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Report on the testing of detectors NR-900EK3M EAGLE, NR-2000 and NR-12C

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Administrative notes

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0.4	Test locations selected for NLJD and wire detectors, IED samples prepared, detectors with diodes and electromagnetic field measurements equipment defined. Plan and programme sent to user.	Tomislav V.B. Vondraček, Oto Jungwirth, Milan Bajić, Tamara Ivelja	20.05.2016
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Abstract: Non-linear junction detectors NR-900EK3M and NR-2000, and a control wire-line detector NR-12C are demonstrated and tested during four days by the Croatian Mine Action Centre – Centre for Testing, Development and Training (HCR-CTRO) in Croatia, in Cerovac, in May 2016. Several changes of conditions enabled estimation of the operational performances of considered equipment. The detectors are approved to be efficient means for detection of simulated improvised explosive devices (IED) and control wire-line, their application is simple and they are user friendly. Selected simulated IEDs were detected in natural open area, on the ground or elevated, behind or inside of obstacles. The calibration of NR-900EK3M was done by half wavelength dipoles with diode, and ranges greater than 76 m were obtained. The NR-2000 detector showed its usefulness if IEDs were behind the obstacles. The NR-12C detector was approved in complex realistic situations.

Contents

1 INTRODUCTION

STT GROUP (Special-purpose Equipment & Technologies) is a registered trademark of two Russian firms – Engineering-Commercial Multiprofile Centre-1 Ltd., and Protection Group - UTTA JSC.

STT GROUP has been developing and serially manufacturing special-purpose equipment, such as Non-Linear Junction Detectors (NLJD) for various missions and command wire detectors. STT GROUP has asked the Croatian Mine Action Centre – Centre for Testing, Development and Training (HCR-CTRO) to test their three detectors[1,2,3,4]:

NR-900EK 3M EAGLE, Non – linear junction detector, (STT Group 2015, p. 8/29)
NR-2000, Non – linear junction detector, (STT Group 2015, p. 15/29).
NR-12C, Handheld control-wire-line detector, (STT Group 2015, p. 9/29).

a b c

Figure 1.1: a) NLJD NR-900EK3M EAGLE. b) NLJDNR-2000. c) Handheld control-wire-line detector NR-12C.

NLJD devices NR-900EK3M EAGLE and NR-2000 are designed for search and detection of different types of covert listening devices, various electronic appliances and electromagnetic waves produced by passive non-linear junctions being illuminated by electromagnetic waves. They are aimed for detection of mines and explosive devices with electronic fuses (activation system) concealed on the ground surface, slightly in the ground (snow), under the road pavement and within various facilities. They enable detection of mines and explosive devices with tightening or push-button fuses, communicational transmitters & receivers, as well as

[1]STT Group (2015). Special-purpose equipment & technologies. PDF. Mission: design, manufacture, use, original equipment against technical reconnaissance terrorist explosion acts. 13/05/2015, STT group of companies: Engineering and Commercial Mutiprofile Centre – 1 Ltd. (ECMC-1), JUTTA Protection Group JSC. 29. pages.
[2] STT Group (2011). NR-12C Handheld Command Line Detector. Accessed 30.05.2016, http://stt-group.com/publications/nr-12c_handheld/
[3] Vladimir Tkach, Igor Parfentsev, Stanislav Zvezhinsky (2015). Mobile detection systems with non-linear radar-detectors. Accessed 30.05.2016, http://stt-group.com/publications/mobile_detection_systems/
[4]NATO (2006). 2006 NATO Counter-IED Advanced research demonstration conference report, The International institute for homeland security, defence and restoration in cooperation with NATO and Spanish Ministry of Defence, N41756-06-06-D-5584 – SP-SI-2615, pp. 54-58.

alarm and remote control system facilities, electronic and electromechanical timers, acoustic, magnetic, optoelectronic sensors and midget TV cameras, built-in metalware, as well as hidden machinery and appliances.

Handheld detector NR-12C enables detection of improvised explosive device (IED) via survey of their control-wire-line. This detector is aimed for the following applications: roads, terrain and various objects inspection for IED, control-wire-lines concealed in the ground, current underground line pass definition, roads and terrain combat engineering reconnaissance, mass public actions anti-terrorist and security support.

HCR-CTRO has derived an Acceptance trial plan and programme for trials of NR-12C, NR-900EK 3M EAGLE and NR-2000 detectors, starting from general requirements given in three documents provided by STT GROUP:

[1] NR 900 EK 3M «EAGLE», NR-900EMS&NR-2000, STT Group Demonstration Program, received 06/05/2016, 8 pages,
[2] NR-12C, STT Group Demonstration Program, received 06/05/2016, 6 pages,
[3] Test Field Requirements for "Eagle" NR 900 EK Practical Demonstrations, STT Group Request for demonstration testing, received 06/05/2016, 2 pages.

Three additional references have been used in development of the testing plan, (Hong 2014), (Fernandez Gonzalez 2012) and (Steinshleiger1984) and for comparative analysis of achieved performances.

The testing was conducted between 23.05.2016 and 27.05.2016 at a HCR-CTRO test site *Cerovac* (near Karlovac, Croatia), results are given in the following chapters.

2 TESTING GOALS AND OBJECTIVES

The goals of the testing were:

- demonstrate and approve technical and basic operational performances of the NLJ detectors NR-900EK3M EAGLE, NR-2000 and handheld control-wire-line detector NR-2000,
- test range of detection for several targets, examples of selected IED in several conditions and orientations of target towards NLJD,
- provide and apply dipoles with diode for reference measurements of NLJD,
- provide NLJD testing in environment without electromagnetic interference,
- test handheld control-wire-line detector in several environmental situations,
- compare achieved technical and operational performances with published results from (Hong 2014), (Fernandez Gonzalez 2012).

The objectives of the testing were to provide relevant and reliable data which enable assessment of the technical and basic operational performances.

Due to the basic nature of the NLJD the following actions have been performed.

- *Mitigation of harmful data which lead to wrong conclusions about operational performances*

The harmful data collected in testing can lead to wrong conclusion about operational parameters of NLJD. HCR CTRO provided controlled testing and measurement conditions to mitigate this event.

- *Open space conditions*

The considered NLJDs belong to the harmonic radar for targets detectable on second or on third harmonic, therefore the testing shall provide “ideal” conditions in “open” space [1], [3]. This means negligible level of interfering radio fields at f_0, $2f_0$, $3f_0$, where f_0 is frequency of transmitter of tested NLJD. HCR-CTRO provided and verified required conditions by measurements of strengths of external radio fields.

- *Dependence of target non-linear response on range from NLJD and a target*

Another aspect is more demanding. Testing of NLJD shall take into account operational features of the harmonic radar transmitting at f_0 and receiving at $2f_0$ and $3f_0$ where the value of target’s signal at radar receiver non-linearly depends on spatial power density (W/m^2) produced by transmitter at target (Steinshleiger 1984, Eq. 20), (Kalabuhov, Tkachev 2001), (Vernigorov 1998), (Vernigorov, Kuznecov 2002).

