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SYSTEMATIC TEST & EVALUATION OF METAL DETECTORS (STEMD)

INTERIM REPORT FIELD TRIAL MOZAMBIQUE

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INSTITUTE FOR THE PROTECTION AND SECURITY OF THE CITIZEN

SENSORS RADAR TECHNOLOGIES AND CYBERSECURITY UNIT

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Systematic Test & Evaluation of Metal Detectors (STEMD)
Interim Report Field Trial Mozambique

EUROPEAN COMMISSION
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This second edition contains corrections to Table 8.1 and Table 8.31 and clarified text on on page 98. Many thanks to Dr Yann Yvinec of the Royal Military Academy of Belgium whose sharp eye detected the errors.

List of abbreviations

ADP	Accelerated Demining Programme
AP	Anti-Personnel Mine
AT	Anti-Tank Mine
BAM	Bundesanstalt für Materialforschung und -prüfung
CEN	Comité Européen de Normalisation
CSIR	Council of Scientific and Industrial Research
CWA	CEN Workshop Agreement
EC	European Commission
FRELIMO	Frente de Libertação de Moçambique
GICHD	Geneva International Centre for Humanitarian Demining
GC	Ground compensation
GRH	Ground Reference Height
IND	Instituto Nacional de Desminagem
IPPTC	International Pilot Project for Technology Co-operation
ITEP	International Test and Evaluation Program
ITOP	International Test Operation Procedures
JRC	Joint Research Centre
L1	Lane 1, or other numbers indicate the number of test lane
MD	Metal detector
PARPA	Plano de Acção para a Redução da Pobreza Absoluta
RENAMO	Resistência Nacional Moçambicana
RSA	Republic of South Africa
SHRIMT	Shanghai Research Institute of Microwave Technology
STEMD	Systematic Test & Evaluation of Metal Detectors

Systematic Test & Evaluation of Metal Detectors (STEMD)

Interim Report Field Trials Mozambique

1 Introduction

This report describes the second field trial of the STEMD project. The concept of STEMD is to conduct tests which are relevant to specific mine and UXO problems in different regions of the world. The project consists of laboratory tests, field trials and training of interested parties in testing methods. Lab tests are being carried out in the laboratories of the JRC Ispra. A trial in Southern Africa was planned from the outset. Mozambique was favoured because of previous experience and because of the existence of a dedicated training site with different types of soils and the availability of local test targets.
Some basic information from the STEMD "Interim Report Field Trial Laos" will be repeated so that this present report may be understood independently. For interested readers the Lao report is available at: http://serac.jrc.it/tethud/ of the JRC, and www.itep.ws ; homepages for test and evaluation in the area of humanitarian demining equipment.

2 Background

2.1 Systematic Test and Evaluation of Metal Detectors

A key milestone in metal detector evaluation was the International Pilot Project for Technology Co-operation (IPPTC) which was conducted from 1998 to 2000, producing a "consumer report" of the detectors available at the time.
The experiences of IPPTC and of those of other trials with international importance were subsequently integrated into CEN Workshop Agreement 14747:2003, henceforth referred to as CWA. This Agreement standardises test methods for both laboratory and field use, and summarises the practical experience and theoretical knowledge of a large number of deminers, engineers, managers, and manufacturers.

Between May and December 2003 an exercise to validate the CWA field trial methodology was conducted by the German Federal Materials Agency (BAM) with the collaboration of the JRC, the German Bundeswehr and the Croatian Mine Action Centre (CROMAC) (Mueller *et al* 2004). In addition to confirming the basic validity of the CWA methods, this project introduced improved techniques for test matrix design, statistical analysis and human-factor analysis which we adopted in the present trial.

STEMD can be regarded as a trial making use of the experience distilled into the CWA and giving an overview of the state of art of the current metal detector fleet. It provides scientifically sound data for the mine action centres and demining organisations and training in the use of CWA. It also provides the donors with information that allows a better understanding of detector performance under different field conditions. The collected data will be added to the catalogue on metal detectors published by GICHD.

2.2 The mine problem in Mozambique

Armed conflict between Portugal & FRELIMO in the 1960s was followed by conflict between the FRELIMO government and RENAMO from1974 until 1992.
During this period, AT and AP mines were widely used. Estimates range from 0.5 million to 2 million. Demining activities in Mozambique developed as follows:

1992: ceasefire signed
1992-95: UNOMOZ established first demining capacity. Commercial and international NGO's also started work.
1995: UN Accelerated Demining Programme (UNADP) was created under the umbrella of UNDP. Later renamed ADP, in Portuguese Programa Acelerado de Desminagem (PAD).
1996: first national mine action centre was established, Comissão Nacional de Desminagem (CND) set up, later renamed Instituto Nacional de Desminagem (IND)
1999: First Meeting of the State Parties to the Ottawa Convention, held in Maputo in May

The National Mine Action Strategy, developed by the Government of Mozambique within the current context, aims at the following main objectives and targets:

- Reduce the risk of damage or death caused by anti-personnel mines;
- Contribute to PARPA, the government's strategy for poverty reduction in Mozambique;
  • Clear all areas of large and medium mine impact;
  • Destroy all unexploded ordnance;
  • Destroy all stocks of landmines;
  • Inspect and signpost the remaining low impact areas; and
  • Set up a civic education programme on the danger posed by mines.

ADP is a nationally executed operational program covering the three provinces of Maputo, Gaza and Inhambane. These efforts are complemented by those of international humanitarian demining non-governmental organizations, which play an extremely important role. These are: Handicap International, operating in the provinces of Inhambane, Sofala and Manica; Norwegian People's Aid (NPA), operating in the central provinces of Tete, Manica, and Sofala; The Halo Trust, concentrating its operations in the northern provinces of Zambezia, Nampula, Niassa, and Cabo Delgado. The above-mentioned demining organisations execute demining operations all the year.
There has also been, and continues to be, a significant contribution from national and private demining companies, via tenders for infrastructure and other specific investment projects.

The established Mine Action Portfolio country team contributes to the National Mine Action Strategy by engaging in the following activities: mine-risk education, victim assistance, demining, and capacity building. One of the more important activities recently agreed upon by demining operators is the need to intensify technical surveys as a means of measuring current contamination levels and establishing a national non-governmental organization to focus on rural development needs. These activities are aligned with the five-year National Mine Action Plan (NMAP) 2002 to 2006 and with the National Strategy on Mine Action. The country team will assist the government in working in these specific areas.

3 Purpose and Objectives of the Trial

The **purpose** of the trials in Mozambique was to:

- Assess recent commercial off-the-shelf detectors believed to be appropriate to Mozambique and for humanitarian demining generally, and
- make the data available for the humanitarian demining community.

Objectives of the trials:

- Compare performance of detectors in different types of Mozambican soils.
- Measure sensitivity of detectors to typical local targets of interest and standard targets
- Train local staff in the CWA
- Collect site information for ITEP

4 Trial preparation and selection of detectors

4.1 Long-term preparation

JRC conducted a small market investigation of test facilities in Mozambique which confirmed our earlier belief that the Accelerated Demining Programme (ADP) site in Moamba was the best choice for the purposes of this trial.

Plate 4-1 Moamba ADP training facility with seven prepared lanes

In this trial we were able to take advantage of 7 prepared lanes used for training purposes by ADP. Lane 1 contains builder's sand from a sandpit about 30km north of Maputo. Lanes 2-6 contain five different soil types from the zone around Moamba, Lane 7 contains soil from Namaacha, adjacent to the Swaziland border. Further details of the soils are given in Chapter 6 (see also ANNEX C).

The main support to carry out the trial was given by ADP, which provided not only its training facility but also the detector operators.

The principle of integrating national and international working demining organisations into the STEMD project helped again to carry out the trial. The National Demining Institute of Mozambique as well as a national demining organisation J.V. Desminagem provided personnel for supervising and the collection of trial data. CSIR agreed to support the trials and sent one geophysicist (Mr Christo Craill).

All equipment was shipped to ADP in early February. Special permission was obtained by the EC delegation in Maputo from the Mozambique Customs for a temporary import.
JRC is in regular contact with manufacturers, two of which requested just before the trials that two of their new models be included.

Figure 4-2 Mozambique (source: UN)
Location of the trial site in Mozambique

Figure 4-3 Location of Trial Site (source: Expedia)

4.2 Personnel and Resources

Data Gathering Team, D. Guelle (also trial team leader), M. Pike – both JRC; Christo Craill CSIR (Mr. Craill is attached to the Defence, Peace, Safety and Security Research Unit within the CSIR on a contract basis.)

- Local personnel
  - The main team of ADP included Mohamed Kadar (Quality Assurance Officer ADP), seven detector operators and one driver. Due to internal problems – strike and illness – the full complement of personnel was available only for two of the ten trial days.
  - IND provided four lane supervisors, and J.V. Desminagem (national NGO) another two supervisors.

The ADP and the J.V. Desminagem teams included experienced demining operators that were familiar with most of the detectors so preparation and instruction in the use of the different detectors could be reduced to a minimum.

4.3 Final field trial preparation and training seminar

An initial equipment check was made in the store after the arrival of JRC staff in the stores and no damage was found. All the equipment was moved to the test site and measurements of soil moisture, temperature and magnetic susceptibility were made.
The next two days were devoted to a training seminar where the JRC staff explained the content and use of CWA 14747 (see ANNEX A). Twenty five participants received practical training for tests which can be carried out under field conditions: in-air and in-soil detection depth measurement, pinpointing and the establishment of sensitivity profile (footprint) for different targets. The emphasis was on the practical application of these tests and their importance to field operations. The latter two tests were not directly applied in the trial, but the knowledge of detector handling gained by the operators in learning them was useful in the trial itself.

Immediately after the seminar practical exercises, instruction of the participants on-site at the test lanes took place, with explanations of the role and tasks of the lane supervisors and detector operators.

Finally, those staff participating in the trial were instructed in the specific plans for lane preparation, measurement and recording of data. The following day, the first set of targets was buried in the lanes.

4.4 Detector selection before the trial

Manufacturers were informed about the trial in Mozambique in July 2004, when the original invitations for the Laos trial were sent out. The companies contacted at that time were:

- Adams Electronics International Ltd
- CEIA S.p.A.
- Ebinger GmbH
- Guartel Ltd.
- Inst. Dr. Foerster GmbH and Co. KG
- Minelab Pty. Ltd.
- Schiebel Elektronische Geräte GmbH
- Vallon GmbH.

To this list, we added one more company: Shanghai Research Institute of Microwave Technology, whose M90 detector we had subsequently learned about from UNMAS, and procured.

The criteria for inclusion were less strict than for the field trial in Laos since we were able to test 12 models instead of 8, because we did not conduct blind reliability testing, which is the most time-consuming test. We therefore did include the Guartel MD8+ and Ebinger 420 HS solar.

The Adams AX777 was found in ergonomic tests in Ispra to be less robust, especially with regard to the electrical contact to the battery. We did not consider it to be suitable for the rugged field conditions in Mozambique and therefore did not include it. No large head UXO-type detector were used in this trial, because UXO items are a less serious problem in humanitarian demining operations in Mozambique, where the main problem is with antipersonnel landmines.

Subsequently, two manufacturers requested that new models that were available should be included in Mozambique. One manufacturer (Vallon GmbH) shipped copies of a model with updated electronics to Mozambique. Another manufacturer (Inst. Dr Foerster) also conducted two days of testing at Ispra with their new model.

The final list of tested equipment was as follows:

- CEIA S.p.A. – MIL-D1
- Ebinger GmbH – Ebex 421 GC & Ebex 420 H-Solar
- Guartel Ltd. – MD 8+
- Inst. Dr. Foerster GmbH and Co. KG – MINEX 2FD 4.500 & MINEX 2FD 4.510
- Minelab Pty. Ltd. – F1A4 & F3
- Schiebel Elektronische Geräte GmbH - ATMID
- Shanghai Research Institute of Microwave Technology – M90
- Vallon GmbH – VMH3 & VMH3 (M)[1]

4.5 Technical details of the detectors tested

Table 4-1 Detector features apparent to the users

Detectors	Manufacturer	Principal Features											
		Mode		Coil		Set-up						Software access	Signal[4]
						Sensitivity adjustment			Ground compensation				
		Static	Dynamic	Single	Double-D	Fixed	Stepped	Continuous	Automatic	Manual	None	YES/NO	A/L/V
MIL-D1	CEIA	X	-	-	X	-	-	X	X	-	-	Y	A
EBEX® 421GC	Ebinger	-	X	X	-	-	-	X	-	X	-	-	A
EBEX® 420HS	Ebinger	-	X	X	-	-	-	X	-	-	X	-	A
MD8+	Guartel	-	X		X	-	3	-	-	-	X	-	A/L
Minex 2FD 4.500	Foerster	X	-	-	X	-	3	-	X	-	-	-	A
Minex 2FD 4.510	Foerster	X	-	-	X	-	3	-	X	-	-	Y	A
F1A4	Minelab	-	X	X	-	X	-	-	X	-	-	Y	A
F3	Minelab	X	-	X	-	X[2]	-	-	X	-	-	Y	A
ATMID™	Schiebel	-	X	X[1]	-	-	-	X	X	-	-	-	A
M90	SHRIMT	-	X	X	-	-	-	X	-	-	X	-	A
VMH3	Vallon	-	X	X	-	-	-	X[3]	X	-	-	Y	A/L/V
VMH3 (M)	Vallon	-	X	X	-	-	-	X[3]	X	-	-	Y	A/L/V

[1] Double coil (separate sending and receiving coils)
[2] The sensitivity level is normally fixed but can be changed (see detailed description in Section 8).
[3] A large number of digitized levels are available, so the adjustment is effectively continuous.
[4] The signal may be delivered to the operator via audio signal (A), LED/display (L), vibration (V) of the handle.

[1] The software-modificated VMH3 does not have an additional name – the (M) was added for differenciation by the authors.

Table 4-1 lists all the detectors that were tested and the features which are most immediately important in use.
The "mode" may be either static, if the detector continues to emit a sound when it is held stationary over a metal target, or dynamic if it must be moved over the target to signal. Some detectors have the receive coil divided into two halves, the "double-D" design, which have a zero line in the middle where the signal stops or changes, to enhance pinpointing. The manner and capability of detection and pinpointing depend on both these factors. The deminer should be aware of them and they should be emphasised during training. A detector with a double-D coil behaves very differently from one with a simple circular coil and it is dangerous to confuse the two, because the shapes of the sensitive areas are different. Similarly, it is important to understand that a dynamic mode detector can be silent, even over a metal object, when it is not moved.

Sensitivity adjustment in some detectors is made with a switch with a limited number of positions , such as low, medium and high, with others it is made with a continuously variable knob and others have fixed sensitivity. Setting of the soil compensation, where the detector has it, is usually made by invoking an automatic procedure which allows the detector to "learn" the soil properties. The Ebinger 421GC is the only detector tested here which has a completely manual adjustment. The CEIA Mil D-1 makes its soil compensation adjustment automatically, but the manual-adjusted sensitivity setting affects it. The detailed procedures are different for each detector and it is important to follow precisely the instructions of the manufacturer for the model in question. Some of the most recent detectors allow the user access to the software via a communications port, for example it may be possible to download updates from the manufacturer, or make special changes to adapt the detector to particular conditions on the operational site. All detectors have an audio indication when metal is detected and this is generally considered superior to visual indication to avoid distracting the operator from looking at the ground. The VMH3 and MD8+ do provide also visual indication by LEDs on the handle. Vallon have also recently introduced a vibrator in the handle as a tertiary indication.

We include here some technical details concerning the working principles of the devices, which are not normally apparent to the user but which are important for engineers. The principle of electromagnetic induction is common to all metal-detectors but there are many variations in the way it is used. The participating detectors represent a broad spectrum of different practical technical solutions[2] (Guelle, Smith, Lewis and Bloodworth) (Table 4-2).

Briefly, the "wave shape" type refers to whether the magnetic field is in the form of a smoothly varying wave or brief pulses. The "polarity" type refers to whether the magnetic field is always in one direction or reverses direction on each pulse or wave, to avoid initiating magnetic influence fuzes. The "domain" type refers to whether the receiving circuit measures the returned signal at specific time points on the wave or extracts and measures sinus wave signals of specific frequencies. Some detectors have separate coils for sending the signal and receiving it, others use just one coil for both.

[2] A discription of the technical solutions and their meaning can be found in more detail in the Metal Detector Handbook - http://serac.jrc.it/tethud/view.php?id=21; (see references).

Table 4-2 Working principles of the detectors

Detectors	Manufacturer	Technical Principles & Design							
		Wave shape		Polarity		Domain		Send/receive Coil	
		Pulse	Continuous wave	Bipolare	Unipolar	Time	Frequency	Single	Separate
MIL-D1	CEIA	-	X	X	-	-	X	-	X
EBEX® 421 GC	Ebinger	X	-	X	-	X	-	X	-
EBEX® 420HS	Ebinger	-	X	X	-	-	X	-	X
MD8+	Guartel	X	-	-	X	X	-	-	X
Minex 2FD 4.500	Foerster	-	X	X	-	-	X	-	X
Minex 2FD 4.510	Foerster	-	X	X	-	-	X	-	X
F1A4	Minelab	X	-	-	X	X	-	X	-
F3	Minelab	X	-	X	-	X	-	X	-
ATMID™	Schiebel	-	X	X	-	-	X	-	X
M90	SHRIMT	-	X	X	-	X	X	?	?
VMH3	Vallon	X	-	X	-	X	-	X	-
VMH3 (M)	Vallon	X	-	X	-	X	-	X	-

5 Methodology and Procedures of the Trial

5.1 Selection of CWA tests

In this trial, we focused on in-air and in soil detector sensitivity, in a wide range of soil types. As such, the detection reliability tests of CWA 8.5, which are statistical blind trials, were not considered best adapted. Instead, we used the in-soil deterministic tests of CWA 8.4 and the in-air tests of CWA 6.5 and 6.6. The main advantage of this approach is that it permitted the testing of a greater number of detectors and soil types in the time available, as there is no critical need for many repetitions. The number of operators required was also fewer. Nevertheless, we did take the precaution of having more than one operator perform each test and having each operator work in two lanes. We planned a test matrix in advance to organise the rotation of the detectors through the lanes.

The trial site conditions allowed the simultaneous use of seven detectors in seven different soil conditions against thirteen targets at nine different depths. This amount of data will give an overview about the different factors influencing the detector performance. These include the technical solutions of the manufacturer, the metal object, shape and position, and distance of the "target" and finally the ground properties, in particular magnetic susceptibility[3]. Some light is also shed on human factors, in spite of all the tests being intended as deterministic, rather than statistical, as will be discussed below.

The final selection of tests was as follows:

CWA Test 8.4 Fixed depth detection tests in soil
CWA Test 6.5 Minimum detectable target as a function of height
CWA Test 6.6 Detection capability for specific targets in air

The in-air testing was conducted with the detectors set at the sensitivities established for each soil type, excluding the first lane where the detector was set up in air to maximum sensitivity. Ideally, we would have liked to perform the in-air tests immediately before or after the in-soil tests, without changing the set-up, but due to the lack of personnel mentioned above, we were obliged to carry out the in-air tests all together, after the in-soil tests had finished.

Test 6.6 conducted with the steel balls of five diameters enables simple detection capability graphs to be plotted (see below). When this test is conducted in air with a complete set of eight or more diameters it becomes *Test 6.5.2 Minimum detectable target as a function of height*. For reasons of time, we only used five diameters in these field trials but full testing compliant with CWA 6.5.2 has been conducted in the laboratory at Ispra.

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[3] Magnetic susceptibility is the degree to which a material can be magnetized in an external magnetic field. If the ratio of the magnetization is expressed per unit volume, volume susceptibility is defined as $\kappa = M / H$, where M is the volume magnetization induced in a material of susceptibility κ by the applied external field H.

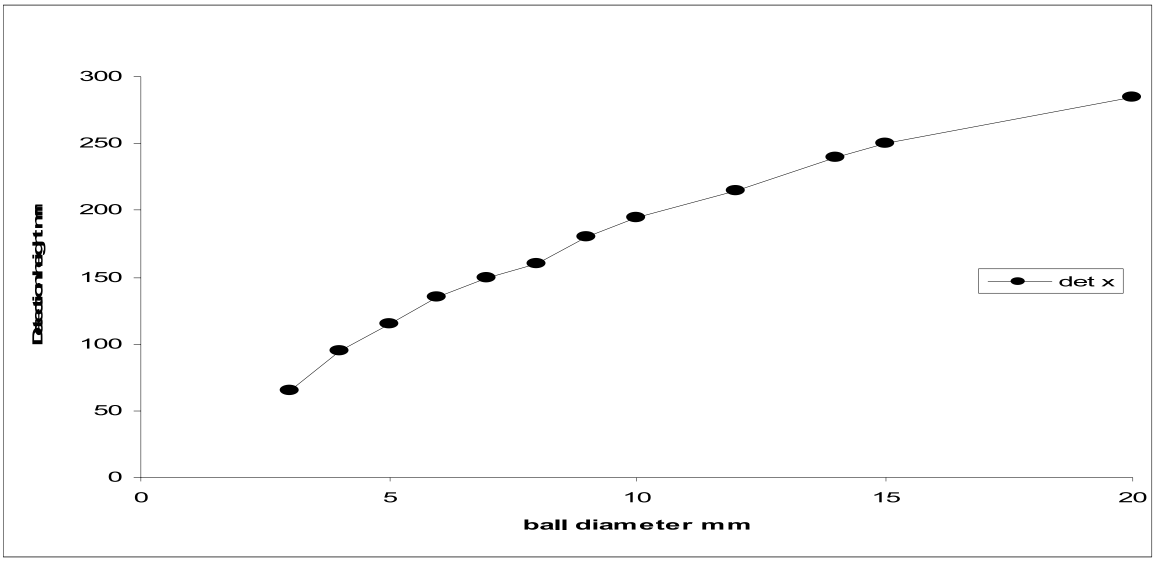


Figure 5-1 Detection height as a function of size for steel balls

5.2 Selection of targets

The selected targets included:

Plate 5-2 Targets used during the trial

- PMN2 and PMN, mines with neutralized fuzes (left)
- Type 72 and Gyata AP simulants, locally used and produced
- R2M2 fuze mounted in 60mm diameter clear plastic holders[4]
- ITOP fuze inserts Mo, Ko, Io,
- 100Cr6 chrome steel balls, 5,7,10,12 and 15mm diameter, placed in wooden containers.

Experiences from earlier tests have shown that there are practical limitations to the accuracy of targets used in tests. It is difficult to find simulants for minimum metal mines if the original metal part is not available; the less metal is present the more difficult it is to find a faithful simulant, common to all detectors. It should also be borne in mind that mines left in the ground will change over time, generally becoming more difficult to detect e.g. as steel parts rust away, so the reality that is being simulated itself is not fixed.
We took the following approach.

- The original PMN and PMN2 mines were rendered safe by taking out the percussion caps, which are a small part of the total metal content for these types. All other metal parts were left as originally produced.
    - The safety pins of both mines were taken off, as would be the case for a laid mine.
- The Gyata and Type 72 simulants were made by ADP for an earlier trial conducted by Mr A V Smith in Autumn 2004. These simulants were designed to give equivalent response to the real mines for the Minelab F1A4, but it is possible that they will not be as accurate simulants for other detectors.
- The R2M2 fuzes are originals, R2M1 and RSA No.8 antitank mine use the same fuze.

[4] An essentially identical fuse is used in the R2M1 antipersonnel mine and the RSA No.8 antitank mine.

- The ITOP simulant fuzes were specifically designed and tested to have electromagnetic properties closely resembling those of real mines. The ones we used here correspond to the following mines:
    - Io = M14, PMA3, VS-1.6
    - Ko = Type 72A, TMA-4, M19, PMA3
    - Mo = VS-2.2, PT Mi-Ba-III

  For more details about the mines and simulated mines see ANNEX B

- The steel balls were used as neutral targets for comparison of test results done in the lab. Note that the balls were always used in the cubic wooden holders, so that each one displaces the same volume of soil regardless of the ball diameter.

5.3 Test matrix

The test included:

7 operators
12 detector types, 2 copies of each type
All detector models were used by each operator
Each operator worked in two lanes

7 lanes on the site
13 types of target (5 steel balls, 5 mines and mine simulants, 3 ITOP fuze inserts)
2 × 9 targets per lane (1 × 9 for PMN)

Table 5-1 Test Matrix

						Lane1	Lane 2	Lane3	Lane 4	Lane 5	Lane 6	Lane 7
			Operators:			**A** **G**	**B** **A**	**C** **B**	**D** **C**	**E** **D**	**F** **E**	**G** **F**
Detectors	12	11	10	9	8	1	2	3	4	5	6	7
	7	12	11	10	9	8	1	2	3	4	5	6
	6	7	12	11	10	9	8	1	2	3	4	5
	5	6	7	12	11	10	9	8	1	2	3	4
	4	5	6	7	12	11	10	9	8	1	2	3
	3	4	5	6	7	12	11	10	9	8	1	2
	2	3	4	5	6	7	12	11	10	9	8	1
	1	2	3	4	5	6	7	12	11	10	9	8
	8	1	2	3	4	5	6	7	12	11	10	9
	9	8	1	2	3	4	5	6	7	12	11	10
	10	9	8	1	2	3	4	5	6	7	12	11
	11	10	9	8	1	2	3	4	5	6	7	12

Table 5-1 shows the manner in which the detectors are cycled through all the lanes, and used by different operators. For example, operator A starts with detector 1 in lane 1, after he has finished, operator G from lane 7 takes it and repeats the measurement in lane 1. Meanwhile , operator A has taken over from operator B with detector 2 in Lane 2 etc. When detectors 1-7 have been tested by two operators in one Lane, detectors 1-6 are moved one lane along, detector 7 is taken out, detector 8 is moved into Lane 1 and the process is repeated. The sequence continues until all detectors have been tested in all lanes.

5.4 Target layout in lanes

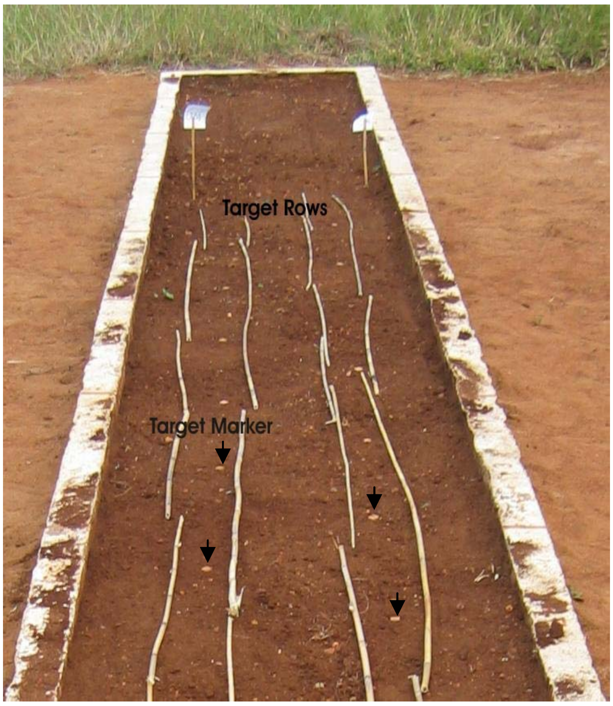
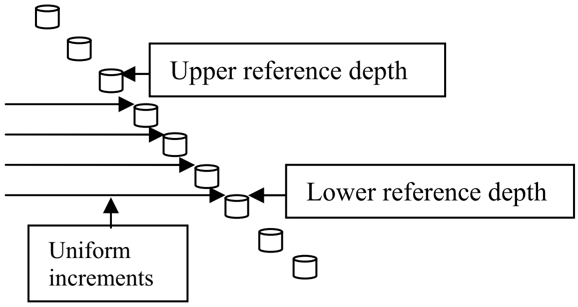


Plate 5-3 Lane 6 with target rows and markers



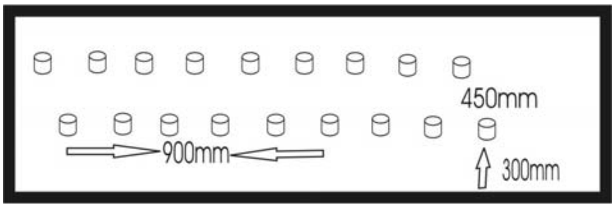


Figure 5-4 Establishment of burial depth and lane lay out (not to scale)

Plate 5-3 shows a photograph of lane 5. Two rows of targets were placed in every lane, excluding the lane which had the original inerted PMN mines, which had only one row of targets. Where there were two rows, the pattern of positions was staggered between them as in Figure 5-4. 5-4, to increase the separation between targets (see also Plates 5-5 and 5-6). Positions for burial of the mines were indicated with small wooden cubes. Thick dried grass stems, similar to bamboo, were laid down to prevent the deminers moving the cubes and to help maintain constant height.

At the start of the lane, a 1m by 1m area was kept free of targets, for adjusting the detector to the ground if necessary. Nine depths were selected, with uniform increments, using the in-air performance of five of the detectors as a guide, as follows. A lower (shallower) reference depth was defined by taking the detector which appeared to have the lowest sensitivity to the target, setting it up to the soil in the lane and establishing the detection height in air. An upper (deeper) reference depth was defined in a similar way, using four detectors which appeared to have highest sensitivity to that target. The burial depths were chosen so that there were four increments between the upper and lower reference depths and two increments below and above (Figure 5-4).

5.5 Daily lane preparation

Plate 5-5 Burial of the PMN mine – because of its large detection halo, only one line was used

Plate 5-6 Preparation of the lane for ITOP targets

The daily lane preparation started with the recovery of the buried targets used in the previous session, excluding the first day when a check of the lanes for metal pieces was done instead. Once the targets had been recovered and checked, the burial depths for the new session were established using in-air measurements as described in Section 5.4. The increments varied between 10mm to 35mm depending on the differences of detection height found in the in-air measurements. The targets were then moved to the next lane and from L7 to L1. The lines for the placement of the targets were drawn, the locations for burying the targets were marked and holes made to the required depths (see Figure 5-5 and 5-6). In stony ground, the corer (Figure 5-6) was used to loosen the soil. In the sand lanes, this was necessary only the first time the targets were buried so, to keep the disturbance of the ground to a minimum, in the sand lanes, the same holes were used again. No attempt was made to compact the soil in any lanes after placing the targets.
The soil was put back into the hole and made even with the surrounding surface.
This form of rotation was repeated every day. The initial idea was at least to have the night for settlement of ground but personnel numbers and time needed in the first days did not allow us to do so. It was important to mark exactly which targets were placed in each lane to avoid confusion. A precision in planting depth of ±5mm was achieved by compacting the ground below the target, using rulers vertically on top of the target and carefully filling the hole with the removed ground (Plates 5-7).

Plate 5-7 Filling of the hole and depth measurement of the target

5.6 Detection Depths in Soils

The maximum detection depth in soil was established by two deminers with both detectors to reduce individual influence on the result. As the first step, both available detectors were set up to maximum sensitivity in air. If the detector reacted to the ground, ground compensation was carried out or, for detectors without compensation, the sensitivity was reduced to a level that the detector could be used without reaction to the soil. In some cases, those detectors had to be lifted to a height where the ground signal stopped but a detection of the targets was still possible. (This method of using a detector is possible but it is not satisfactory, because the risk that a ground signal will be registered as a target signal is very high. The main reason for this is that it is very difficult to maintain a constant height above the ground, beyond 30-50mm.)

The height above the ground at which it was possible to use the detector was recorded for every lane.

Detectors with ground compensation (GC) were set up to the ground conditions if they reacted with a signal when moving them close to the ground.

The detector operator started from the lowest burial depth and proceeded to the next level. When the detector did not 5 times confirm a signal above the target, the previous depth was registered as max detection depth. Nevertheless, the operator tried the next two deeper levels for confirmation that no further detection was possible.

Where the supervisor was not sure about the detection signal, he instructed the operator to make a comparison with the signal from the previous depth. Only when both operator and supervisor, agreed that the signal had been confirmed 5-times was it accepted. Pinpointing the signal was also used as an additional confirmation in certain cases. If the operator and supervisor were still unsure about a detection, or if other complications, such as questions regarding the setup of the detector arose, they consulted the senior staff.

5.7 In Air Detection Height – detector setup to soil

As above mentioned, the in-air maximum detection height was established with all detectors after the in-soil measurements were finished. For measuring this the JRC-jigs were used and placed on available plastic cones to have enough height for excluding ground interference on the in-air measurements (Plate 5-8) .


Plate 5-8 In-air measurement jig

The procedure was that the detector was set up to the lane in the same way as for in-soil measurements. The detector was placed on the top of the jig after a rough measurement of the target distance in air was executed and height slightly less than this was used as the start for the measurements. If a clear signal was produced by the detector, the height (distance) was increased until the last level where the detector could produce a clear signal five times in a row. For double-D search heads it was accepted that this signal was produced under only one of the Ds. In some cases, when there was a problem exactly to define the maximum distance, the measurement was repeated, this time raising the platform in increments instead of lowering it.

The distance increments used were to recorded to ±5mm precision, in accordance with CWA, the jig itself is graduated in millimetres.
The detectors without GC were prepared in the same way as they were for the in-soil detection measurements. For non-GC detectors which were used in soil at a significant additional height above the ground to eliminate the soil signal, this height was subtracted from the in air measurement.

5.8 Limitations of detector sensitivity measurements in the field

Any measurement made in the field is likely to be less controlled than a laboratory measurement, as is recognised in the CWA. We describe here some factors which could have led to signals being recorded incorrectly as detections, even after all the precautions described above had been taken.

Depending on the soil conditions and the efficiency of the ground compensation, it may be possible to eliminate completely the soil noise, so the only reaction is to metal. Some of the detectors still have background soil noise either continuously or in reaction to inhomogeneities in the ground, i.e. parts with different electromagnetic properties to the surrounding area or “hot stones” in a neutral environment or the other way around.

Some detectors may give background noise due to drift of the electronics or the presence of electromagnetic fields from external sources. A noise cancel function is provided in most of the detectors, typically activated by holding the detector in the air and pushing a button. The detectors vary in the sophistication of their noise cancellation: from simple zeroing to complex intelligent processing. Particularly for the detectors with less effective noise cancellation, there is always a risk of electromagnetic noise being falsely declared as a detection. It should also be remembered that ground compensation circuits may be subject to electronic drift.

