Mine-detection test facilities at TNO-FEL test location "Waalsdorp"

Jan Rhebergen and Peter Zwamborn
TNO Physics and Electronics Laboratory
PO Box 96864
2509 JG The Hague
The Netherlands

1. SUMMARY

As part of the TNO-FEL Ultra-Wide-Band Ground-Penetrating-Radar (UWB-GPR) project, a test facility for controlled GPR experiments was planned. Construction of this sand-box test facility has recently been completed. At the same site another test facility, for evaluating various commercial of the shelf (COTS) sensors for the Dutch humanitarian de-mining program HOM2000, has been realised. This article describes the test facilities themselves as well as the frame-work in which they were realised.

2. INTRODUCTION

In recent years the research into mine-detection systems at the TNO Physics and Electronics Laboratory (FEL) has increased substantially. Apart from establishing a firm knowledge base and experience through ambitious projects such as UWB-GPR, the TNO-FEL has also been actively involved with the Dutch ministery of defence's, HOM2000, humanitarian demining project. Both the TNO-FEL de-mining/mine-detection focus-program, of which UWB-GPR is a key component, and the involvement in the HOM2000 humanitarian program have spawned the need for good testing and experimenting facilities. Over the past year, two rather uniques facilities have been developed and completed. The first is a facility specifically for testing UWB-GPR systems and for data acquisition. The second is a multi-sensor mine-detection test facility for evaluating systems under controlled but realistic conditions.

3. TESTING FACILITY FOR CONTROLLED UWB-GPR EXPERIMENTS

In this section we will describe the development of the first test facility which has been constructed at TNO-FEL for carrying out controlled experiments with a ground-penetrating radar system. This test facility has been developed in cooperation with the Delft University of Technology, where a parallel project in the area of ground-penetrating radar is being carried out. One of the principal goals was to perform the neccesarry analytical and design work to support the construction of an experimental facility, where target objects can be buried in a sand medium and illuminated by an ultra-wideband electromagnetic field. The sand medium should be a realistic, yet controlled environment in which objects of interest can be buried. The electromagnetic field scattered by the buried object has to be observed and diagnosed for the benefit of developing an computer database containing the responses of a large number of objects (i.e.landmines etc.)

3.1 COOPERATION WITH DELFT UNIVERSITY OF TECHNOLOGY

The Delft University of Technology, is engaged in a ground-penetrating radar project called "Improved ground-penetrating radar technology". This project started in January 1996 and will end in December 1999. It is supported by the Dutch Technology Foundation STW, (Stichting voor de Technische Wetenschappen) under contract number DMB55.3649. The objective of the project is the development of a new electromagnetic technique for the geological characterisation of the shallow subsurface of the earth. In this particular STW project four different parts are distinguished.

- The first part of the project comprises the design and realization of a transportable ground-penetrating radar system. This subproject concentrates on the development of antennas in a frequency band that ranges from 200 MHz up to 1 GHz. It consists of a transmitting and receiving device, in which time-domain signals (nanosecond pulses) are generated, received and processed.
- The second part of the project contains the construction of a full-size testing site in order to perform controlled experiments with the ground-penetrating radar system.
- The third part of the project comprises the development of a fast and accurate electromagnetic modeling method. This modeling method provides the basis for the electromagnetic imaging and furthermore provides a means to check the performance of a field measurement over a known geological situation. Adequate measurements at the testing site should provide the input data.
- The final part of the project comprises the development of practical strategies and processing algorithms with the final goal, the realization of the actual image. Not only the test site will be used, also more realistic geological sites will be investigated and a compared to existing ground-penetrating tools and conventional techniques.

The development of the new ground-penetrating radar system at Delft University of Technology will take place in a cooperation between the International Research Center for Telecommunications Transmission and Radar (IRCTR) and the Centre for Technical Geoscience (CTG), research school. IRCTR is hosted by the Faculty of Electrical Engineering and is directed by Prof. Dr. L.P. Ligthart. CTG is a cooperation between the Laboratory of Electromagnetic Research of the Faculty of Electrical Engineering (directed by Prof. Dr. P.M. van den Berg) and the section Technical Geophysics of the