The received power in NLJD depends on range R from it to target as follows: R^{-6} for $2f_0$ and R^{-8} for $3f_0$, whereas ordinary radar has dependence R^{-4}. These facts make the quantitative testing of NLJD extremely complex.

- *Minima of received signals*

The operator positions NLJD, Fig. 3.3, at height H_1 above ground. The target lies on the ground or at height H_2, Fig. 3.2, (on the soil surface, $H_2 = 0$, on the plastic chair $H_2 = 0.5$ m, on the dielectric wooden stand $H_2 = 1.2$ m). Horizontal distance between the operator and the target is D (in the test this will change), Fig.3.5. Due to this geometry, the propagation of electromagnetic waves on f_0, $2f_0$, $3f_0$ has well known behaviour, maxima and minima (even zeros) appear at certain ranges D. The data at the location of minima & even zeros can derive wrong conclusions about NLJD operational performances, Fig. 3.6.

- *Soil conductivity*

Electromagnetic parameters of the soil at the test site have a significant impact on the results. Therefore, the conductivity of soil samples will be analysed and added to the set of testing results.

3 TESTING ENVIRONMENT & AUXILIARY DATA

The testing was performed in form of a trial at a HCR-CTRO test site *Cerovac*.

Two separate test areas have been prepared, several required field conditions have been fulfilled and necessary measurements taken in order to objectify meaningful and relevant trial data.
The testing was initially planned to take ten days, but a representative of the DOK-ING company shortened it to four working days and one reserve day. The testing was done as follows:

23.05.2016: Testing of NR-900EK3M “EAGLE”, the soil was dry,
24.05.2016: Testing of NR-900EK3M “EAGLE”, the soil was wet,

25.05.2016: Testing of NR-12C,
27.05.2016: Testing of NR-2000.

The operator of detectors was Igor Parfentsev. He demonstrated the full procedure, from checking the quality of environment for NLJD analysis, search of NLJD by second harmonic response, discrimination of third harmonics, manual scanning in direction of potential IED at different heights, behind or inside of the obstacles. Also, he performed wire detection operations with NR-12C in different environment conditions and scenarios.

As part of the demonstration, the Croatian team was taught to operate the detectors themselves: Milan Bajić - NR-900EK3M EAGLE, Tamara Ivelja - NR-900EK3M EAGLE, NR-2000, NR-12C and Ivan Balić - NR-900EK3M EAGLE, NR-2000.

a b c

Figure 3.0: Detectors in action: a) NR-900EK3M EAGLE, b) NR-2000, c) NR-12C

Five soil samples were taken on 24th of May along the test area (Fig. 3.1) on vertical central axis at the distance of 7m, 13.5m, 16m, 18.3m and 20m.
The electric specific conductivity of the dryed soil samplesis was in range from 0.1054 to 0.1061 S/m (13.1).

3.1 *NLJ Detectors NR-900EK3M EAGLE and NR-2000*

For NLJ detectors NR-900EK3M EAGLE and NR-2000 a rectangular area (50x15 m) free from possible interference sources was provided, Fig. 3.1a), Fig. 3.1b), as well as requested obstacles, Fig.3.1c).

a)

b)

c)

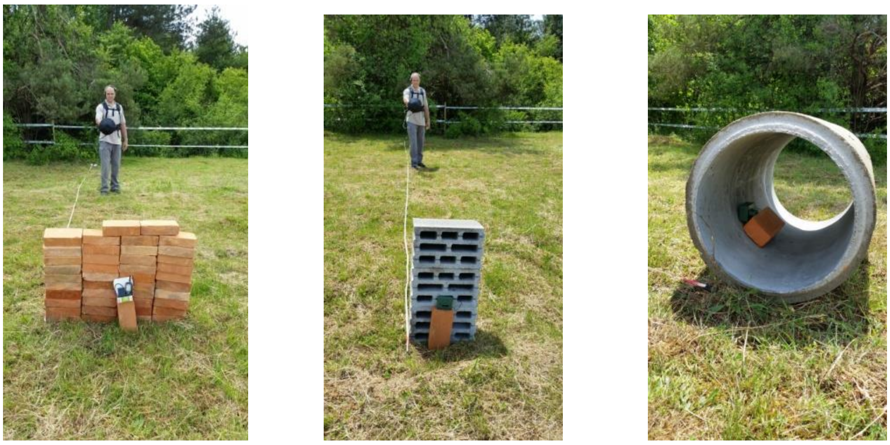
Figure 3.1: NR 900EK3M EAGLE and NR 2000 test lane 50x15 m at the Cerovac test-site. a) Polygon position marked on a satelitte map. The red arrow indicates the direction of b) a view from the ground. c) A view of the test lane with different obctacles.

A ceratain number of targets was choosen for detection testing. Detection was conducted with respect to a different target orientation and position. Orientation was changed in the clockwise direction in increments of 90°. Positions of targets were diverse; on a dielectric stand 120 cm high, on a plastic chair 50 cm high, on the ground and concealed behind different obstacles, Fig. 3.2 a), b), c), d), e), f).

a) H2= 1.20 m

b) H2=0.50 m

c) H2=0 m



d) e) f)

Figure 3.2: Basic spatial relations of NLJD demonstration testing.

a) b) c) d)

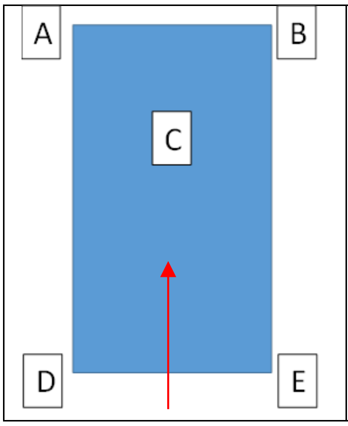
Figure 3.3: A search for targets combines approaching a suspected area with different types of scanning. For NR-900EK3M EAGLE the following typical heights were used: a) minimum H1=1.1 m, b) maximum H1=1.7 m. Examples of scanning with NR 2000 and targets behind the objects are shown in c) and d).

The results of the testing of NLJ detector NR-900EK3M are given in chapter 4.1, and the results for detector NR-2000 in chapter 4.2.

3.1.1 NLJ Detector NR-900EK3M EAGLE

- *Levels of interfering electromagnetic fields at the test area for the testing of NLJD NR-900EK3M EAGLE demonstration testing*

The level of possible interefering electromagnetisc fields was checked at the test area, Fig. 3.1 a), the results for frequencies of NLJD NR-900EK3M EAGLE are shown in Fig. 3.4. Radio interferences are negligible at NR 900EK 3M EAGLE transmitter frequency, they are weak and will not excite non-linearity at metal surfaces. At the location A at frequencies of second harmonic, interference level is -73 dBm, at frequencies of third harmonic, the interference level is -87 dBm.



	Transmitter MHz/dBm	Second harmonic MHz/dBm	Third harmonic MHz/dBm
A	846/-63	1851/-73	2419/-87
B	clean	clean	clean
C	845.4/-85	clean	clean
D	clean	clean	clean
E	845/-90	clean	clean
Clean means signal level < -90 dBm			

Figure 3.4: Levels of interfering electromagnetic fields in the test lane 50x15 m for NR 900EK 3M EAGLE at locations A, B, C, D and E. The red arrow indicates direction of the test area in Fig 3.1.