To a certain extent, the deminer is able to recognise background noise and distinguish it from a true detection. But he is normally not able to distinguish between a signal from a test target and one from other sources. If a specific source of false alarms is located near to a test target, its signals could influence the result. We cannot be sure that every false alarm was recognised as such and investigated during the trial. Some obvious contradictions in the results may, in our opinion, only be explained in this way. In particular, we highlight in the results cases where there are major discrepancies between the in-air and in-soil data.

Some of the detectors could not be used on high sensitivity because the background noise overwhelmed the signal strength of any target. Where this occurred, it is noted in the individual assessment of the detectors in Section 8.

An obvious possible source of error is incorrect adjustment or handling of the detector. Although precautions of training and supervision were taken to avoid these errors, we cannot be absolutely certain that none occurred.

In these tests, unfortunately, some reduction of the planned manpower occurred, so that the senior staff were obliged to carry out certain operations themselves, which meant that they had less time available to investigate problematic cases in situ.

5.9 Estimate of uncertainty

When trial data is used to judge whether or not a detector is able to achieve the sensitivity required for a particular task, or to compare the merits of different detectors, it is important to allow for the experimental uncertainties which are inevitably present. If two results differ by an amount less than the calculated uncertainty they should be regarded as essentially indistinguishable. We attempt here to quantify the known contributions of uncertainty in our measurements and to explain how we combined the estimates to arrive at overall figures.

In-soil measurements
Operator subjectivity, detector dependent : $\Delta o = \pm$ 10mm typical
Resolution, target and sensitivity dependent : $\Delta r = \pm$ 5mm to ± 20mm
Variation in height above soil surface: $\Delta h = \pm$ 5mm
Burial depth : $\Delta b = \pm$ 5mm

The operator subjectivity is reduced by √2 because test repeated by two operators.

Total $\Delta = \pm \sqrt{\tfrac{1}{2}\Delta o^2 + \Delta r^2 + \Delta h^2 + \Delta b^2}$

For the steel balls, Δ was about ±14mm
For the mines, it was on average ±15 mm and a maximum of 22mm

In air-measurements
Operator subjectivity, detector dependent : $\Delta o = \pm$ 10mm typical
Resolution : $\Delta r = \pm$ 5mm always
1 operator always

Total $\Delta = \pm \sqrt{\Delta o^2 + \Delta r^2} = \pm \sqrt{1.25}$ cm =±11mm

Uncertainty in percentage change
Some of the results below are expressed as percentage changes from a reference measurement. The uncertainty in these values is a combination of the uncertainties for the two, which may be shown to be

$$\left[\Delta\left(\frac{y-y_{ref}}{y_{ref}}\right)\right]^2 = \frac{1}{y^2{}_{ref}}\left[(\Delta y)^2 + (\Delta y_{ref})^2\left(1+\frac{(y-y_{ref})^2}{y_{ref}{}^2}\right)\right]$$

The following simpler formula is a good approximation and has the advantage of being independent of the depth *y*, so that a single uncertainty value can be used for each target-soil combination, without the need to calculate it for each data-point. Since, in practice, the uncertainty estimates are similar in all lanes, in this report we further simplify the estimate by using an average figure.

$$\left[\Delta\left(\frac{y - y_{ref}}{y_{ref}}\right)\right]^2 = \frac{1}{y^2_{ref}}\left[(\Delta y)^2 + (\Delta y_{ref})^2\right] .$$

6 Soil properties

6.1 Introduction

Some soils contain minerals which cause a reaction by a metal detector even when there is no metal present. In such situations, the operator is obliged to turn down the sensitivity of the detector, unless it is equipped with a ground-compensation circuit which can be adjusted to reduce the influence of the ground. The test site at Moamba, with its seven graded lanes, is ideally suited to investigating the performance of the detectors in different soil conditions; the emphasis of the trial was on this question. Measurements of the magnetic susceptibility, the frequency dependence of the magnetic susceptibility and the ground reference height (GRH) were made during the trial. In very general terms, the magnetic susceptibility is the main physical property which measures how much the ground couples electromagnetically with the field produced and detected by the detector coil and he GRH is an empirical measurement of the effect of the ground on the detector.
More specifically, the susceptibility is the extent to which the magnetic field is increased by the soil minerals. Generally it is a small number: a soil with a susceptibility of 0.01 would be considered “severe” in the terminology of the CWA. All good modern detectors are designed to be usable in magnetic soils but they may still be affected if the susceptibility has a strong “frequency dependence”, that is to say, if its susceptibility at high frequencies is significantly less than at low frequencies. It is therefore usually considered that the greater the frequency dependence, the more uncooperative is the soil for metal detectors. In all the examples we have seen, the GRH increases with the frequency dependence of the susceptibility.

6.2 Ground Reference Height

The ground reference height is the height above the soil at which a detector sounds as it is brought down onto the surface from above, in the absence of metal. A neutral soil has a GRH of zero and very severely noisy soil a GRH of tens of cm. In order to compare different ground reference heights it is necessary to standardize on a specific detector and calibrate it in a consistent manner i.e. set the detectors to a repeatable sensitivity for measuring the GRH. This is necessary for two reasons. First, the detector must always be set up in the same way if the GRH readings are to be meaningful. Second, the electronic units of most detectors are “individual” and must be set to a common benchmark for their results to be interchangeable when different detectors are used.

The Schiebel Metal Detector AN19/2 M7 is suitable for this measurement because it has continuous adjustment of sensitivity and operates in the static mode. It has been widely-used in the past and is well-known to most organisations. We describe here two methods we use to calibrate it for the GRH measurement. The sensitivity after calibration will sufficiently similar to give equivalent GRH results, whichever of the two methods is used. The calibration should be done before measuring the GRH at each site.

The targets to be used for this process are either the Schiebel test piece (delivered with each detector) or a 10mm diameter chrome steel ball (10mm Ø 100 Cr6).

a) The Schiebel test piece is held 100mm away of the centre from the search-head in air. The sensitivity knob is then moved clockwise to a point where a reading starts. This should be repeated several times for confirmation. The distance to the Schiebel test piece should not be measured from the real position of the metal piece but from the bottom of the arrow on the plastic cover (base of the arrow).

b) A 10mm diameter chrome steel ball is placed 140mm away from the centre of the search-head in air. The sensitivity knob is then moved clockwise to a point where a reading starts. This should be repeated several times for confirmation. [5]

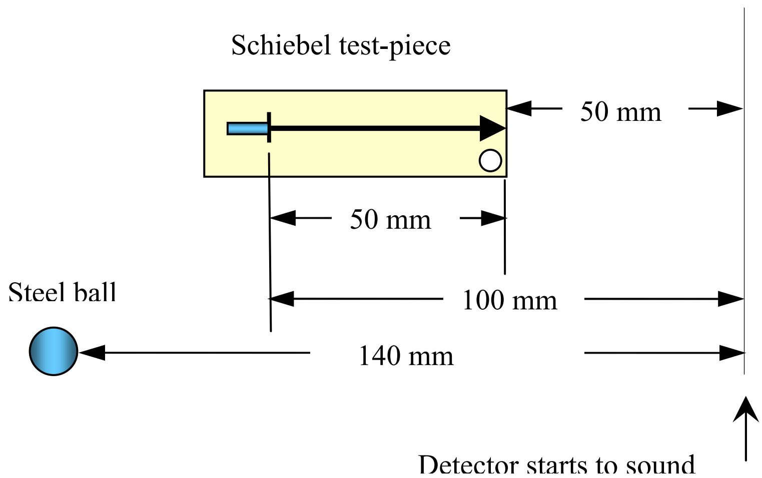


Figure 6-1 Two calibration methods for ground reference height measurement using a Schiebel

Use the marking and add another 50mm for the Schiebel Test Piece, or use a 10 mm Ø 100Cr6 ball at 140 mm distance to the centre of the search head.

The point at which the detector ceases to make a definite sound is somewhat subjective but if a point is chosen in the same way during the Ground Reference Height measurement as during the calibration procedure, the results should be reproducible. At least five GRH measurements should be made at each place where a reading is taken and the results should normally be within ± 5 mm of each other. This level of accuracy is both achievable in field conditions and useful. The final GRH result is then calculated as an average of the five readings.

The ground reference height (GRH) was measured once with each of five Schiebel detectors AN19/2 M7, calibrated so that a standard test piece created a signal at a distance of 10cm to the centre of the search head. The correlation between the GRH and the frequency dependence of susceptibility may be clearly seen by comparing the dotted and green curves in Figure 6-3.

[5] **Note:** The search-head of early versions of the Schiebel AN19 may be particularly sensitive to ground and atmospheric moisture. When it was the most widely used metal-detector in HD, deminers in some countries were advised to wrap the search-head in a plastic bag before using the detector on wet grass or in damp conditions.

6.3 Magnetic Susceptibility Meter

The magnetic susceptibility measurements presented in this report were carried out using a Bartington MS2 system. The system used consists of a meter (MS2) and two different sensors (MS2B and MS2D). The MS2B is a chamber which is used to obtain mass or volume susceptibility measurements of soil samples (Plate 6-1 left). It operates at 2 frequencies (0.465kHz and 4.65kHz), and so gives an indication of the frequency dependence. The MS2D is a handheld probe operating at 958Hz with a coil similar to that of metal detector which probes the upper parts of the soil surface directly in situ without disturbance of the soil by sampling (Plate 6-1 right) but does not by itself indicate the frequency dependence.

Plate 6-2 Bartington MS2 configuration for sample (MS2B-left) and field measurements (MS2D-right)

Measurements were made in all lanes with the MS2D and 10ml samples were taken and measured with the MS2B. Results are shown in Table 6-1 below, the frequency dependence is indicated in the column "Low Frequency Susceptibility minus High Frequency Susceptibility".

Table 6-1 Susceptibility measurements in lanes 1 to 7

Lane	Magnetic Susceptibility measured with the Bartington MS2 meter (SI)			Low Frequency Susceptibility minus High Frequency Susceptibility	GRH (mm)	CWA classification
	MS2B (465Hz)	MS2D Loop (968Hz)	MS2B (4650Hz)	MS2B (465Hz) minus MS2B (4650Hz)	Schiebel AN19 Mod 7	
1	2	2	2	0	0	Neutral
2	11	9	11	1	9	Neutral
3	130	95	124	6	83	Moderate
4	868	671	842	25	168	Severe
5	1112	890	1082	30	180	Severe
6	636	466	591	45	211	Severe
7	2885	2231	2829	57	210	Very Severe

The data shown in Table 6-1 are averaged data. The measurements of the susceptibility with the D coil did not change significantly from day to day. The two-frequency data differed very little from data measured at Ispra in 2002, 2003 using the same type of instrument, from samples of the Moamba lanes 1-6 taken in 2001 (lane 7 was constructed in Spring 2005).

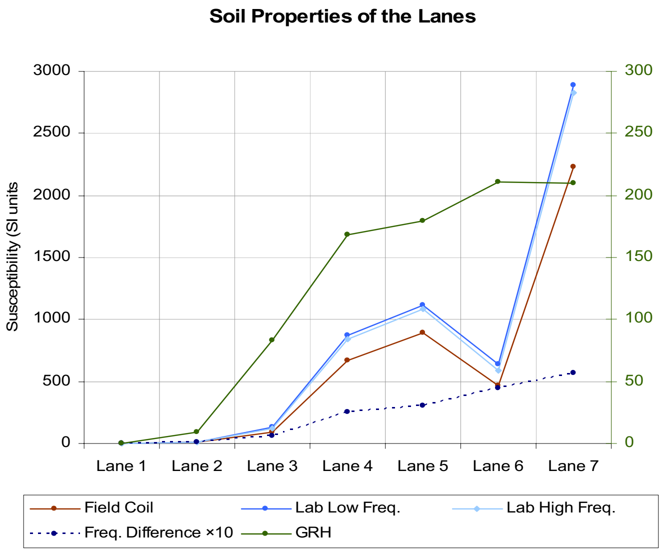


Figure 6-3 Magnetic susceptibilityand ground reference height in the seven test lanes

Figure 6-3 is the graphical representation of Table -6-1. The curves demonstrate a continued increase of the magnetic susceptibility from L1 to L7 with the exception from L5 to L6. Different are the results for the GRH and differences between low and high frequency measurements in this case which both increase continuously. In general the reaction of the detectors follow these curves. The lower the plotted values the lower the influence of the ground on the detectors.

6.4 Expected dependence of the sensitivity on the soil magnetic properties

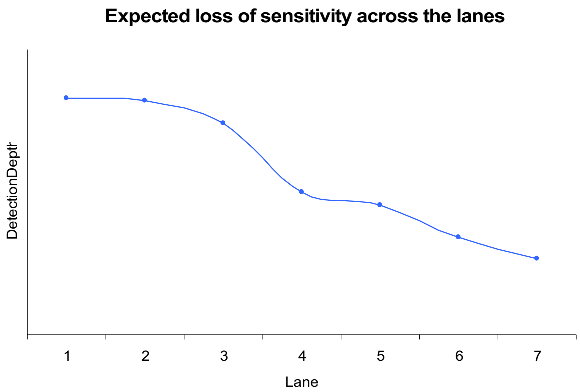


Figure 6-4 Expected reaction of detectors to ground magnetic properties from Lane 1 to Lane 7

When there is noise from the soil which the detector cannot compensate, the alarm threshold must be raised i.e. the detector's sensitivity must be reduced, to allow it to be used. If this reduction in sensitivity varies smoothly with the magnetic properties; that is to say, with the difference between the LF and HF susceptibilities and the GRH shown in Figure 6-3, then from Lane 1 to Lane 7 one would expect it to vary qualitatively as shown in Figure 6-4.

In Chapters 7 and 8 , it will be seen that all of the detectors without soil compensation follow approximately the trend of Figure 6-4, in some cases the detector's sensitivity even falls to zero (not usable). Of the soil compensating detectors, some follow this curve but for others the curve is flatter, because the soil compensation electronics has prevented the loss of sensitivity in the higher numbered lanes. The detection depth in the more severe soils strongly depends on the solution found by the manufacturers for processing the ground data so that the detector does not lose sensitivity. So the curve of detection depth against Lane number is a measure of how efficiently the soil compensation circuit works.

It should be borne in mind that the designer cannot just optimise the soil compensation to the exclusion of other considerations. Efficient soil compensation would be of no merit if the sensitivity value itself was poor i.e. if the detector was equally bad in all soils. Two design philosophies can reasonably be adopted: either to optimise for efficient soil compensation and good sensitivity or to optimise for the best sensitivity achievable under any given soil conditions.

7 Results: Comparison of all detectors

7.1 Introduction

This chapter will give a direct comparative overview of the results of all participating detectors. Individual assessments of each detector are given separately in Chapter 8.
In Chapter 7 we first present consolidated results for all targets and describe the typical trends then give results target by target and discuss results which stand out as of particular interest. Throughout Chapter 7, detectors will be listed alphabetically, all seven soil types and in-air data are on a single graph. For easier reading and understanding, legends and explanations for the graphs and tables are added in a fold-out pages ANNEX C to F, which can be viewed when reading each part of the report.

For L1, for both the in-soil and in-air measurement, the detector was set up to maximum sensitivity in air, because the detector could always be used in this way without reaction to the ground in L1, since it is almost inert. For the other in-air and in-soil results the detector was setup individually to the soil in each lane.

7.2 Consolidated results and general trends

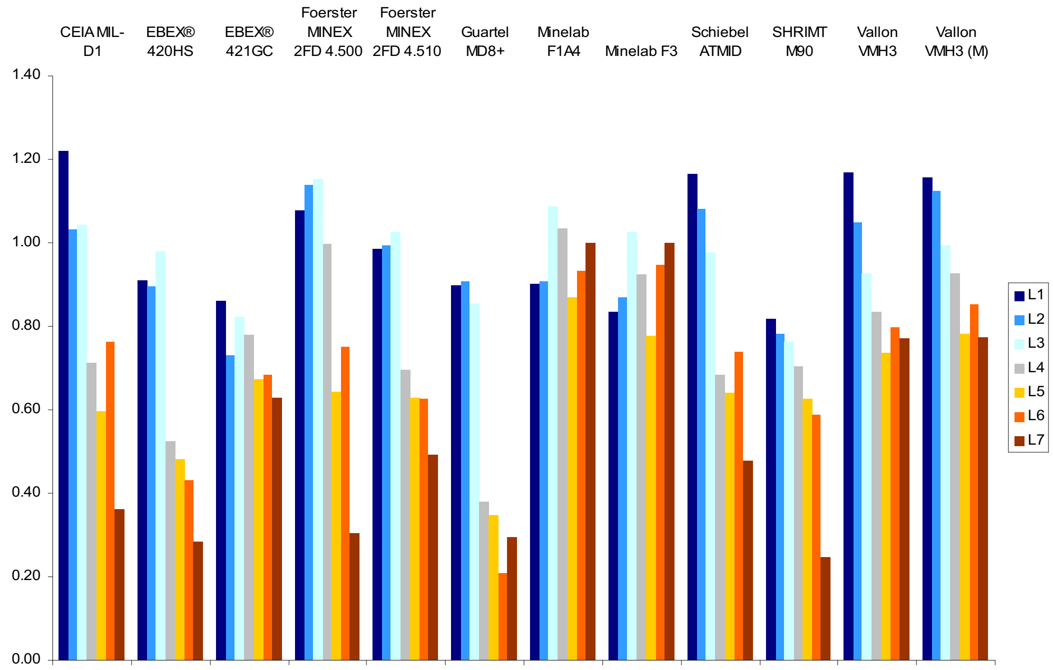


Figure 7-1 Detectors' normalised sensitivity to the average sensitivity of all detectors for all targets in Lane 1

Figure 7-1 shows the in-soil detection depth data normalised to L1 global average i.e. all detectors and targets. The graph shows the pattern of reaction to the soil properties.

The graph does not include cases where some detectors could not be used to detect smaller targets, this can only be found in the individual targets' graphs and the assessment of the detectors.

The main trends visible are:

a) A general pattern of significant loss of sensitivity with lane number, i.e. with increasing frequency dependence of soil magnetic susceptibility and ground reference height. Some detectors show this effect more than others.
b) There are some cases where there are peaks after Lane 1. This is especially so in Lanes 2 and 3. Six of the twelve detectors have values greater than the Lane 1 value in at least one of these lanes.
c) For some detectors, there is a pronounced fall at Lane 4. This effect is especially apparent for the CEIA, EBEX 420HS, MD8+ and ATMID.
d) Six detectors have Lane 6 values greater than those of Lane 5.

Some other effects are visible when the in-soil data is compared with the data measured in-air, after the detectors have been set up to each lane.:

e) In general, the in-soil depths are greater than the in-air heights.
f) The trend in sensitivity across the lanes in-air does not always follow the same pattern as the trend in soil. We will highlight cases where the trends are in the opposite sense.

Discussion

The general pattern of the sensitivity falling in the higher lane numbers is as expected according to the explanation in section 6.4.

The exceptional behaviour of the Minelab detectors is due to their good soil compensation and also because of the design philosophy adopted, which is to optimise for equal performance in all conditions rather than to achieve the best possible performance in any given conditions as in e.g. the Vallon detectors (see Chapter 8 for more detail).

The pronounced falls in Lane 4 are to be expected from the magnetic properties in Figure 6-3.
The rises in Lane 6 with respect to Lane 5 may be connected with the fact that the L5 susceptibility itself is lower than that of L6, even though the frequency difference is greater i.e. that these instruments are responding partly to the absolute susceptibility as well as to the frequency difference.

Our explanations for the slightly higher sensitivity measured in Lanes 2 and 3 are more tentative. Because of the small size of the changes, and the fact that only two operators used each model in each lane, operator subjectivity cannot be ruled out. It may be due to the default adjustment of the phases and timings being not quite appropriate for the targets used here, so that the compensation cycle actually improves the alignment slightly. However, the effect is seen to some degree even for the 420HS, MD8+ and SHRIMT, which do not have soil compensation. Another possible explanation is that the detectors are responding to the void in the soil formed by the target body, and this effect is slightly greater in Lanes 2 and 3. However, in Lane 2 , one would expect this effect to be negligible.

7.3 Individual Target results

The targets are grouped according to type – first the steel ball as a neutral shape, then the rendered safe mines, followed by the simulants, each ordered according to the response they cause in most of the detectors. This indicates how the detectors behave to the reduction of metal content in the targets.

Figures 7-2 to 7-10 shows the individual results of the rendered safe mines, simulant mines, ITOP inserts, and the 100Cr6 steel balls and allow the direct comparison of all participating detectors' sensitivities in air and in-soil to the named target in the headline. Results for all lanes are grouped for each detector. Lane numbers 1 to 7 are indicated below the detector names (soil property details are described in ANNEX C fold-out page 1. Sensitivity of the detector to the target is shown on the *y*-axis: the achieved heights in-air are indicated above the *x*-axis in blue and the achieved depth in-soil below the *x*-axis in brown. Light and dark shades are used to differentiate between detectors.

The red lines on the graphs for the used targets indicate 130mm, which is the Mozambican national standard clearance depth, the UN norm for its own operations and the IMAS default recommendation. The line is also added in the in-air data and spheres for easier visual comparison.

The trends visible in the consolidated data and described above are also visible on the individual target graphs, but all of the effects are not always seen for every target.

7.4 Comparative results for detectors: 10mm steel ball in cubic holder

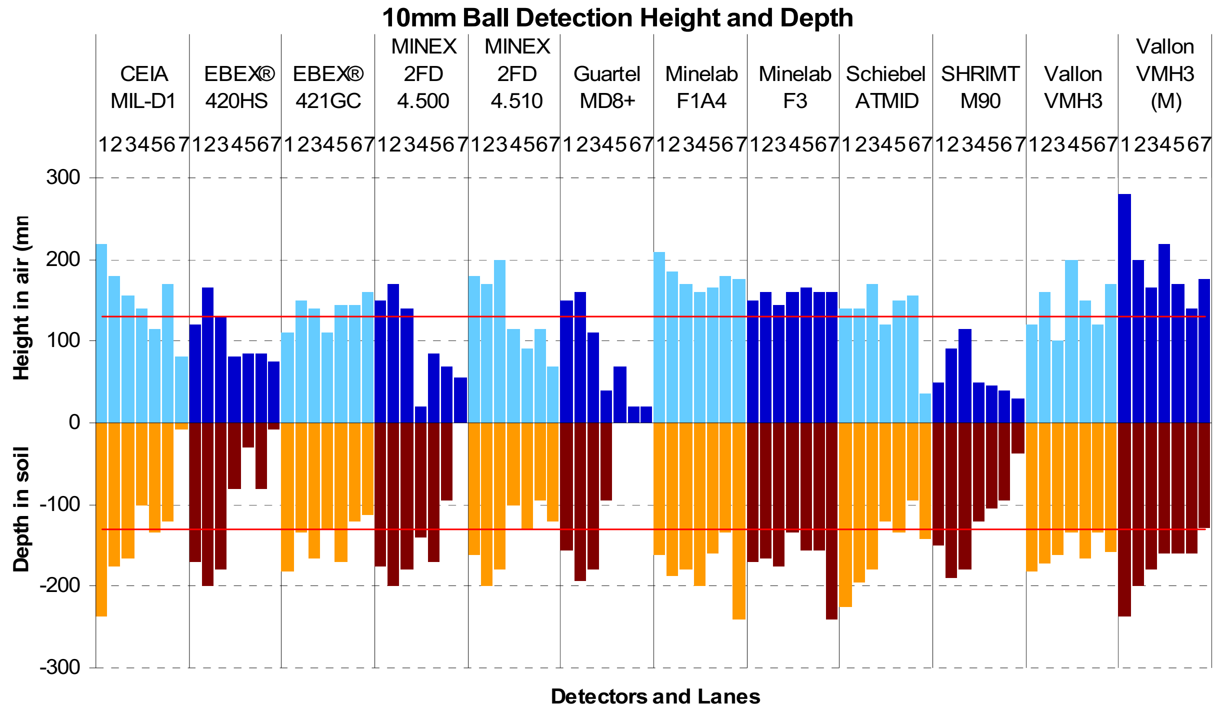


Figure 7-2 Detectors' sensitivity comparison for the 10mm ball across the test lanes.
Uncertainty ±11mm in-air, ±14mm in-soil

The 10mm 100Cr6 chrome steel ball is used as a reference target in several of the CWA tests. Its metal content is comparable to a small to medium sized AP landmine. For all tests in this trial, the ball was mounted in the wooden holder described above.

a) *General tendency:* Most of the detectors follow the expected general tendency and lose sensitivity from L1 to L7 in-soil and in air, the Ceia MIL D1 and Vallon VMH3 (M) displaying this especially clearly, but the Minelab detectors are exceptions, even giving increased sensitivity in soil in L7. The loss of sensitivity is sufficiently strong for some of the detectors, such as the MINEX 4.500 and the Guartel MD8+, that they are unusable in some lanes.
b) *Lanes 2 and 3:* there are seven detectors with results in these lanes that are better than in L1.
c) *Lane 4:* Eleven of the twelve detectors have a pronounced decrease of sensitivity in L4 in comparison with L1 or L3. The exception is the Minelab F1A4.
d) *Lanes 5 and 6:* For this target, there are few examples of L6 sensitivity greater than L5.
e) *Higher sensitivity for in-soil data:* Eleven detectors achieved in some lanes significantly better results in-soil than in-air.
f) *Opposite trend in sensitivity in-air to in-soil:* This can be seen quite clearly for the EBEX® 421 GC in Figure 7-2. If one looks at the first three lanes, eight of the detectors have increases or decreases in sensitivity in the in-air data that are either not mirrored in soil or there is an opposite tendency. Some examples: The 421 GC has a sensitivity peak in-air at L2 and a decrease in-soil; the MINEX 4.510 has in L2 a decrease in sensitivity in-air and a peak in-soil; the Minelab F1A4 a decrease in-air and increase in-soil, similarly but not to a significant extent the F3 from the same manufacturer; etc. In summary, this effect appears again for eight detectors for L1 to L3, and similar effects can be found in other lanes.

7.5 Comparative results to used targets: rendered safe mines

Antipersonnel mine PMN

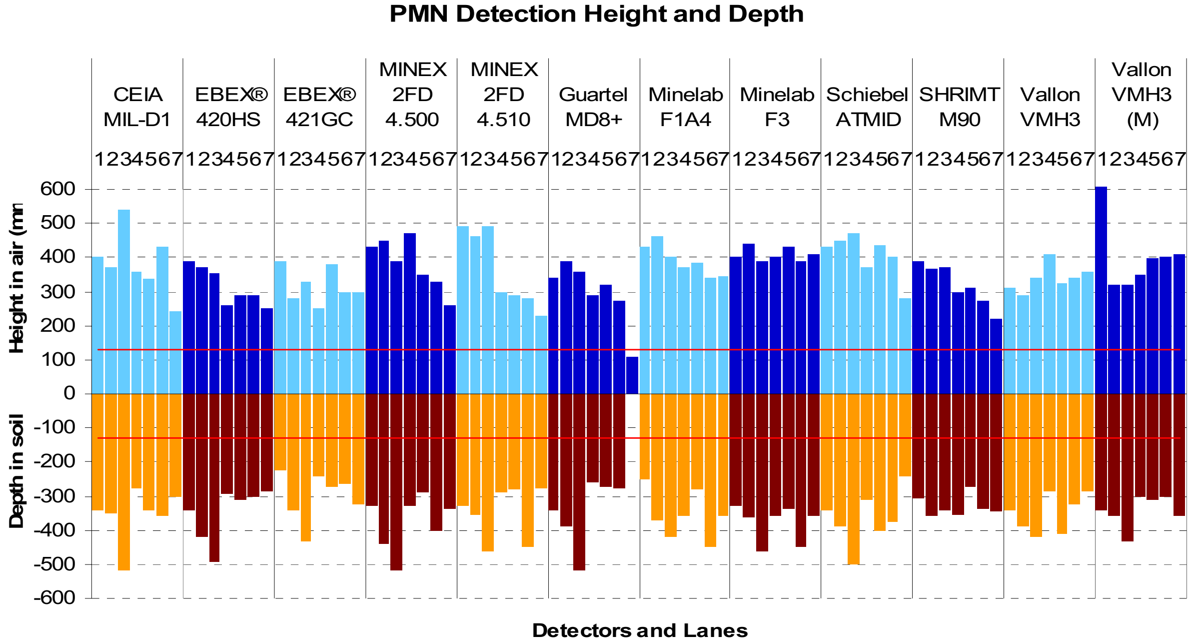


Figure 7-3 Detectors' sensitivity comparison for the PMN across the test lanes
Uncertainty ±11mm in-air, ±17mm in-soil

Of the targets used in the trial, the PMN causes the strongest response by all the detectors because of the large diameter of the metal retaining ring around its cap and the large metal fuze components. The concrete bed of L1 allowed a burial depth of only 340mm, measured to the top of the mine. Nine out of twelve detectors achieved the 340mm limit in L1, all except the 421GC, F1A4 and M90. Experiments in the laboratory have not confirmed the results, they are for those detectors achieving 340 above this. All detectors achieved the 130mm standard depth in all soils, except the MD8+ in L4.

a. *General tendency:* The loss of sensitivity with lane number is not very well-marked. Peaks of sensitivity in L3 are seen for eleven detectors, and another peak at L5 or L6 for eight detectors (excl. 420HS, MD8+, M90 – all without GC; VMH3 (M)): if we take the L3 as reference for maximum sensitivity again all are significantly loosing sensitivity (excl M90).
b. *Lanes 2 and 3:* All detectors have L2 and/or L3 results greater than L1, in soil.
c. *Lane 4:* eleven of the twelve detectors (all except M90) have a pronounced decrease of sensitivity in L4 in comparison with L1 or L3.
d. *Lanes 5 and 6:* Substantially greater in-soil sensitivity is seen in L6 than in L5, for both Foersters and both Minelabs.
e. *Higher sensitivity for in-soil data:* Not generally confirmed for this target.
f. *Opposite trend in sensitivity in-air to in-soil*: The 4.500 and both Vallon detectors display opposing trends for the first four lanes. The Ebinger 420 HS shows it for the first three lanes.

Antipersonnel mine PMN2

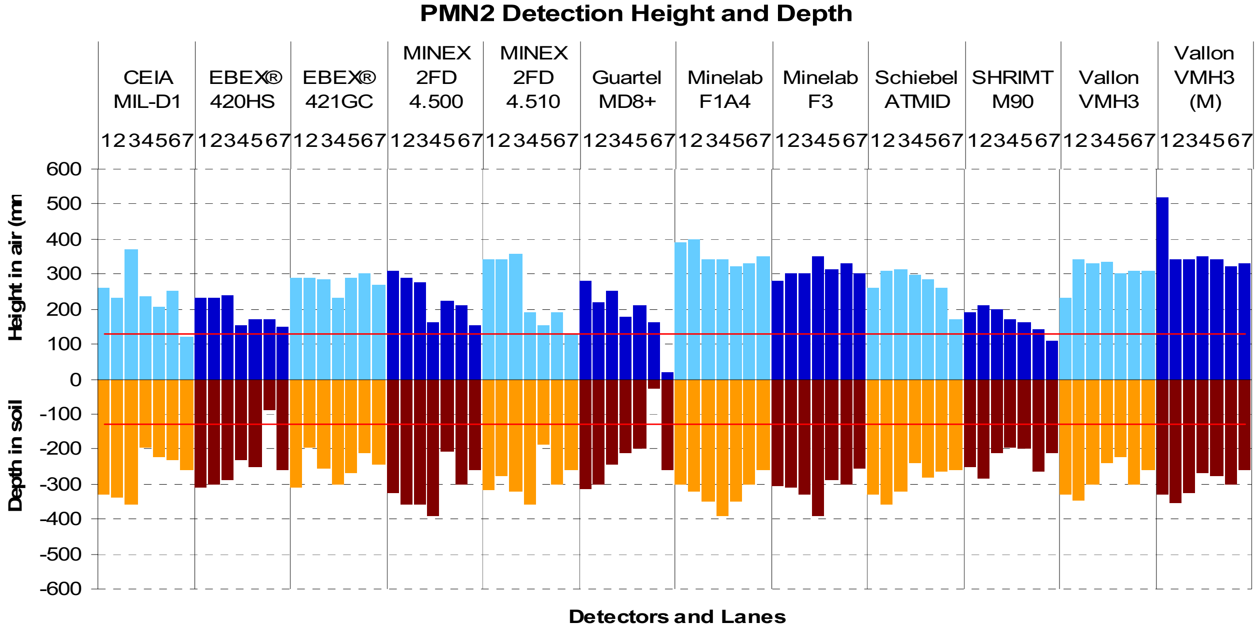


Figure 7-4 Detectors' sensitivity comparison for the PMN2 across the test lanes. Uncertainty ±11mm in-air, ±16mm in-soil

The PMN2 also produces quite a strong response. All participating detectors with ground compensation could easily detect the mine to the standard 130mm depth in all ground conditions available on the test site, but the 420 HS and theMD8+, detectors without ground compensation had difficulties in L6.