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Faculty of Mining and Petroleum Engineering (directed by Prof. Dr. J.T. Fokkema). Prof. Dr. J.T. Fokkema is also the project leader of the STW project and as such the point of contact for TNO FEL.
The third part of the STW project (the development of a electromagnetic modeling method) is partly sponsored by TNO-FEL. TNO-FEL has awarded a research grant for a post-doc to participate in the project for one year. The second part of the STW project, which is the construction of the test facility, is performed in cooperation with the Electromagnetics Section of TNO FEL, since such a testing facility was also needed for the another TNO FEL project namely,UWB GPR. The test facility was built on the premisses of TNO FEL (completed July 1997) and will be used for both projects. It is clear that a cooperative effort in the development of such a testing facility has many advantages, which not only includes the sharing of the financial burden.
The project at Delft University of Technology sponsored by STW and the UWB-GPR project at TNO-FEL sponsored by the Netherlands Army are complementary; knowledge and experience that is gained in the projects can be exchanged as well as for example measurement data. Both projects differ in signal processing; the STW project aims at detection only; characterization or classification is postponed until the imaging step can be satisfactorily performed. TNO-FEL aims at the exploitation of the singularity expansion method to perform detection ***and*** classification. Furthermore, since a university is not a defence research institution, the goal of their ground-penetrating radar system is directed towards civil applications, like engineering activities and environmental and archeological investigations. Examples are the detection of cables and pipes, the determination of the stability of dikes, the detection of leakage and the and the spreading of (in)organic pollution and so on, and not primarily landmines.

3.2 CONSTRUCTION OF THE TESTING FACILITY

Within the framework of the cooperation with the Delft University of Technology, a full size testing facility has been designed and constructed on the premisses of TNO FEL, in order to perform controlled radar experiments. The testing facility has been completed in July 1997. It is located in the dunes directly behind the TNO-FEL building, on a location that was formerly known as the "EMP site" where electromagnetic pulse experiments were once carried out.

The test facility consists of a buried wooden box. The dimensions of this box are 10 m x 10 m wide and 3 m deep (300 cubic meters). The box has been fully dug in into the ground, hence the bottom of the box located three meters below the ground level. Special care has been taken not to use any metal parts in the construction of the box or in the vicinity thereof. The sandbox is filled with clean (homogeneous) river sand from the (Dutch) Caland canal. In order to keep the condition of the sand in the box optimal and to prevent pollutions from the outside (for example ground water) entering the box, a drainage system was installed and the inside of the box was covered with a watertight plastic lining. To prevent the weather from influencing the test conditions and to protect the measuring equipment, a large tent covers the entire site. Additionally, a wooden shed is available for storage of personal computers and measurement equipment. While filling the box with sand, special care was taken to get a homogeneous profile. Current tests indicate that this was not entirely successful but should be good enough to work with. Later on in this study we will probably empty the box and refill the box with a different ground composition. To facilitate the measurement of EM transmissions into the ground a square PVC tube running from the surface of one side to the bottom of the other side has been installed about one meter from the edge of the sandbox.

On the next page we show a small photo gallery which shows the progress in the construction of the UWB-GPR test facility.