Besides the electromagnetic fields from active transmitters, the junctions of disimilar metal surfaces can produce electromagnetic waves on third harmonic frequency of the NLJD. Thefeore, the area for testing of NLJD was checked and cleared from any metal objects which can cause the third harmonic. This was verified by calibrating search made with NLJD before the measurements. Although the area clear of non-linear metal junctions was provided, one day a testing of a demining machine was under way at a distance > 150 m from the test lane. Besides the second harmonics caused by the electronics of the remote control system of the machine, strong third harmonics were detected when NR 900EK 3M EAGLE was directed in the direction of the machine.

- *Non monotonic decrease of electric fields model caused by interference of direct and reflected waves*

The behaviour of electromagnetic fields in the considered NLJD case is very complex (Steinshleiger 1984), thus we consider only a simplified model of interference, Fig. 3.5.

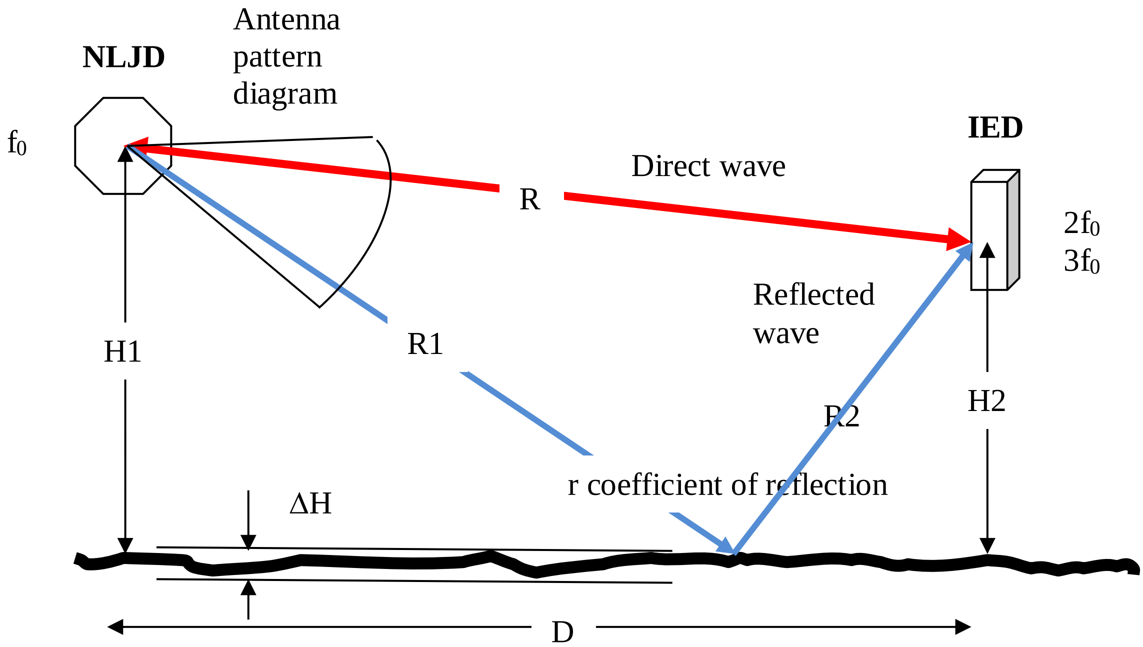


Figure 3.5.: Basic geometry of NLJD testing at the area in Fig. 3.1. D is horizontal distance, H1 – height of NLJD, H2 – height of IED, f_0 – frequency of NLJD transmitter, $2f_0$ – frequency of second harmonic generated by IED, $3f_0$ – frequency of third harmonic generated at contact surfaces of different metals.

If the main lobe of the antenna pattern diagram of NLJD covers ground surface, which has a coefficient of reflection r, then the result is interference of direct and reflected waves, Fig. 3.5. If the variations ΔH of the ground surface satisfy $\Delta H < \lambda D/(8(H1+H2))$, where λ are wavelengths of NLJD transmitter (0.356 m), of the second harmonic (0.178m), of the third harmonic (0.118m) the surface is electrically smooth. For the case of a smooth surface and reflection coefficient r ~ 1, dependence of electric field is analysed on a distance D, for the set of H1, H2 parameters and shown in Fig. 3.6.

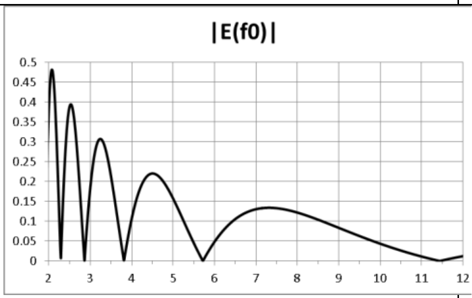
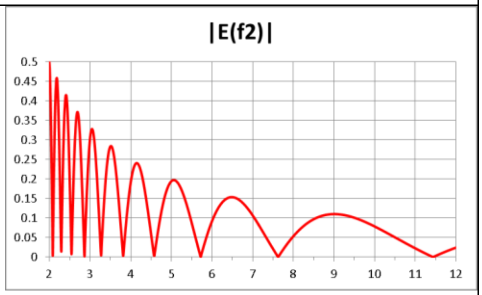
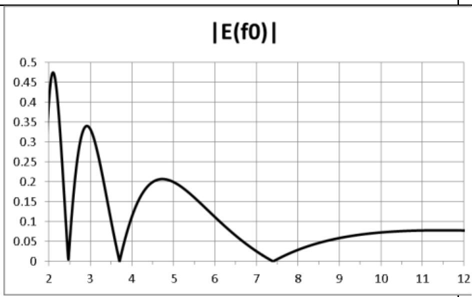
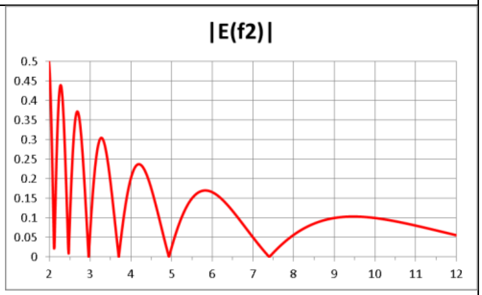
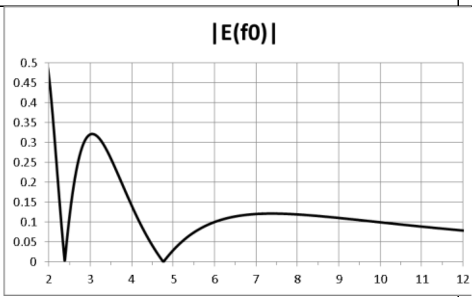
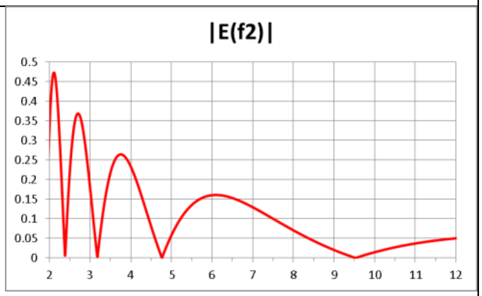
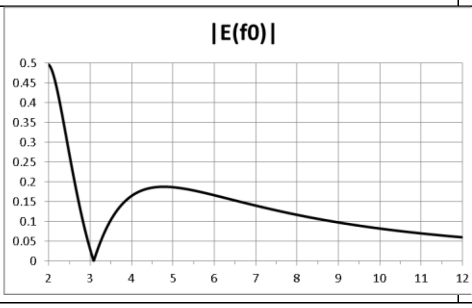
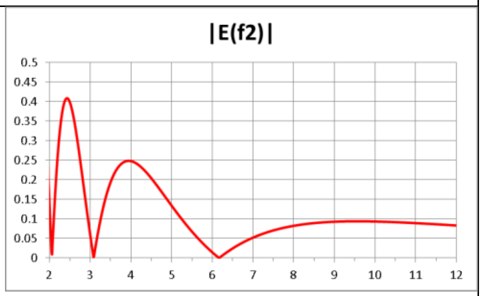
<table>
<tr><th>Heights</th><th>Distance D from NLJD → IED</th><th>Distance D from IED → NLJD</th></tr>
<tr><td>a)Relative E field strength for H1=1.7m H2=1.2m</td><td></td><td></td></tr>
<tr><td>b)RelativeE field strength for H1=1.1m H2=1.2m</td><td></td><td></td></tr>
<tr><td>c)RelativeE field strength for H1=1.7m H2=0.5m</td><td></td><td></td></tr>
<tr><td>d)RelativeE field strength for H1=1.1m H2=0.5m</td><td></td><td></td></tr>
</table>