PMN2 graph:

a. *General tendency:* The loss of sensitivity with lane number is not well–marked but is more clearly seen than for the PMN; the in-soil L7 results are without exception lower than the L1 results. Peaks in intermediate lanes are less prominent than for the PMN.

b. *Lanes 2 and 3:* nine detectors have instances of in-soil sensitivities in L2 or L3 greater than those of L1.

c. *Lane 4:* six detectors have a pronounced decrease of sensitivity in L4 but five (421 GC, both Foerster, both Minelabs) show peaks there.

d. Lanes 5 and 6: six of the twelve detectors have L6 results higher than L5, but the difference is mostly small.

e. *Higher sensitivity for in- soil data*: most of the in-soil sensitivities are higher than the in-air but there are many exceptions.

f. *Opposite trend in sensitivity in-air to in-soil:* for MINEX 4.500 and Minelab F1A4

7.6 Comparative results to used targets: mine simulants

Simulant Gyata-64

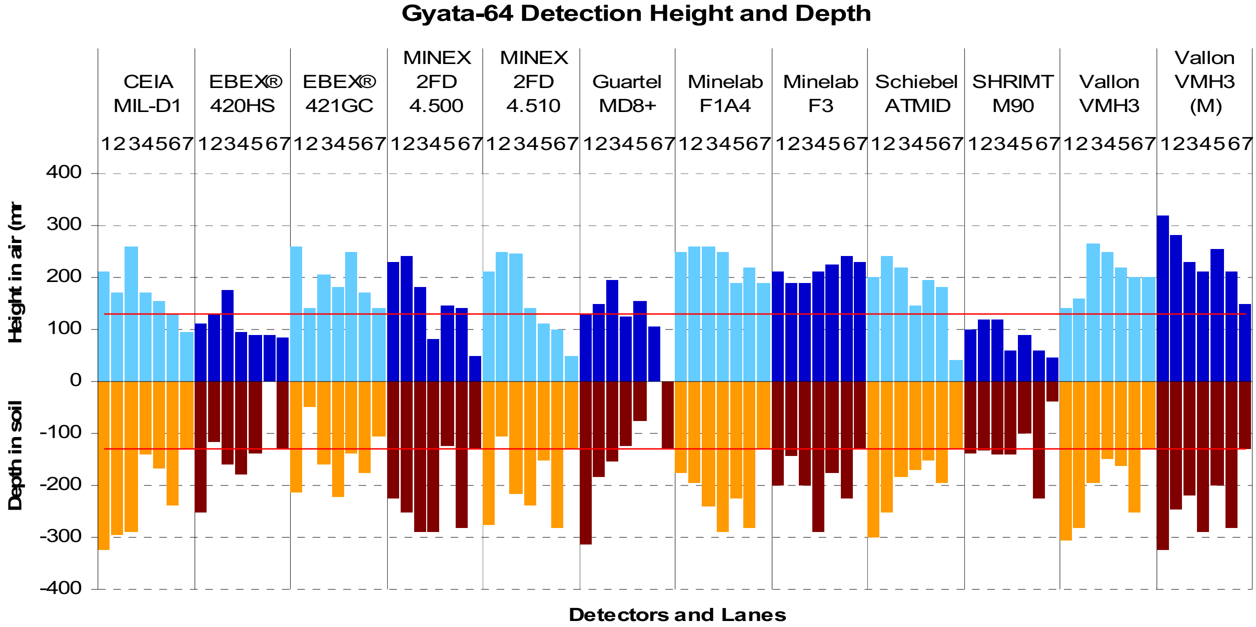


Figure 7-5 Detectors' sensitivity comparison for the Gyata-64 across the test lanes. Uncertainty ±11mm in-air, ±15mm in-soil

The Gyata-64 simulant ranks next after the PMN and PMN2 mines in the signal strength it produces. Most of the detectors with ground compensation can detect it to 130mm (excluding the 421 GC in L2, L7 and the MINEX 4.510 in L2).

Gyata-64 graph:

a. *General tendency:* There is a reasonably clear loss of sensitivity across the lanes for most detectors, with several exceptions. For all detectors, the in-soil sensitivity in L7 is less than that in L1.

b. *Lanes 2 and 3:* There are only two clear examples of in-soil sensitivities in L2 or L3 being greater than those in L1.

c. *Lane 4:* Only the Mil D1 and VMH3 show a pronounced drop in sensitivity at L4 and the EBEX 420HS, MINEX 4.510, both Minelabs and the VMH3(M) show peaks there.

d. *Lanes 5 and 6:* Ten of twelve detectors have L6 sensitivities higher than L5, the exceptions being the 420HS and MD8+ which were unusable there.

e. *Higher sensitivity for in-soil data:* this is seen for the Mil D-1 and 4.500, and in certain cases for other detectors but it is not confirmed generally.

f. *Opposite trend in sensitivity in-air to in-soil:* for VMH3 from L1 to L3, in some lanes it is also seen in the Foersters.

g. **Insert Mo: = antitank mines VS-2.2, PT Mi-Ba-III**

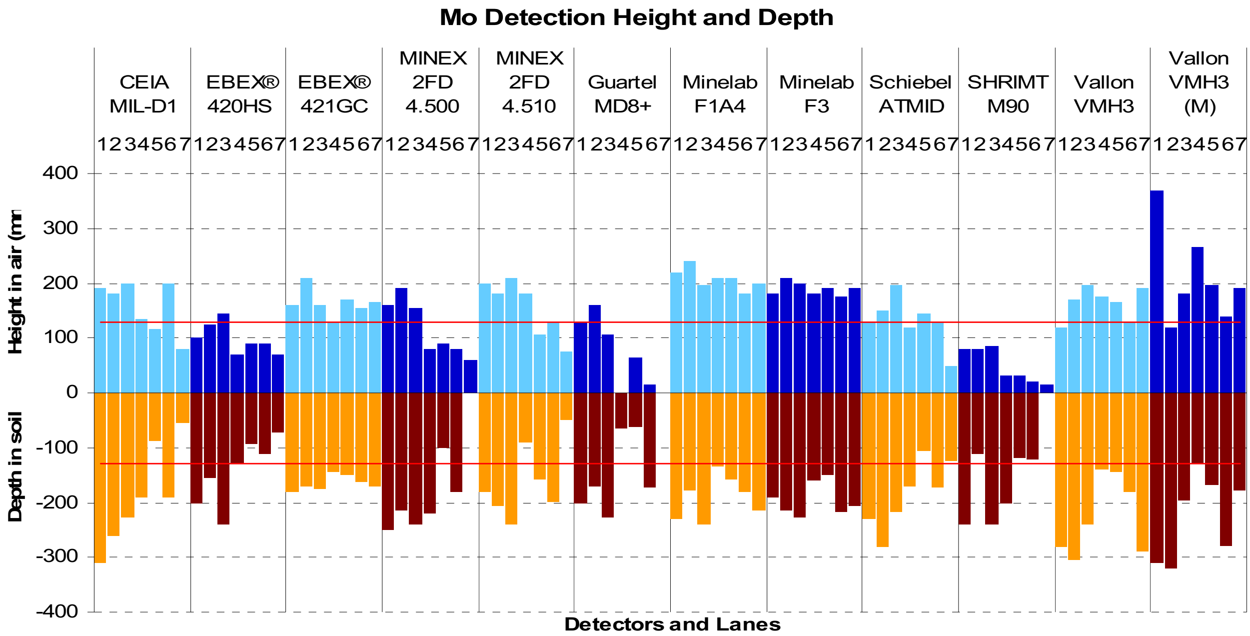


Figure 7-6 Detectors' sensitivity comparison for the ITOP Mo across the test lanes. Uncertainty ±11mm in-air, ±17mm in-soil

The Mo insert is one of the larger format ITOP simulant fuzes. Its metal content is a 38mm long aluminium tube. It is designed to be used with the larger ITOP mine body simulants, to simulate AT mines such as the VS-2.2 and Pt-Mi-Ba-III. In the tests reported here it was buried without a body. The response of most detectors was less than to the Gyata simulant. Five detectors could detect it in all lanes to 130mm standard depth. (NB This target was also used extensively in the IPPTC trials.)

Mo graph:

a. *General tendency:* There is a general fall in detection depths across the lanes in soil but there are many exceptions. Eight detectors have clearly lower detection depths in L7 soil than in L1.
b. *Lanes 2 and 3:* Eight detectors have examples of detection depths in L2 or L3 greater than those in L1.
c. *Lane 4:* A pronounced drop in sensitivity between L3 and L4 is seen in most detectors, in-soil or in-air or both.
d. *Lanes 5 and 6:* All detectors have greater in-soil sensitivity in L6 than in L5. In two cases (421GC and M90) the difference is small.
e. *Higher sensitivity for in- soil data:* confirmed for some detectors in L1 to L3, (CEIA, both Ebingers, ATMID, both VMH3).
f. *Opposite trend in sensitivity in-air to in-soil:* There are no very clear cases

g. **Insert Ko: = antipersonnel mine Type 72A, anti-tank mines TMA-4, M19**

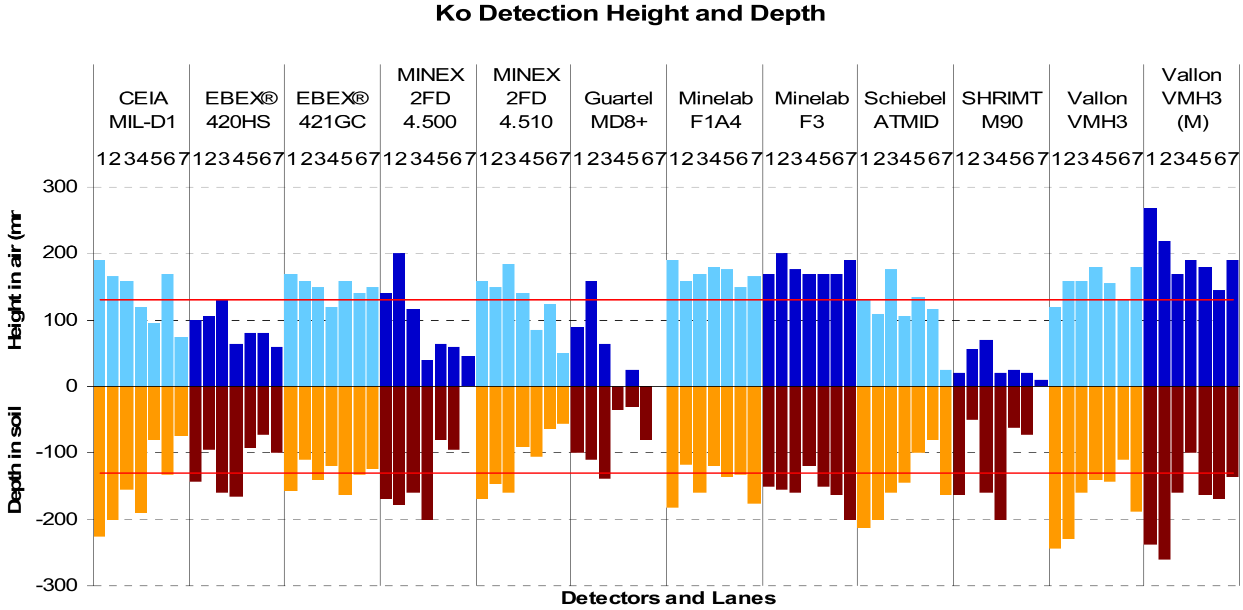


Figure 7-7 Detectors' sensitivity comparison for the ITOP Ko across the test lanes
Uncertainty ±11mm in-air, ±17mm in-soil

The Ko insert is one of the smaller format ITOP simulant fuzes Its metal content consists of a 7mm steel pin and a 12.7mm long aluminium tube. It is designed to be used with the smaller ITOP mine body simulants, to simulate AP mines such as the 72A. It is also produced in the larger format version, with the same metal content, to simulate AT mines such as the TMA-4 and M19. In the tests reported here it was buried without a body. The response of all the detectors was less than to the Mo, as expected. No detectors could detect the Ko in all lanes to the 130mm standard depth.

Ko graph:

a) *General tendency:* The fall in sensitivity across the lanes is present but not very well-marked, seven detectors showing some in-soil sensitivities greater than those of L1. All detectors except the Minelab F3 have lower sensitivities in soil in L7 than in L1.
b) *Lanes 2 and 3:* Five detectors have values in L2 or L3 greater than those in L1, but most of the differences are small.
c) *Lane 4:* pronounced drops in L4 in-soil are seen for the 4.510, MD8+, F3, and VMH3(M).
d) *Lanes 5 and 6:* Six detectors have higher in-soil sensitivities in L5 than L6.
e) *Higher sensitivity for in-soil data:* confirmed for most lanes for MIL D1, 420HS, ATMID and VMH3 (M) .
f) *Opposite trend in sensitivity in-air to in-soil:* for L3-L6 4.500, L4-L6 for 4.510.

Insert Io: = M14, PMA3, VS-1.6

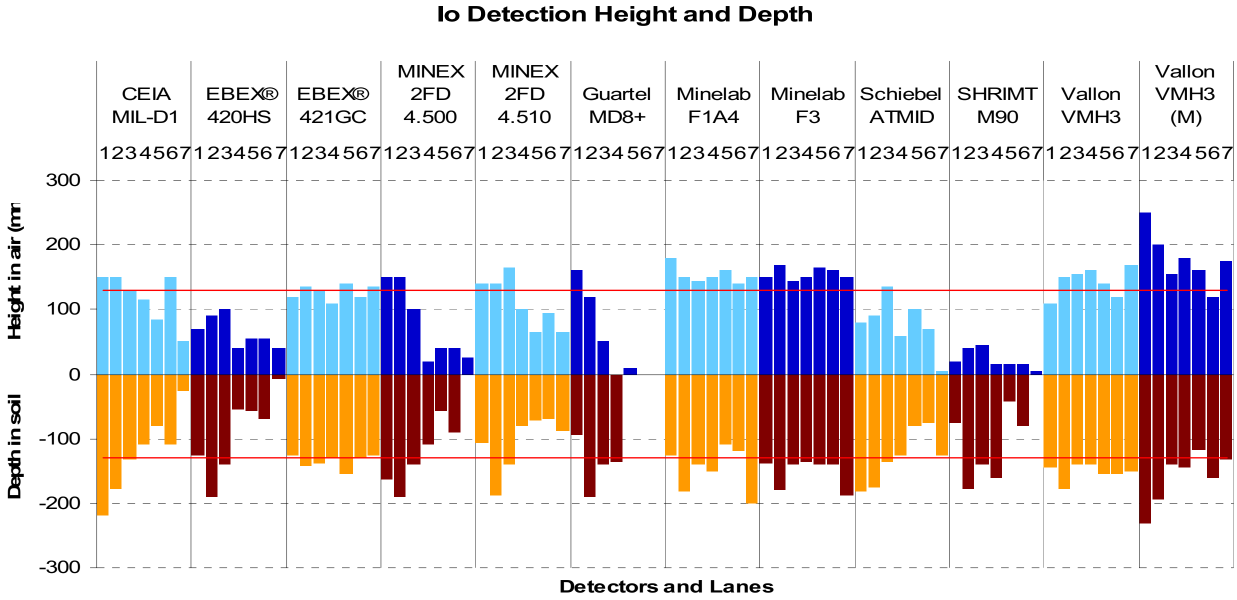


Figure 7-8 Detectors' sensitivity comparison for the ITOP Io across the test lanes
Uncertainty ±11mm in-air, ±15mm in-soil

The Io insert is one of the smaller format ITOP simulant fuzes. Its metal content consists of a 12.7mm long aluminium tube, narrower than that of the Ko. It is designed to be used with the smaller ITOP mine body simulants, to simulate AP mines such as the M14 and PMA3. It is also produced in the larger format version, with the same metal content, to simulate very low metal content AT mines such as the VS-1.6 In the tests reported here, it was buried without a body. The response of all the detectors was mainly less than to the Ko, as expected, however, the VMH3 and F3 did succeed in detecting all lanes to the 130mm standard depth.

Io graph:

a. *General tendency:* The in-soil results are characterised by very substantial decrease of sensitivity from L1 to L7 for all detectors without GC (420HS, MD8+, M90) and for the MIL-D1, 4.500. Other detectors with GC significantly lose sensitivity from L1 to L7, the 4.510, ATMID and VMH3 (M). A third group, the 421 GC, both Minelabs and the VMH3 maintain to a certain degree their sensitivity across the lanes.
b. *Lanes 2 and 3*: nine detectors show L2 or L3 sensitivities in-soil greater than those of L1.
c. *Lane 4 reaction:* two detectors (420HS, 4.510) have a pronounced fall in sensitivity at L4 in-soil and decrease of sensitivity in L4 in comparison with L1 or L3.
d. *Lanes 5 and 6:* six detectors have higher sensitivity in-soil in L5 than in L6, in some cases marginally significant.
e. *Higher sensitivity for in-soil data:* confirmed for some detectors in L1 to 2, (CEIA, both Ebinger, ATMID) but not as clear as for other targets.
f. *Opposite trend in sensitivity in-air to in-soil:* for L1 to L2 MD8+ and F1A4, L2 to L3 420 HS and ATMID. Flat in air, rise in soil seen in L1 to L2 4.500 and 4.510.

Simulant T72

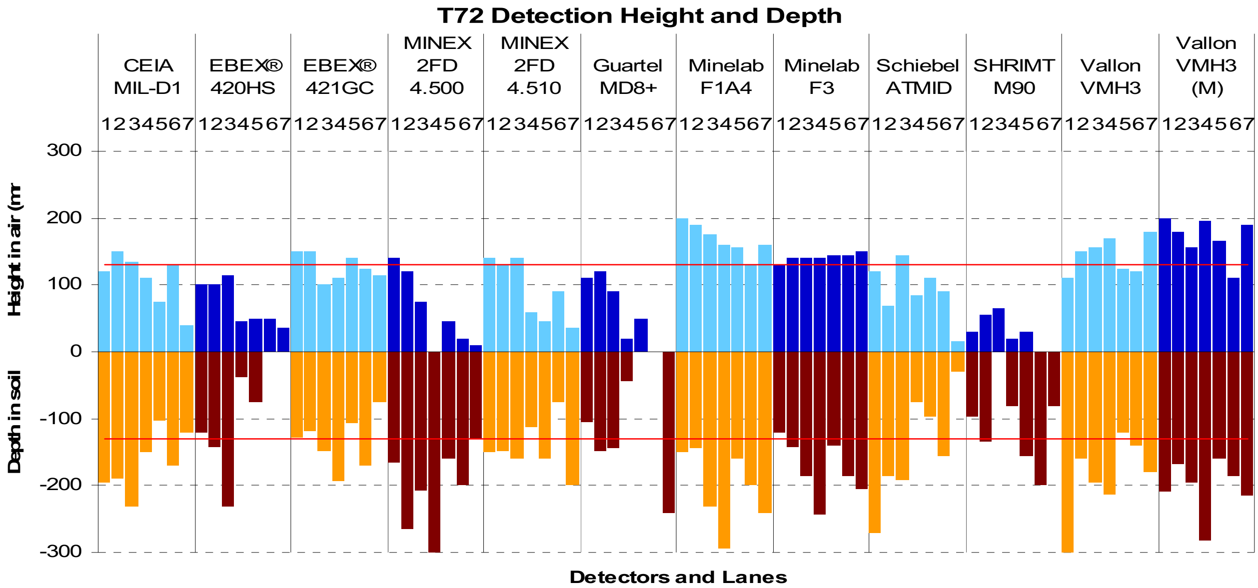


Figure 7-9 Detector Comparison per target and lanes: Simulant AP T72
Uncertainty ±11mm in-air, ±14mm in-soil

The simulant T72 gave a signal intermediate between the Ko and Io, with some exception to this order, depending on the detector. Note that this is a somewhat weaker signal than expected, since the Ko is supposed to give the same signal as a T72 mine. There were again several lanes where the detectors with GC were not able to detect it to standard depth across the lanes. Three detectors can detect it in all lanes to 130mm standard depth.

T72 graph:

a. *General tendency:* The in-soil results are characterised by very substantial decrease of sensitivity from L1 to L7 for all detectors without GC (420HS, MD8+, M90) and for the MIL-D1 and 4.500. Other detectors with GC significantly lose sensitivity from L1 to L7 4.510, ATMID, VMH3 (M). A third group the 421 GC, both Minelab, the VMH3 maintain to a certain degree their sensitivity across the lanes.
b. Lanes 2 and 3: All detectors except the ATMID and the Vallons have cases of either L2 or L3 in-soil sensitivities greater than those of L1.
c. L4 reaction: Mil D1, 420HS, MD8+ and ATMID show pronounced falls at L4.
d. L5 and L6: nine detectors show L6 sensitivities in-soil greater than those of L5.
e. *Higher sensitivity for in-soil data:* confirmed for some detectors in L1 and L 2, (CEIA, both Foerster, ATMID), not as clear as for other targets.
f. *Opposite trend in sensitivity in-air to in-soil:* for L2 and L4 4.500, L4 and L4 4.510, L3, L4,L6 F1A4.

Simulant Antipersonnel mine R2M1, R2M2; antitank mine No 8 RSA

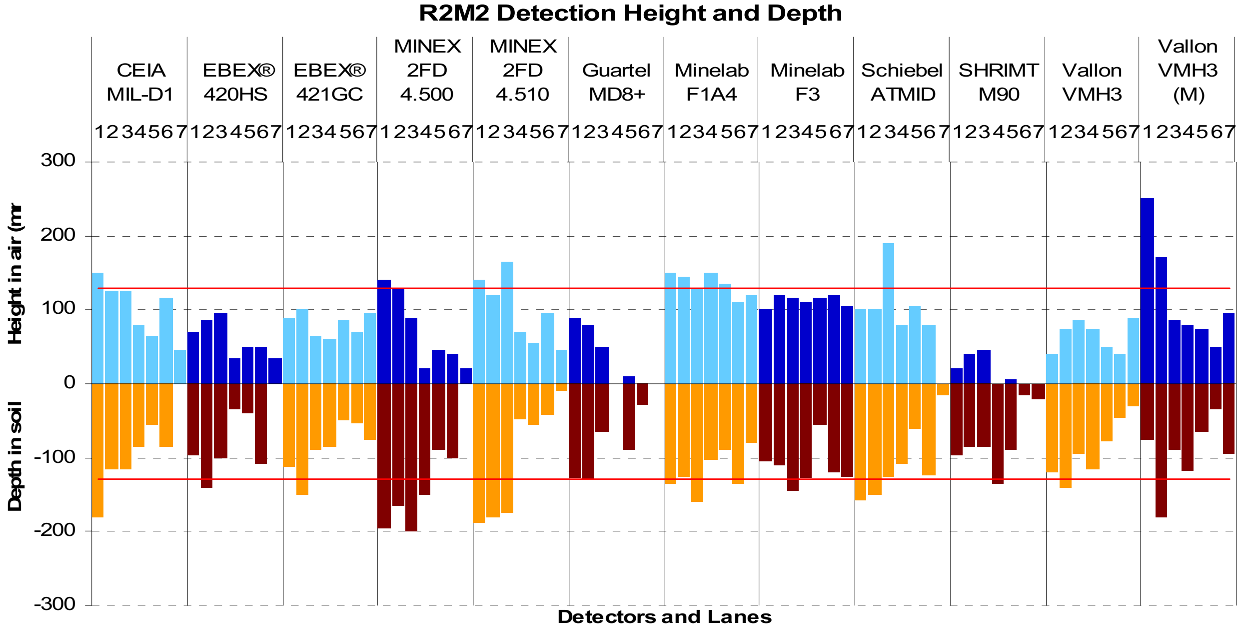


Figure 7-10 Detector Comparison per target and lanes: Simulant AP R2M1, R2M2; AT No 8 RSA
Uncertainty ±11mm in-air, ±14mm in-soil

Out of all used targets this was the most problematic object for all detectors. It is produced from the original fuze of the above mentioned mines and an ITOP equivalent is not known to us. Only few detectors can detect this target in 130mm depth and that also only in L1 to L3, the 4.500 up to L4, from L4 non achieves the 130mm.

R2M2 graph:

a. *General tendency:* The in-soil results are characterised by very substantial decrease of sensitivity from L1 to L7 for all detectors without GC (420HS, MD8+, M90) and for the MIL-D1 and 4.500 & 4.510. Other detectors with GC significantly lose sensitivity from L1 to L7, ATMID, VMH3. A third group the 421 GC, both Minelab, the VMH3 (M) maintain to a certain degree their sensitivity across the lanes.
b. *Lanes 2 and 3:* Six detectors both EBEX®, Vallon, Minelab have cases of either L2 or L3 in-soil sensitivities greater than those of L1.
c. *L4 reaction:* Mil D1, 420HS, MD8+, both MINEX, F1A4 and ATMID show pronounced falls at L4.
d. *L5 and L6:* five detectors (MIL-D1, 420HSBoth Minelab, ATMID), show L6 sensitivities in-soil greater than those of L5.
e. *Higher sensitivity for in-soil data:* confirmed for some detectors mainly in L1 to L4 but also happen in L5, (both EBEX®, both Foerster,MD8+, M90, VMH3), not as clear as for other targets and more spread across the lanes.
f. *Opposite trend in sensitivity in-air to in-soil:* for L3 F1A4, VMH3 and L5 ATMID.

8 Individual Detector Descriptions and Results

8.1 Introduction to the individual detector results

This section gives the individual technical description of each participating metal detector, its results, and remarks based on experiences during the trial.

Each detector has a short description of technical solutions that influence use and performance.

The results consist of the sensitivity to the test targets in the different soil types present in the lanes. Because of the varying nature of soils in which the trials were performed, comparing the results in the different lanes gives an indication of the loss of sensitivity, and of the ability of the ground compensation feature, when integrated, to overcome this. At the time of writing, completely effective ground compensation is still difficult to implement, so some loss of sensitivity does occur for almost all detectors.

"Graph description"
Figures 8-2 to 8-43 relate a detector's in-air and in-oil sensitivity to a group of targets in all lanes. There are three target groups:
Mines – include the PMN and the PMN-2 mines which have higher metal content than all the other targets. The signal from the PMN is particularly strong because of a metal ring which holds the rubber cover to the plastic body of the mine.
Simulants – include the Gyata AP and a Type 72 simulants, which were made locally for training and testing purposes. ITOP inserts were also used. These have similar metal content to fuzes of commonly found minimum metal mines (Io and Ko) and also anti-tank (Mo) mines.
Spheres – 5, 7, 10, 12, and 15mm 100Cr6 Chrome steel balls were also included for comparison purposes. The diameters used during the trial were. In-lab results in Ispra suggest that the detection height always increased with increasing sphere size. This was also generally observed in the in-air results from Mozambique.
Each graph displays the different lanes on the x-axis and the sensitivity along the y-axis. In-air results are shown as positives whilst in-soil results are negative. Targets are individually coloured, and include their respective known uncertainties displayed as error bars. The results for a given target are joined to facilitate interpretation.
As a benchmark, dotted lines were included in-soil to reflect the 130mm Mozambican and international standard clearance depth, and also in-air for easier in-air/in-soil comparison (except for sphere/balls graphs).

"Table explanation"
Tables 8-1 to 8-31 (except technical tables) show the percentage change in sensitivity of all observations with respect to in-air maximum sensitivity (in italics). This was the setting used for measurements in Lane 1.
Values in red are not only greater than the in-air maximum reference but also above known experimental uncertainties (in lilac). The values highlighted in yellow indicate the maximum loss for a particular target.
As the ITOP inserts were not used with ITOP bodies, they cannot be considered faithful representations of their intended targets. As such, ITOP insert results were not considered in the tables.

Annex C -a foldout page- provides complementary soil and detector information which can ease the interpretation of both graphs and tables.

8.2 CEIA S.p.A., metal detector MIL-D1

Plate 8-1 MIL-D1 during the trial

The MIL-D1 is a continuous wave, static mode detector. It uses a bipolar waveform to avoid the initiation of magnetic igniters and has a double D search head for easy and accurate pinpointing.
Further, the detector has:

- automatic ground compensation
- continuously changeable sensitivity control
- volume control
- a reset feature if the background noise increases
- different audible signals for detector status, and target classification
- different audio tones, one for each part of the double D search head for easier pin-pointing of the target
- possibility of modifying some parameters and upgrading software using an optional separate box

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil for PMN and PMN-2

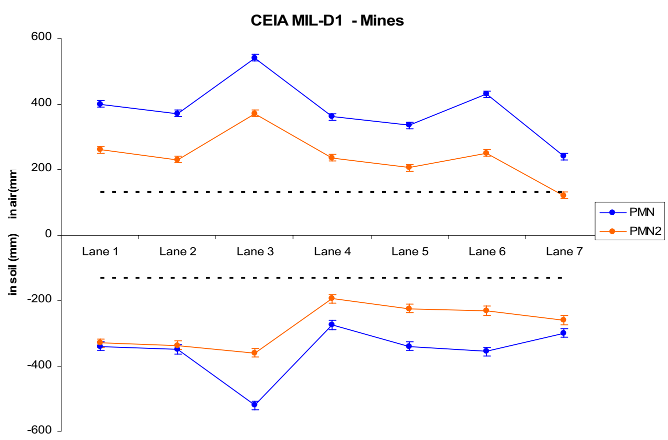


Figure 8-2 In-air and in-soil sensitivity for mine targets

Figure 8-2 shows the achieved maximum detection height/depth of the MIL-D1 to the real mine targets used during the trial.
For lanes 3 - 6, the in-air heights are similar to the in-soil depths but, surprisingly, in lane 7 much better performance was achieved in soil than in air. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, -40% in air when set-up to L7, and 31% in soil when set-up to L4.
For the PMN-2, the corresponding values were -54% in-air L7 and -61% in-soil L4.
In air, there are two peaks, one in L3 and one in L6. This is repeated only in L3 for in-soil plot. In L3, the sensitivity values are even better than in the more neutral Lane 2. The concrete bed in L1 allowed only a burial depth of 340 mm (top of the target) so we are unable to say if deeper detection of the PMN was possible. A possible explanation for the increase of sensitivity in L3 may be due to the details of the soil compensation process. L3 is the first of the lanes to have an appreciable, if small, susceptibility, therefore one would expect the detector to align differently to the way it aligns in L1 and L2, apparently yielding a higher sensitivity in this case.

The peak in L6 may be associated with the fact that the soil has lower absolute magnetic susceptibility than L5, although its frequency dependence and GRH are higher. This peak in the sensitivity curve may indicate that the MIL-D1 is more sensitive to the absolute level of the magnetic susceptibility than to the frequency dependence.

Table 8-1 MIL D1 & Mine targets: percent change of sensitivity with respect to L1 maximum in-air value.

CEIA MIL D1	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to maximum in-air value						
In-Air	PMN	***400mm***	-8%	35%	-10%	-16%	8%	-40%	8%
	PMN-2	***260mm***	-12%	42%	-10%	-21%	-4%	-54%	12%
In-Soil	PMN	-15%	-13%	30%	-31%	-15%	-11%	-25%	10%
	PMN-2	27%	30%	38%	-25%	-13%	-11%	0%	16%

When the detector is set-up to Lane 3, anomalous sensitivity measurements of up to 42% above the Lane 1 values were seen, both in-air and in-soil. Other measurements follow the expected trend of decreasing sensitivity from L1 to L7, with the exception of a small anomaly for the PMN in L6. Surprisingly, the loss of sensitivity for the in-soil measurements in L4 is nearly triple that for the in-air measurements. Conversely in L7, the in-air measurements are worse.

Both mines may be detected by the MIL D1 at the required standard depth of 130mm.

Detection height in air and depth in soil for mine simulants

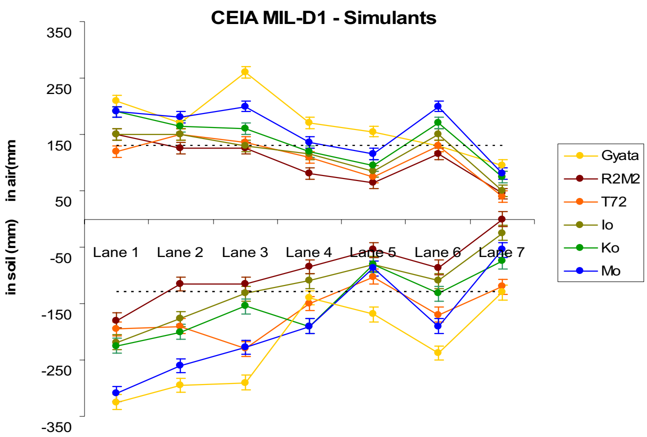


Figure 8-3 In-air and in-soil sensitivity for simulants

The grouped targets in Figure 8-3 include all mine simulants used during the test. The results are similar in general tendency to those shown in the graph for real mines. That is to say, the detector loses sensitivity as magnetic susceptibility increases. In L6, where the susceptibility decreases, the detection ability increases. The worst losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata, -55% in air and 38% in soil, both when set-up to Lane 7. For the T72, the corresponding values were -67% in-air L7 and -15% in-soil L5. The maximum loss of sensitivity for the R2M2 were -70% in-air L7 and the detector was not able to detect the target in L7.

The increases of sensitivity for the Gyata and T72 in soil are highly anomalous and we are unable to explain them. The detector has first difficulties to achieve the recommended clearance standard with the simulants representing mines of the type R2M2, PMA 3, M14, VS-1.6 by L2-L3, a further decrease of sensitivity follows to L5, then a slight improvement in L6, and in L7 none of the simulants could be detected to the standard depth. In air, the peak in L6 observed for the real mines is also observed for the simulants. In soil, the peak in L6 is observed too.

By L4, half of the targets are not detected to the required clearance depth. By L7, no targets are detected to the required depth.

Table 8-2 MIL D1 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

CEIA MIL D1	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to maximum in-air value						
In-Air	Gyata	***210mm***	-19%	24%	-19%	-26%	-38%	-55%	15%
	T72	***120mm***	25%	13%	-8%	-38%	8%	-67%	26%
	R2M2	***150mm***	-17%	-17%	-47%	-57%	-23%	-70%	21%
In-Soil	Gyata	55%	40%	38%	-33%	-20%	13%	-38%	18%
	T72	63%	58%	92%	25%	-15%	42%	0%	30%
	R2M2	20%	-23%	-23%	-43%	-63%	-43%	-100%	24%

Anomalously high sensitivity values of up to 24% above reference in-air and up to 92% above reference in-soil stand out, in L1 to L3 for the targets Gyata and T72. Other measurements follow the general trend of falling sensitivity from L1 to L7, excluding L6. The detector just gave a signal to the surface laid R2M2 simulant. Note that the strongly anomalous high values for the Gyata-64 and T-72 in Lanes 1 to 3 are greater than those in-air of the same lanes.

Detection height in air and depth in soil for steel balls

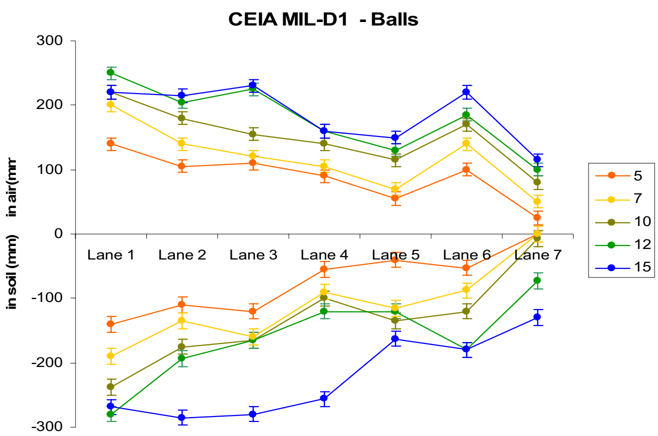


Figure 8-4 In-air and in-soil sensitivity for balls

In Figure 8-4 the practical field tests show a few exceptions to expected order in the in-soil measurements. But most of them are within the known uncertainties, excluding the 12mm ball in L6. The maximum losses in air are at L7 for all balls, which vary from 22% for the 5mm, 75% for the 7mm, 64% for the 10mm, 60% for the12mm to 48% for the 15mm ball. In-soil the maximum losses were correspondingly 100%, 100%, 97%, 71%, and 41%.