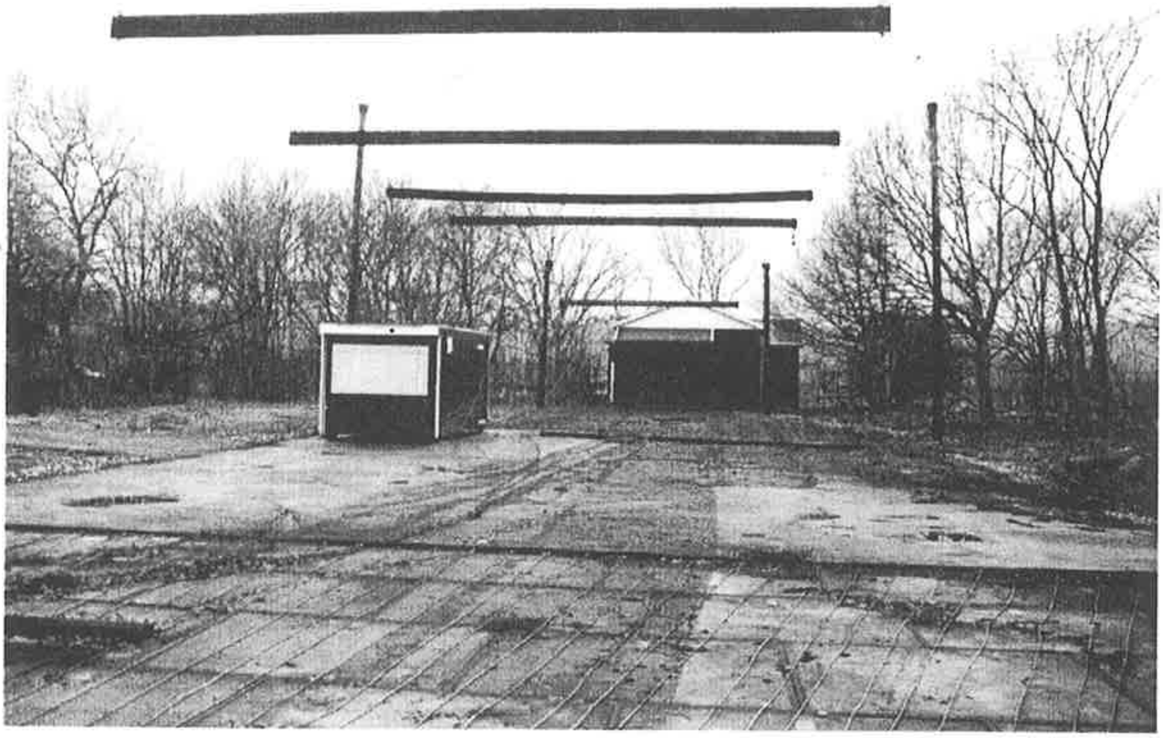

Figure 3.1 Old situation. Location of the test site in the dunes near TNO-FEL. This location was formerly known as "EMP site" where electromagnetic pulse experiments were carried out.

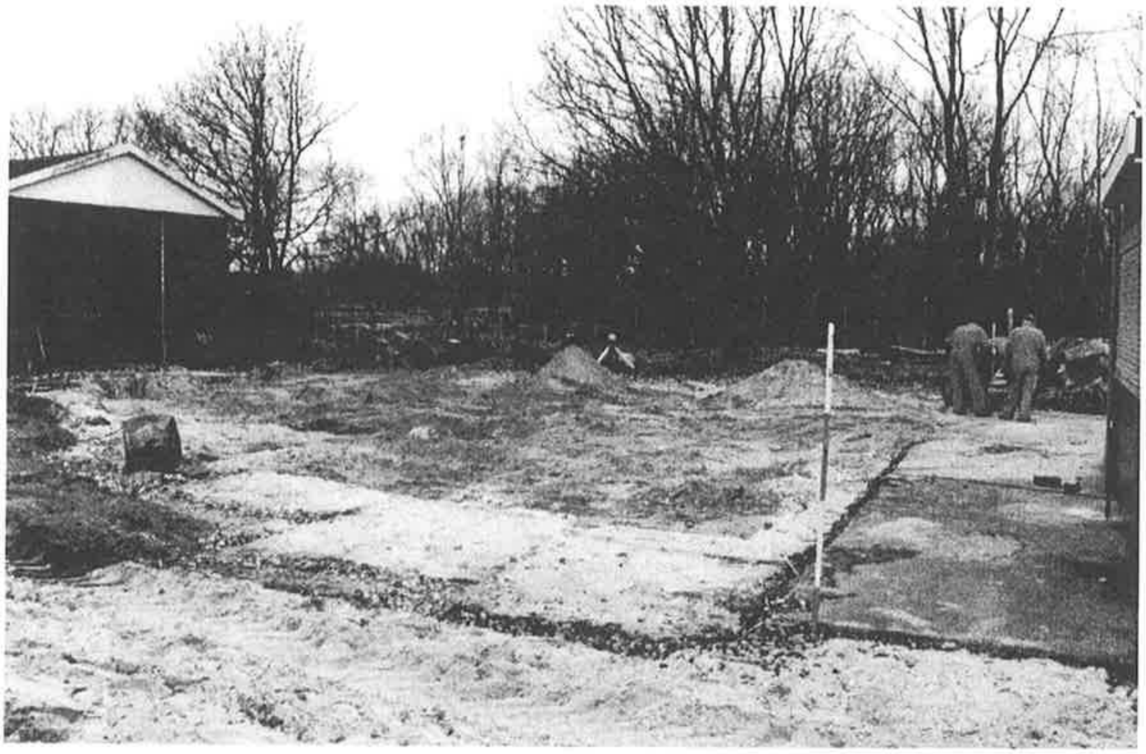

Figure 3.2 Start of the activities. Dismantling of the EMP site. The location is being prepared for construction activities. In the background the (green) wooden storage shed, where the equipment is kept, is visible.