Figure 3.6: The appearance of local maxima and minima of relative electric (E) field for basic geometry applied in the testing of NLJD NR-900EK3M EAGLE, for case r~1, and electrically smooth surface.

The change of relative strength of the electric field $|E(f_0)|$ of NLJD in direction towards IED and of electric field of the second harmonic |E(f2)| in direction from IED towards NLJD is analysed for a case of electrically smooth surface. Note that for flat, smooth areas, asphalt roads, macadam roads and dirt roads, this phenomenon can show a significant impact.

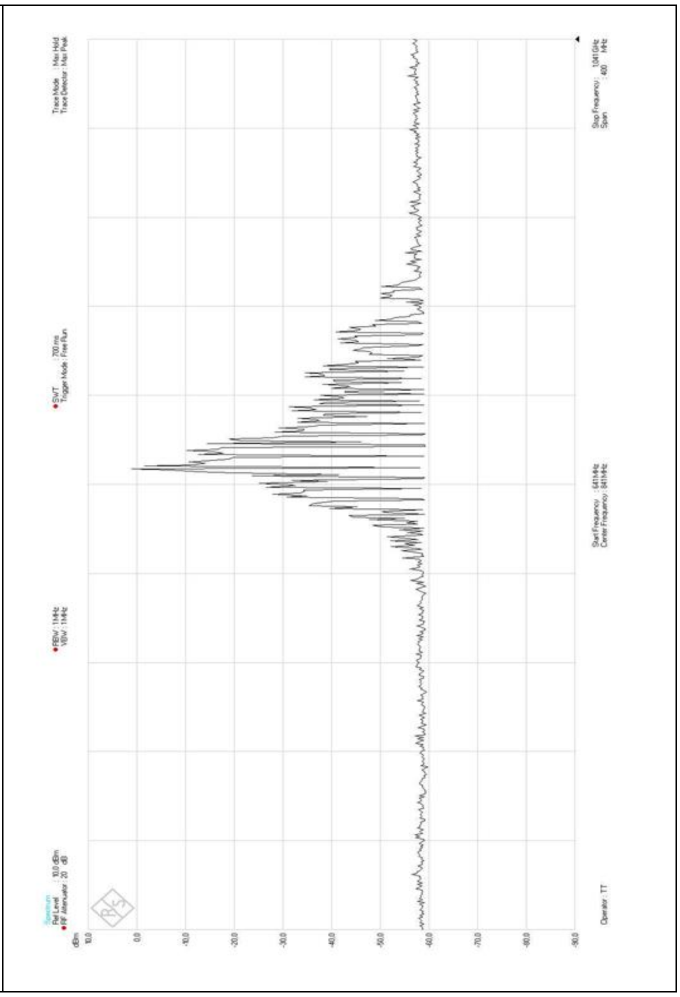
The diagrams in Fig.3.6 show locations of field minima in direction from NLJD towards IED and the opposite, from IED towards NLJD for selected combinations of H1 and H2. Note that the operator can decrease the number of minima from 5 to 3 for f0 and from 10 to 6 for f2 by sweeping in the vertical plane, Fig. 3.6a, Fig. 3.6b. A similar effect appears in Fig. 3.6c and Fig. 3.6d. Note that the described topics are only intended for understanding of spatial |E| fields' behaviour and not for calculation of measured fields.

Due to the decreased duration of the testing from initially planned 10 to 4 working days, further analysis of the impact of the interference on the results was not conducted.

- *Spectrum of NLJD NR-900EK3M EAGLE*

The spectrum of NLJD NR-900 EK3M EAGLE transmitter was measured by Rohde Schwarz Spectrum analyser FSH8 and passive antenna, Fig. 3.7.

Measurement Setup	
Name	: Sweep
Date	: 25 / 5 / 2016
Time	: 13:49:16
Instrument	: FSH8 - 115242/018
Firmware Version	: V2.61
Instrument Mode	: Spectrum
Meas Mode	: Spectrum
Uplink	: ---
Downlink	: ---
Channel (uplink)	: ---
Center Frequency	: 841 MHz
Frequency Offset	: 0 Hz
Span	: 400 MHz
Ref Level	: 10,0 dBm
Ref Offset	: 0,0 dB
Range	: 100 dB
RF Attenuation	: Manual
RF Attenuator	: 20 dB
Preamplifier	: Off
RF Input	: 50 Ohm
RBW	: 1 MHz
VBW	: 1 MHz
SWT	: 700 ms
Trigger Mode	: Free Run
Trigger Level	: ---
Trigger Delay	: ---
Trace Mode	: Max Hold
Trace Math	: Off
Trace Detector	: Max Peak
Limit Line 1	: ---
Limit Line 2	: ---
Primary Transducer	: ---
Secondary Transducer	: ---
Gated Trigger	: Off
Gate Mode	: Edge
Gate Delay	: 0 s
Gate Length	: 400 us



a)

b)

Figure 3.7: a) The spectrum of NR-900EK3M EAGLE transmitter was measured. b) by Rohde Schwarz Spectrum Analyser FSH8.