These losses of sensitivity for the spheres are similar to the results for the minimum metal content simulants above.

The 15mm sphere in soil gave a surprisingly low result in Lane 1 but this result was due to 1 reading taken from 4 being much lower than others, and so shifting the average. Also surprising is that the in-soil result for the 15mm sphere was much greater than in-air result. This cannot be explained by void effect because L1 soil is inert.

The peak in the results in L6 mentioned above is significant and follows a regular pattern, especially for the in air results.

General remarks

During the 2 weeks of the trial, no difficulties in use or technical questions arose. The detector had no problems in completing its automatic soil compensation process in all lanes, except sometimes in Lane 7 where the procedure had to be repeated. This detector is the only one tested in which soil compensation is made over a wider area, rather than with the head at a single horizontal position, so the reaction to small changes should not have as much influence as when compensating only on a search head sized region. We noticed during practice that some operators did not fully turn sensitivity to maximum to perform ground compensation. A minor recommendation would be that this manual intervention be made automatic (i.e. detector defaults to high sensitivity during ground compensation).

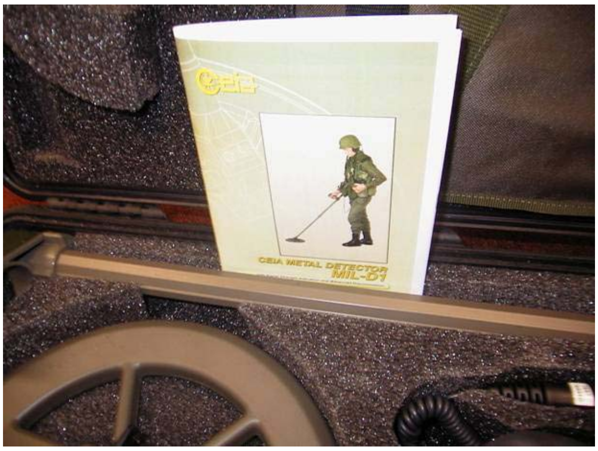
If the detector is moved a little faster than normal, there is a short signal delay after the target passes the zero-line of the double-D search head. This can easily be avoided by slowing down the speed when a signal starts on one side of the search head. This has importance for the accuracy of the pinpointing process (as a static detector it does not influence on the sensitivity).

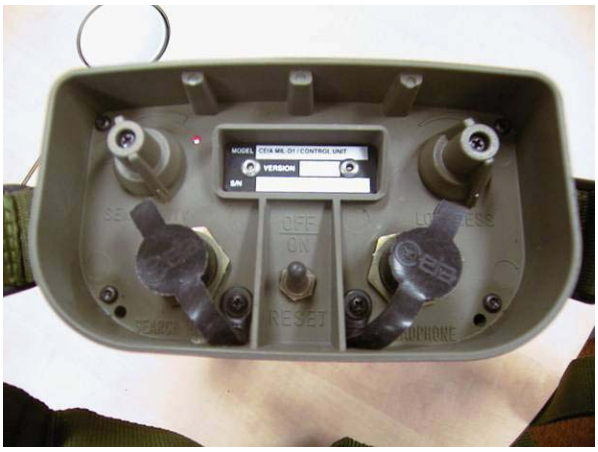
The loss of sensitivity with the increasing electromagnetic properties of the ground was substantial, especially in the area of low metal content mines.

Table 8-3 Technical data CEIA MIL D1

Metal detector:	**CEIA MIL-D1**		
Working technology	Continuous wave induction		Bipolar, triangle wave, frequency domain (3 frequencies used), static mode, separate sending and receiving coil
Price	2700	Euro	Without VAT – Unit price
Operational aspects			
Min- Max shaft length	97-149	cm	Continuous length adjustment
Weight	1.6 / 3.2	kg	Carrying C/Box ; C/Box fixed to shaft
Ground compensation	Yes		Automatic after initiation
User interactions			
Target signals	Audio		2 tone pinpointing, large metal alarm tone
System signals	Audio		Confidence click, low battery alarm
Access to software	Yes		Sensitivity adjustment
Equipment Design			
Design			2 piece design with possibility of attaching control box to shaft
Search head	Circular, 28cm		Double-D design
Speaker/headphones	Yes, internal/ Yes		
Batteries	LR20 × 4		
Package			
Operator manual	Yes		Format A5 – English - Not plasticized
Instruction card	Yes		Format single page A5 – English/French – Plasticized
List of content	Yes		Format single page A5 – English/French – Plasticized
Test piece	Yes		
Case dimensions	97 × 45 × 15	cm	
Case mass (full)	12.70	kg	With all accessories + one set of battery
Case type – material	Hard case – Plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4.77	kg	With all accessories + one set of battery

Picture details MIL-D1





8.3 Ebinger GmbH, metal detector EBEX ® 421GC

Plate 8-5 Ebex 421GC during the trial

The EBEX® 421 GC is a pulse induction, dynamic mode detector. It uses a bipolar waveform to avoid the initiation of magnetic igniters. The single send-and-receive coil is circular with a 200mm diameter search head.
The detector has:

- manual ground compensation
- continuously changeable sensitivity control
- external speaker or headphone
- battery container for C-cells, that may be replaced by an accumulator (see pictures below)

The detector has a modular design whereby different elements can be screwed on. Such elements include a UXO head, different power options, and a length extension. The detector may be extended and used with an armrest and a handle.

Further technical details and pictures are provided after the assessment.

Detection height in air and depth in soil for the PMN and PMN-2

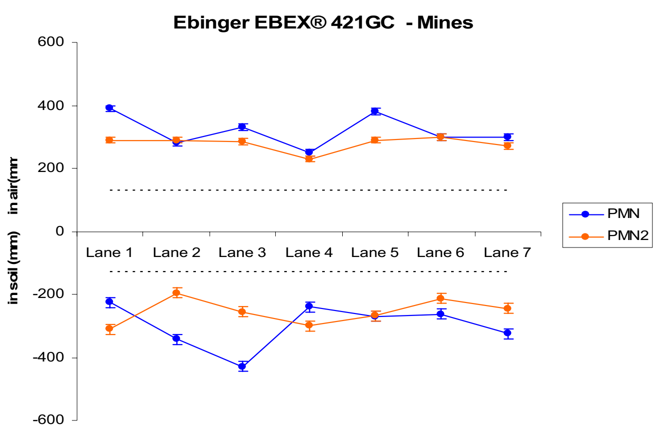


Figure 8-6 In-air and in-soil sensitivity for mine targets

Figure 8-6 illustrates the maximum detection height/depth achieved with the real mine targets used during the trial. The results for the PMN do not show a consistent decrease from L1 to L7. The sensitivity in L4 (~ 36%) is significantly lower than in L3, which one might expect, because the soil magnetic properties are markedly worse than in L3 (Figure 8-6). However, there is no further drop in sensitivity in L5-L7, so one cannot conclude that the sensitivity of the EBEX 421GC always gets worse with the soil properties. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, 36% in air and 42% in soil, surprisingly not in L7 but L4 in-air and L1 in-soil. For the PMN-2, the corresponding values were 21% in Lane 4 and 33% in Lane 2. The sensitivities vary significantly from one lane to another but not in a manner simply associated with the soil properties.

In Figure 8-6, the changes from one lane to another are not even in the same direction in air as in soil. In fact, it is usually in the opposite direction. For example, the PMN2 in L4 gives a reduced sensitivity in air , with respect to the neighbouring lanes L3 and L5, whereas in soil it has an increased sensitivity.

Table 8-4 EBEX 421GC & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

EBEX® 421 GC	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Uncertainties
		Height in air	Change with respect to maximum height in-air value						
In-Air	PMN	***390mm***	-28%	-15%	-36%	-3%	-23%	-23%	8%
	PMN-2	***290mm***	0%	-2%	-21%	0%	3%	-7%	11%
In-Soil	PMN	-42%	-12%	10%	-38%	-31%	-33%	-17%	10%
	PMN-2	7%	-33%	-12%	3%	-7%	-27%	-16%	13%

The yellow highlighted figures indicate the maximum loss of sensitivity for the detectors, which, for the in-soil data, is surprisingly not in L4 as for the in-air data.
The detector is able to detect both mines to the recommended depth under all lane conditions. The decrease of 42% in the neutral sand of L1 is not explainable.

Detection height in air and depth in soil to mine simulants

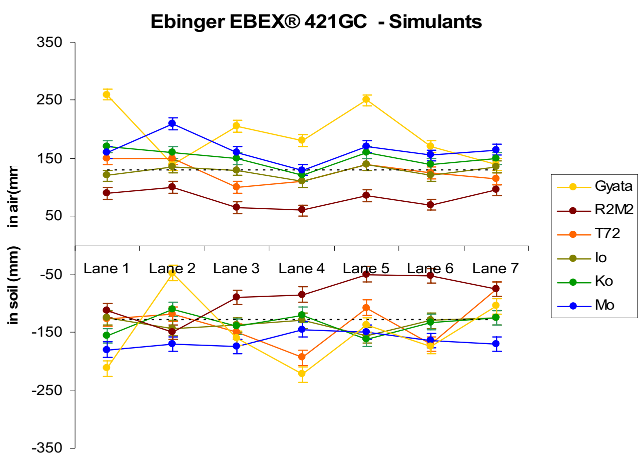


Figure 8-7 In-air and in-soil sensitivity for simulants

The detector show losses of sensitivity that vary significantly from lane to lane but the curves remain relatively flat around a certain average loss. The worst losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata 46% in-air in L2&L7 and 82% in-soil, when set-up to L2. (The last figure looks anomalous, since the loss in Lane 7 was only 60%). For the T72, the corresponding values were 33% in Lane 3 and 50% in L7. The maximum losses for the R2M2 were 28% in-air L3 and 44% in-soil to L5. We draw attention to the peak in soil in L4 and L6 for the Gyata and T72, which are not expected from the soil properties but are also seen in several other detectors.

In general the detector can detect most of the simulants to the recommended clearance standard of 130mm excluding the R2M2, and excluding in L 7, where only the Mo target is detectable deeper than 130mm. The in soil data do not show the same steady trend as the in-air data and the differences cannot be explained by the known experimental uncertainties. They include significant changes in the order of detectability of the targets. The detector could keep a certain level of sensitivity for most targets, excluding the Gyata and T72, as evidenced by the relatively flat curves.

Table 8-5 EBEX 421GC & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

EBEX® 421 GC	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Uncertainties
		Height in air	Change with respect to maximum height in-air value						
In-Air	Gyata	***260mm***	-46%	-21%	-31%	-4%	-35%	-46%	12%
	T72	***150mm***	0%	-33%	-27%	-7%	-17%	-23%	21%
	R2M2	***90mm***	11%	-28%	-33%	-6%	-22%	6%	35%
In-Soil	Gyata	-18%	-82%	-38%	-14%	-47%	-33%	-60%	14%
	T72	-15%	-21%	-1%	29%	-28%	13%	-50%	24%
	R2M2	25%	67%	0%	-6%	-44%	-42%	-17%	40%

Sensitivity values of up to 67% above reference in-soil stand out (L2&L4 for T72 and R2M2) when the other measurements follow the general trend of losing sensitivity from L1 to L7.
The maximum loss of 82% in soil and 46% in air in L2 for the Gyata are obviously out of the normal order. They may possibly have been caused by an error of set-up technique, however, the data were collected by different operators on different days. High losses of 47% in L5 and 60% in L7 are more expected: .

Detection height in air and depth in soil for steel balls

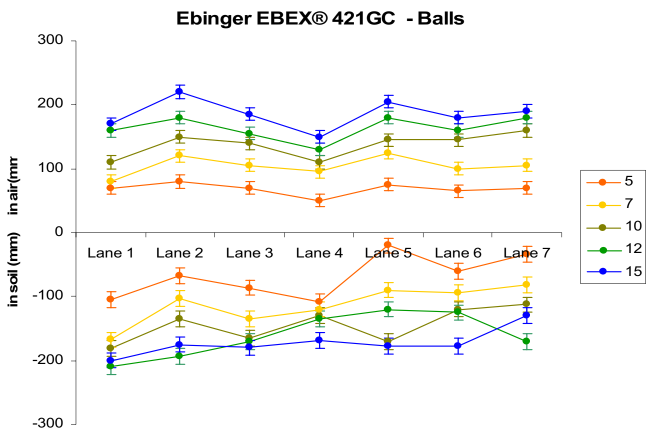


Figure 8-8 In-air and in-soil sensitivity for balls

In Figure 8-8 the practical field tests show a few exceptions to the expected order for the in the in-soil measurements. There are significant losses of sensitivity from L1 to L7 if one looks at the results in air for the targets >10mm and for all targets in soil. The in-air data especially show a good level of average sensitivity. The lower results in L1 compared with L2 and L5 in air are surprising, it appears that the adjustment of the time-domain circuit to the soil has actually increased its sensitivity to the steel balls used in this test. However, the in-soil data were all better in L1 than the in-air data. This is very hard to explain, given that L1 is almost inert magnetically. The result for L2, which is also nearly inert, is much more what would be expected: approximately equal values in air and in soil.
Significant losses in air are seen only at L4, for the 10, 12, and 15mm balls. In-soil, significant losses were in different lanes for different ball size. The L5 results for the 10mm and 12mm balls are out of the normal order, as are the L7 results for the 12 and 15mm balls.

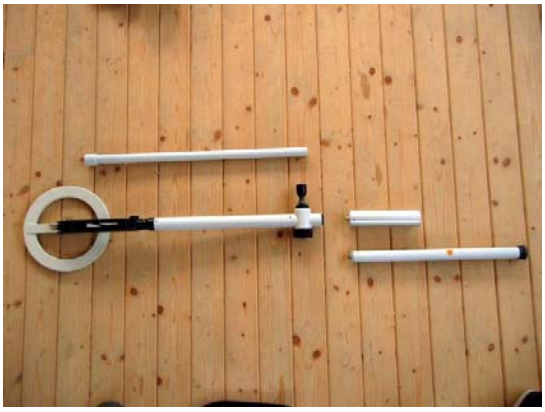
The peak in the results in L2 is significant for the in air results and follows a regular pattern. However, the in-soil data have a slight but significant trough in L2, excluding the 12mm ball, but a less regular pattern overall for the order of the detectability of the balls versus their size, compared with the in air results.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector had no problems in compensating the ground influence in all lanes and could well cope with the physically different structures of the soils i.e. the stones as well as with the magnetic properties. The signal interpretation is easy because there is little background noise.
to help with adjustment at different sites.

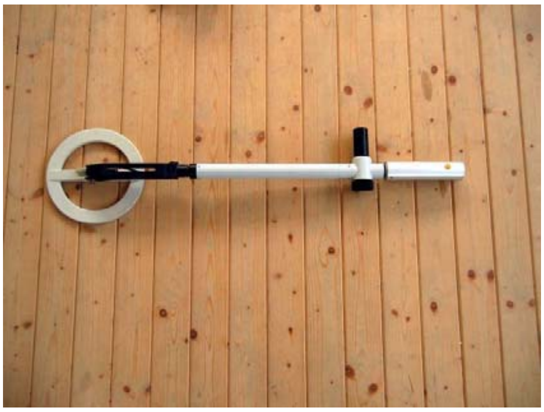
Table 8-6 Technical data EBEX® 421 GC

Metal detector:	**Ebex 421 GC**		
Working technology	Pulse induction		Bipolar pulse, dynamic mode, single sending and receiving coil
Price	2360	Euro	Without VAT – Unit price
Operational aspects			
Min- Max shaft length	87.5-148 ; 114-174(*)	cm	With cell ; (*): with battery extension
Weight	2.35 ; >2.7(*)	kg	With cell ; (*): with battery extension
Ground compensation	Yes		Manual
User interactions			
Target signals	Audio		
System signals	Audio		Confidence click, low battery alarm
Access to software	No		
Equipment Design			
Design			1 piece modular design
Search head	Circular, 23cm		
Speaker/headphones	Yes, external/ Yes		Speaker/headphone doubles as power switch
Batteries	C Cells × 8 or rechargeable pack		
Package			
Operator manual	Yes		Format A5 – English - Not plasticized
Instruction card	No		
List of content	Yes		In manual
Test piece	Yes		
Case dimensions	81 × 34 × 13	cm	
Case mass (full)	6.7	kg	With all accessories + one set of battery
Case type – material	Hard case – Plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	3.4	kg	With all accessories + one set of battery

Pictures EBEX® 421 GC



The detector with the modular extension (above) and the two possible power attachments (right).
The armrest and handle are not displayed



The detector in short configuration with the rechargeable battery pack
The armrest and handle are not displayed

Sensitivity knob (left), soil compensation adjustment knob (middle), and loudspeaker (right) which can be covered by a protective cylinder.

8.4 Ebinger GmbH, metal detector EBEX® 420 HS

Plate 8-9 EBEX 420 HS detector during the trial

The metal detector EBEX® 420 HS is a sine wave, dynamic mode detector. The bipolar waveform will avoid the initiation of magnetic fuses. The detector operates off a standard 9V accumulator, which is kept charged by a small solar panel mounted above the search head. This is a unique concept not applied by any other manufacturer to our knowledge.

Further, the detector has:

- no ground compensation
- continuously changeable sensitivity control
- a tube extension and armrest for the handle so that the detector may be used in standing, kneeling or prone positions.

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

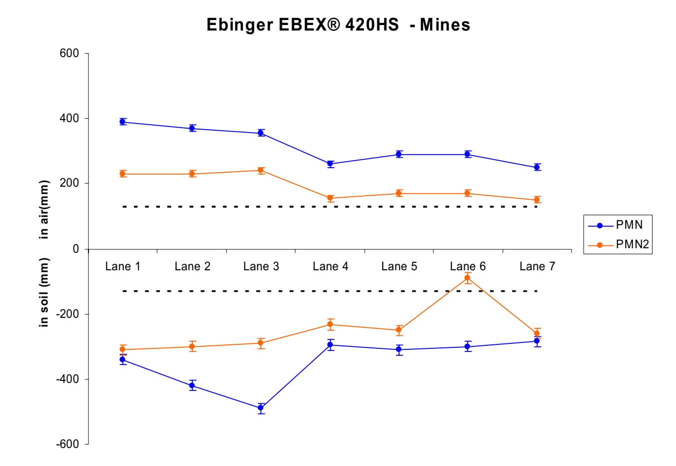


Figure 8-10 In-air and in-soil sensitivity for mine targets

Figure 8-10 shows the achieved maximum detection height/depth of the EBEX® 420 HS – Solar to the real mine targets used during the trial.

The data of the in-air measurement look very consistent in their structure and display the expected loss of sensitivity from L1 to L7. The worst losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, -36% in air and 27% in soil, both when set-up to Lane 7. For the PMN-2, the corresponding values were 35% in Lane 7 and 61% in Lane 6. (The last figure looks anomalous, since the loss in Lane 7 was only 13%).

In general, for both mines, the in-soil values are significantly better than the in-air values, excluding L6 for the PMN 2, which we are unable to explain. This is particularly apparent in the PMN result for Lanes 2 and 3. In air and in-soil, there is a significant loss at L4, as expected from the soil properties. The concrete bed in L1 allowed only a burial depth of 340 mm (top of the target) so we are unable to say if deeper detection of the PMN was possible).

Table 8-7 EBEX 420 HS & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

EBEX® 420 HS	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Uncertainties
		Height in air	Change with respect to maximum height in-air value						
In-Air	PMN	***390mm***	-5%	-9%	-33%	-26%	-26%	-36%	8%
	PMN-2	***230mm***	0%	4%	-33%	-26%	-26%	-35%	14%
In-Soil	PMN	-13%	8%	26%	-24%	-21%	-23%	-27%	10%
	PMN-2	35%	30%	26%	1%	9%	-61%	13%	16%

Both mines may be detected by the EBEX®420 HS at the required standard depth of 130mm, excluding the PMN 2 in L6 .

Detection height in air and depth in soil to mine simulants

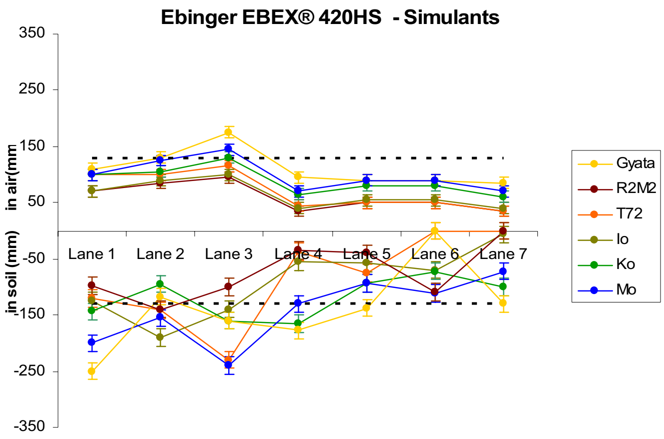


Figure 8-11 In-air and in-soil sensitivity for simulants

The grouped targets in Figure 8-11 include all mine simulants used during the test. The results are similar in the general tendency shown in the graph for real mines. The in-air data have a significant peak in L3 with increased sensitivity. Further, the detector loses sensitivity as magnetic susceptibility increases.

The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata 23% in air and 100% in soil, when set-up to L7 for in-air measurements and L6 for in-soil. (The last figure looks anomalous, since the loss in L7 was only 18%). For the T72, the corresponding values were 65% in Lane 7 and 100% in Lane 6&7. The maximum losses for the R2M2 were 50% in-air and 100% in-soil both to L7.

The in-air results look very consistent and similar to the mine curves above, Figure 8-11, excluding the peak in L3. The detector achieved better average results for the in-soil measurements to maximum sensitivity results, which we are not able to explain. The in-soil data demonstrate that for certain targets in L5 and L6 the detector should not be used, since it is not capable of detecting them at the depth required by national standards (130mm). The in soil data do not show the steady trends across the lanes seen in air and this cannot be explained by the known uncertainties. It is possible that additional experimental uncertainties were present of which we are not aware. In this respect, the in-soil results of Figure 8-11 are confusing. There are significant losses and increases of sensitivity, possibly connected with the fact that there is no ground compensation so that the individual ability of the operator may have had a substantial influence. Significant changes to the sensitivity to both sides, plus and minus, can be seen in the in-air data, even to the point that the target order changed.

In general the detector has from the beginning in L1 difficulties to detect the R2M2, T72, and the Io targets in soil. This improves to L2-L3 and from L4 the detector is not able to achieve the required clearance standard of 130mm.

Table 8-8 EBEX 420 HS & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

EBEX® 420 HS	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***110mm***	18%	59%	-14%	-18%	-18%	-23%	28%
	T72	***100mm***	0%	15%	-55%	-50%	-50%	-65%	31%
	R2M2	***70mm***	21%	36%	-50%	-29%	-29%	-50%	44%
In-Soil	Gyata	127%	7%	45%	61%	25%	-100%	18%	34%
	T72	20%	41%	130%	-63%	-25%	-100%	-100%	36%
	R2M2	39%	100%	43%	-50%	-43%	55%	-100%	51%

Anomalously high sensitivity values of up to 59% above reference in-air and up to130% above reference in-soil stand out. In-soil L1 to L3 for all targets higher sensitivity up to 130% was achieved when later the loss was 100% to all of them. The lanes 5 & 6 are the real limits for the use of this detector. Skilled operators may be able to use the detector in more severe conditions, as here in L7, by lifting the detector high enough above the surface to suppress the ground signal but this technique should never be allowed in normal clearance operations (see below).

<u>Detection height in air and depth in soil to steel balls</u>

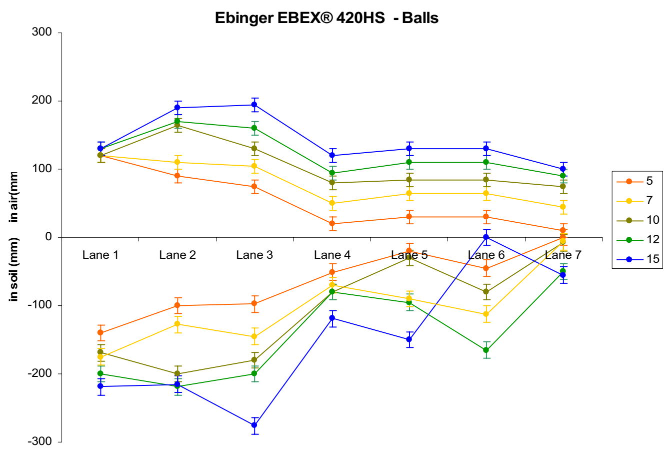


Figure 8-12 In-air and in-soil sensitivity for balls

The in-air data displays a regular pattern (Figure 8-12). There were a few exceptions to this in the in-soil, one is the 15mm ball in L6. There is significant loss of sensitivity from L1 to L7 in air and it is worse in soil. There is some evidence for an increase of sensitivity from L1 to L3, i.e. the two peaks in L2 and L3 for the balls >10mm. Significant losses in air after Lane 4 are seen only at L7 for all balls, which range from 92% for 5mm, 63% for 7mm, 38% for 10mm, 31% for 12mm to 23% for 15mm. In-soil, the maximum losses occurred almost always in L7 and were 100%, 95%, 94%, 62% and 58% respectively. The in-soil sensitivities were all better in L1 to L3 than the in-air data.

The peak in the results in L2&3 mentioned above are significant for the in air results and follows a regular pattern. The in-soil data have a significant peak in L3 for the 15mm ball. The other peak in L6 is significant for the in-soil measurements with 5,7,10, and 12mm balls to the results in L5. Surprisingly the 15mm ball was recorded as undetectable in L6, which we are not able to explain.

During the 2 weeks of the training and trial, on some days the accumulators supplied did not retain their charge on an overnight charging. We did not investigate in detail why this occurred but it may be due to cold damage during storage in Italy in the winter. After the replacement of the accumulators, no further problems were experienced. Although there is the use of normal 9V

batteries foreseen we established during the lab tests interference of the solar panel (noise of the loudspeaker) if it was turned to the light.
The absence of ground compensation made the use of the detector quite dependent on the individual abilities of the operator. The detector could be used in the different lanes by reducing the sensitivity so that the ground did not create a signal and in L7 by also lifting it to a height where no signal was received from the ground. As stated above, we do not recommend this technique because it is difficult to keep the constant level above the ground required to avoid the ground signal.

An anomalous behaviour of the detector was registered when used in L7. When lowered onto the ground, the detector did not react with a signal in spite of the very high magnetic susceptibility. Only when the detector was lifted did it give a signal. It was possible to use this effect for detection of larger targets i.e. if a signal was produced when the detector was lowered the target was considered to be detected.

The achieved in-soil results of L1 and the trend of the subsequent lanes clearly demonstrate the normal trend of sensitivity loss from L1 to L7. The reaction of the detector to the ground forces the operator to reduce the sensitivity or to lift the detector, so that by L7 sensitivity is reduced to zero for the 5mm ball.

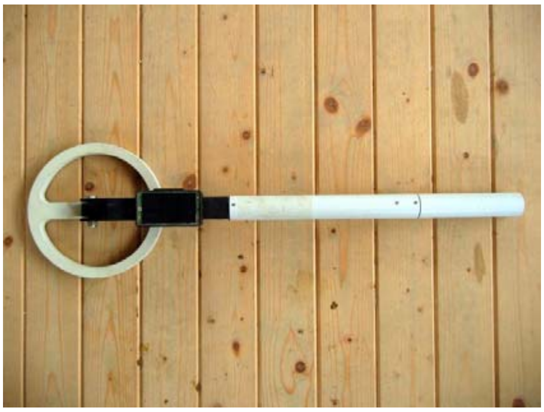
The loss of sensitivity with the increasing electromagnetic properties of the ground was significant and depends strongly on the type of the target. We do not recommend use of this detector for finding minimum metal mines when the ground conditions are similar to L3 or worse. The simple construction and low power consumption may make it valuable in less severe ground conditions.

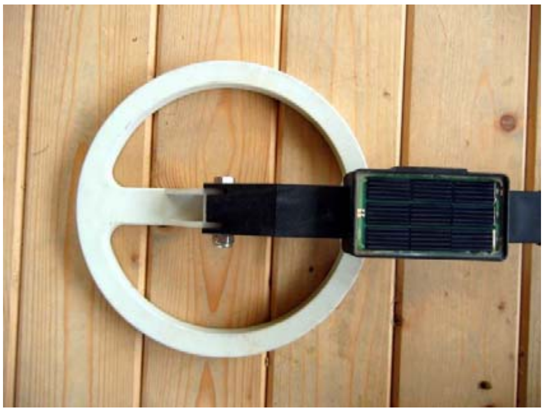
Table 8-9 Technical data EBEX® 420 HS

Metal detector:	**Ebex 420 HS**		
Working technology	Sine wave induction		Dynamic mode detector, single sinus wave, bipolar to avoid initiating magnetic fuzes.
Price	1899	Euro	Without VAT – Unit price
Operational aspects			
Min- Max shaft length	64	cm	Small version
Weight	1.2	kg	Small version
Ground compensation	No		
User interactions			
Target signals	Audio		
System signals	Audio		Confidence click, low battery alarm
Access to software	No		
Equipment Design			
Design			1 piece modular design. Extension available
Search head	Circular, 20cm		
Speaker/headphones	Yes, internal/ No		
Batteries	PP3 rechargeable × 1		Integrated solar panel
Package			
Operator manual	Yes		Format A5 – English - Not plasticized
Instruction card	No		
List of content	Yes		In manual
Test piece	Yes		
Case dimensions	81 × 34 × 13	cm	
Case mass (full)	5.2	kg	With all accessories + one set of battery
Case type – material	Hard case – Plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	1.9	kg	With all accessories + one set of battery

Pictures EBEX® 420 HS

The short version of the EBEX 420 HS in its transport case





The solar panel (right) is mounted on the search head shaft

From left: sensitivity adjustment, battery compartment, internal speaker and power knob.

8.5 Guartel Ltd., metal detector MD8+

Plate 8-13 Metal detector MD8+ during trial

The MD8+ is a pulse, dynamic mode metal detector. It uses unipolar waveform, and has a double D search head for easy and accurate pinpointing.
Further the detector has:

- no ground compensation
- 3 fixed sensitivity increments
- volume control
- optical indication of signal strength and position (relative to search head axis)
- the same audio tone for each part of the double D search head

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

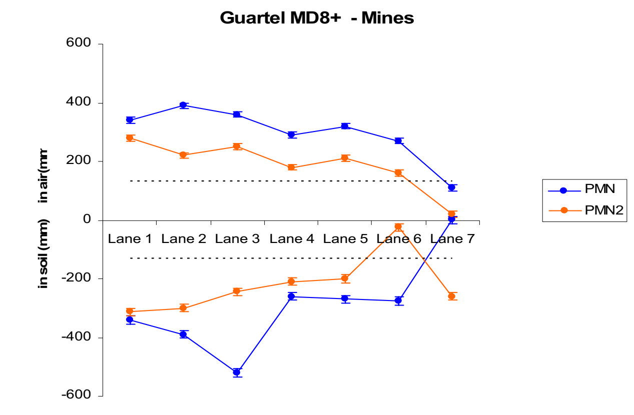


Figure 8-14 In-air and in-soil sensitivity for mine targets

Figure 8-14 shows the achieved maximum detection height/depth of the MD8+ to the real mine targets used during the trial. Both targets are, in comparison to the other targets used, relatively easy to detect due to their high metal content.
The data of the in-air measurement look consistent in their structure and display the expected loss of sensitivity from L1 to L7. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, 68% in air and 100% in soil both at L7. For the PMN-2, the corresponding values were 93% in L7in-air and 91% in-soil L6.
In general, for both mines, the in-soil values indicate the loss of sensitivity from L1 to L7 and that starting with L6 the detector is not able to detect both mines, although there is a figure in L7 that is close to the in air data for the PMN-2. In-soil, there is again an unexpected increase of sensitivity at L3 for the Gyata, that cannot be explained by the known uncertainties as well as for the PMN-2 in L7.
The concrete bed in L1 allowed only a burial depth of 340 mm (top of the target) so we are unable to say if deeper detection of the PMN was possible).

Table 8-10 MD8+ & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

MD8+	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***340mm***	15%	6%	-15%	-6%	-21%	-68%	9%
	PMN-2	***280mm***	-21%	-11%	-36%	-25%	-43%	-93%	11%
In-Soil	PMN	0%	15%	53%	-24%	-21%	-19%	-100%	12%
	PMN-2	12%	7%	-13%	-25%	-29%	-91%	-7%	13%

Both mines may be detected by the MD8+ at the required standard depth of 130mm only to L5 for the PMN-2 and to L6 for the PMN.

Detection height in air and depth in soil to mine simulants

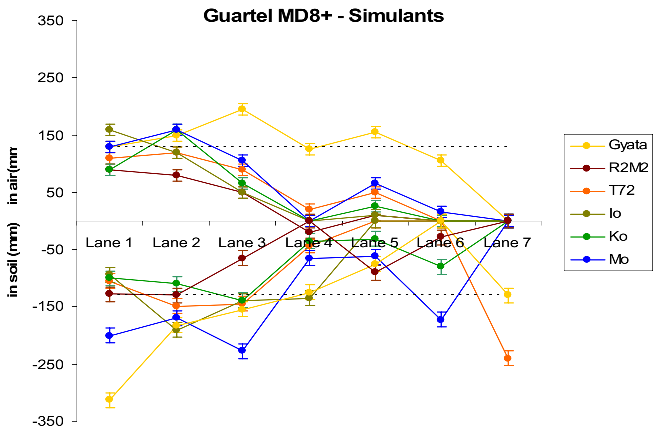


Figure *8-15* In-air and in-soil sensitivity for simulants

The grouped targets in Figure 8-15 include all mine simulants used during the test. The metal content of the imitated mines is low: they are minimum metal content mines. The in-air data indicate a rapid loss of sensitivity from L1 to L4, excluding the Gyata. Further, the detector's signal interpretation is difficult and only for the Gyata could acceptable results be achieved to L6.
The in-soil data starts with higher values of L1 to the in-air results for the Gyata, R2M2, and Mo. Further the detector loses sensitivity for different targets at different lanes to zero. The interpretation would be a guesswork and we would recommend that this detector can only be used when the conditions of deployment are not worse as in L3.
The maximum losses of sensitivity with respect to the Lane 1 in-air as well as in-soil measurements were to all targets at one point 100%, i.e. not usable for detection. The more detailed information is below in Table 8-11.
The detector has from the beginning in L1 difficulties to detect the grouped targets to the recommended standard clearance depth 130mm, excluding the Gyata and the Mo target.