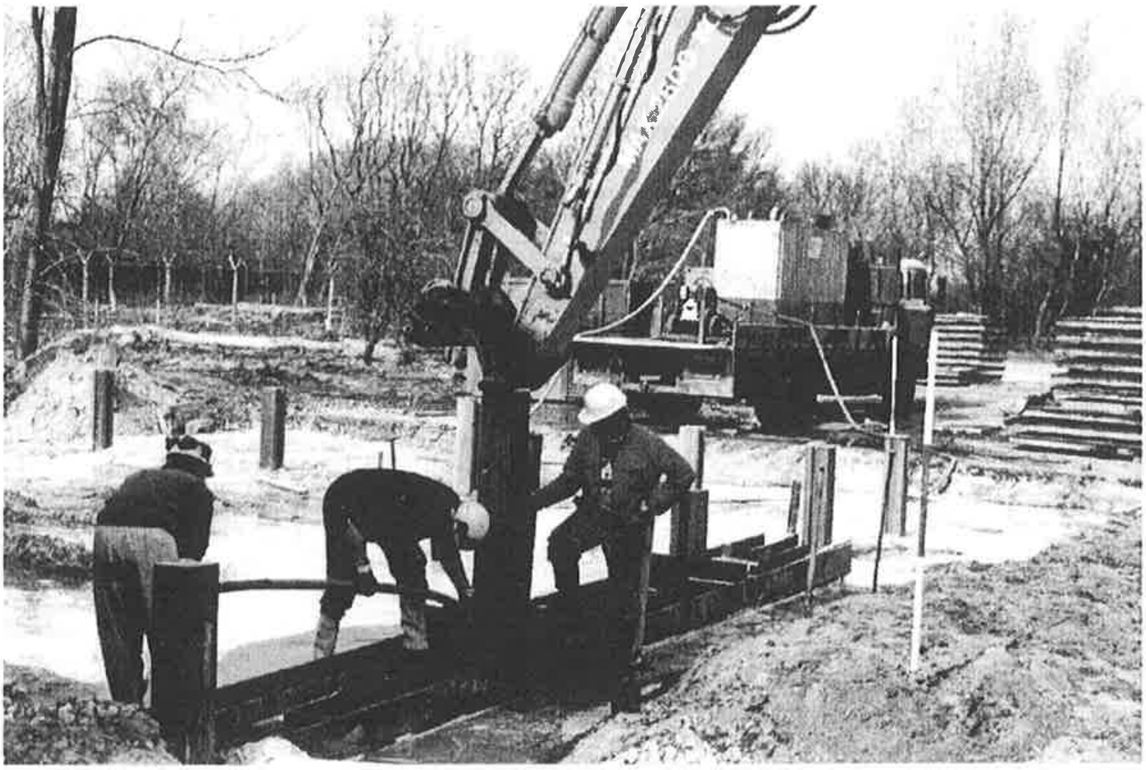

Figure 3.3 Start of the construction of the wooden box. First, some wooden piles are driven into the ground. The piles are used as a framework to strengthen the construction of the walls.

Figure 3.4 Construction of the walls of the box using wooden beams. The wood that was used to construct the box was tropical hardwood from Central Africa.

Figure 3.5 While the walls of the box were being constructed, the soil at the location was removed simultaneously.

Figure 3.6 Last part of the digging phase. The wooden box is almost finished.

Figure 3.7 Closing of the wooden box.

Figure 3.8 The inside of the box is covered with a watertight plastic lining in order to prevent pollution from the outside (for example ground water) entering the box.

Figure 3.9 Installation of the drainage system in the wooden box.

Figure 3.10 Overview photo. The wooden box is now ready to be filled with sand.