3.1.2 NLJ Detector NR-2000

NR-2000 is a multipurpose non-linear junction detector (NLJD) used for searching for various electronic devices that contain semi-conductor components, such as mobile phone and SIM card detection, electronic components of remote control improvised explosive device (RC IED) investigation in urban environment under strong interference conditions, eavesdropping device and other unauthorised electronic appliance detection and localization. This detector works at higher frequencies, has higher spatial resolution and positioning acuraccy and detection ranges are smaller if compared to detection ranges of NR-900EK3M EAGLE. STT GROUP Requirements for demonstration [1], [3] do not define different procedures regarding NR-2000 and NR-900EK3M EAGLE. The same test area was used for both detectors, although smaller ranges were used for NR-2000. The results for NR-2000 are given in chapter 4.2.

3.2 *Handheld control-wire-line detector NR-12C*

For control-wire-line detector NR-12C several environment test settings were prepared in order to inspect detection possibilities of the device. The main goals of the trial were to determine possible depth of detection, boundaries of detection, and the first and last wire signal's response.

The NR-12C device is used in 2 different operational configurations regarding its signal generator and antena. First configuration, Fig. 3.8a), is for wire detection while scanning the area of interest, while the second configuration, Fig. 3.8b), is for "following" the wire signal after detection.

a) b)

Figure 3.8.: Handheld wire detector NR12-C. a) Configuration for wire detection. b) Configuration for "following" the wire signal.

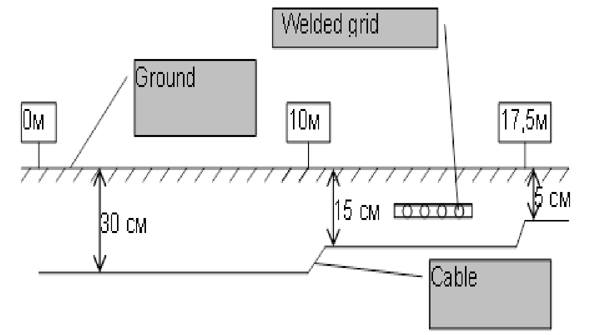
First testing scenario

The test lane in an even area 25 x 20 m, Fig. 3.8a), without obvious ground abnormalities was prepared for NR-12C detection testing. Inside the prepared ditch, Fig. 3.9 b), twenty meters long, adequate wire and a welded metallic grid 1 x 1m were embedded as requested, Fig.3.9c).

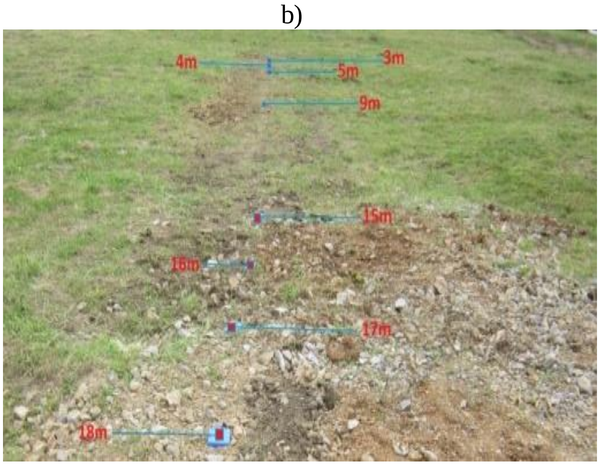
After embedding, the grass cover (turf) was carefully restored and reference pegs (benchmark) were arranged, Fig. 3.9d).

a)

b)



c)



d)

Figure 3.9 NR-12C test lane 25 x 20 m at the test site Cerovac. a) Polygon position marked on a satelitte map. b) Ditch preparation for control wire embedding. c) Plot of the IED control-wire-line imitator embedding. d) Reference pegs (benchmark) potions.

The aim of this testing scenario was to inspect possibilities of detecting wire on different depths, as well as determining position of welded metallic grid and boundaries of detection for both targets.

Second testing scenario

For the second testing scenario, a part of a 25 m long wire was positioned as shown in Figure 3.10 a). One part of the wire was embedded on the depth of 5cm, Fig. 3.10 b), while the other part of the wire was laid on the bottom of the ditch covered with app 30 cm of water, Fig. 3.10 c).

a) b) c)

Figure 3.10: Area for NR-12C second testing scenario at the Cerovac test site. a) Position of the wire marked on a satellite map (red line). b) Soil preparation and control wire embedding. c) Ditch covered with app 30cm of water used for lining the wire.

The frst goal of this testing scenario was to inspect NR-12C possibilities of detection of wire under water, which was enabled by laying the wire on the bottom of a ditch covered with water. The sencond goal was to determine the distances of the first and last detection of the wire.
The operator was not aware of the position of the wire.

Third testing scenario

For the third testing scenario a 55 m long wire was used. The wire was positioned in a way to imitate an operator's real working conditions. The wire was laid down in three different ways; embedded at 5cm depth, laid on the bottom of the ditch covered with water and placed on the ground surface covered with dense vegetation, Fig. 3.11.

a)

b) c) d)

Figure 3.11: The area for NR-12C third testing scenario at the Cerovac test site. a) Position of the wire marked on a satellite map (red line). 1st red line segment – the wire was embedded at 5cm depth, the 2nd red line segment – the wire was laid down on the bottom of the ditch covered with app 30cm of water, the 3rd red line segment – the wire was placed on the ground surface covered with dense vegetation. b) Wire embedded at 5cm depth. c) The wire laid down on the bottom of the ditch covered with water. d) The wire placed on the ground surface covered with dense vegetation.

Sveral goals were set for this scenario in order to assess NR-12C possibilities for detection of the wire in operator's real working conditions. Since the operator was not aware of the position of the wire, the first goal was to determine the wire position by inspecting the area. The second goal was to "follow the wire" and to determine the first and last wire response. Scanning of the area started down the road, 200 meters from the 1st wire segment.

4 TESTING RESULTS

4.1 *NR-900EK 3M EAGLE TESTING- results*

Date: 23.05.2016.
Location: HCR-CTRO Cerovac test site
Tested detector: NR-900EK3M "EAGLE"

1st TEST
Description:
Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch
Height – Dielectric stand 120 cm
Weather conditions: Dry

Figure 4.1 Toy car, IR sensor, NOKIA1616+El Switch at 1.20 m.

Orientation	I	II	III	IV	V
Toy Car	13m	11.5m	15.5m	13.5m	17.2m
IR sensor	27.2m	20m	30m	22m	
NOKIA1616+El.S.	14m	19.3m	17m	18.5m	

2nd TEST

Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch

Height – Plastic chair 50 cm

Weather conditions: Dry

Figure 4.2. Toy car, IR sensor, NOKIA1616+El Switch at 0.5 m.

Orientation	I	II	III	IV	V
Toy Car	17m	18m	16.5m	20m	19.5m
IR sensor	25.5m	21m	28m	23m	
NOKIA1616+El.S.	16	19.3m	22m	20m	

3rd TEST

Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch

Height – Ground level

Weather conditions: Dry

Orientation	I	II	III	IV	V
Toy Car	11m	14m	13m	12m	12.5m
IR sensor	12m	11m	14m	13m	
NOKIA1616+El.S.	13.5m	15m	14m	12.5m	

4th TEST
Description:

Target – Mortar shell 120mm

Height – Ground level

Weather conditions: Dry

Mortar shell 120mm

Detection – 2-3m

Figure 4.3. Mortar shell 120 mm, on the ground.