Table 8-11 MD8+ & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

MD8+	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***130mm***	15%	50%	-4%	19%	-19%	-100%	24%
	T72	***110mm***	9%	-18%	-82%	-55%	-100%	-100%	28%
	R2M2	***90mm***	-11%	-44%	-100%	-89%	-100%	-100%	35%
In-Soil	Gyata	140%	40%	19%	-4%	-42%	-100%	0%	29%
	T72	-5%	35%	32%	-60%	-100%	-100%	118%	32%
	R2M2	42%	44%	-28%	-100%	0%	-68%	-100%	40%

Anomalously high sensitivity values of up to 118% above reference in-soil stand out. On the other side no detection in two lanes before. The experimental uncertainties of this detector are already much higher than for the others but they also cannot explain the results. From L4, the detector was in general not usable. To overcome this and obtain some results, the operators had to work with the search head lifted clear from the ground. This approach should not be used in the field.

Detection height in air and depth in soil to steel balls

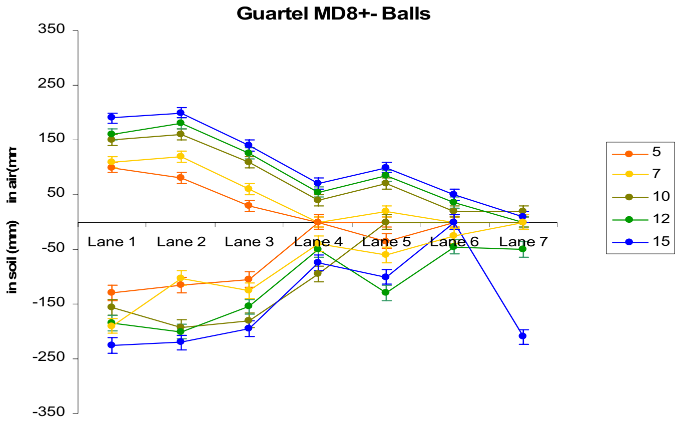


Figure 8-16 In-air and in-soil sensitivity for balls

In Figure 8-16 the practical field tests show a exceptions to the expected order in the in-soil measurements. In comparison with the results of the simulants the performance of the detector is much more conform with the in-air results. With the exception of the 15mm ball in L7, most of the other results are within the known uncertainties. There is significant loss of sensitivity from L1 to L4 looking at the results in air and in-soil. There is also a peak in L5 with improvement to L4 for the targets > 10mm, which is repeated in-soil.

During the 2 weeks of the training and trial, no technical questions arose. The detector has no soil compensation and from L4 to L7, it was very difficult to understand if the signals were caused by metal or by the ground. In general this detector should not be used if the ground conditions are worse than described for L3, or in places with inhomogeneous soil with low level susceptibility.

The loss of sensitivity with the increasing electromagnetic properties of the ground was extreme.

Table 8-12 Technical data Guartel MD8+

Metal detector:	**Guartel MD8+**		
Working technology	Pulse induction		Pulse, dynamic mode metal detector. It uses unipolar waveform, and has a double D search head for easy and accurate pinpointing
Price	2059	Euro	Without VAT – without transport case (+140€)
Operational aspects			
Min- Max shaft length	107-132	cm	Continuous length adjustment
Weight	2.4	kg	
Ground compensation	no		
User interactions			
Target signals	Audio/Visual		1 tone pinpointing, LEDs indicate signal strength and position relative to centre of search head
System signals	Audio/Visual		Confidence click, low battery alarm (sound and LEDs)
Access to software	No		
Equipment Design			
Design			2 piece design
Search head	Truncated ellipse, L:27, W:20	cm	Double-D design
Speaker/headphones	Yes, internal/ Yes		
Batteries	LR20 × 3		Detector goes in “sleep” mode when not moved
Package			
Operator manual	No		
Instruction card	Yes		Format single page A4 – English – Plasticized
List of content	No		
Test piece	No		
Case dimensions	80 × 33× 18	cm	
Case mass (full)	9.2	kg	With all accessories + one set of battery
Case type – material	Hard case – metal		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	3.38	kg	With all accessories + one set of battery

Pictures Guartel MD8+

8.6 Inst. Dr. Foerster GmbH and Co. KG, metal detector Minex 2FD 4.500

Plate 8-17 2FD 4.500.01 during the trial

The MINEX 2FD 4.500.01 is a compact, continuous wave, static mode metal detector. The bipolar waveform will avoid the initiation of magnetic igniters. It has a double D search head for easy and accurate pinpointing. Further the detector has:

- automatic ground compensation
- 3 fixed sensitivity levels
- volume control
- a reset feature if the background noise increases
- different audible signals for the detector status
- two different audio tones sounds, one for each part of the double D search head, for defining the target position

The MINEX 2FD 4.510 is the upgraded version of the 2FD 4.500. The aspect is identical, except for a serial interface, and completely new internal hardware. See section 8.7

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

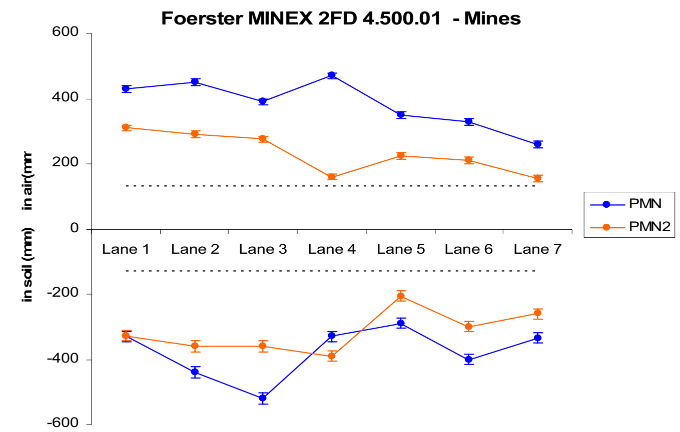


Figure 8-18 In-air and in-soil sensitivity for mine targets

Figure 8-18 shows the achieved maximum detection height/depth of the MINEX 2FD 4.500.01 to the real mine targets used during the trial.
The data of the in-air measurement look very consistent in their structure and display the expected loss of sensitivity from L1 to L7,excluding the Gyata in L4 in-air measurement. The worst losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, -40% in air at L7 and 33% in soil L5. For the PMN-2, the corresponding values were 50% in L7in-air and 33% in-soil L5.

Although the in-air data show a clearer and more consistent trend, it should not be concluded that they are necessarily more accurate than the data from the in-soil test, which is more realistic and complete. The in-soil results are, however, more difficult to interpret than the in-air data.

In general, for both mines, the in-soil values are better in L3 than the maximum sensitivity in-air reference, which we are unable to explain. This is particularly apparent in the PMN-2 result for L2 to L 4. In air and in-soil, unexpected increase/loss at L4, that are contradicting. The PMN has in-air an increase of sensitivity and a loss for the in-soil measurement when for the PMN-2 the other way around. The concrete bed in L1 allowed only a burial depth of 340 mm (top of the target) so we are unable to say if deeper detection of the PMN was possible).

Table 8-13 MINEX 2FD 4.500.01 & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

MINEX 2FD 4.500.01	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Uncertainties
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	**430mm**	5%	-9%	9%	-19%	-23%	-40%	7%
	PMN-2	**310mm**	-6%	-11%	-48%	-27%	-32%	-50%	10%
In-Soil	PMN	-23%	2%	21%	-23%	-33%	-7%	-22%	9%
	PMN-2	6%	16%	16%	26%	-33%	-3%	-16%	12%

Both mines may be detected by the MINEX 2FD 4.500.01 at the required standard depth of 130mm.

Detection height in air and depth in soil to mine simulants

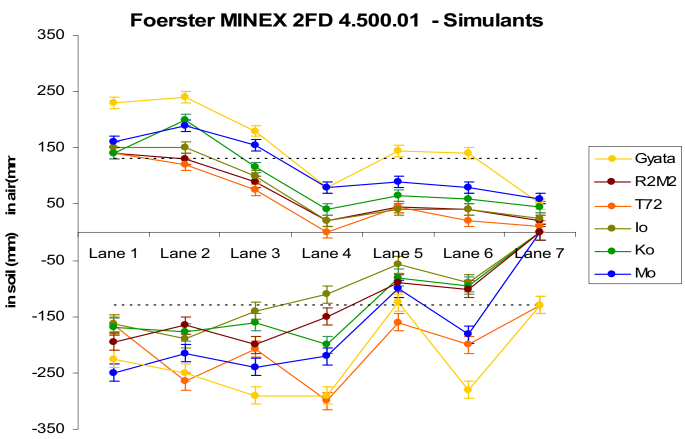


Figure 8-19 In-air and in-soil sensitivity for simulants

The in-air data have a significant peak in L2 for the Mo and Ko targets. Further, the detector loses sensitivity significantly as magnetic susceptibility increases for the in-air values from L1 to L7. The in-soil data starts with higher values L1 for the T72 and R2M2 has an increase of sensitivity to L3&L4 coming to zero for most of the targets in L7, excluding the Gyata and the T72.

The worst losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata 78% in air and 43% in soil, when set-up to Lane 7 for in-air and for in-soil measurements. For the T72, the corresponding values were 100% L4 and 93% L7 in air but only 7% in L7 in soil. The maximum losses for the R2M2 were 86% in-air for L4 and L7 and 100% in-soil to L7. The in-air results look consistent and indicate significant loss of sensitivity with increasing magnetic susceptibility. The detector achieved better average results for the in-soil measurements than the reference value in-air results, which we are not able to explain. The in soil data do not show the same steady trend as the in-air data and the differences cannot be explained by the known experimental uncertainties. In this respect, the in-soil results of Figure 8-19 are confusing. There are significant losses and increases of sensitivity, possibly connected with the fact that the detector is very sensitive to inhomogeneous ground and signals in the more complicated ground conditions, starting with L4. Individual ability of the operator may have had an additional influence.. Significant changes both above and below the in-air sensitivity occurred, even to the extent that the order of target detectability changed.

The in-soil data demonstrate that the detector is not able to detect certain targets in L5 to L7, and so should not be used in similar conditions if these or similar targets are expected. The detector has, from L4, difficulties in detecting targets to the recommended standard: in L4 in soil the Io is not detected at 130mm and in L5 only the T 72 is detected at 130mm and in L6 only the Gyata, T72 and Mo. For L7 the detector could not compensate the ground and the results were achieved by lifting the detector above the ground: a technique that would not be allowed for these targets in clearance operations.

Table 8-14 MINEX 2FD 4.500.01 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

MINEX 2FD 4.500.01	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***230mm***	4%	-22%	-65%	-37%	-39%	-78%	14%
	T72	***140mm***	-14%	-46%	-100%	-68%	-86%	-93%	22%
	R2M2	***140mm***	-7%	-36%	-86%	-68%	-71%	-86%	22%
In-Soil	Gyata	-2%	9%	26%	26%	-46%	22%	-43%	16%
	T72	18%	89%	48%	114%	14%	43%	-7%	25%
	R2M2	39%	18%	43%	7%	-36%	-28%	-100%	25%

Anomalously high sensitivity values in-soil of up to 114% above reference stand out. In-soil L1 to L4 for most targets higher sensitivity up to 114% was achieved when, in the higher numbered lanes, the loss was 100% to all of them in L7(no ground compensation). Good operators may still be able to use the detector in such conditions by reducing the sensitivity and raising the detector above the ground so that the signal or interference from the ground stops. We recommend that this technique is never used in normal clearance operations because it is too operator-dependent to be safe.

Detection height in air and depth in soil to steel balls

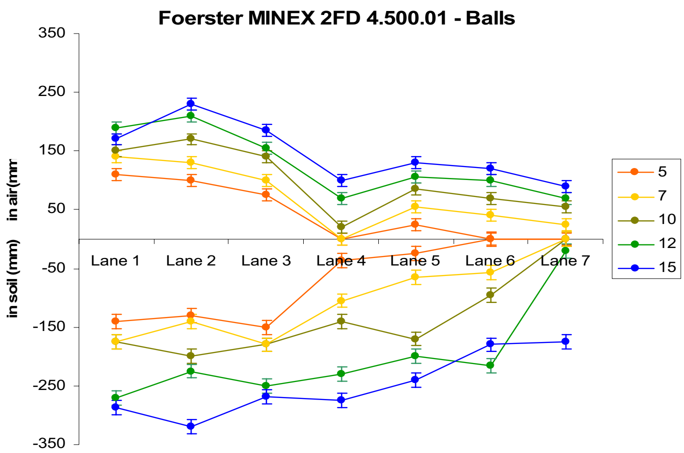


Figure 8-20 In-air and in-soil sensitivity for balls

In Figure 8-20 the practical field tests show a few exceptions to the expected order in the in-soil measurements. There is substantial loss of sensitivity from L1 to L7 if one looks at the results in air, which is worse in soil due to the higher results in L1. There is an increase of sensitivity from L1 to L3. This is based on the results with maximum sensitivity in air and the peak in L2 for the ball 15mm. Significant losses in air and in soil begins with L4. The max losses in air are 100% for 5mm, 82% for 7mm, 63% for 10mm, 63% for 12mm and 47% for 15mm. In-soil the maximum losses were in L7 and were 100%, 100%, 100%, 89%, and 3% respectively. The in-soil data were all better in L1 to L3 than the in-air data.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector was unable to complete its automatic soil compensation process in L7. The physically different structures of the soils i.e. the stones as well as the magnetic properties produced difficulties for the operators by creating false alarms in the absence of metal. In general, signal interpretation with this detector is difficult when inhomogeneous ground conditions are combined with magnetic ground properties. It is possible that some points where the sensitivity appeared to be greater than the in-air reference may have been due to false alarms from the soil, in the lanes starting from L4. The loss of sensitivity with the increasing electromagnetic properties of the ground was substantial, especially in the area of low metal content mines.

8.7 Inst. Dr. Foerster GmbH and Co. KG, metal detector Minex 2FD 4.510

The MINEX 2FD 4.510 is the new upgraded version of the 4.500 described above. It has the same external appearance and general technical characteristics: it is a compact, one-piece, static mode metal detector with dual-frequency sinusoidal, bipolar waveform and double D search head.

The differences are:

- new electronic hardware that retains the last setup to the ground conditions.
- serial interface for
    - software setup to local conditions
    - data logging.

Because the set-up is retained in memory, if the user wishes to use the detector at maximum sensitivity, an in-air set up should be performed.

Detection height in air and depth in soil to PMN and PMN-2

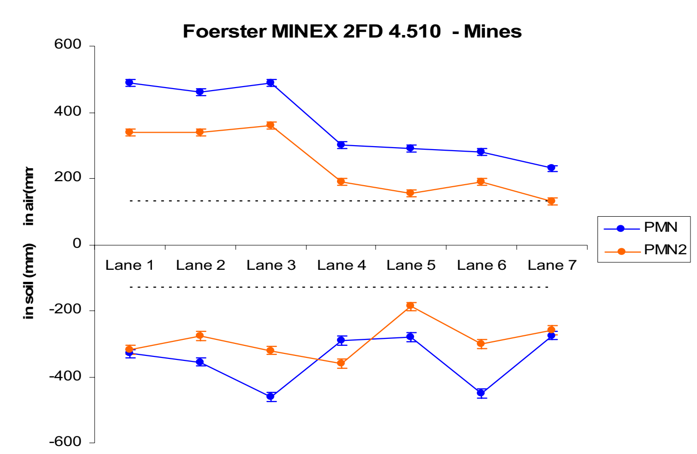


Figure 8-21 MINEX 4.510 in-air and in-soil sensitivity for mine targets

Figure 8-21 shows the achieved maximum detection height/depth of the MINEX 2FD 4.510 to the real mine targets used during the trial.
The maximum losses of sensitivity with respect to the L1 in-air measurements were, for the PMN, -53% in air and 44% in soil both at L7. For the PMN-2, the corresponding values were 62% in L7 in-air and 45% in-soil L5. The data of the in-air measurement look very consistent in their structure and display the expected loss of sensitivity from L1 to L7. In general, for both mines, the trend in the values is more complicated than that of the simpler in-air data, as with the 4.500.01. The departures from a simple trend are beyond what can be explained by the known uncertainties This is particularly apparent in the PMN result. The PMN results for L6 in-soil and the PMN-2 increased sensitivity from L3 to L4 are surprising.
The concrete bed in L1 allowed only a burial depth of 340 mm (top of the target) so we are unable to say if deeper detection of the PMN was possible in this lane.

Table 8-15 MINEX 2FD 4.510 & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

MINEX 2FD 4.510	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***490mm***	-6%	0%	-39%	-41%	-43%	-53%	6%
	PMN-2	***340mm***	0%	6%	-44%	-54%	-44%	-62%	9%
In-Soil	PMN	-33%	-28%	-6%	-41%	-43%	-8%	-44%	8%
	PMN-2	-7%	-18%	-6%	6%	-45%	-12%	-24%	11%

Both mines may be detected by the MINEX 2FD 4.510 at the required standard depth of 130mm.

Detection height in air and depth in soil to mine simulants

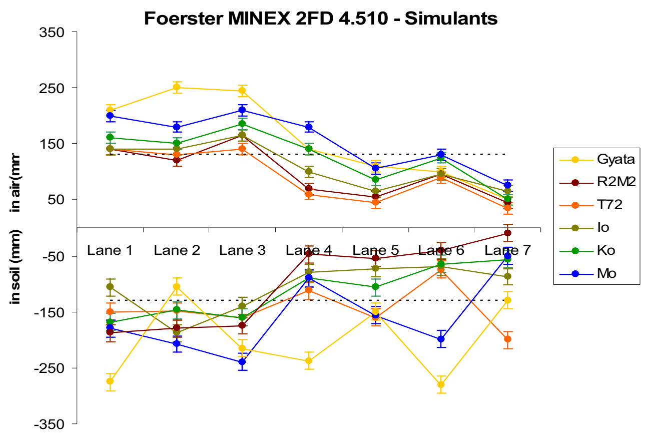


Figure 8-22 MINEX 4.510 in-air and in-soil sensitivity for simulants

The in-air data demonstrate consistently a significant loss of sensitivity as magnetic susceptibility increases for the in-air values from L1 to L7. The in-soil data do not have this consistency and significant departures from a simple trend are present, including in the order of detectability the targets.

The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata 76% in air when set-up to L7 and 50% in soil L2. For the T72, the corresponding values were 75% in Lane 7 and 46% in L6. The maximum losses for the R2M2 were 68% in-air and 93% in soil, both for L7. The in-soil data demonstrate that for certain targets from L4 to L7 the detector is not able to maintain the recommended clearance depth of 130mm. The in soil data do not show the same steady trend as the in-air data and the differences cannot be explained by the known experimental uncertainties. There are significant losses and increases of sensitivity, possibly connected with the fact that the detector is still sensitive to inhomogeneous ground. Soil signals in the more complicated ground conditions, starting with L4, may have sometimes been misinterpreted as metal signals. Individual ability of the operator may have had an influence.

The detector has, from L4, difficulties in detecting targets to the recommended standard. In L4, only the Gyata may be detected deeper than130mm. In L5 the Gyata, T 72 and Mo are detected at 130mm and in L6 the Gyata and Mo.

For L7 this model could compensate the ground, which is an improvement on the previous version 4.500. The L7 in-soil results shown here were obtained by normal handling of the detector, without raising it off the surface.

Table 8-16 MINEX 2FD 4.510 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

MINEX 2FD 4.510	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***210mm***	19%	17%	-33%	-48%	-52%	-76%	15%
	T72	***140mm***	-7%	0%	-57%	-68%	-36%	-75%	22%
	R2M2	***140mm***	-14%	18%	-50%	-61%	-32%	-68%	22%
In-Soil	Gyata	31%	-50%	2%	13%	-29%	33%	-38%	18%
	T72	7%	6%	14%	-20%	14%	-46%	43%	25%
	R2M2	34%	29%	25%	-66%	-61%	-71%	-93%	25%

Anomalously high sensitivity values in soil of up to 43% above in-air reference stand out but are much less than the equivalent values for the older model, version 4.500, where they were as great as 114% above in-air reference.

Detection height in air and depth in soil to steel balls

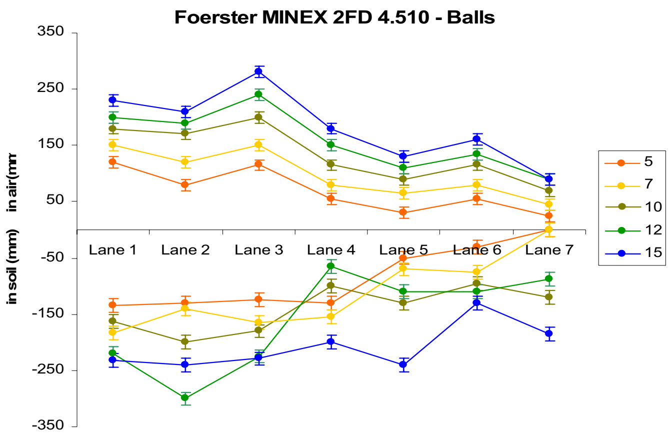


Figure 8-23 MINEX 4.510 in-air and in-soil sensitivity for balls

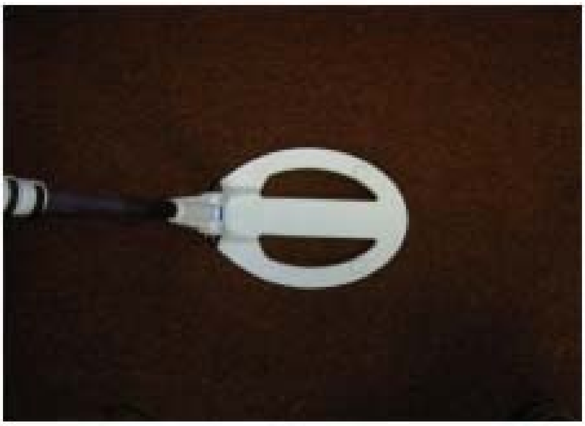
Figure 8-23 shows the ball size and detection height in air and depth in soil. In lab results in Ispra, the detection height always increases with the size of the target, confirmed here with the in-air data. In Figure 8-23 the practical field tests show a few exceptions to this in the in-soil measurements but most of them are within the known uncertainties. There is significant loss of sensitivity from L1 to L7 if one is looking at the results in air, and a similar trend is seen in soil. There is an increase of sensitivity from L1 to L3 for the ball 10mm and 12mm balls. Significant losses in air and in soil begins with L4. In L7 the max losses in air are 79% for 5mm, 70% for 7mm, 61% for 10mm, 55% for 12mm and 61% for 15mm. In-soil, the L7 losses were 100%, 100%, 33%, 56% and 20% from 5 to 15mm balls, which were all maximum losses excluding the 12mm and 15mm balls, where the max losses were 68 % and 43% in L6.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector was always able to complete its automatic soil compensation process, even in L7. But the physically different structures of the soils i.e. the stones as well as the magnetic properties still produced difficulties for the operators by creating false alarms without the presence of metal. Both the sensitivity and indication of the signals has been improved and made louder, so that it is easier to interpret. There is still a signal interpretation problem when inhomogeneous ground conditions are combined with magnetic ground properties, although it is reduced in comparison with the previous model. Some of the cases where sensitivity greater than in-air reference was recorded may have been due to misinterpretation of ground signals as metal signals.
The loss of sensitivity with the increasing electromagnetic properties of the ground was substantial, especially in the area of low metal content mines.

Table 8-17 Technical data MINEX 2FD 4.500.01 and MINEX 2FD 4.510

Metal detector:	**MINEX 2FD 4.500.01 and 4.510**		
Working technology	Sinus wave induction		Two sinus waves, bipolar, frequency domain, static mode, separate sending and receive coils, double-D receive coil
Price	2990	Euro	Without VAT
Operational aspects			
Min- Max shaft length	85-160	cm	Continuously adjustable
Weight	2.6	kg	
Ground compensation	Yes		Automatic after initiation
User interactions			
Target signals	Audio		2 tone pinpointing
System signals	Audio/Visual		Confidence click, low battery alarm (sound and LEDs)
Access to software	Yes for 4.510		
Equipment Design			
Design			1 piece design
Search head	ellipse,L:29, W:21	cm	Double-D design
Speaker/headphones	Yes, internal/ Yes		
Batteries	LR20 ×3		
Package			
Operator manual	Yes		A4, not plasticized - English
Instruction card	No		
List of content	Yes		In manual
Test piece	Yes		
Case dimensions	98 × 27× 33	cm	
Case mass (full)	9.4	kg	With all accessories + one set of battery
Case type – material	Hard case – plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	3.75	kg	With all accessories + one set of battery

Picture details MINEX 2FD 4.500.01 & 4.510



The 4.510 has the same appearance except for a serial interface near the sensitivity switch

8.8 Minelab Pty. Ltd., metal detector F1A4

Plate8-24 F1A4 during the trial

The F1A4 is a pulse, dynamic mode detector, using a unipolar waveform. A patented multiple pulse-width technology is used for improved soil compensation.
Further, the detector has:

- automatic ground compensation
- fixed sensitivity
- a reset feature if the background noise increases
- noise cancel function so that detectors can adjust to the surrounding electromagnetic field including the work of nearby detectors
- plugging the earpiece will not switch off the integrated loudspeaker of the electronic unit. An optional earpiece which mutes the loudspeaker is also available
- different audible signals for the detector status as well as for target classification
- continuous confidence tone

The Minelab design ensures that the operator does not accidentally change sensitivity whilst working.

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

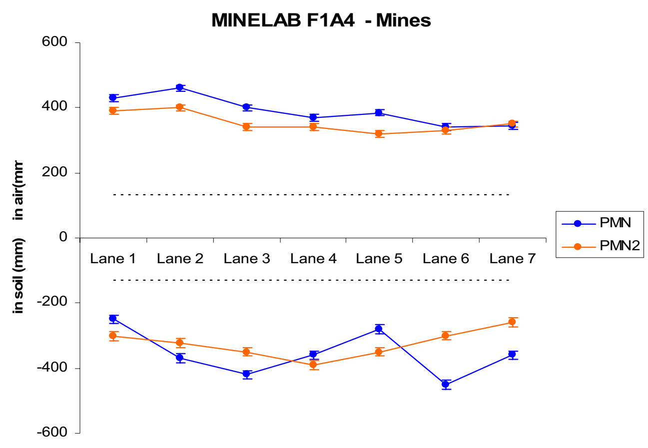


Figure 8-25 In-air and in-soil sensitivity for mine targets

Figure 8-25 shows the achieved maximum detection height/depth of the F1A4 to the real mine targets used during the trial. The data of the in-air measurement look consistent in their structure and display the expected loss of sensitivity from L1 to L7. The curves are relatively flat and show that the general loss of sensitivity is not too much influenced by the necessary ground compensation starting in L3.
The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the PMN, -20% in air when set-up to L7 and -35% in soil L5. For the PMN-2, the corresponding values were -18% in-air L5 and -33% in-soil L7. The loss of sensitivity in soil of 42% in L1 is based on the allowed burial depth that was limited to 340mm (top of the target) due to the concrete bed of the lane. So we were not able to establish if a deeper detection was possible.
The in-soil data in Figure 8-25 from the practical field tests show a few exceptions to the in-air measurements. L1 for the PMN was explained above, further the detector loses sensitivity to L5 comes to higher sensitivity as in air in L6 within the known uncertainties and losing sensitivity

again in L7. Surprisingly the detector has its highest sensitivity to the PMN-2 in L4, where most detectors are significantly losing sensitivity.

Table 8-18 Minelab F1A4 & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

Minelab F1A4	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***430mm***	7%	-7%	-14%	-10%	-21%	-20%	7%
	PMN-2	***390mm***	3%	-13%	-13%	-18%	-15%	-10%	8%
In-Soil	PMN	-42%	-14%	-2%	-16%	-35%	5%	-16%	9%
	PMN-2	-22%	-17%	-10%	0%	-10%	-23%	-33%	10%

Both mines could be easily detected by the Minelab F1A4 at the required standard depth of 130mm under all available ground conditions at the trial site.

Detection height in air and depth in soil to mine simulants

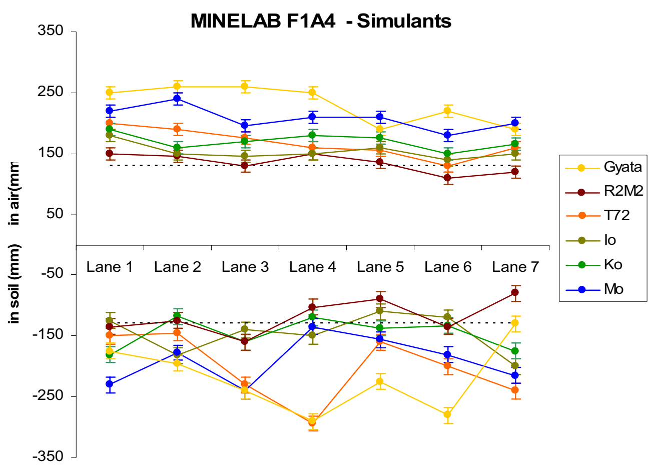


Figure 8-26 In-air and in-soil sensitivity for simulants

The results are similar in general tendency to those shown in the graph for real mines. That is to say, the detector loses sensitivity as magnetic susceptibility increases. In L6 where the susceptibility decreases an increase of sensitivity is indicated. But the large increase of susceptibility between L6 and L7 (from 636 to 2885 SI units) influenced on two targets (Gyata, R2M2) only. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata, -24% in air and 48% in soil, both when set-up to L7, the same loss was in-air at L5. For the T72, the corresponding values were -35% in-air L6 and -25% in-soil L1, when in L7 -20% only. The maximum loss of sensitivity for the R2M2 were -27% in-air L6 and -47% in-soil L7. The increases of sensitivity for the Gyata and T72 in soil are highly anomalous in L4 and in L5 for the Gyata and we are unable to explain them.

The detector has first difficulties to achieve the recommended clearance standard of 130mm with the simulants representing mines of the type R2M2, PMA 3, T72, M14, VS-1.6 by L4 to L7. An in-air increase of sensitivity is visible.

The sensitivity loss concerning the standard clearance depth concerns mainly the R2M2 and the Io ITOP L5&6. The Kop ITOP is within the known uncertainties at the limits to the clearance standard. All other targets may be detected in all lanes to 130mm depth.

Table 8-19 Minelab F1A4 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

Minelab F1A4	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Uncertainties
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***250mm***	4%	4%	0%	-24%	-12%	-24%	12%
	T72	***200mm***	-5%	-13%	-20%	-23%	-35%	-20%	16%
	R2M2	***150mm***	-3%	-13%	0%	-10%	-27%	-20%	21%
In-Soil	Gyata	-30%	-22%	-4%	16%	-10%	12%	-48%	15%
	T72	-25%	-28%	15%	47%	-20%	0%	20%	18%
	R2M2	-10%	-17%	7%	-32%	-40%	-10%	-47%	24%

Anomalously high sensitivity values of to 47% above reference in-soil stand out in L4, L5 &L7 for the T72 and L4 for the target Gyata. Other measurements follow the general trend of losing sensitivity from L1 to L7, excluding the mentioned before. The loss of sensitivity to the R2M2 in-soil is not created by the amount of metal but by the type of used metal, stainless steel. The increase of sensitivity for the Gyata and T72 is a phenomenon we cannot explain. Similar cases of increased sensitivity appeared with other detectors and targets too.

Detection height in air and depth in soil to steel balls

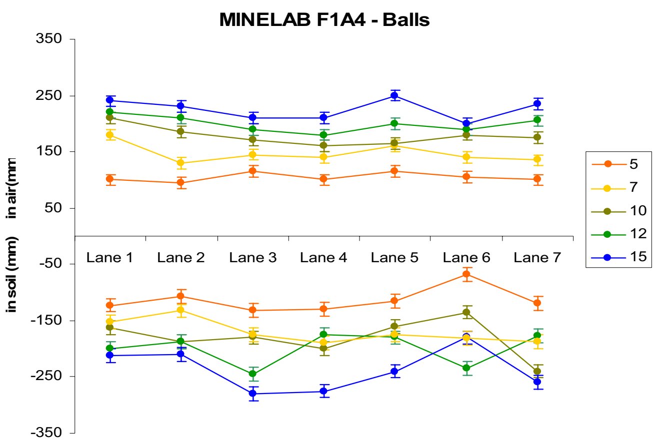


Figure 8-27 In-air and in-soil sensitivity for balls

In Figure 8-27 the practical field tests show a few exceptions to the expected order in the in-soil measurements. But most of them are within the known uncertainties.

The maximum losses in air are distributed at different lanes, which vary from -5% in L1 for the 5mm, -28% for the 7mm, -24% L4 for the 10mm, -18% L4 for the 12mm to -17% L6 for the 15mm ball. In-soil the maximum losses were correspondingly to 5mm L6 -33%, 7mm L2 -26%, 10mm L6 -36%, 12mm L5 -20%, and 15mm L6 -25%. These losses of sensitivity for the spheres are similar to the results for the minimum metal content simulants above. This may be due to their size and metal content being similar.

For the in-soil data there two peaks one in L3 and one L7 where a significant increase of sensitivity to L1 or the lane before to most of the targets is shown.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector had no problems in completing its automatic soil compensation process in all lanes and could well cope with the physically different structures of the soils i.e. the stones as well as with the magnetic properties. The signal interpretation is easy because of the relatively low background noise. The detector kept a good level of sensitivity to all lanes. The distribution of the maximum loss to different lanes may in this case be a part of the uncertainties we are not aware about. A possibility may be the used metal for the simulants.

The loss of sensitivity with the increasing electromagnetic properties of the ground was significant but most of the used targets i.e. mines and simulants of mines could be detected in all lanes to 130mm depth.

