the magnetometer readings.

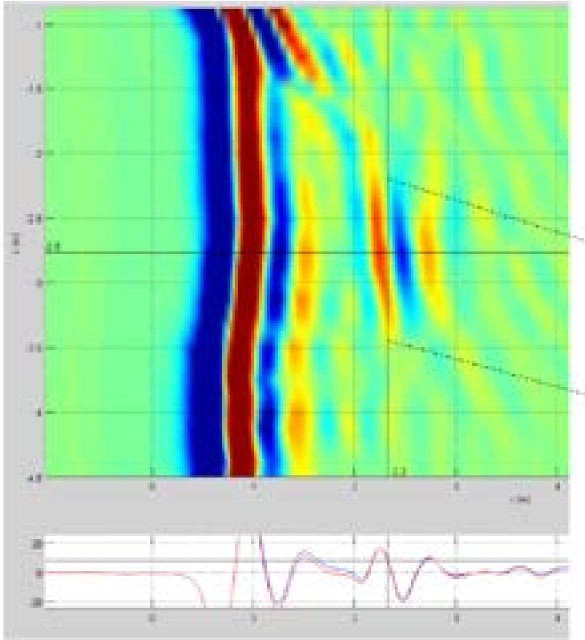
In an UXO detection project in the capital city of Germany reflection data from TISA 2D was acquired to help with the investigation of possible UXO locations.

Process

Several boreholes were drilled around different target locations spread over the whole city. TISA 2D reflection measurements were conducted to a maximum depth of around 7 meters below the surface. The soil conditions were described as ranging from dry sands to loamy sand in one target location.

Conclusion

In the data set below a strong reflection is visible in a depth range of 2.5 to 3.5 m below the surface. The radial distance of the reflection from the borehole is around 2.3 meters. Excavation of the object showed the presence of a 250 Kg aerial bomb. TISA 2D is a valuable addition to the typically used suite of detecting tools for UXO's.



250 Kg aerial bomb in TISA 2D data

Same object during recovery

Project: Finding Construction Piles at a Shipyard

The Netherlands is very active in shipbuilding. Major shipyards are gathered around the mouths of the great rivers and in the large ports of the country. The reworking of the land by the sea and intensive agriculture have made the soil very heterogeneous, wiping out previous building history. In addition, many UXO's ended on the Dutch ports during World War II.

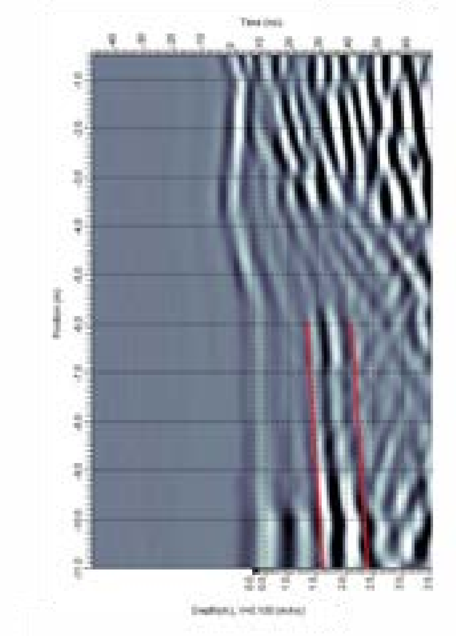
T&A Survey investigated for a client as to whether a target site for a future shipyard (inset figure) was loaded with old construction piles or with UXO's. This was done to prevent large excavation costs for false readings of possible UXO's. Given the anticipated depth, dimensions and material of the two types of objects, TISA 2D was chosen to tell the objects apart.

Process

Surface magnetometry was used first to define the regions of interest and to define the target locations for TISA 2D. Several boreholes around each target locations were drilled and TISA 2D deployed to distinguish the two types of objects. The soil conditions on the survey site were described as intervals of dry sand and clay.

Conclusion

An example of an imaged pile can be seen in the figure below. The elongated reflection in a depth range of 6-11 meters below the surface indicates the presence of a pile, rather than a point shaped UXO. With the results of this survey TISA 2D could explain the nature of the magnetic disturbances and prevent the need for an expensive UXO excavation. TISA 2D is the right tool for these kinds of jobs, as it is highly sensitive to planar reflectors like piles and pillars.



The elongated reflection with a length of several meters indicates the presence of a pile

Project: Concrete Wall Location

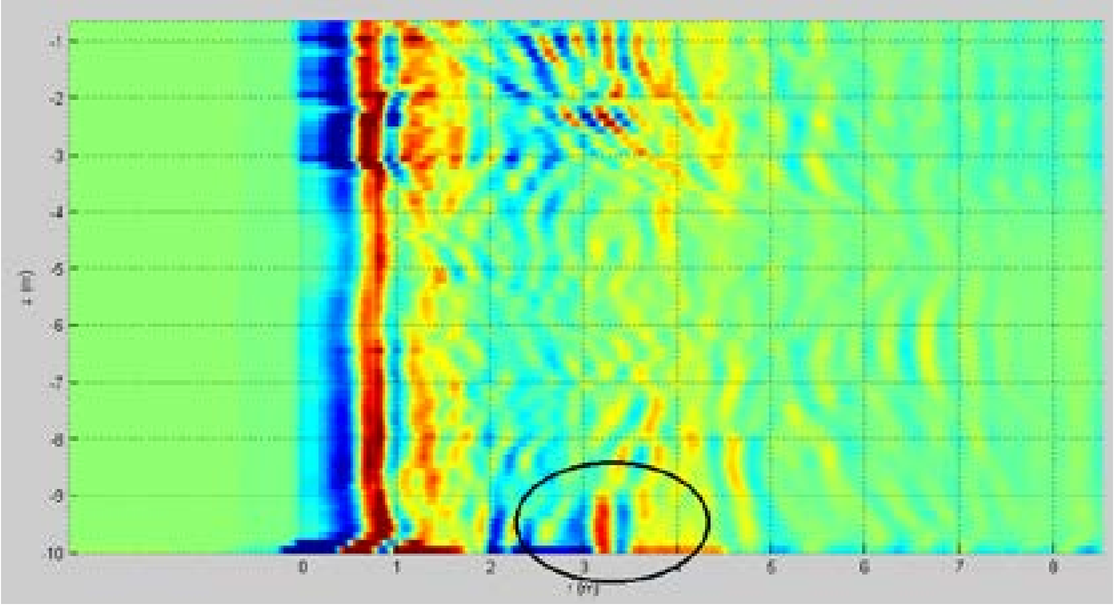
Structural remnants of World War II (WWII) infrastructure even today still presents problems. A new construction project in the Dutch seaside town of Noordwijk was plagued by not knowing the precise location of the remaining tunnels adjacent to an old WWII bunker. The new construction required the determination of the exact location of these tunnels to conduct precise steered drilling for a new underground power line.