Date: 24.05.2016.
Location: HCR-CTRO Cerovac test site
Tested detector: NR-900EK3M "EAGLE"

1st TEST
Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch

Weather conditions: Wet

I. Toy Car - III orientation

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	18.5m	12.5m

II. Infra-Red sensor - III orientation

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	29m	23.5m

III. NOKIA1616 with electronic switch - I orientation

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	22m	17m

2nd TEST

Description:

Targets – Meteo station, Remote Control, NOKIA5130c, NOKIA5130c with electronic switch, Light switch

Height – Dielectric stand 120 cm

Weather conditions: Wet

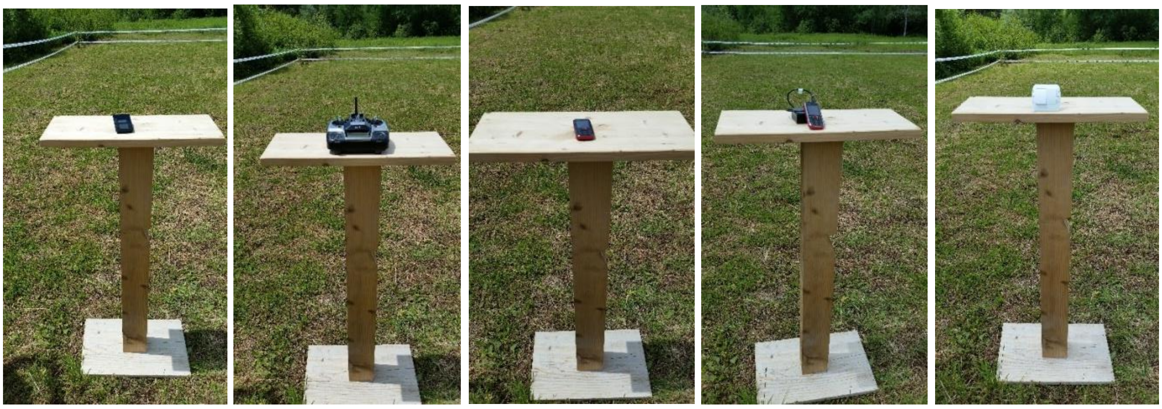


Figure 4.4: Meteo station, Remote Control Unit for unmanned aerial vehicle, NOKIA5130c, NOKIA 5130c+El. Switch, Light switch.

Orientation	I	III
Meteo station	12m	13.5m
Remote Control	18.3m	20m
NOKIA5130c	11m	10.5m
NOKIA5130c+El.S.	18	20
Light switch	1.7m	

3rd TEST

Description:

Targets – Meteo station, Remote Control, NOKIA5130c, NOKIA5130c with electronic switch
Height – Ground level
Weather conditions: Wet

Orientation	I	III
Meteo station	9m	9m
Remote Control	16.5m	17m
NOKIA5130c	7m	7m
NOKIA5130c + El.S.	16m	17.5m

4[th] TEST

Description:

Targets – Infra-Red sensor, NOKIA1616 with electronic switch

Environment – Targets hidden by different obstacles

Weather conditions: Wet

I. RED BRICK (“half”)

Target height – 0.25m

Obstacle width – 0.12m

Infra-Red sensor	NOKIA1616 with electronic switch
	
Position - III, Detection – 7m	**Position - IV, Detection – 8m**

Figure 4.5 Two targets behind red brick half width.

II. RED BRICK (“Full”)

Target height – 0.12m

Obstacle width – 0.25m

Infra-Red sensor

Position - III, Detection – 5.5m

Figure 4.6 Two targets behind red brick full width.

III. BRICK BLOCK

Target height – 0.25m

Obstacle width – 0.19m

Infra-Red sensor

Position - III, Detection – 10.5m

Figure 4.7 Target behind a brick block.

IV. CEMENT BLOCK

Target height – 0.25m

Obstacle width – 0.2m

Infra-Red sensor

Position - III, Detection – 11.5m

Figure 4.8 Target behind a cement block.

V. CEMENT TUBE (inside)

Target height – 0.25m

Obstacle width – 0.05m

Diameter – 0.6m

Infra-Red sensor

Position - III, Detection – 7.5m

Figure 4.9 Target inside of a cement tube.

VI. CEMENT TUBE (behind)

Target height – 0.25m

Obstacle width – 0.05m

Diameter – 0.6m

Infra-Red sensor

Position - III, Detection – 4m

Figure 4.10: Target behind a cement tube.

Date: 24.05.2016.
Location: HCR-CTRO test site Cerovac
Tested detector: NR-900EK3M "EAGLE"

1st TEST

Description:

Targets – Calibration targets: STT GROUP diode, HCR CTRO Half-wave dipole with balun and diode, HCR CTRO Half-wave dipole with diode

Weather conditions: Dry

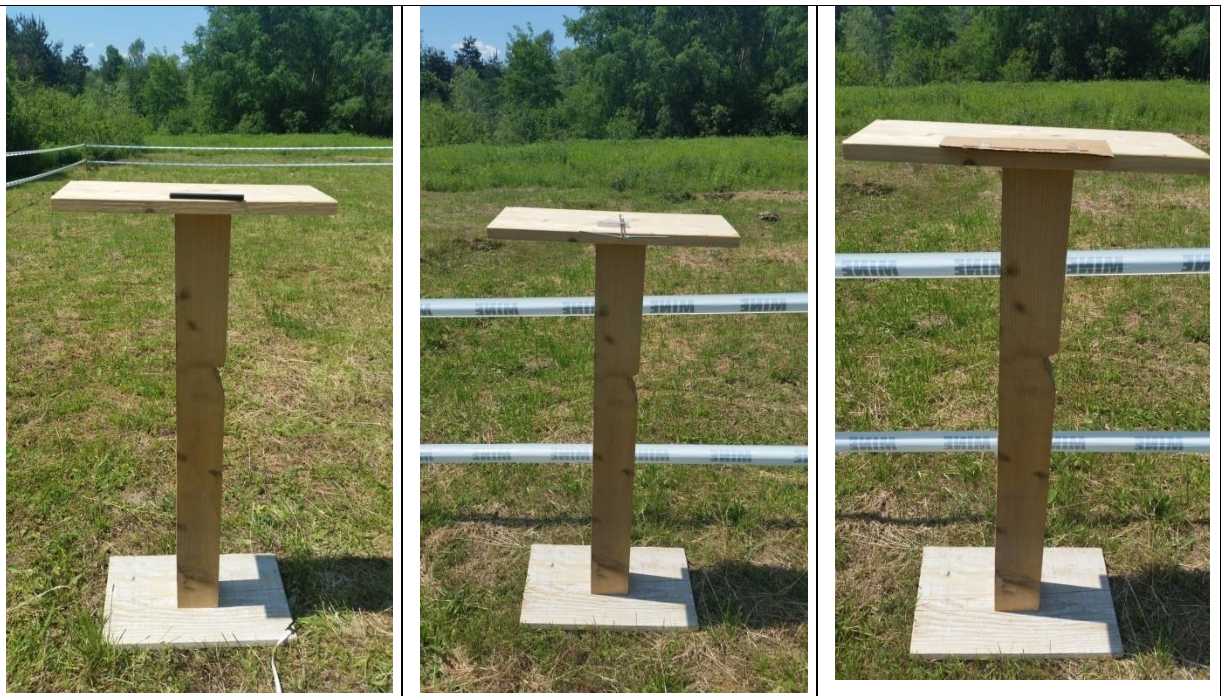


Fig. 4.11: Calibrating targets: STT GROUP diode, HCR CTRO half-wave dipole with balun and diode, HCR CTRO half-wave dipole with diode.