Table 8-20 Technical data Minelab Metal detector F1A4

Metal detector:	**Minelab F1A4**		
Working technology Price	Pulse induction 1969	 Euro	Dynamic mode. Patented multiple pulse width technology for improved soil compensation, Without VAT
Operational aspects			
Min- Max shaft length	100-137	cm	Continuously adjustable
Weight	3.1	kg	With control box fitted to shaft
Ground compensation	Yes		Automatic after initiation
User interactions			
Target signals	Audio		
System signals	Audio/Visual		Confidence tone, low battery alarm (sound and LED)
Access to software	Yes		Via RS232 port
Equipment Design			
Design			2 piece design. Control box can be fitted to shaft
Search head	circular, 21	cm	
Speaker/headphones	Yes, internal/ Yes		
Batteries	LR20 × 4		
Package			
Operator manual	Yes		A5, not plasticized – English, water proof, tear resistant
Instruction card	Yes		Single A5 page, plasticized - English
List of content	Yes		On the instruction card
Test piece	Yes		
Case dimensions	86 × 34× 19	cm	
Case mass (full)	8.6	kg	With all accessories + one set of battery
Case type – material	Hard case – plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4	kg	With all accessories + one set of battery

Picture details Minelab F1A4

8.9 Minelab Pty. Ltd., metal detector F3

Plate 8-28 Detector F3 during the trial

The Minelab F3 is a compact one-piece, pulse dynamic mode detector. A patented multiple pulse-width technology is used for improved soil compensation. It uses bipolar pulses to avoid the ignition of magnetic fuzes.
Further, the detector has:

- automatic ground compensation
- fixed sensitivity. This can only be changed by using special coloured caps which are fitted to the electronic unit. This approach avoids accidental changes of sensitivity during use
- a reset feature if the background noise increases
- earpiece that will not switch off the integrated loudspeaker of the electronic unit. Optionally, an earpiece that will mute the internal loudspeaker is available
- continuous confidence tone

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

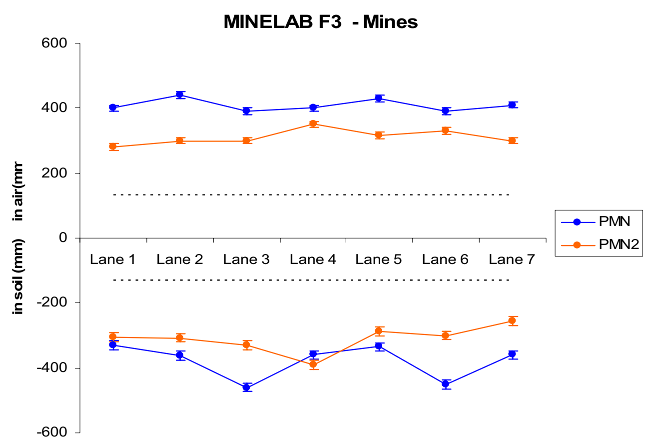


Figure 8-29 In-air and in-soil sensitivity for mine targets

Figure 8-29 shows the achieved maximum detection height/depth of the F3 to the real mine targets used during the trial. The data of the in-air measurement look consistent in their structure and indicate no or minimum loss of sensitivity for the in-air results. The curves are flat and express that the general loss of sensitivity is not really influenced by the necessary ground compensation starting in L3.
The loss of sensitivity with respect to maximum sensitivity in-air measurements is reduced to the Gyata and was -3% for the L3&L6. All other in air results are above the in air measurements. The maximum loss of sensitivity in soil of 18% in L1 is based on the allowed burial depth that was limited to 340mm (top of the target) due to the concrete bed of the lane. So we were not able to establish if a deeper detection was possible. The other loss of 16% in L5.
The in-soil data in Figure 8-29 from the practical field tests show significant differences to the in-air measurements. L1 for the PMN was explained above, further the detector has a peak of sensitivity at L3 loses sensitivity to L5 another peak at L6 and losing sensitivity again in L7. For the PMN-2 the highest sensitivity as in-air as well as in-soil was measured in L4. This is similar to the F1A4 reaction and contrasts with the other detectors.

Table 8-21 Minelab F3 & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

Minelab F3	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***400mm***	10%	-3%	0%	8%	-3%	3%	8%
	PMN-2	***280mm***	7%	7%	25%	13%	18%	7%	11%
In-Soil	PMN	-18%	-9%	15%	-10%	-16%	13%	-10%	10%
	PMN-2	9%	10%	18%	39%	3%	7%	-9%	13%

The in-soil data are mirrored in-air measurements for the PMN-2 with the highest level of sensitivity in L4. The same but in a negative way can be said for the PMN, where the lowest level of sensitivity in air was measured the highest level in soil was achieved L3&L6.
Both mines could be easily detected by the Minelab F3 at the required standard depth of 130mm under all available ground conditions at the trial site.

Detection height in air and depth in soil to mine simulants

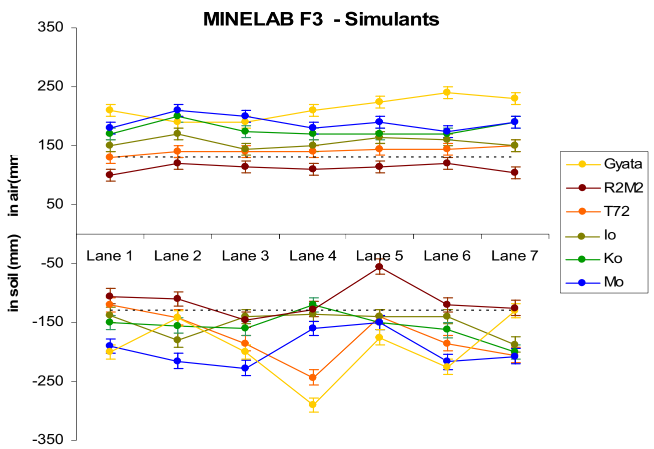


Figure 8-30 In-air and in-soil sensitivity for simulants

The results are similar in general tendency to those shown in the graph for real mines. In-air the detector loses only sensitivity to the Gyata in L2&L3. All other results are above the values from maximum sensitivity in-air L1 and within the known uncertainties. The results of the in-soil data are quite different. In L4 there is a peak for the Gyata and T72 and in L5 the general negative peak in sensitivity. The large increase of susceptibility from L6 to L7 (636 to 2885 SI units) influenced on the Gyata results only. The other targets can be detected as in L6 or even deeper as there. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were, for the Gyata, -10% in air in L2&L3 and -38% in soil when set-up to L7. For the T72, a loss of sensitivity appeared only with -8% in-soil in L1, when in L7 -+58% were established, which we are not able to explain. A loss of sensitivity for the R2M2 was only with -45% in-soil L5.

Table 8-22 Minelab F3 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

Minelab F3	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***210mm***	-10%	-10%	0%	7%	14%	10%	15%
	T72	***130mm***	8%	8%	8%	12%	12%	15%	24%
	R2M2	***100mm***	20%	15%	10%	15%	20%	5%	31%
In-Soil	Gyata	-5%	-32%	-5%	38%	-17%	7%	-38%	18%
	T72	-8%	9%	42%	88%	8%	42%	58%	27%
	R2M2	5%	10%	45%	28%	-45%	20%	25%	36%

Anomalously high sensitivity values of to 88% above reference in-soil stand out in L3, L4, L6&L7 for the T72 and L4 for the target Gyata. The increases of sensitivity for the Gyata and T72 in soil are highly anomalous in L4 for the Gyata and for the T72 in four lanes, we cannot explain them but they are a general repetition of the F1A4 behaviour. The increase of sensitivity for the Gyata and T72 is a phenomenon we cannot explain. Other measurements follow no pattern. Similar cases of increased sensitivity appeared with other detectors and targets too.

The detector has difficulties to achieve the recommended clearance standard of 130mm with the simulant representing the mines of the type R2M2, R2M2 , and the AT No8 (RSA) from L1 to L7. Two other simulants are to the limits of the 130mm but within the known uncertainties at some places.

Detection height in air and depth in soil to steel balls

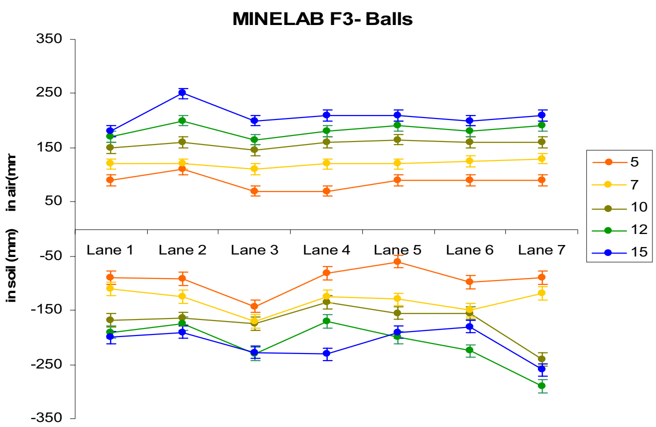


Figure 8-31 In-air and in-soil sensitivity for balls

In Figure 8-31 the practical field tests show a few exceptions to the expected order in the in-soil measurements.
The maximum losses in-air are all in L3, which graduate from -22% for the 5mm, -8% for the -7mm, -3% for the 10mm, ---3% for the 12mm to positive for the 15mm ball. In-soil the maximum losses were distributed to different lanes and were correspondingly to 5mm L6 -33%, 7mm L1 -8%, 10mm L4 -10%, and positive for 12mm and 15mm.
For the in-soil data there are two peaks one in L3 and one L7 where a significant increase of sensitivity to L1 or the lane before to most of the targets is shown.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector had no problems in completing its automatic soil compensation process in all lanes and could well cope with the physically different structures of the soils i.e. the stones as well as with the magnetic properties. The signal interpretation is easy because of the low background noise. The detector kept a good level of sensitivity to all lanes and targets. The maximum loss to different lanes may in this case be a part of the uncertainties we are not aware about, and may be also connected with the metal used for the simulants.
There are common pattern in the loss and increase of sensitivity between both Minelab detectors, F1A4 and F3. This is visible in all groups of targets that certain targets stand out in their results and repeated by the other detector.

Table 8-23 Technical data Minelab F3

Metal detector:	**Minelab F3**		
Working technology	Pulse induction		Static mode. Patented multiple pulse width technology for improved soil compensation, uses bipolar pulses to avoid the ignition of magnetic fuzes.
Price	2450	Euro	Without VAT
Operational aspects			
Min- Max shaft length	60-148	cm	Continuously adjustable
Weight	3.2	kg	
Ground compensation	Yes		Automatic after initiation
User interactions			
Target signals	Audio		
System signals	Audio		Confidence tone, low battery alarm, equipment faults
Access to software	Yes		Via RS232 port
Equipment Design			
Design			1 piece design.
Search head	circular, 21	cm	
Speaker/headphones	Yes, internal/ Yes		Speaker continues functioning when headphones plugged in. Optional earpiece which disables speaker is also available
Batteries	LR20 × 4		
Package			
Operator manual	Yes		A5, not plasticized – English, water proof , tear resistant
Instruction card	Yes		Single A5 page, plasticized - English
List of content	Yes		On the instruction card
Test piece	Yes		
Case dimensions	86 × 46× 19	cm	
Case mass (full)	11.9	kg	With all accessories + one set of battery
Case type – material	Hard case – plastic		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4.25	kg	With all accessories + one set of battery

Picture details Detector F3

8.10 Schiebel Elektronische Geräte GmbH, metal detector ATMID™

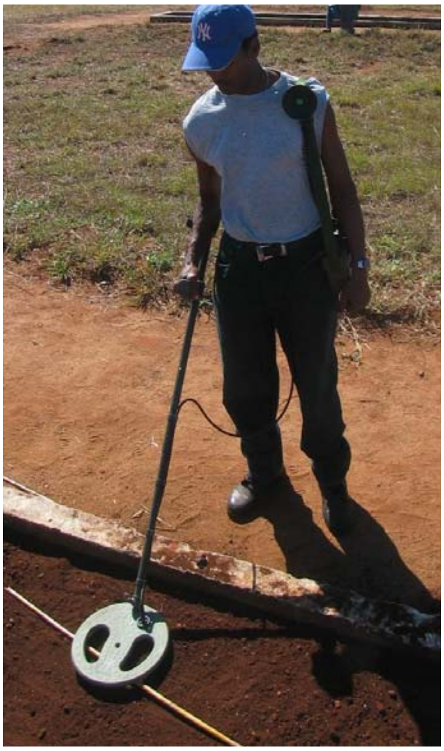


Plate 8-32 ATMID™ during the trial

The Schiebel ATMID™ is a continuous wave dynamic mode detector.
Further, the detector has:

- Semi-automatic ground compensation
- continuous sensitivity control
- volume control
- different audio signals for the detector status as well as for target classification

The Schiebel ATMID is built in the traditional way with a telescopic pole, the cable connected to the search head outside the pole, and a separate electronic box which can be fixed to the shaft with optional clips. The search head and the earphone are to be connected with the electronic box..

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

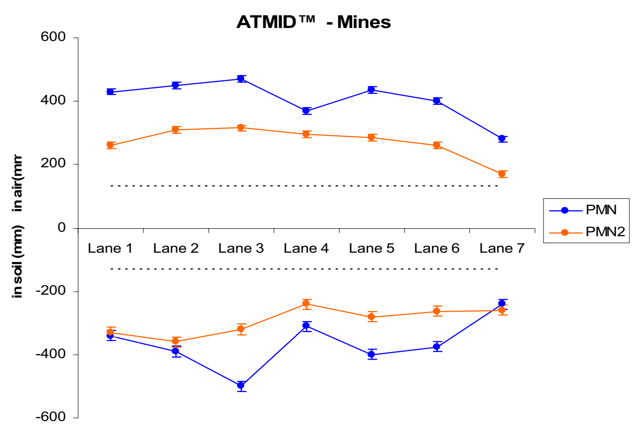


Figure 8-33 In-air and in-soil sensitivity for mine targets

Figure 8-33 shows the achieved maximum detection height/depth of the ATMID™ to the real mine targets used during the trial. The data of the in-air measurement look consistent in their structure and indicate loss of sensitivity from L1 to L7 as expected. The in-air results have significant negative peak at L4.
The maximum loss of sensitivity with respect to the L1 in-air measurements were for the Gyata -35% in-air and -44% in-soil both for L7 and was correspondingly for the PMN-2 in air -35% L7 and in-soil -8%L4. The loss of sensitivity in soil of -21% in L1 may be based on the allowed burial depth that was limited to 340mm (top of the target) due to the concrete bed of the lane. So we were not able to establish if a deeper detection was possible.
The in-soil data in Figure 8-33 from the practical field tests show significant differences to the in-air measurements. L1 for the PMN was explained above, further the detector has a peak of sensitivity at L3 loses sensitivity to L4 another peak at L5 and losing sensitivity again to L7. For the PMN-2 the highest sensitivity was in L2 with 38% above the highest sensitivity in-air.

Table 8-24 ATMID™ & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

ATMID ™	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to sensitivity height in-air value						
In-Air	PMN	***430mm***	5%	9%	-14%	1%	-7%	-35%	7%
	PMN-2	***260mm***	19%	21%	13%	10%	0%	-35%	12%
In-Soil	PMN	-21%	-9%	16%	-28%	-7%	-13%	-44%	9%
	PMN-2	27%	38%	23%	-8%	8%	1%	0%	14%

Both mines could be easily detected by the ATMID at the required standard depth of 130mm under all available ground conditions at the trial site.

Detection height in air and depth in soil to mine simulants

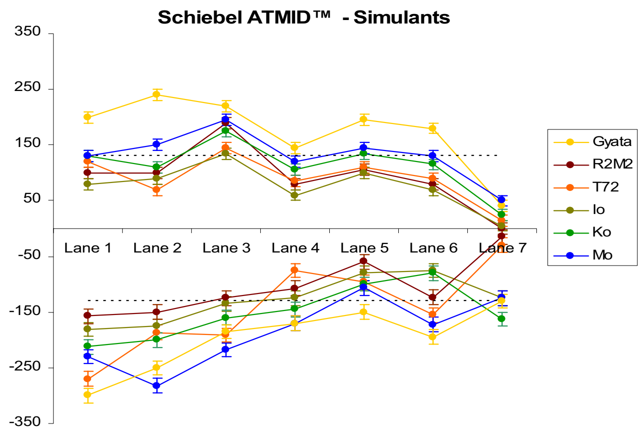


Figure 8-34 In-air and in-soil sensitivity for simulants

The results are similar in general tendency to those shown in the graph for real mines, i.e. the detector is losing sensitivity from L1 to L7. The in-air data show to peaks with significant changes of sensitivity one in L3 another in L5. The results of the in-soil data are quite different. In general the detector is losing sensitivity from L1 to L5 has a peak in L6. For two ITOPs (Io, Mo) the loss from L1 goes to L6 and there is a peak for both at L7. The maximum losses of sensitivity with respect to the Lane 1 in-air measurements were all in L7, for the Gyata, -80% in-air and in-soil -35%, for the T72 in-air -88% and in-soil -75%, for the R2M2 100% in-air and -85% in-soil.

Table 8-25 ATMID™ & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

ATMID ™	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***200mm***	20%	10%	-28%	-3%	-10%	-80%	16%
	T72	***120mm***	-42%	21%	-29%	-8%	-25%	-88%	26%
	R2M2	***100mm***	0%	90%	-20%	5%	-20%	-100%	31%
In-Soil	Gyata	50%	25%	-8%	-15%	-25%	-3%	-35%	19%
	T72	125%	55%	59%	-38%	-20%	29%	-75%	30%
	R2M2	58%	50%	25%	8%	-40%	24%	-85%	36%

Anomalously high sensitivity values of to 125% above reference in-soil stand out in the first three lanes in air as well as in soil. The increase of sensitivity for all of the targets is a phenomenon we cannot explain. Similar cases of increased sensitivity appeared with other detectors and targets too. Changes in the order of the targets have no real influence on the general tendency of the sensitivity behaviour.

The detector has difficulties to achieve the recommended clearance standard of 130mm from L3 with the simulant representing R2M2, followed by the other targets in the following lanes. The only target that can be detected from L1 to L7 in the depth of 130mm is the Gyata.

Detection height in air and depth in soil to steel balls

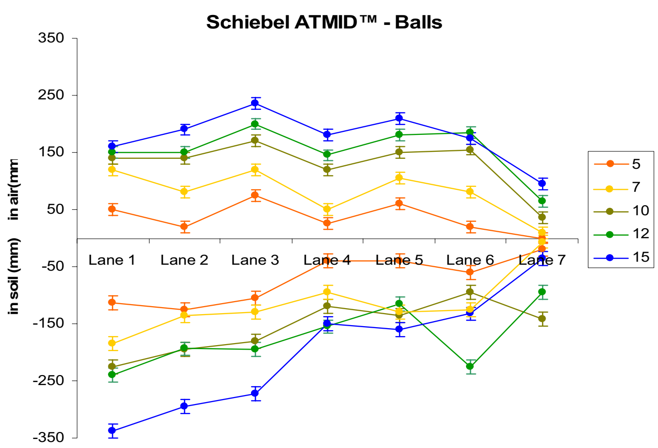


Figure 8-35 In-air and in-soil sensitivity for balls

The general tendency is the loss of sensitivity from L1 to L7 and that the in-soil data are better than the in-air data for the first three lanes partially to the 4th lane too. In Figure 8-35 the practical field tests show exceptions to expected order in the in-soil measurements.
The maximum losses in-air are all in L7, which vary from -100% for the 5mm, -92% for the -7mm, -75% for the 10mm, -56% for the 12mm and -41% for the 15mm ball. In-soil the maximum losses were all in L7 too, excluding 10mm in L6. The results were correspondingly to 5mm -63%, 7mm -95%, 10mm L6 -32%, 12mm -37%, and 15mm -37%.
For the in-air data there are two peaks one in L3 and one L5 where a significant increase of sensitivity to L1 or the lane before to most of the targets is shown. The in-soil data show a significant drop of sensitivity from L1 to L4, a certain stabilisation to L6 and a further drop in L7.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector had no problems in completing its automatic soil compensation process in all lanes and could well cope with the physically different structures of the soils i.e. the stones as well as with the magnetic properties. The signal interpretation is easy because of the low background noise. The detector had a substantial loss of sensitivity from L1 to L7. There is a pattern in the loss and increase of sensitivity to the groups of targets. The L4 is the breaking point in sensitivity for in-soil data and the L3&L5 peaks in-air. General for all groups of targets is the higher sensitivity in the first three lanes.

Table 8-26 Technical data ATMID

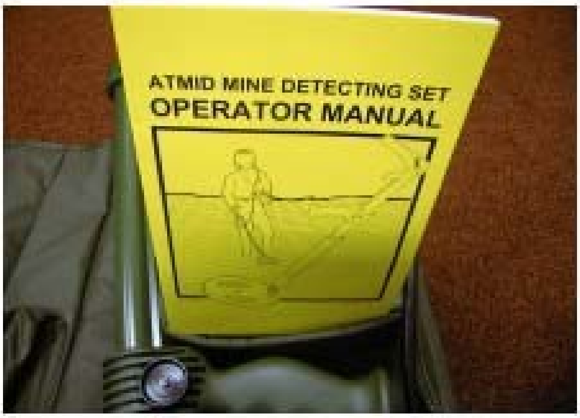
Metal detector:	**Schiebel ATMID**		
Working technology	Sinus wave induction		Dynamic mode. Single frequency continuous wave, bipolar to avoid initiation of magnetic fuzes.
Price	3050	Euro	Without VAT
Operational aspects			
Min- Max shaft length	116,126,136	cm	3 fixed increments
Weight	1.5	kg	
Ground compensation	Yes		Semi-automatic after initiation
User interactions			
Target signals	Audio		large metal alarm tone
System signals	Audio/Visual		Confidence click, low battery alarm (audio+LED)
Access to software	No		
Equipment Design			
Design			1-piece design. Control box can be fitted to shaft with optional clips
Search head	Circular, 26.5	cm	
Speaker/headphones	optional / yes		headphones can be used as speaker by turning volume up
Batteries	LR20 × 4		
Package			
Operator manual	Yes		A5, not plasticized - English
Instruction card	Yes		Single A5 page, plasticized - English
List of content	Yes		
Test piece	Yes		
Case dimensions	80× 31× 12	cm	
Case mass (full)	7	kg	With all accessories + one set of battery
Case type – material	Hard case – metal		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4.75	kg	With all accessories + one set of battery

Picture details ATMID







8.11 Shanghai Research Institute of Microwave Technology, M90 metal detector

Plate 8-36 M90 during the trial

The M90 is a continuous wave, dynamic mode detector. It has an integrated high frequency (GPR) block, for detection of the non-metallic parts of the mine. Further, the detector has:

- Possibility to operate either with or without the GPR
- no ground compensation
- continuously changeable sensitivity control
- volume control

In these tests, the SHRIMT M90 was only operated in metal detector mode. The GPR was not tested.

The M90 is built in the traditional way with a telescopic pole, cable connected to the search head inside the pole, and a separate electronic box. The search head and the earphone are to be connected with the electronic box. The sensitivity is changeable by the operator.

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil for PMN and PMN-2

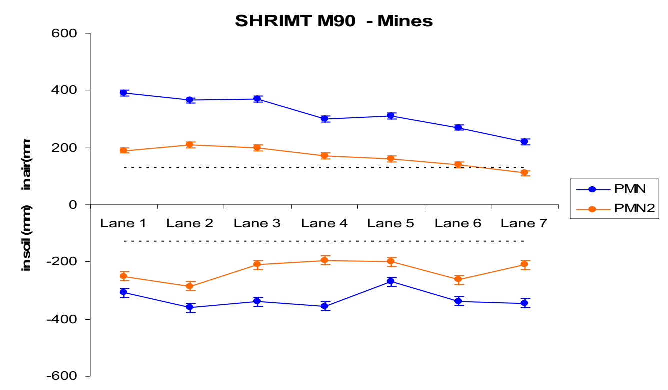


Figure 8-37 In-air and in-soil sensitivity for mine targets

Figure 8-37 shows the achieved maximum detection height/depth of the M90 to the real mine targets used during the trial. Both targets are, in comparison to the other targets used, relatively easy to detect due to their high metal content. The data of the in-air measurement look consistent in their structure and indicate loss of sensitivity from L1 to L7 as expected.

The maximum loss of sensitivity with respect to the L1 in-air measurements were for the Gyata -44% in-air for L7 and -31% in-soil L5 and was correspondingly for the PMN-2 in air -42% L7 and in-soil no loss of sensitivity. The in-soil data have in general much less losses of sensitivity assessing the results from L1 to L7. The data in Figure 8-37 show for both mines a quite flat curve which is surprising for a detector without ground compensation. The sensitivity to the PMN keeps on a higher level than in L1 in all lanes excluding L5 where the maximum loss of sensitivity is -31% to the PMN. There is a significant decrease of sensitivity for the L3 to L5 and again in L7 for the PMN-2.

Table 8-27 M90 & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

M90	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***390mm***	-6%	-5%	-23%	-21%	-31%	-44%	8%
	PMN-2	***190mm***	11%	5%	-11%	-16%	-26%	-42%	16%
In-Soil	PMN	-21%	-8%	-13%	-9%	-31%	-13%	-12%	10%
	PMN-2	32%	50%	11%	3%	5%	38%	11%	20%

Both mines could be easily detected by the M90 at the required standard depth of 130mm under all available ground conditions at the trial site.

Detection height in air and depth in soil for mine simulants

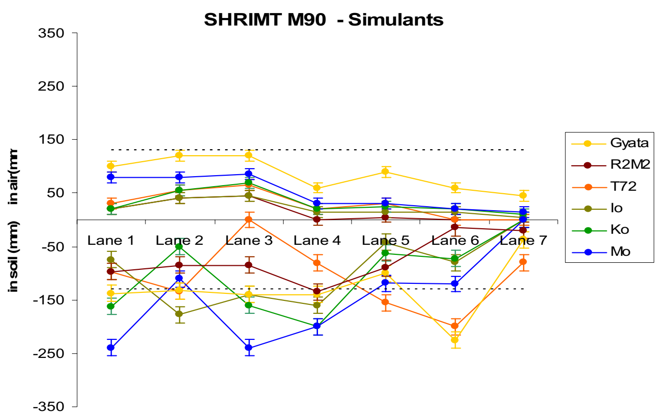


Figure 8-38 In-air and in-soil sensitivity for simulants

The in-air data are consistent, but the results show that the detector has poor sensitivity for all targets in all lanes. The in-soil data are not consistent, swinging from low to high values for no obvious reasons. The Gyata and R2M2 data are the most consistent sets. The Ko and Mo are similar in their structure but the T72 and Io do not seem to fit in any pattern. The reason for this we see in the general low sensitivity of the detector and the necessary individual operator setup of the detector to the lanes. The mixture of the possibility to reduce sensitivity and to lift the detector to the moment when the ground interference stops is so manifold in its effect that is will be difficult to repeat this setup for another person. We would not recommend to use this detector where the mines simulated by the used targets are expected.

Table 8-28 M90 & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

MD 90	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***100mm***	20%	20%	-40%	-10%	-40%	-55%	31%
	T72	***30mm***	83%	117%	-33%	0%	-100%	-100%	104%
	R2M2	***20mm***	100%	125%	-100%	-75%	-100%	-100%	156%
In-Soil	Gyata	38%	33%	40%	40%	0%	125%	-63%	37%
	T72	225%	346%	-100%	171%	417%	567%	167%	119%
	R2M2	388%	325%	325%	575%	350%	-25%	0%	178%

The detector has difficulties to achieve the recommended clearance standard of 130mm for all targets in one or the other lane.

Detection height in air and depth in soil to steel balls

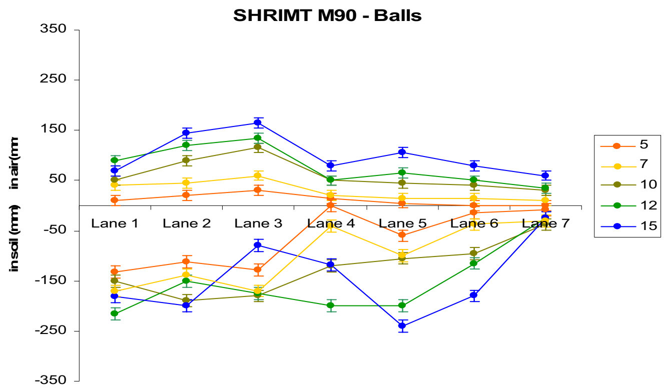


Figure 8-39 In-air and in-soil sensitivity for balls

The general tendency is the loss of sensitivity from L1 to L7 and that the in-soil data are better than the in-air data for the first three lanes partially to the 4th lane too. In Figure 8-39 the practical field tests show exceptions to this in the in-soil measurements.

The maximum losses in-air and in-soil are all in L7 and for some targets already before L7. The results differ for the 5mm -100% L6&L7, for the -7mm -975%, for the 10mm -40%, for the 12mm -61% and for the 15mm ball -14%. In-soil the maximum losses were all in L7 too, excluding the 5mm in L4. The results were correspondingly to 5mm -100%, 7mm -22%, 10mm -25%, 12mm -72%, and 15mm -64%.

For the in-air data there are two peaks one in L3 and one minor L5 for 12 and 15mm balls where a significant increase of sensitivity to L1 or the lane before to some targets is shown.. The peak in L5 is repeated in-soil for the 5, 7, and 15mm balls. The in-soil data show a significant drop of sensitivity from L1 to L4 for the three smaller balls, the peak at L5 and a further drop in L7. The in-soil data demonstrate also a much higher sensitivity in the first three lanes to most of the targets as the in-air data.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector has no soil compensation and the operator had to reduce the sensitivity or to lift the detector to reduce the ground noise. A combination of both was quite effective but is also dangerous when used in real minefields, because it may result in missing mines. This specific set up can only be done for one target. The signal interpretation is not easy because a loss of height will create a signal that does not differ from ground noise. The detector has a low basic sensitivity to the group with the minimum metal content mines and substantial loss of sensitivity from L1 to L7. Therefore we would not recommend to use the detector where such mines are expected. There is a pattern in the loss and increase of sensitivity to the groups of targets. The L4 is the breaking point in sensitivity for in-soil data and the L3&L5 peaks in-air. General for all groups of targets is the higher sensitivity in the first three lanes. It is worth to be mentioned that the a slight move of the sensitivity knob around one millimetre may change the sensitivity essentially (during lab tests up to 40-60%) if the threshold to maximum sensitivity use is nearly achieved.

Table 8-29 Technical Data SHRIMT M90

Metal detector:	**SHRIMT M90**		
Working technology	Dual-sensor sinus wave induction MD and GPR		Single sinus wave, bipolar, frequency domain, dynamic mode. Integrated high frequency (GPR) block .
Price		Euro	Without VAT
Operational aspects			
Min- Max shaft length	73-156	cm	continuously adjustable
Weight	3.3	kg	
Ground compensation	No		
User interactions			
Target signals	Audio		
System signals	Audio		Confidence click, low battery alarm
Access to software	No		
Equipment Design			
Design			
Search head	Square, 26	cm	
Speaker/headphones	no / yes		
Batteries	LR6 × 10		
Package			
Operator manual	Yes		A5, not plasticized - English
Instruction card	No		Single A5 page, plasticized - English
List of content	No		
Test piece	No		
Case dimensions	55× 32× 16	cm	
Case mass (full)	9	kg	With all accessories + one set of battery
Case type – material	Hard case – metal		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4.25	kg	With all accessories + one set of battery

Picture details M90

8.12 Vallon GmbH, Detector VMH3

The Vallon VMH3/VMH3 (M) share the same appearance but the VMH3(M) has new software. They both are compact one piece dynamic detectors using time domain bipolar pulse wave to avoid the initiation of magnetic igniters.

Plate 8-40 VMH3 and VMH3(M) during the trial

Further, the detectors have:

- A specific “difficult soil” mode with automatic ground compensation. Compensation settings are kept.
- nearly continuously changeable sensitivity control via LED indication
- volume control
- a reset feature if the background noise increases
- different audio signals for detection signal, detector status but no “confidence click”
- detection signal can be indicated by one or any combination of the following:
    - audio signal
    - LEDs
    - vibration of the handle
- interface for software upgrade and data logging

Further technical details and pictures are added after the assessment.

Detection height in air and depth in soil to PMN and PMN-2

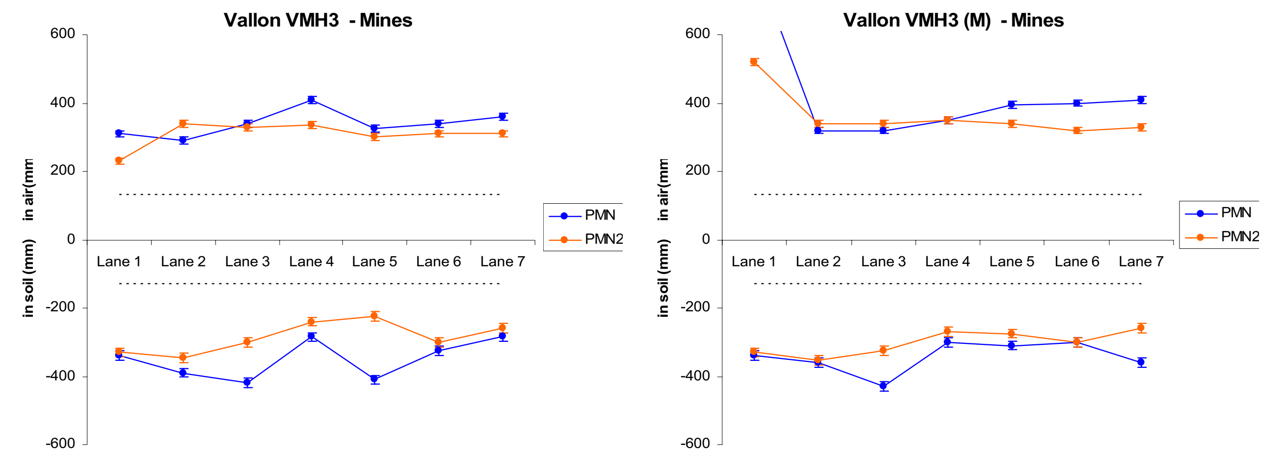


Figure 8-41 In-air and in-soil sensitivity for mine targets

Figure 8-41 shows the achieved maximum detection height/depth of the VMH3/VMH3 (M) to the real mine targets used during the trial. Both targets are, in comparison to the other targets used, relatively easy to detect due to their high metal content. The both graphs allow an easy and

direct comparison of the data and demonstrate the result of the software update. The data of the in-air measurement look consistent in their structure and indicate loss of sensitivity from L1 to L7 as expected for the in-soil data. The in-air results have significant peak at L4 for the Gyata for the VMH3. There is a very extreme increase of in-air sensitivity to all targets for the VMH3 (M). This will effect on the figures for the loss of sensitivity to the other lanes but curves indicate clearly that the sensitivity does not decrease as drastically as the figures indicate.
The maximum loss of sensitivity for the VMH3 with respect to the L1 in-air measurements were for the Gyata -6% L2 in-air and -8% L4 in-soil and was correspondingly for the PMN-2 in air positive VMH3 all lanes, and in-soil -2 in L5.
For the VMH3 (M) we will use a different approach due to the before mentioned extreme improved high in-air sensitivity. We will assess the maximum difference between the lanes which will in this case better express the changes of sensitivity between the lanes. This was in-air for the PMN 11% and for the PMN-2 only 5%. Accordingly the data in-soil were for the PMN 15% and for the PMN-18% of maximum change of sensitivity loss between all lanes.
The loss of sensitivity in soil in L1 may be based on the allowed burial depth that was limited to 340mm (top of the target) due to the concrete bed of the lane. So we were not able to establish if a deeper detection was possible.
The in-soil data in Figure 8-41 from the practical field tests show significant differences to the in-air measurements for the PMN. L1 for the PMN was explained above, further the detector has a peak of sensitivity at L4. The entire curve is mirrored in the opposite way in soil. Where a maximum sensitivity is in air a maximum loss of sensitivity is in soil. Where the sensitivity increase in-air the in-soil data decrease. Several other detector demonstrate a similar surprising result.