Process

To assess the locations of the tunnel network, two boreholes were drilled to a maximum depth of 11 meter below the surface. One of the two boreholes, shown in the above photo, was located approximately 3 meters from the expected lateral position of the tunnel network. From both boreholes TISA 2D reflection data were acquired and subsequently interpreted for the location of buried tunnel structures.

Conclusion

One of the two data sets shows a relatively strong reflection in a depth interval of 9-10 m below the surface. With a calculated soil velocity of 13 cm/ns the lateral distance from the borehole was found to be around 3 meters. This reflection, as marked in the figure below, was interpreted as the top section of the adjacent tunnel network.



TISA 2D reflection data with the top part of the tunnel system indicated by the black

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Case Study: Detection of metal cylinders

Measurements

Detectability of metal cylinders with the TISA 2D radar system was tested in an experimental setup at a test site with three different boreholes. The soil type was silty sands, with a shallow groundwater table at a depth of 0.8 meters below the surface. Two different borehole configurations were used to test the detectability of the metal pipes.

1. A metal cylinder with a diameter of 130 mm and a length of 1 meter was placed inside a borehole. The test object was suspended at a depth of 5 meters below the surface. TISA 2D was deployed in a second borehole at a horizontal distance of 1.8 meters from the first borehole. This borehole allowed measurements down to a depth of 7 meters below the surface.

2. A bigger metal cylinder with a diameter of 200 mm and a length of 0.8 meters was placed inside a borehole. The test object was again suspended at a depth of 5 meters below the surface. TISA 2D was deployed in a second borehole at a horizontal distance of 2.9 meters from the first borehole. This borehole allowed measurements down to a depth of 8.4 meters below the surface.

Results

Figure 1 shows the recorded data in the above described configuration 1. The vertical axis of this figure shows the depth below surface level, starting at 0 meter in the upper left corner. The horizontal axis shows the arrival time of the reflected signal given in nanoseconds. The dataset shown in Figure 1 is corrected for the reflections of the nearby borehole. At an arrival time of 50 ns strong reflections are visible in a depth range of 4.5 to 5.5 meters. The hyperbolic reflection patterns are typical for an object with limited vertical extension, like the used test cylinder.

Figure 2 shows the data for measurement configuration 2, where the metal cylinder is placed in a horizontal distance of 2.9 meters from the measuring borehole. The presented data is processed in the same way as Figure 1 and shows a reflection hyperbola starting at an arrival time of 75 ns. Despite the 60 % larger distance between TISA 2D and the metal cylinder, the data clearly shows the reflection signature of the test object in around 5 meters depth.

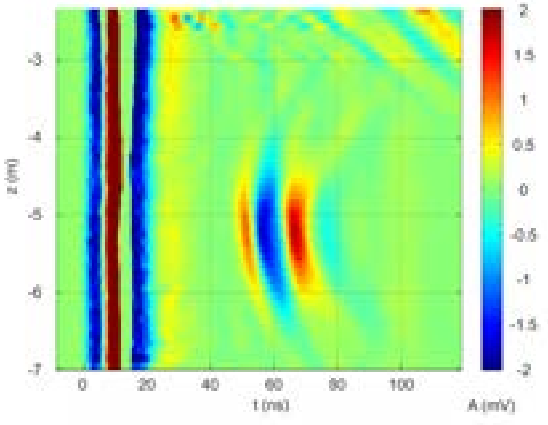

Figure 1

Reflection of a metal cylinder with 130 mm diameter in a distance of 1.8 meter from the borehole radar.

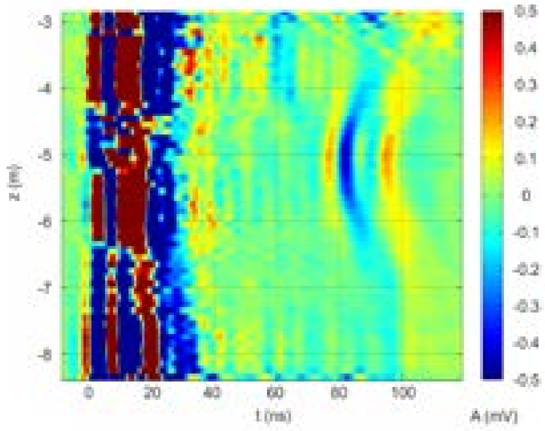

Figure 2

Reflection of a metal cylinder with 200 mm diameter in a distance of 2.9 meter from the borehole radar.

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