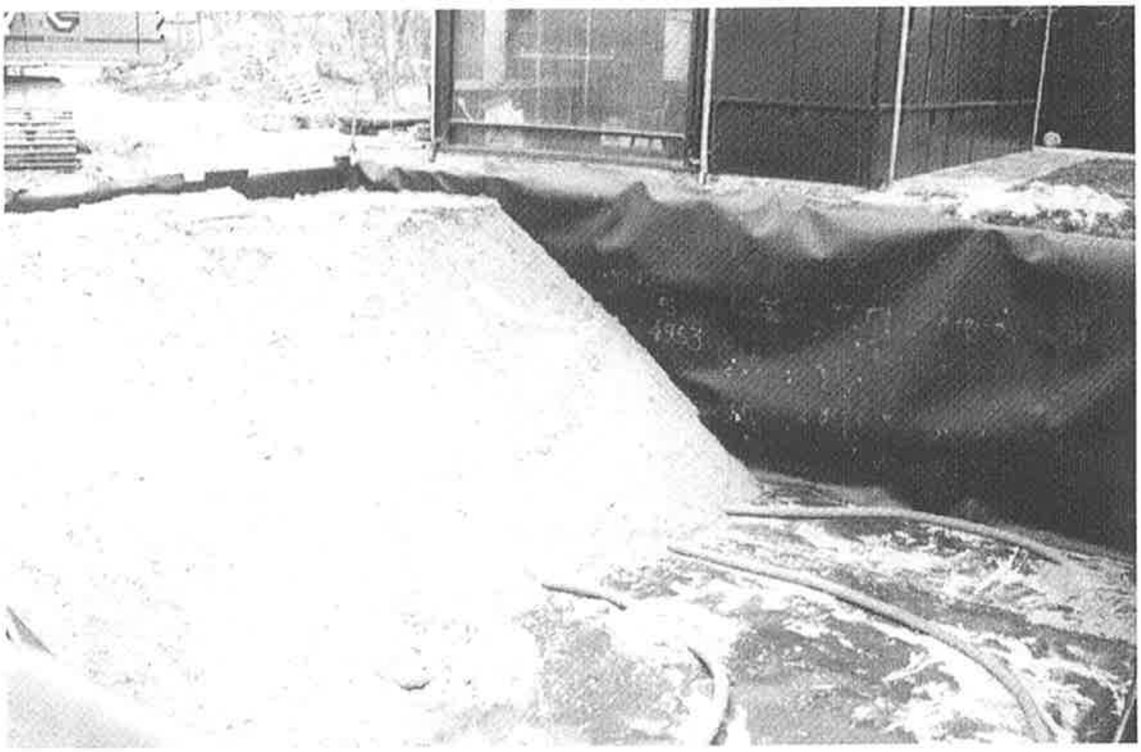

Figure 3.11 The wooden box is filled with clean (homogeneous) sand.

Figure 3.12 Installation of a square PVC tube running from the surface of one side to the bottom of the other side of the box, facilitating measurements of EM transmissions into the ground.