I. Diode (STT GROUP)

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	Detection 10 m	Detection 5 m

II. Half-wavelength dipole with balun and diode (HCR CTRO)

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	Detection> 70 m	23.5 m

III. Half-wavelength dipole with diode (HCR CTRO)

Height	dielectric stand - 120 cm	Ground level - 0cm
Distance	Detection> 76 m	21

4.2 *NR-2000 TESTING- results*

Date: 27.05.2016.
Location: HCR-CTRO Cerovac test site
Tested detector: NR-2000

1st TEST
Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch
Height – Dielectric stand 120 cm
Weather conditions: Wet

Figure 4.12: Toy car, IR sensor, NOKIA1616+El Switch at 1.20 m.

Orientation	I	II	III	IV	V
Toy Car	3.5m	6m	5.8m	5.9m	4.3m
IR sensor	13.5m	12.5m	16m	12m	
NOKIA1616+El.S.	3.1m	3.4m	4.8m	3m	

2nd TEST
Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch
Height – Ground level
Weather conditions: Wet

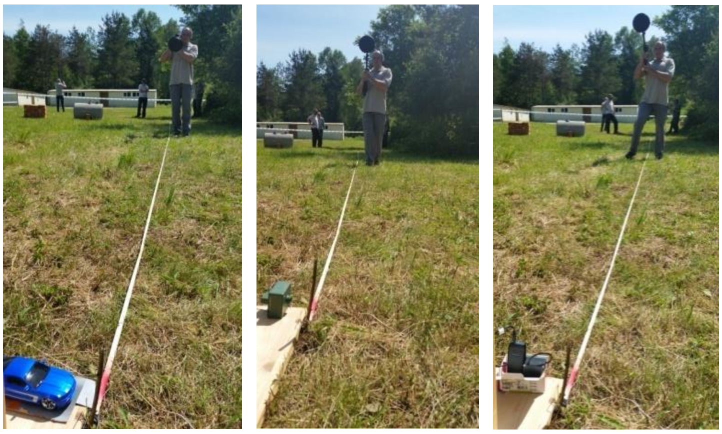


Figure 4.13: Toy car, IR sensor, NOKIA1616+El Switch at ground level.

Orientation	I	II	III	IV	V
Toy Car	5m	7m	6.9m	5.9m	6.3m
IR sensor	14.8m	8.6m	11.1m	10.6m	
NOKIA1616+El.S.	6.3m	5m	5.8m	3.5m	

3rd TEST

Description:

Targets – Toy car, Infra-Red sensor, NOKIA1616 with electronic switch
Environment – Targets hidden by different obstacles
Weather conditions: Wet

I. RED BRICK ("Full")

Target height – 0.25m
Obstacle width – 0.25m

Toy car	Infra-Red sensor	NOKIA1616 with electronic switch
		
Position - I, Detection – 1m	**Position - I, Detection – 4.2m**	**Position - I, Detection – 1m**

Figure 4.14 Targets behind a full brick wall.

II. BRICK BLOCK

Target height – 0.25m

Obstacle width – 0.19m

Toy car	Infra-Red sensor	NOKIA1616 with electronic switch
		
Position - I, Detection – 3.4m	**Position - I, Detection – 11m**	**Position - I, Detection – 2.8m**

Figure 4.15 Targets behind a brick block.

III. CEMENT BLOCK

Target height – 0.25m

Obstacle width – 0.2m

Toy car	Infra-Red sensor	NOKIA1616 with electronic switch
		
Position - I, Detection – 1.3m	**Position - I, Detection – 3m**	**Position - I, Detection – 1m**

Figure 4.16: Targets behind a cement block

IV. CEMENT TUBE (inside)

Target height – 0.25m
Obstacle width – 0.05m
Diameter – 0.6m

Toy car	Infra-Red sensor	NOKIA1616 with electronic switch
		
Position - I, Detection – 3m	**Position - I, Detection – 6.3m**	**Position - I, Detection – 1.7m**

Figure 4.17: Targets inside a cement tube

V. CEMENT TUBE (behind)

Target height – 0.25m
Obstacle width – 0.05m
Diameter – 0.6m

Toy car	Infra-Red sensor	NOKIA1616 with electronic switch
		
Position - I, Detection – 0.8m	**Position - I, Detection – 2.7m**	**Position - I, Detection – 0.8m***

* Distance of detection for target height 0.25m and 0m.

Figure 4.18: Targets behind a cement tube

4.3 *NR-12C TESTING - results*

1st scenario

Description:

Weather conditions: Wet
Location – Cerovac test site, prepared area of 25 x 20 m (Fig. 3.9)
Wire position: embedded on 30cm, 15cm, 5cm
Wire length: 20m

Detection:

The operator started to scan the area, Fig. 4.20, from the middle position (position - 9m) and was able to detect the embedded wire regardless of the depth. The first response was detected at the distance of 168cm from the beginning (position - 0m) of the wire at the depth of 30cm, while the last response was detected at the distance of 100cm before the end (position -18m) of the wire at the depth of 5cm, Fig 4.19. Position of the welded grid was also detected.

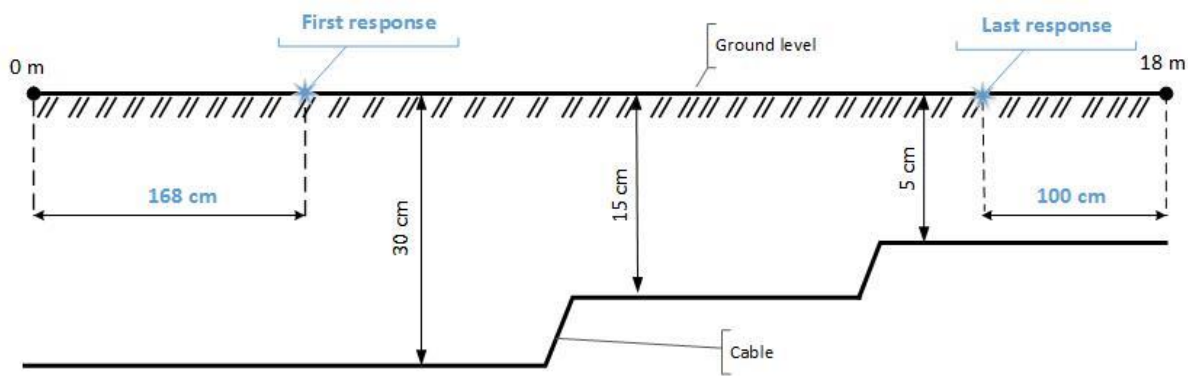


Figure 4.19 - Plot of the IED control-wire-line first and last response.

a) b)

Figure 4.20: The operator scanning the area

After both targets were detected, the operator determined boundaries of the wire position, Fig 4.21a), as well as boundaries of the welded grid, Fig. 4.21b). For the wire it was possible to do so inside 25cm and for the welded grid inside the area around 1.5m x 1.5m.