Table 8-30 VMH3 & VMH3 (M) & mine targets: percent change of sensitivity with respect to L1 maximum in-air value

VMH3	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***310mm***	-6%	10%	32%	5%	10%	16%	10%
	PMN-2	***230mm***	48%	43%	46%	30%	35%	35%	14%
In-Soil	PMN	10%	26%	35%	-8%	32%	5%	-8%	13%
	PMN-2	43%	50%	30%	4%	-2%	30%	13%	16%
VMH3 (M)	**Target**	**Lane 1**	**Lane 2**	**Lane 3**	**Lane 4**	**Lane 5**	**Lane 6**	**Lane 7**	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	PMN	***820mm***	-61%	-61%	-57%	-52%	-51%	-50%	4%
	PMN-2	***520mm***	-35%	-35%	-33%	-35%	-38%	-37%	6%
In-Soil	PMN	-59%	-56%	-48%	-63%	-62%	-63%	-56%	5%
	PMN-2	-37%	-32%	-38%	-48%	-47%	-42%	-50%	7%

Both mines could be easily detected by both Vallon detectors at the required standard depth of 130mm under all available ground conditions at the trial site.

Detection height in air and depth in soil to mine simulants

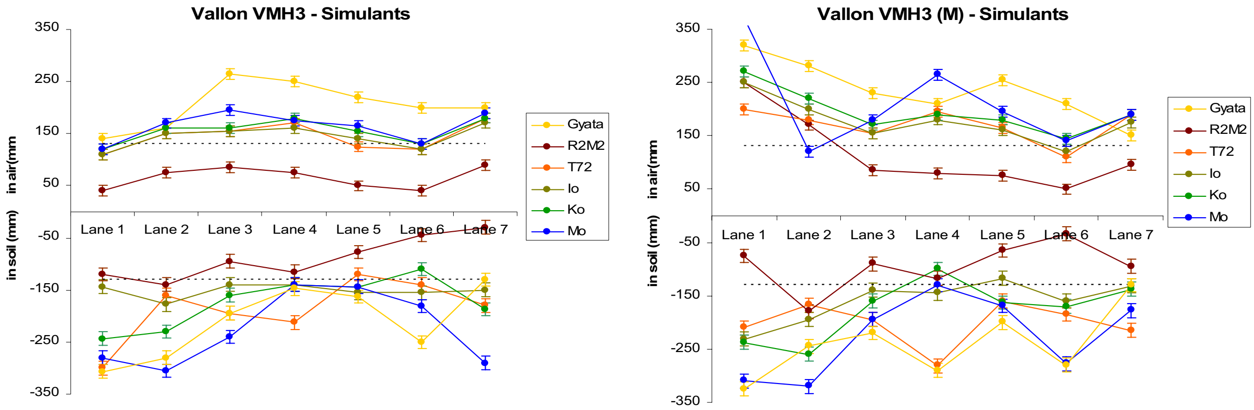


Figure 8-42 In-air and in-soil sensitivity for simulants

The results are similar in general tendency to those shown in the graph for real mines, i.e. the detector is losing sensitivity from L1 to L7 in soil. The in-air data show two peaks with significant changes of sensitivity for the VMH3 one in L3 another in L7. The VMH3 (M) has a very different structure of the curves. The Gyata results are different to the other targets. There are for the other targets two peaks one in in-air, one in L4 another in L7.
The results of the in-soil data are quite different. In general the VMH3 is losing sensitivity from L1 to L4 and further for most of the targets to L7, with three peaks for different lanes and targets (L4, L5,L7). For the VMH3 (M) the structure of the curves has changed two four peaks for L2 (Mo, Ko, R2M2), L4 (G, T72, R2M2), L6 (G, Mo, Io), and L7 (T72, R2M2).
There were no losses of sensitivity for the VMH3 with respect to the maximum sensitivity in-air measurements, all results were better than the in-air. For the in-soil data of the VMH3 in L7 -7% for the Gyata, -25% for the R2M2 were measured. The T72 results stayed in the in positive level with plus 9 % to maximum sensitivity.
For the VMH3 (M) we will again compare the differences between the lanes, due to the before mentioned extreme improved high in-air sensitivity. We will assess the maximum difference between the lanes which will in this case better express the changes of sensitivity between the lanes. This was in-air for the Gyata 40% and for the T72 42 %, and R2M2 38%. Accordingly the data in-soil were for the Gyata 61% and for the T72 61%, and the R2M2 about 80%.

For both detectors significant changes of the results in-air and in-soil data were measured. The in-soil data again have significant differences in the results for the both detectors.

Table 8-31 VMH3 & VMH3 (M) & Simulants: percent change of sensitivity with respect to L1 maximum in-air value

VMH3	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***140mm***	14%	89%	79%	57%	43%	43%	22%
	T72	***110mm***	36%	41%	55%	14%	9%	64%	28%
	R2M2	***40mm***	88%	113%	88%	25%	0%	125%	78%
In-Soil	Gyata	119%	100%	39%	5%	16%	79%	-7%	27%
	T72	173%	45%	77%	93%	9%	27%	64%	32%
	R2M2	200%	250%	138%	188%	94%	13%	-25%	89%

VMH3 (M)	Target	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	**Uncertainties**
		Height in air	Change with respect to Lane 1 height in-air value						
In-Air	Gyata	***320mm***	-13%	-28%	-34%	-20%	-34%	-53%	10%
	T72	***200mm***	-10%	-23%	-3%	-18%	-45%	-5%	16%
	R2M2	***250mm***	-32%	-66%	-68%	-70%	-80%	-62%	12%
In-Soil	Gyata	2%	-23%	-31%	-9%	-38%	-13%	-59%	12%
	T72	5%	-16%	-3%	41%	-20%	-8%	8%	18%
	R2M2	-70%	-28%	-64%	-53%	-74%	-87%	-62%	12%

An anomalously high sensitivity value of 250% above reference to maximum sensitivity for the VMH3 in-soil and in-air stands out. The increase of sensitivity for all of the targets for the VMH3 is a phenomenon we cannot explain. (An extreme result of 2500% was checked under lab conditions but could not be reproduced.) Similar cases of increased sensitivity appeared with other detect ors and targets too. Changes in the order of the targets have no real influence on the general tendency of the sensitivity behaviour.

Both detectors have difficulties to detect the R2M2 target to the standard depth of 130mm. Most of the targets can be detected but some of them are close to the limits as for the VMH3 the T72 L5 and Ko L6. The targets change for the VMH3 (M) to all ITOPs (Io,Ko,Mo) in L4 and to Io in L5.
The phenomenon of the reversed reaction to the in air results appears for some targets Gyata, T72 in L4 for the VMH3 and for the VMH3 (M) with the Gyata, T72, and Mo again L4 and partially L6. Those targets are in their groups the biggest that reacts in this way. The T72 as a smaller one has an opposite direction to the bigger targets.

Detection height in air and depth in soil to steel balls

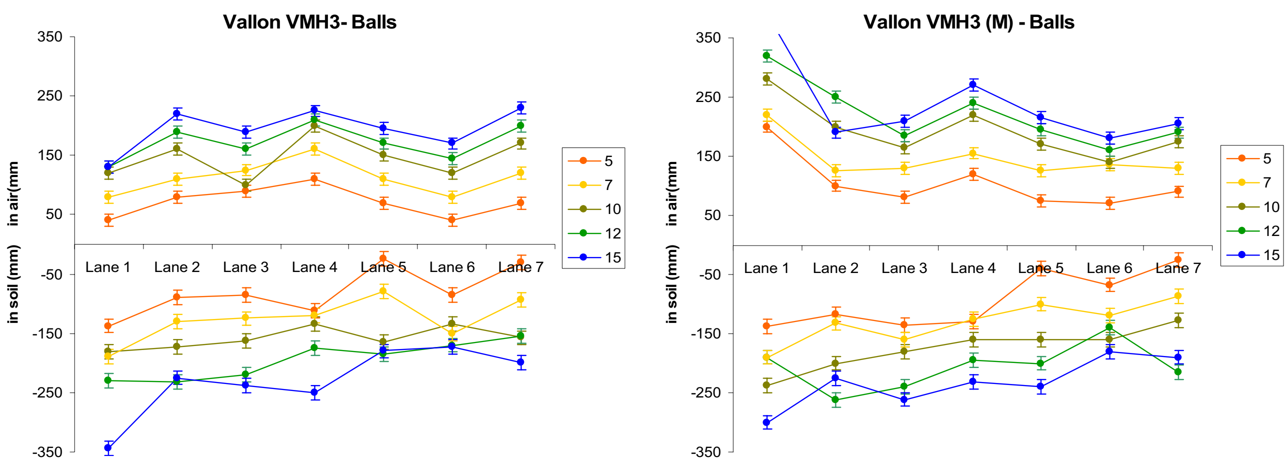


Figure 8-43 In-air and in-soil sensitivity for balls

The general tendency for the VMH3 is the increase of sensitivity from L1 to L7 in-air with three peaks L2, L4, L7.and the opposite in-soil. The general loss of sensitivity from L1 to L7 in-soil is interrupted by an opposite reaction to the in-air data of the smaller targets(5,7mm balls) in L6.
For the VMH3 (M) we have three peaks in-air L1, L4, L7 and a general loss from L1 to L7. The in-soil data show a general loss of sensitivity from L1 to L7. There is a similar reaction in L6 as for the VMH3 but less significant.

There are no losses of sensitivity in air for the VMH3. The in-soil data where in general all better from L1 to 7 in comparison to the maximum in-air measurement excluding the 5mm ball in L7 with -25%, due to the low in air results.
For the VMH3 (M) The general tendency and structure is similar excluding L1 with an extreme increase of in-air sensitivity. From L2 the data are at the same level as in air and decrease to L7. L6 has as well as the VMH3 a peak for the smaller targets.

During the 2 weeks of the training and trial, no difficulties in use or technical questions arose. The detector had no problems in completing its automatic soil compensation process in all lanes. There were problems with background noise for the VMH3 on a significant higher level than with the VMH3 than with the VMH3 (M). The operator had to reduce the sensitivity down to 50% for the VMH3 to be able to work in the more complicated ground conditions from L4 upwards. Both detectors have still essential losses of sensitivity to the smaller targets. With increased metal content the sensitivity of the VMH3 (M) has an essentially reduced loss or even kept the level depending on the lane. The pattern of sensitivity of the detectors is similar but the VMH3 (M) curves are more flat. There is a pattern in the loss and increase of sensitivity to the groups of targets. The L4 and partially L6 are the breaking points in sensitivity for in-soil changes. For the VMH3 for all groups of targets is the higher sensitivity in-soil in respect to the maximum detection height in-air for the first three lanes. The VMH3 (M) achieves similar results in-soil in L1 but is losing less sensitivity in the other lanes.

Table 8-32 Technical data VMH3 and VMH3(M)

Metal detector:	**Vallon VMH3 & VMH3(M)**		
Working technology	Pulsed induction		Dynamic mode. Pulsed induction. Bipolar to avoid initiation of magnetic fuzes.
Price	2420	Euro	Without VAT - including optional headphone for VMH3
Operational aspects			
Min- Max shaft length	76-134	cm	continuously adjustable
Weight	2.5	kg	
Ground compensation	Yes		Separate mode, automatic after initiation
User interactions			
Target signals	Audio/Visual/Vibration		Any combination is possible; large metal tone
System signals	Audio/Visual/Vibration		NO confidence click, low battery alarm
Access to software	Yes		Data logging, system upgrade
Equipment Design			
Design			1-piece design
Search head	Truncated ellipse /L:31, W:17	cm	
Speaker/headphones	Yes, internal / yes		
Batteries	LR20 × 3		high-capacity rechargeable batteries and charger provided with VMH3
Package			
Operator manual	Yes		A5, not plasticized - English
Instruction card	Yes		
List of content	Yes		In manual
Test piece	Yes		
Case dimensions	84× 30× 25	cm	
Case mass (full)	5.45	kg	With all accessories + one set of battery
Case type – material	Padded soft case – Plastic/Fabric		
Protection	Yes		Dust, rain, vibration
Backpack	Yes		
Mass backpack (full)	4.8	kg	With all accessories + one set of battery

Picture details VMH3 & VMH3 (M)








The VMH3 (M) looks identical to the VMH3, the only difference being the colour (green) and more LEDs on the control panel.

9 Lessons learned

The logistical organisation of a detector trial can be quite complicated.
When detectors are to be sent to several different locations in turn to be tested, the project schedule is vulnerable to any unforeseen delays. An on-site update of the political, social, meteorological and logistical situation is necessary and may reduce the risk of a project failing. For example, this present trial was affected by a strike of deminers due to financial difficulties at ADP.

We recommend that all steps are planned as thoroughly as possible, preparations begun and, if possible, contracts signed, about two months in advance of a field trial. Manufacturers should be informed as soon as it is certain the trial will go ahead. Key things to be arranged are:
visas, vaccinations and security briefings for personnel; money transfers for contracted organisations including shippers and a cash reserve for contingencies; transport to country, transport in country and accommodation for personnel; safety precautions on site; communications with home base; insurance, customs permits, packing and storage for equipment.
Planning of personnel should include a reserve for sickness or absence, especially when the overall numbers are small and the impact of an absence is greater. All this is in addition to the technical organisation of the trial, which is a quite separate question.

10 Conclusions

Included CWA tests:
CWA Test 8.4 Fixed depth detection tests in soil
CWA Test 6.5 Minimum detectable target as a function of height
CWA Test 6.6 Detection capability for specific targets in air

The sensitivity loss from L1 to L7 for the detectors without GC was so large that some targets which could be comfortably detected to the required depth of 130mm in L1 could not be detected even much nearer to the surface in the higher numbered lanes. Therefore we would recommend not allowing the use of them where the soil properties are worse than L3.

For detectors with very substantial sensitivity loss from L1 to L7, it is important that the users are aware about the ground conditions and check the reliability of the detector's detection ability to the expected mines in the working area. Even for the other detectors, the same precaution rules should be similar because the metal content and the reaction of the ground may be different to the conditions we could investigate here.

The selected tests allowed a direct comparison of the sensitivity of the detectors to the chosen targets in seven different soil types. The in-air measurements with the set-up to all lanes, the measurement of the maximum height/depth to all targets in both media gave a set of data which raise some unexplained phenomenon, they are:

- The significant increase of sensitivity in other lanes, in comparison to the electromagnetically nearly neutral Lane 1, mainly for the second and third lane for eight detectors, with the exception of Minelab detectors that have increased sensitivity in all lanes excluding L4.
- Examples of opposing trends across the lanes in the in-air data and the in-soil data. For most targets and detectors, there are cases where a loss of sensitivity in-air coincides with an increase of sensitivity in-soil.

Both results concern detectors of different technical design: continuous wave and pulse induction, frequency and time domain. All targets show generally higher sensitivity when measured in-soil than when measured in-air, with the detector set up to the soil, across all the lanes. The increase is not restricted to certain induction or detection principles (pulsed, CW etc.) but seems to be connected with the ground properties and/or the metal content of the used targets. Four detectors (MIL D1, 421 GC, ATMID, VMH3) show the increase of sensitivity only for two or three targets: the PMN2, Mo, and T72.

In general, in-air maximum detection heights, measured with the detectors set-up to a particular ground, are not equal to the in-soil maximum detection depth in the same ground. There did not seem to be any simple and direct way to predict in-soil performance from the in-air measurements.
At the time of writing, it appears that it is necessary to carry out in-soil measurements to obtain reliable in-soil data. Accordingly, this should be considered during the next CWA review along with the ground reference height technique described before (section 6.2).

11 Recommendations regarding detector use

Based on the data measured during the trial and the difficulties experienced during use, we recommend that the detectors without GC are deployed only in ground conditions which are no more severe than those of L1 to L3. For those detectors it is very important to know what are the ground conditions in the area of deployment and which targets are expected.

Of the detectors tested, both Minelabs, the EBEX 421GC and both Vallons have superior ground compensation abilities. For the Vallons, some loss of sensitivity with soil properties can still be discerned with the smaller targets.

Minimum metal mines are still the main detection problem. Even the detectors with good soil compensation could not always detect the smaller targets to the required depth in all lanes.

- *Ground magnetic properties (magnetic susceptibility, GRH)*
    - These should be measured and recorded as a survey task because it has to be known for planning and proper use of the detector fleet (see decrease in detection capability with growing magnetic response in the test lanes).
    - Existing geological and soil maps should also be consulted.
    - It is also desirable for GRH data to be collated internationally.

- *Training*
    - Deminers should be trained to understand that the detector could detect only to a limited depth. The concept of the sensitivity cone, the idea that the footprint is narrower at greater depths, should be explained to them.
    - They should also understand that the orientation, size and shape of the target affect the signal strength.

12 Annexes

12.1 ANNEX A Additional Training Exercises

One of the objectives of the trial was to train the local staff in the use of the CWA. To this end, training was also included in sensitivity profile measurement and pinpointing precision measurement, which were not themselves performed in the trial. These two tests are intended for evaluation of detectors and are included in the CWA for that reason. But they also are very useful as training exercises in detector handling, because they reveal the spatial behaviour of the detector i.e. how it responds to targets at different locations in the neighbourhood. The exercises were therefore also helpful to ensure the operators knew how to handle the detectors in the trial.

Sensitivity Profile (CWA Test 6.7)

The sensitivity profile (also named “sensitivity cone” or “area”, “footprint”) is the region within which a detector can detect a particular object. Unfortunately, this concept is not familiar to many people working in the field. The practical importance of the footprint for establishing the advance of the search head during the search for mines, or the ability to detect a target or not are often not known to deminers or their supervisors. The three main factors determining the profile are:

- the sensitivity of the detector (technical solutions),
- the metal content of the target,
- the ground compensation ability of the detector.

Plate 12-1 Determination of the cone’s “width”/”depth”

Plate 12-2 The same but with a “dynamic” detector

The establishment of the sensitivity profile gave a three-dimensional understanding about the detection ability to different targets.

By using a 5mm steel ball, the fuze of the R2M2 (Plate 12-1), or the PMN mine and repeating it in the different soil types, the deminers were able to see for themselves that not all detectors can deal with all types of ground. The reduction of the sensitivity to the targets in the more difficult ground conditions surprised most of the participants.

Pinpointing (CWA Test 9.2 Target location accuracy)

Pinpointing the source of the detector signal was demonstrated to the participants of the training and the main attention focused to the differences in pinpointing between a "Double-D" search head and other detectors. Pinpointing the source of the signal increases efficiency and safety of the deminers, but the accuracy of pinpointing is not just dependent on the deminer's skills. The metal content of the target and depth of it, the particular detector, and the operator's ability all affect the potential for accuracy. In laboratory conditions a well-trained technician may achieve an accuracy of a few millimetres but it may not be realistic to pinpoint with an accuracy greater than 40mm with the same detector in the field. This level of accuracy is usually still acceptable because it is within the radius of the smallest mine. A double D search-head can increases pinpointing accuracy. The "zero" line in the middle of the search head allows an easy and accurate pinpointing from two directions. With other detectors, approaching from each side is usually enough to allow the centre of the target to be determined as shown below.

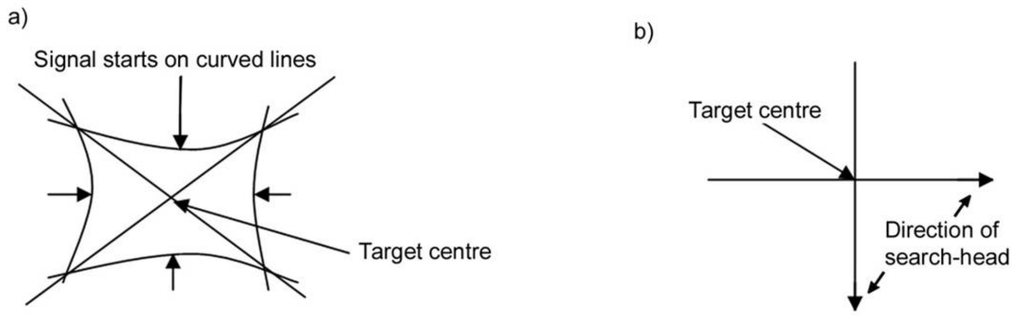
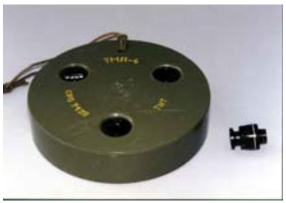


Figure 12-3*:* Pinpointing with simple search head (a), and double-D (b)

12.2 ANNEX B - Mines and simulated mines[6]

Used Target Type			Technical Information	
Mines	Rendered safe		**AP** PMN (Russia) Weight (g): 550 — Diameter (mm): 112 Explosive (g): 240 — Height (mm): 56 Expl.Type: TNT — Operating pressure (kg): 8-25	
Mines	Rendered safe		**AP** PMN-2 (Russia) Weight (g): 420 — Diameter (mm): 120 Explosive (g): 100 — Height (mm): 53 Expl.Type: TNT/ RDX — Operating pressure (kg): 15	
Simulants	Local		**AP** Gyata-64 (Hungary) Weight (g): 520 — Diameter (mm): 106 Explosive (g): 300 — Height (mm): 61 Expl.Type: TNT — Operating pressure (kg): 5	
Simulants	Local		**AP** T72 (China) Weight (g): 140 — Diameter (mm): 78 Explosive (g): 51 — Height (mm): 38 Expl.Type: TNT — Operating pressure (kg): 5-10	
Simulants	Industrial		**AP** R2M1 (2), (AT No.8 same fuze) (RSA) Weight (g): 128 — Diameter (mm): 69 Explosive (g): 58 — Height (mm): 57 Expl.Type: RDX/wax — Operating pressure(kg): 3-7	
Simulants	ITOP (inserts)	Io	**AP** M14 (USA) Weigh (g)t: 100 — Diameter(mm) : 56 Explosive (g): 29 — Height(mm) : 40 Expl.Type: Tetryl — Operating pressure(kg) : 9-16	
Simulants	ITOP (inserts)	Io	**AP** PMA-3 (Yugoslavia) Weight (g): 180 — Diameter (mm) : 111 Explosive (g): 35 — Height (mm): 40 Expl.Type: Tetryl — Operating pressure(kg): 8-20	
Simulants	ITOP (inserts)	Io	**AT** VS-1.6 (Italy) Weight (kg): 3 — Diameter (mm): 222 Explosive (kg): 1.85 — Height (mm): 92 Expl.Type: TNT/ RDX — Operating pressure:(kg) 180-220	

[6] The technical data about the mines were taken from “Jane’s Mines and Mine Clearance” Sixth Edition 2001-2002; the pictures of the mines are from “ORDATA Online” James Madison University

Used Target Type			Technical Information					
Simulants	ITOP (inserts)	Ko	**AP** T72 (China)	Weight (g): Explosive (g): Expl.Type:	140 51 TNT	Diameter (mm): Height (mm): Operating pressure (kg):	78 38 5-10	
			AT TMA-4 (Yugoslavia)	Weight (kg): Explosive (kg): Expl.Type:	6 5.5 TNT	Diameter (mm): Height (mm): Operating pressure (kg):	284 110 100-200	
			AT M19 (USA)	Weight (kg): Explosive (kg): Expl.Type:	12.56 9.53 TNT/ RDX	Diameter(mm): Height (mm): Operating pressure (kg):	332 94 332	
		Mo	**AT** Vs-2.2 (Italy)	Weight (kg): Explosive (kg): Expl.Type:	3.5 2.2 TNT/ RDX	Diameter (mm): Height (mm): Operating pressure (kg):	230 115 180-220	
			AT Pt MiBa-III (Czechoslovakia)	Weight (kg): Explosive (kg): Expl.Type:	9.9 7.2 TNT	Diameter (mm): Height (mm): Operating pressure (kg):	330 101 200-450	

South Africa Used Fuze Assembly Datasheet						
Used in mine types:			**AP R2M1 (2), AT No.8**			
Fuze mechanism type			**Spring-driven, ball retained**			
Item	**Description**	**Quantity**	**Dimensions (mm)**		**Material**	**Mass (mg)**
			Diameter	**Length**		
1	Ball bearing	3	3,2		Chrome steel	130
2	Spring	1	6.0 (outer) 1,0 (wire)	12,5 normal 9,5 (compressed)	Spring steel	788
3	Striker pin	1	0,5 (tapered)	10,0	316 Stainless steel	187
4	Detonator tube	1	7,0, 0,5 wall thickness	7,5	Aluminium	217
Total metal content						1,582g

12.3 ANNEX C - Soils and graph legend fold out

Soil Classification

The chief soil forming factors which operate to produce a particular sol are parent material, climate and organisms which interact within a particular topographic environment over a certain span of time, producing changes with depth in the soil parent material. The parent material may be a residual soil formed by the weathering of bedrock in situ or a transported soil such as collovium, alluvium or wind blown sand. In other words, pedogenesis transforms a more or less isotropic parent material into an anisotropic (layered) soil with the main cause of differentiation achieved with the movement of rainwater.

The parent material of the different test lanes are either sedimentary or igneous (volcanic). The alluvial soils of Lanes 1 to 3 cannot be connected to a specific parent material. The parent materials for Lanes 4 and 5 are unknown and the black colour may indicate a layer of organic enrichment. The parent material for Lanes 6 to 7 is volcanic rock of the Libombo Group consisting of rhyolite with the reddish colour caused by dispersed iron oxide, which will yield high magnetic susceptibility values.

Since we are dealing with highly disturbed samples in the test lanes (transported), for instance the absence of a pebble marker, typical classification and parameter testing schemes are not really applicable. The physical properties of soil include texture, structure, consistence, density and weight relationships, pore space and porosity, colour, and temperature.

There are various schemes used for soil taxonomy, and may include the following parameters :

Horizonation (surface and subsurface),
Content - clay, moisture, coarse fragment content,
Size - grade of sand,
Texture - fine sandy loam, clay load, etc.

Some possibly relevant material about the ADP training lanes in Moamba (Mozambique). There are 7 lanes each 10m long, 1m wide and about 0,5m deep containing various soils representative of soils in the southern parts of Mozambique (except lane 1 which is pure clean sand). The lanes were established in 2000 (excluding L 7 spring 2005) and the only resulting compaction/layering is due to time and the elements.

Two types of magnetic susceptibility measurements were carried out. In-situ measurements were done with a Bartington MS2-D Coil Probe (1 frequency largish volume analysis), and dual frequency analysis was performed using a Bartington MS2- B Coil on soil samples (two per lane).

Soil description in the lanes

- Lane 1
  - Soil type : Sand
  - Colour: Clean white
  - Composition: Quartz + feldspate. No dark minerals. Well washed, fairly well sorted.
  - Grain size : Small to medium.
  - Layering : None
- Lane 2
  - Soil type: Sand
  - Colour: Med red
  - Composition: Quartz & feldspate
  - Grain size: small to medium
  - Layering: Definite, light layer at the top, red at the bottom. According to D.Guelle, the soil was uniformly red when the lane was established
- Lane 3
  - Soil type: Sand
  - Colour: Med red
  - Composition: Quartz, feldspate, schists, organic material
  - Grain size: small to medium
  - Layering : None
- Lane 4
  - Soil type : Silt, forms “clay” crack when dry. Low clay content (5%)
  - Colour : Black
  - Composition : Contains fragments of weathered rock appearing to be igneous, typical granite composition
  - Grain size : small grain size (<1mm)
- Lane 5
  - Soil type : Forms “clay” crack when dry. Highest clay content (15-20%)
  - Colour : Black
  - Composition : Contains fragments of weathered rock appearing to be igneous.
  - Grain size : Med grain size – typical granite composition (2mm)
- Lane 6
  - Soil type : Silt
  - Colour: Red soil – ferri oxides
  - Composition : Yields “clay” cracks when dry. Large fragment (15mm) of quartz. Poorly sorted.
  - Grain size: small grain size.
- Lane 7
  - Soil type : Silt/Collovium
  - Colour : Red soil – ferri oxides
  - Composition : Consists mainly of fragments of weathered riolyte volcanic rocks.
  - Grain size : No obvious size
  - Sorting : Rubble – not sorted, rounded at all

Legend for graphs & tables

The graphs in Chapter 7 allow the direct comparison of the in-air and in-soil sensitivity of all the detectors to a given target in all lanes (i.e soil type).
Sensitivity observations are on the *y*-axis in either blue (in-air) or brown (in-soil).

The graphs in Chapter 8 allow the direct comparison of the in-air and in-soil sensitivity for a given detector to a group of targets.

All graphs, except spheres/balls, have a dotted lines in-soil representing the 130mm Mozambican national standard clearance depth which corresponds to the IMAS and UN standards. To facilitate visual perception, similar lines were added in-air.

The tables in Chapter 8 present the relative changes in sensitivity with respect to the in-air maximum sensitivity for a given detector.
This sensitivity setting was used for Lane 1 in-soil measurements.
Values in red indicate that the observation is greater than that found in the in-air L1 reference value, and beyond what can be accounted by the known experimental uncertainties (shown in lilac in the last column).
Values highlighted in yellow figures indicate the maximum loss for a particular target.
ITOP inserts were not considered here as they were used without their appropriate bodies which does not allow a completely faithful comparison with their imitated mines.

Brief description of targets

Mines include the PMN and the PMN-2 mines with neutralized fuzes.
Simulants typically have a similar shape and metal content to the mines they reproduce. During the trial, these included the Type 72, Gyata, R2M2 and ITOP inserts (Io, Ko, and Mo).
Spheres, or balls, made of 100Cr6 Chrome Steel.