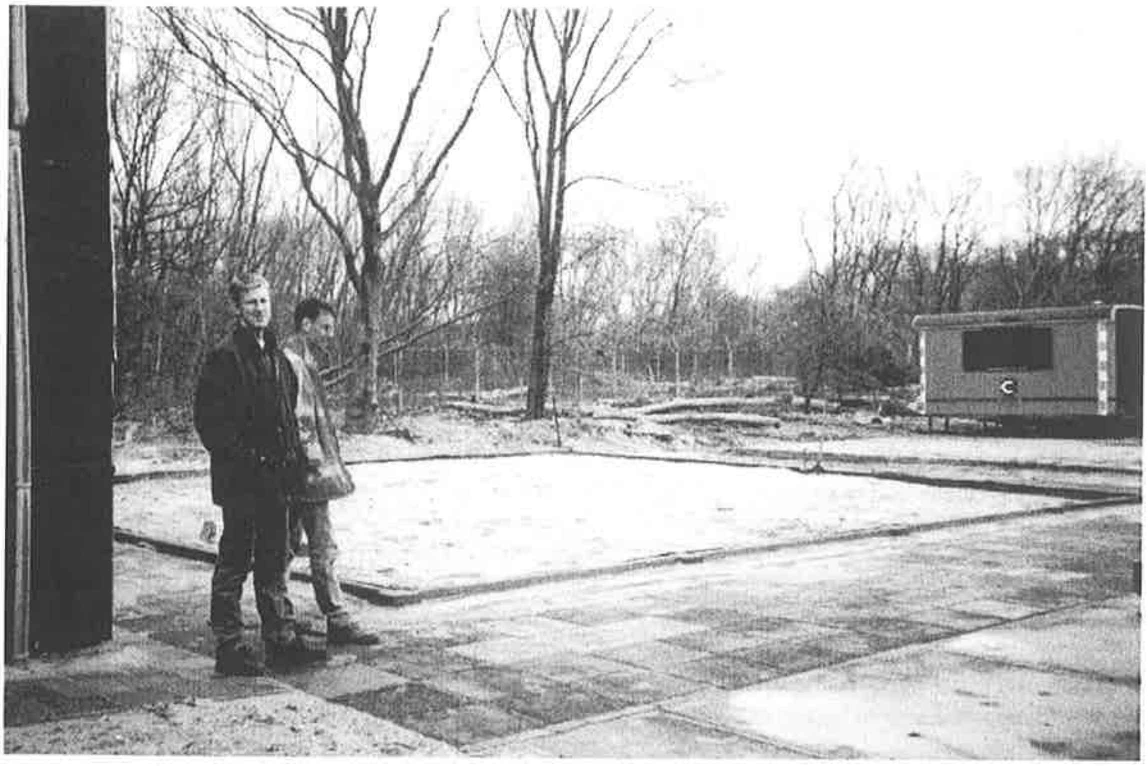

Figure 3.13 The wooden box is now ready to be used for ground-penetrating radar experiments. Presently the whole sandbox is covered by a huge tent.

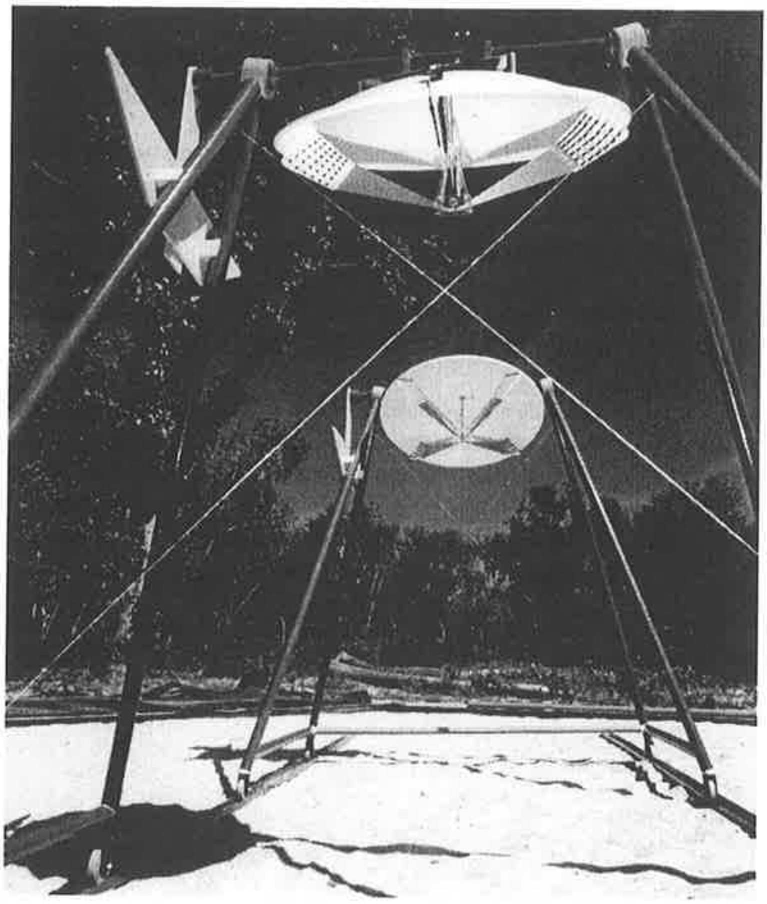

Figure 3.14 The TNO-FEL impulse radiating antennas (IRA) constructed as part of the UWB-GPR systems.