More details on targets can be found in Section 5.2 and Annex B

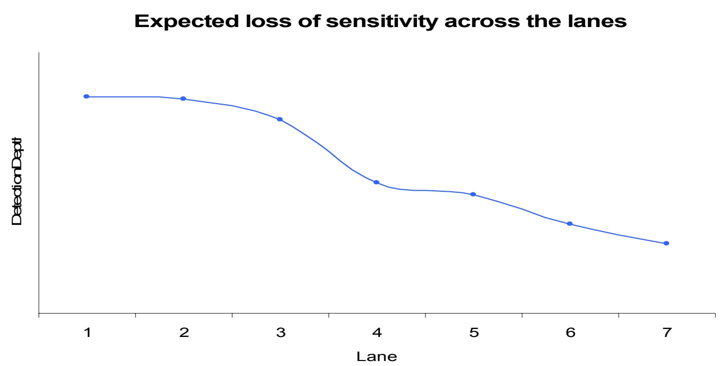
Selected detector properties

Detector	Wave shape: pulse	Wave shape: cont.wave	Domain: time	Domain: frequency	Sensitivity: fixed	Sensitivity: variable	GC: Yes	GC: No
MIL-D1	-	X	-	X	-	X	X	-
421 GC	X	-	X	-	-	X	X	-
420HS	X	-	X	-	-	X	-	X
MD8+	X		X	-	-	X	-	X
4.500	-	X	-	X	-	X	X	-
4.510	-	X	-	X	-	X	X	-
F1A4	X	-	X	-	X	-	X	-
F3	X	-	X	-	X	-	X	-
ATMID™	-	X	-	X	-	X	X	-
M90	-	X	-	X	-	X	-	X
VMH3	X	-	X	-	-	X	X	-
VMH3 (M)	X	-	X	-	-	X	X	-

More details on detectors properties can be found in Sections 4.4 & 4.5

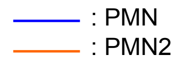
Lane	Soil Type	Susceptibility (SI)	Frequency Dependence (SI)	GRH (mm)
1	Sand	2.4	0	0
2	Sand	8.5	1	9
3	Sand	95.2	6	83
4	Silt with clays	671.3	25	168
5	Silt with clays	890.4	30	180
6	Silt with clays	465.8	45	211
7	Silt/Collovium	2231.2	57	210

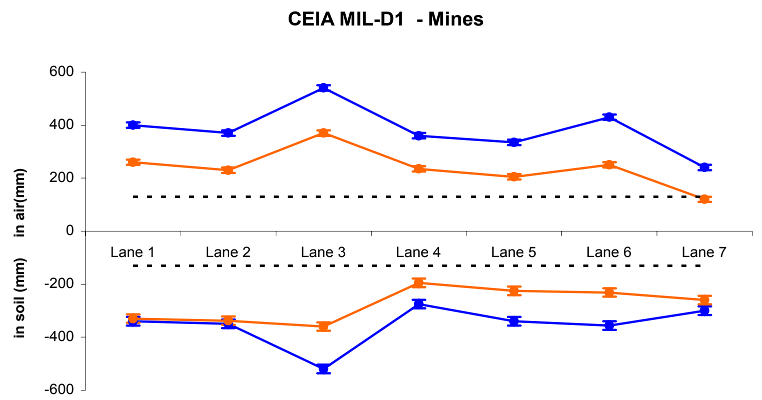
More details on soils can be found in Chapter 6

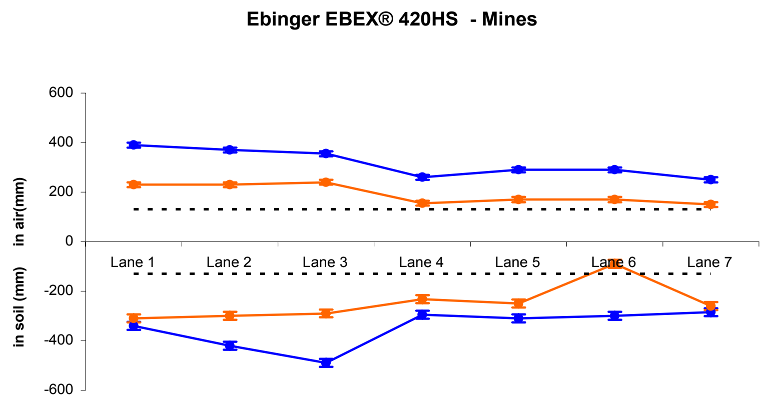


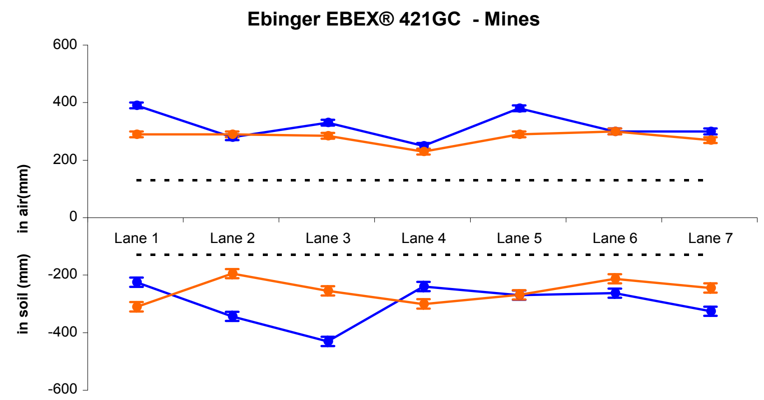
12.4 ANNEX D - Fold out page 2: Mines

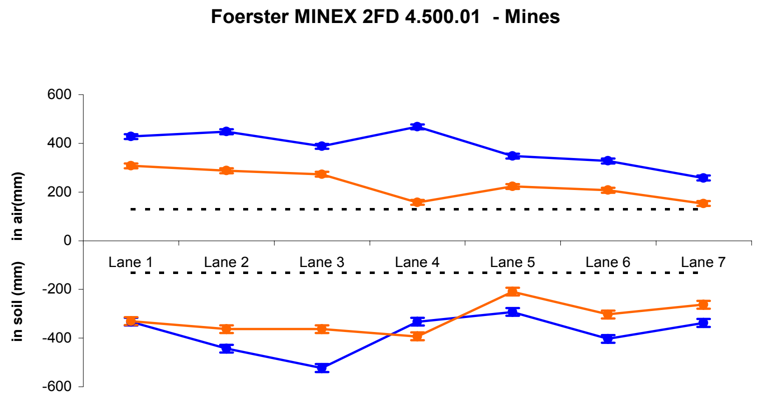
ANNEX D: Fold out 2

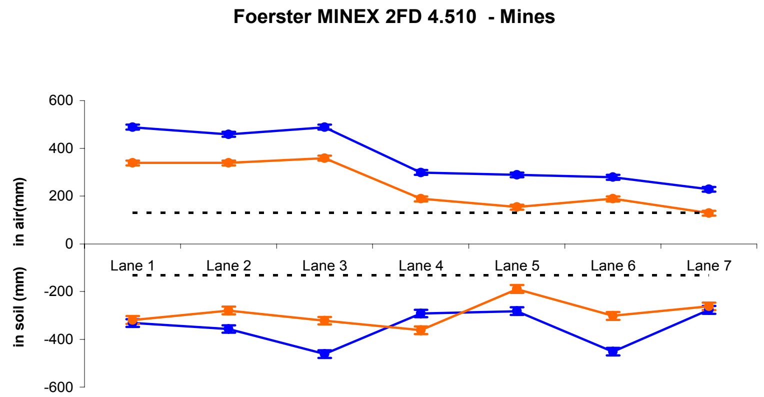


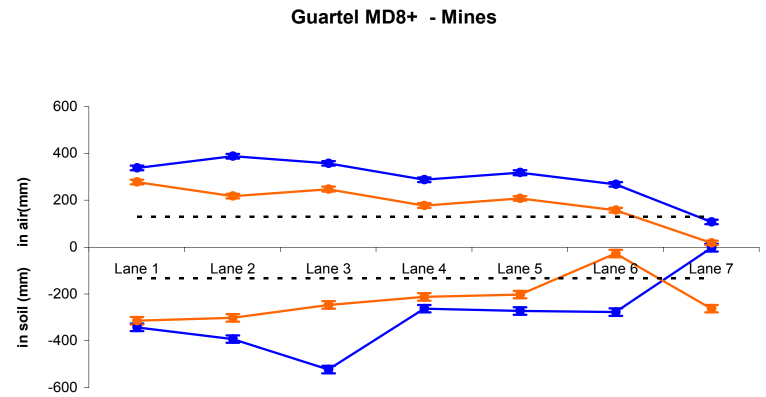


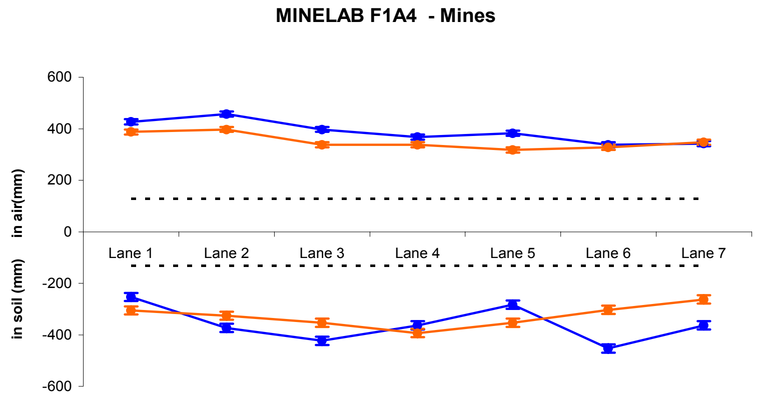


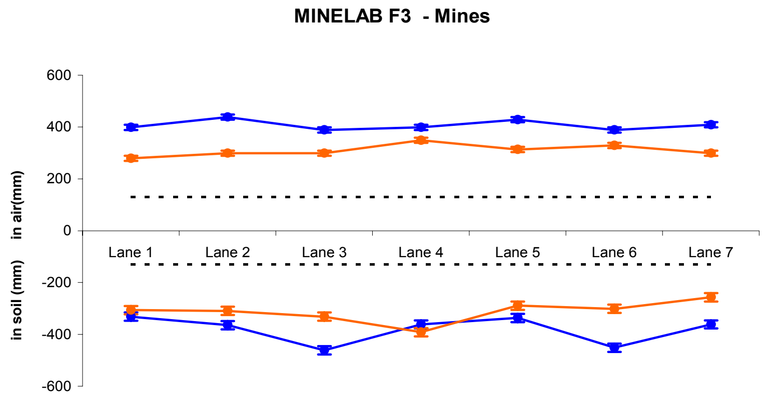


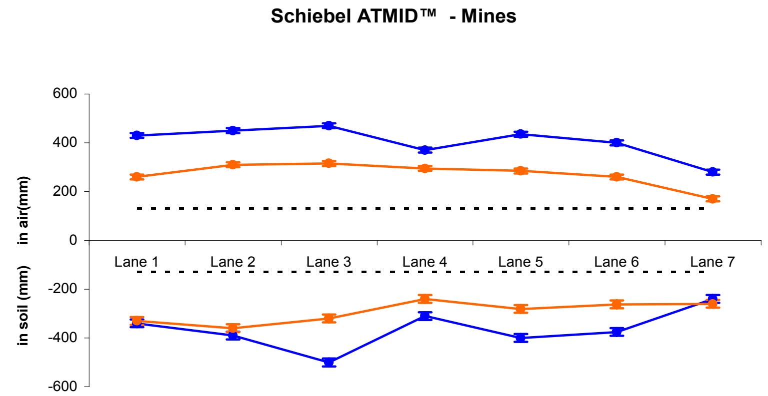


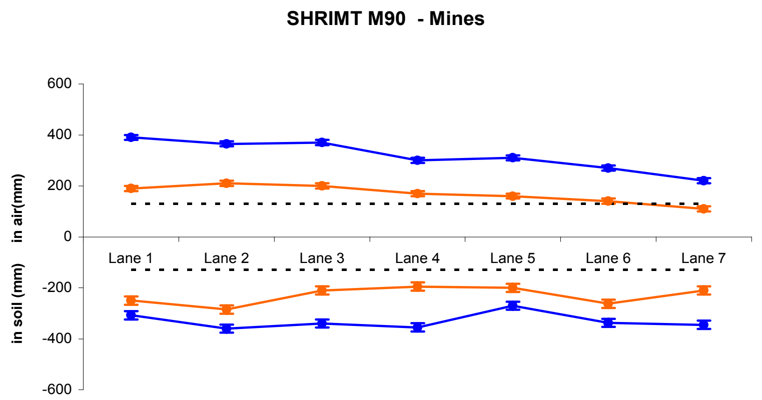


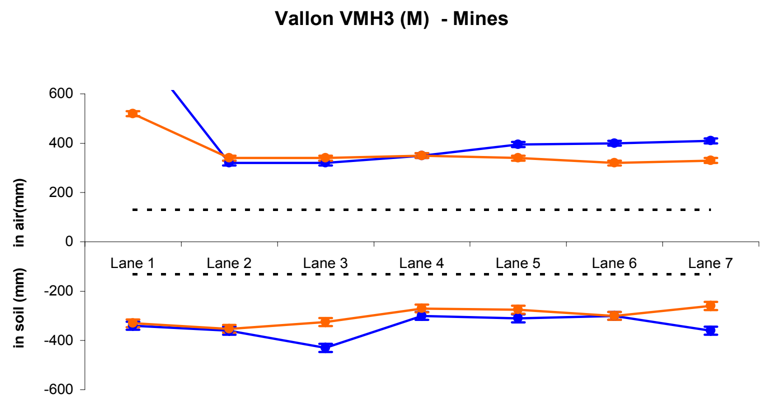


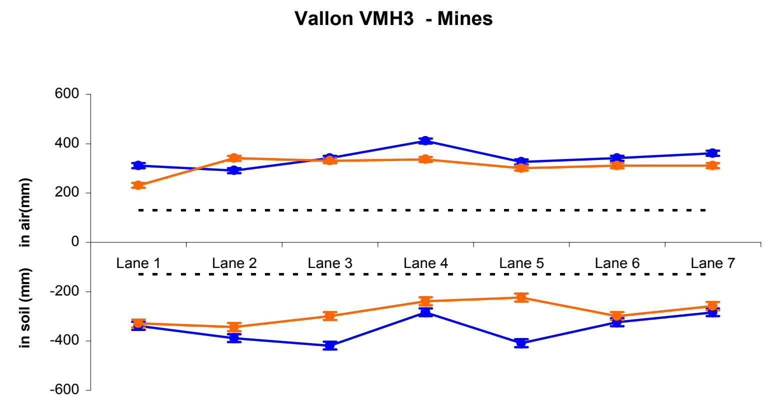








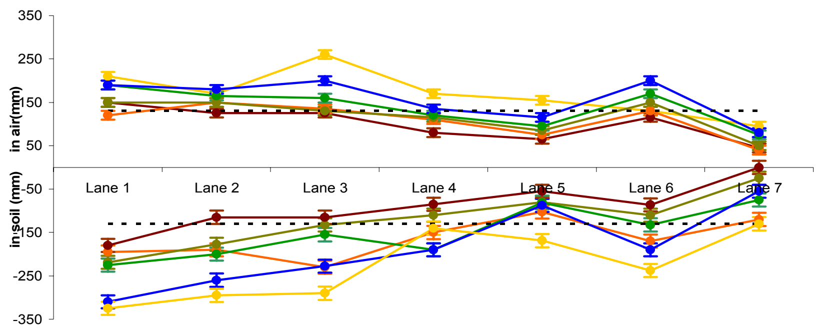




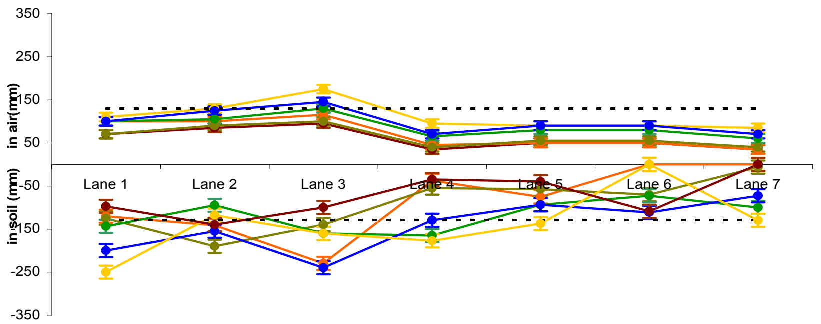
12.5 ANNEX E - Fold out page 3: Simulants

: Gyata
: R2M2
: T72
: Io
: Ko
: Mo

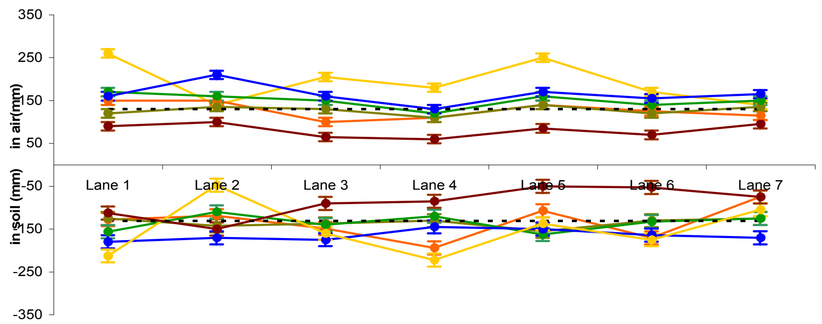
CEIA MIL-D1 - Simulants



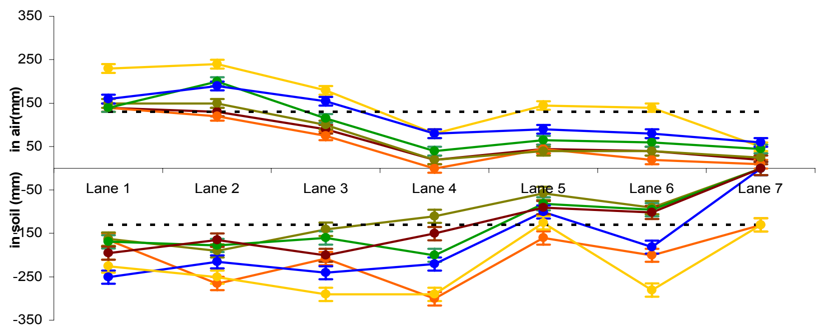
Ebinger EBEX® 420HS - Simulants



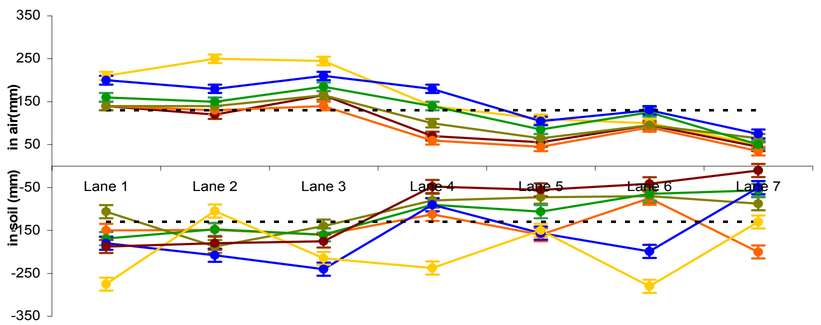
Ebinger EBEX® 421GC - Simulants



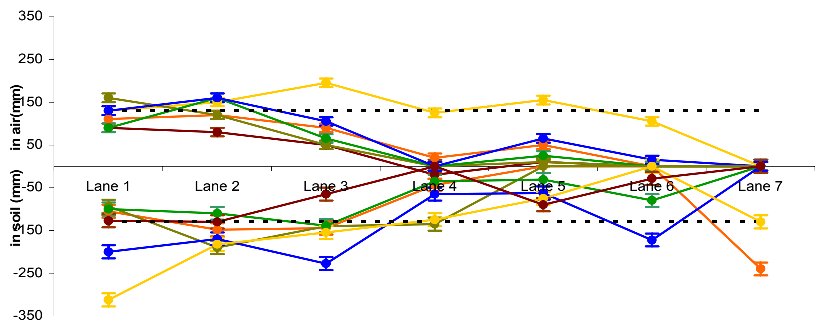
Foerster MINEX 2FD 4.500.01 - Simulants



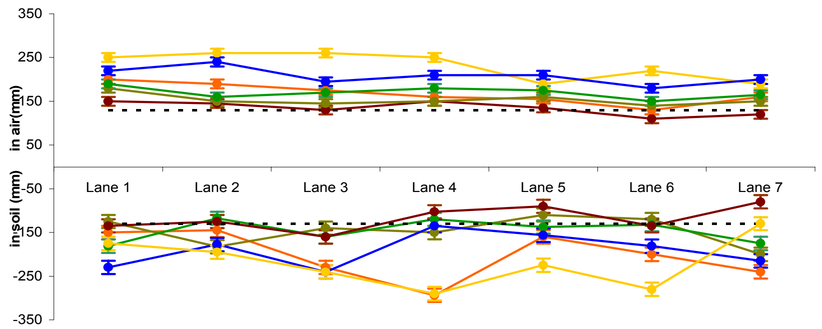
Foerster MINEX 2FD 4.510 - Simulants



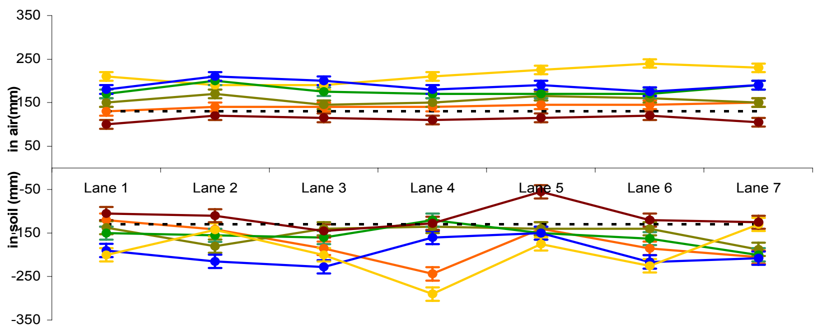
Guartel MD8+ - Simulants



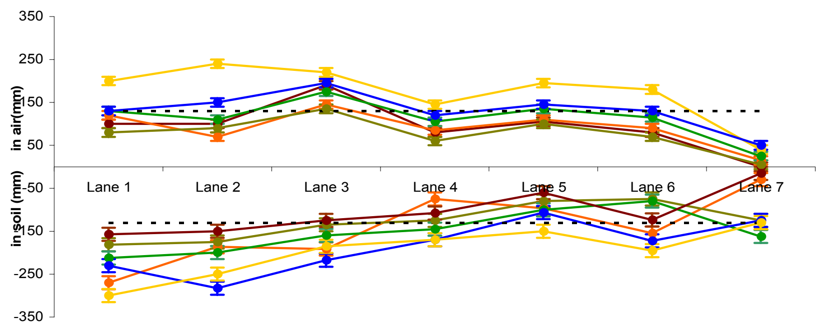
MINELAB F1A4 - Simulants



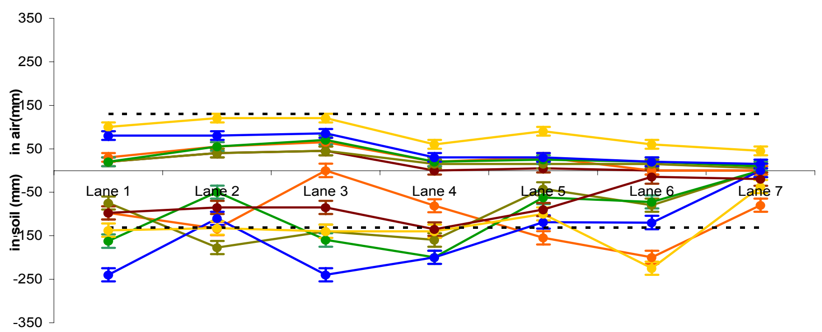
MINELAB F3 - Simulants



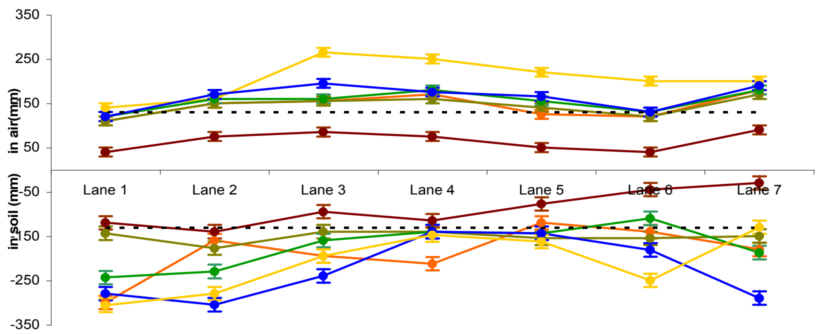
Schiebel ATMID™ - Simulants



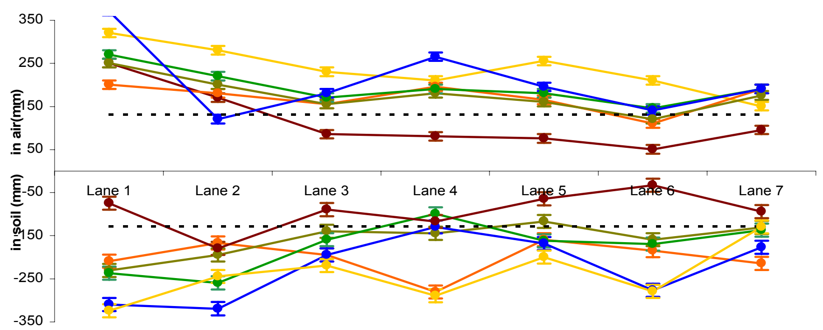
SHRIMT M90 - Simulants



Vallon VMH3 - Simulants

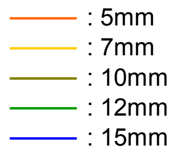


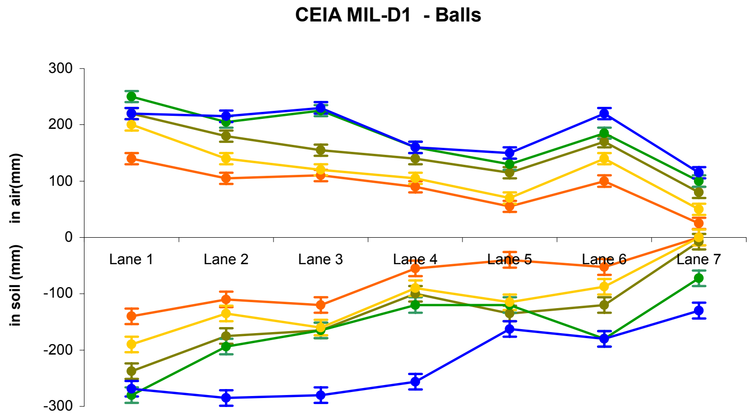
Vallon VMH3 (M) - Simulants

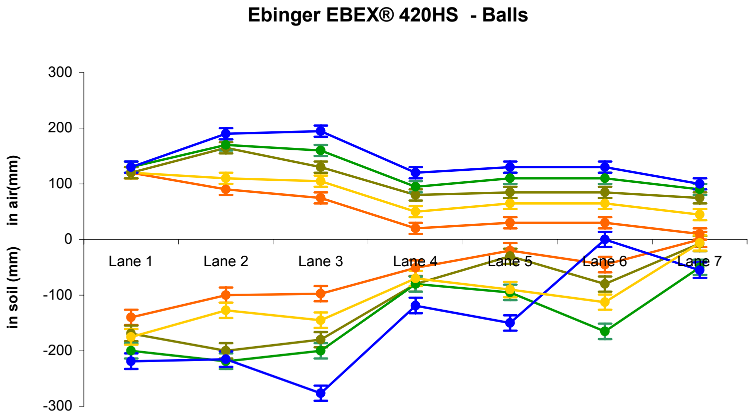


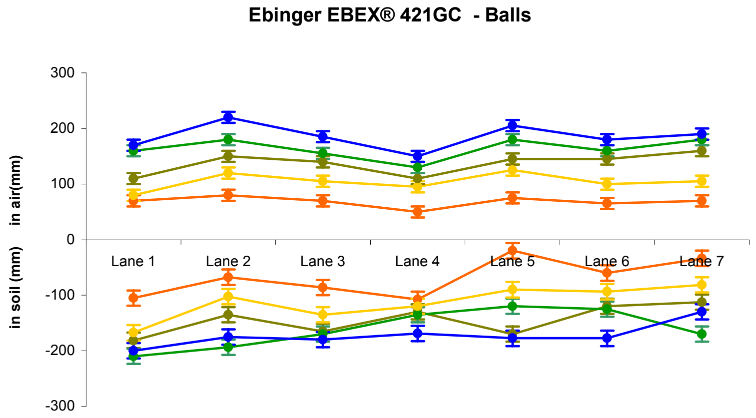
12.6 ANNEX F - Fold out page 4: Spheres/Balls

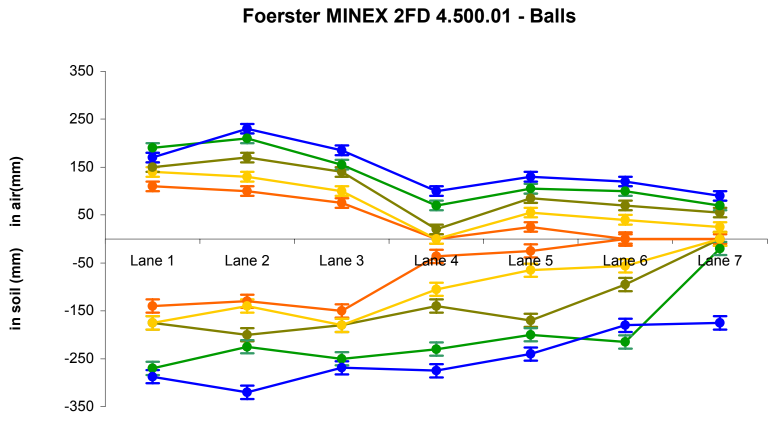
ANNEX F: Fold out 4

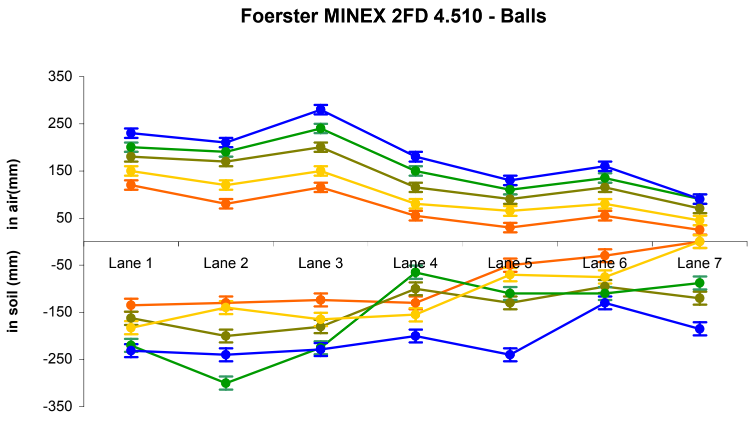


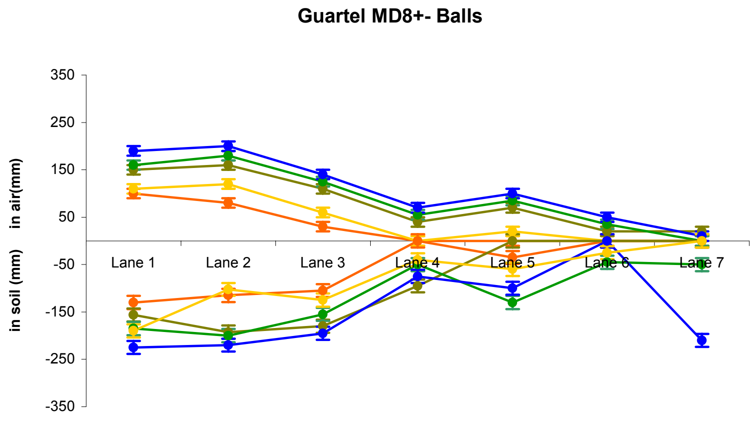


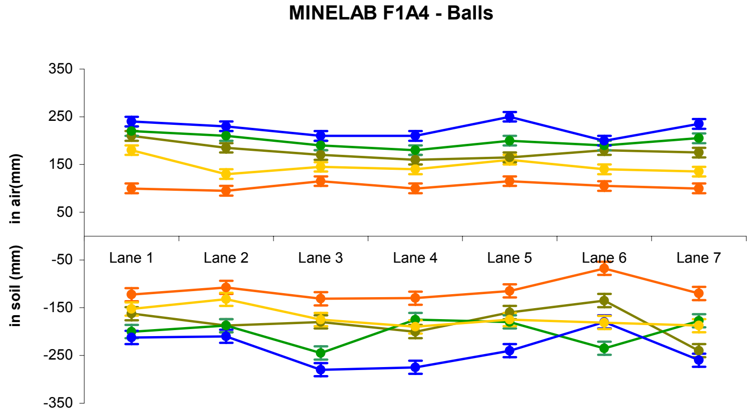


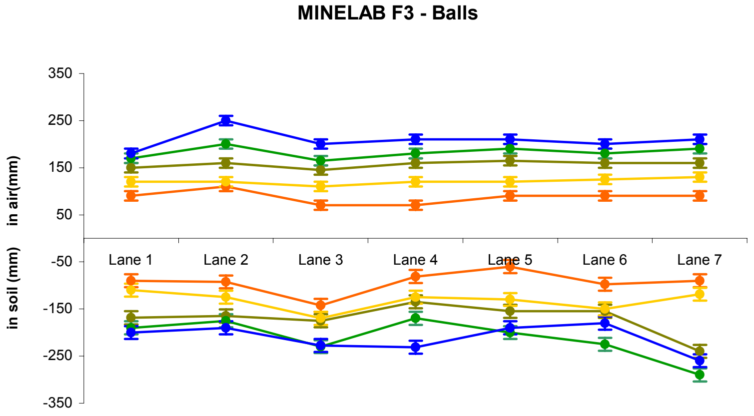


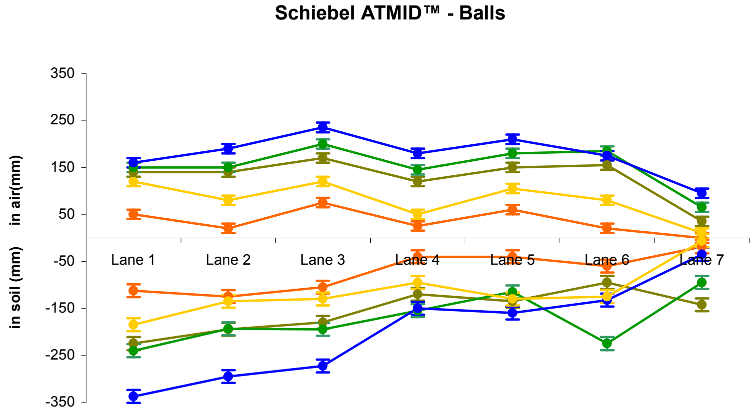


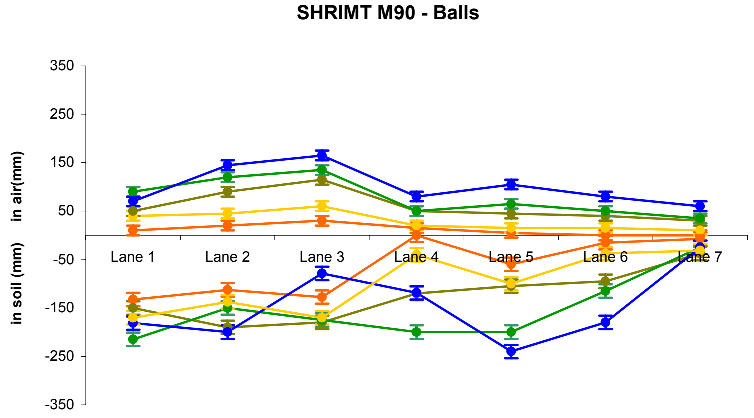


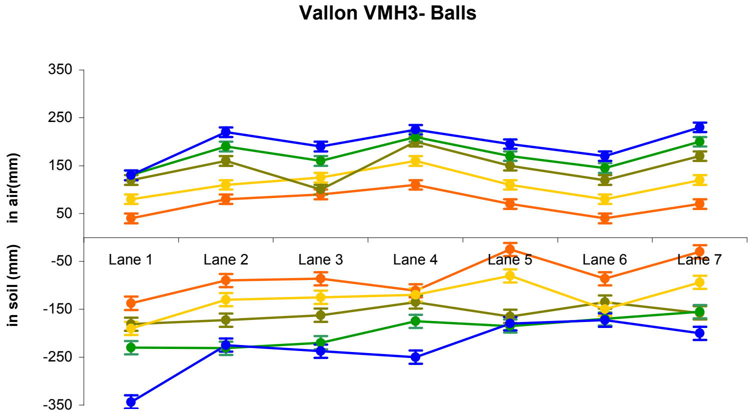


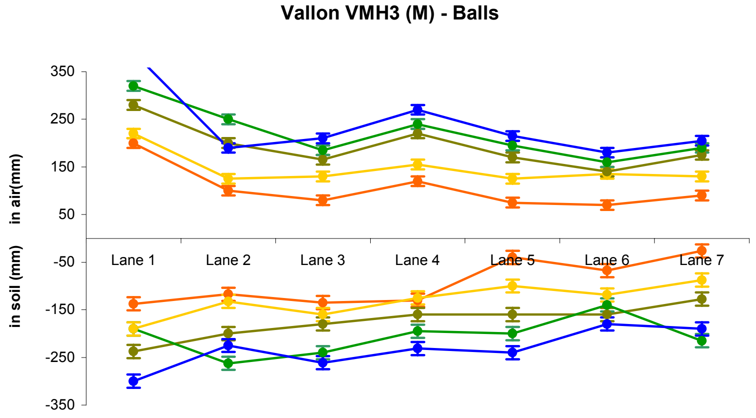












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