4. HOM2000 TEST FACILITY

The other testfacility on the TNO test-site "Waalsdorp" is the HOM2000 test facility. The main purpose of this facility is the testing of commercial off the shelf (COTS) sensors that can be used for, and/or improved for mine-detection. Currently four sensor type are evaluated. Metal detectors, thermal infrared imaging detectors, and ground penetrating radars. For each sensor type, four systems are being tested

4.1 CONTRUCTION

The HOM2000 test facility consists of six test lanes. Each lane has a length of 10m, width of 3m and a depth of 1.5m. Every lane contains a different kind of soil representative of soil found in actual minefield locations. The kinds of soil used are, sand, clay, peat, soil with a high iron content, forrest soil, and rocky soil.

The test facility was constructed in such a way as to minimize external influences. No metal components are allowed inside a zone of 5m around the whole test-rig. Of course the test lanes themselves were also constructed without the use of any metal whatsoever. The facility was constructed along a north-south axis so that infra-red sensors would not have to take measurements in their own shadow. A groundwater level management system was also installed to be able to keep the groundwater table as a constant level. To facilitate accurate positioning of the sensors a non-metal measurement platform was designed and installed.

4.2 MEASUREMENT PLATFORM

The measurement platform is basically a big 10m long pvc/glassfibre bridge (tubular). Wheels on either end of the bridge are running on rails located at the head and foot of the test lanes. In this way the whole bridge can be moved over one of the test lanes. Once in position the bridge can be locked into place by a nylon bolt which fits in one of a series of holes every 0.05m. The sensor is mounted on a small belt driven trolley which is running on tracks over the full length of the bridge. The trolley has a small platform with mechanical adaptors to facilitate the mounting of the different sensors. At the end of the bridge, just outside the 5m metal-free zone, an electro-motor is connected to the belt pulling the trolley along the bridge. The maximum speed of the trolley is about 10m/minute. Braking is gentle but an emergency brake will stop the trolley abruptly in case it is needed.

To be able to record the position of the sensor acurately a laser distance meter is mounted on the far side of the bridge. The laser beam is reflected off a reflector mounted on the trolley and an accurate position reading and time-stamp is registered so many times per second. This way an accurate record of the position of the sensor is available for each sensor.

4.3 SURROGATE LAND-MINES

Inside every test-lane a number of surrogate land-mines and potential false alarms are buried at different locations and depths. These landmines are representative of what is typical in a real minefield. The emphasis however is mainly on anti-personel mines although some anti-tankmines are also burried (and of course a couple of false targets were also put in place). Control of the whole test-site and testlanes is quite strict as not to disturb the measurement conditions. Not only this but also security is an important reason to impose strict access control.

Once buried, the mines will not be dug up again. In fact a certain time (months!) has to be allowed to let the mines settle in the ground because it takes quite a while before the ground disturbance created when burrying the mines is deminished. To be able to do some exprimenting a small area of each testlane was set aside. This area can be used to burry sensors or reference objects. To be able to determine the charactersitics of the sensor with respect to "virgin" soil each test-lane also contains a small areas devoid of any surrogate landmines or false targets.

The construction of the surrogate landmines was done is such a was as to optimise it's resemblance to actual live mines. The resemblance to real mines is not just visual but care was also take to use materials whose electromagnetic and thermal properties closely match those of actual landmines. Details of the construction are not included here but could under certain conditions (constrains) be made available to others.

The following pictures show the construction of the measurement platform. In the picture you can see the antenna array and tick-wheel of a commercial GPR system which is mounted on the platform. For actual measurements the tick-wheel interface will be connected to the output of the laser position indicator.

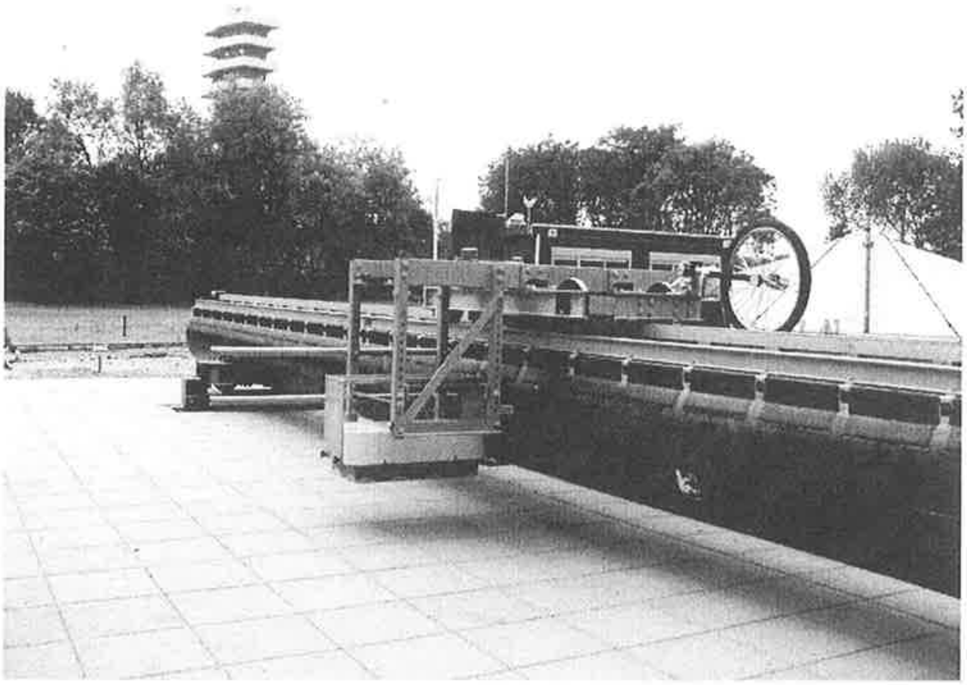

Figure 4.1 A view of the HOM2000 measurement platform. In the background the tent covering the UWB-GPR test facility can be seen. In the distance one notices the TNO-FEL radar tower.

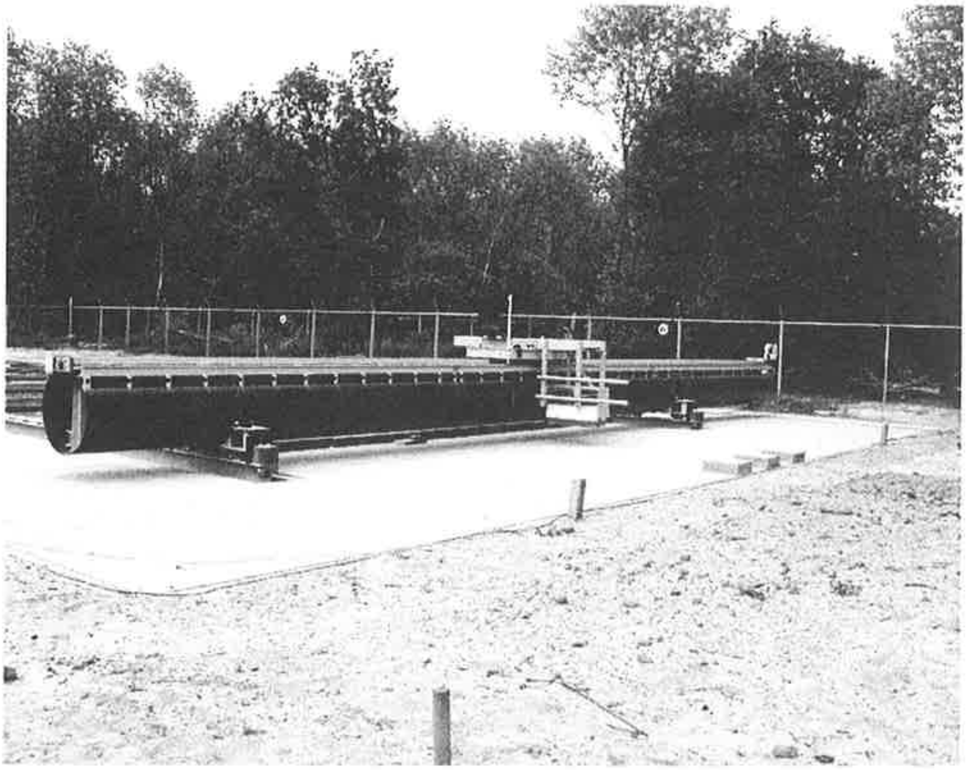

Figure 4.2 A view in the opposite (northerly) direction. The test lanes are just about visible. Due to the sensitive nature of the test facility more detailed pictures are not allowed.