Figure 4.21: Boundaries of detection. c) Boundaries of wire detection with indicated (red line) wire orientation. b) Boundaries of welded grid detection

2nd scenario

Description:

Weather conditions: Wet

Location – Cerovac test site (Fig. 3.10)

Wire position: embedded at 5cm, inside the ditch covered with water

Wire length: 25m

Detection:

After scanning the area and detecting the wire position with NR-12C, the operator followed the wire signal.

He was able to follow the signal of the embedded wire, but also of the wire positioned under the water, Fig. 4.22 . The last detection of the wire signal was at the distance of 160cm from the one end of the wire and 20cm from the other.

Figure 4.22: Following the signal of the wire positioned on the bottom of a ditch covered with water

3rd scenario

Description:

Weather conditions: Wet

Location - Cerovac test site (Fig. 3.11)

Wire position: embedded at 5cm, inside the ditch covered with water, placed on the ground surface covered with dense vegetation

Wire length: 55m

Detection:

The operator started scanning the area in order to find unknown position of the wire searching along the road and over the ditch by the road, Fig. 4.23. Detection of the wire was possible regardless of the soaked soil and high water content in the ditch, Fig. 4.24. After detection, the operator continued following the wire signal into the area with dense bushes and trees, Fig. 4.25. The last response was at the 210cm before the end of the wire.

.

a) b)

Figure 4.23: The operator scanning the area with NR-12C. a) Scanning the road area. b) Scanning over the dich filled with water.

Figure 4.24: Position of wire detection (yellow plastic pin)

Figure 4.25: Working with detector NR-12C in high and dense vegetation.

5 LIST OF PARTICIPANTS

1. Vladimir N. Tkach, STT Group, Chairman of the board
2. Andrei N. Bykov, STT Group, ECMC-1, General Director
3. Assist. Professor Igor V. Parfencev, PhD, STT Group, ZAO Group Jutta, Development and design
4. Konstantin Darmaniyan, Consultant of DOK-ING
5. Ivan Balić, DOK-ING
6. Oto Jungwirth, Head of Testing and Certification Department, HCR-CTRO
7. Tomislav V.B. Vondraček, Test site manager, HCR-CTRO
8. Tajmin Tadić, HCR-CTRO
9. Tamara Ivelja, Mag. Eng., HCR-CTRO, University of applied sciences Zagreb
10. Milan Bajić, PhD, Ret. LtC, HCR-CTRO Scientific Council

6 LIST OF EQUIPMENT AND SUPPLIES

8.1. Detector NR 12C .... 1-2 item/s
8.2. Detector NR 900EK.. 1-2 item/s
8.3. Detector NR 2000 .... 1-2 item/s
8.4. Improvised radio-controlled explosive device imitator with peripheral operation unit (“electronic switch”) based on a portable radio set passive IR sensor (LX-820), controlled by radio via peripheral operation unit .... 1 set
8.5. Improvised radio-controlled explosive device imitator with peripheral operation unit (“electronic switch”) based on NOKIA 1616 mobile + battery .... 1 set
8.6. Toy car (no battery) .... 1 set
8.7 Spectrum Analyser ANRITSU (TVZ)……………………….…….1
8.8 Rohde Schwarz Spectrum Analyser……………………………....1
8.9 Dipole with balun and diode (TVZ)……………………………….1
8.10 Dipole with diode (TVZ)…………………………………………1
8.11 LogPeriodic Dipole Antenna……………………………………..1
8.12 Mortar shell 120 mm……………………………………………1

8.13 Meteo station……………………………………………………...1
8.14 Remote control unit for UAV + battery………………………….1
8.15 Mobile NOKIA5130c + battery…………………………………..1
8.16 Light switch………………………………………………………1
8.17 Red Brick ……………………………………………………..50 pcs
8.18 Cement block…………………………………………………..4 pcs
8.19 Cement tube……………………………………………………1
8.20. Set of tools and material for temporary marking........................1 set
8.21. Desk for placing "Eagle" units and searching targets not in operation 1 item
8.22. Manila paper sack with dry sand ....6 items
8.23. Wooden board (2.0 x 1.5 m) made of 25 mm planks ....1-2 items
8.24. Miner's cable...20 m
8.25. Dedicated area for demonstration "Eagle" NLJD capabilities for searching targets - remote radio controlled explosive devices (RC IED imitators) with peripheral operation unit ("electronic switch") ....1 item
8.26. Dedicated area for demonstration "Eagle" capabilities for searching targets (RC IED imitators) concealed behind various obstacles.............................1 item
8.27. 4 WD vehicle ....1 item
8.28. Digital photo camera...1 item
8.29. Laptop ....1 item
8.30. Mobile phone...(091) 1 item
8.31 Meter ....1 item
8.32. Measuring tape (50 m) ....1 item
8.33 Metal grid (1x1m) ....1 item

STT GROUP provided items 8.1 – 8.6, HCR-CTRO provided items 8.7 – 8.33.

7 SAFETY AND PROTECTIVE MEASURES

1 All persons present at the CEROVAC test site should be aware of General safety measures and shall comply with them, and during specific activities, they also shall comply with Special safety measures according to the activities.
2 Access to the CEROVAC test site will be allowed only to the persons that were properly and timely announced and that have signed the statement that they are aware of safety measures relating to General and Special Safety Measures.
3 Access to the test-site is possible only in company of an employee of HCR-CTRO. The employee of HCR-CTRO cannot leave the test site while there are other persons present at the test site.
4 The employee of HCR-CTRO is the first person to arrive and the last one to leave the test site.
5 All vehicles should be parked at the parking lot.
6 All persons that are allowed access to the test site are allowed access to the cabin.
8 All trial participants are required to follow trial manager's and/or test-site manager's instructions.
9 Making fire and open flames are strictly forbidden.
10 Smoking at the test-site is allowed at the foreseen place, which will be pointed out by HCR-CTRO employee on request.
11 Consummation of alcoholic beverages is strictly forbidden at the test sites.

12 Consummation of illegal substances is strictly forbidden, and may lead to legal consequences as it is foreseen by the Criminal Law of the Republic of Croatia.
13 Intoxicated persons will be denied access to the test-sites.
14 An employee of HCR-CTRO has to inform the director of HCR-CTRO about any unforeseen events, and upon arrival to the HCR-CTRO office, write a report on incident.
15 Visitors to the CEROVAC test site must comply with General safety measures.
16 Exposure to electromagnetic waves of NLJDs is harmful and shall be avoided.

8 CONCLUSIONS

Testing of the non-linear junction detectors was done in three combinations: a) targets are at height H2 = 1.2 m, b) targets are at the ground level, H2 = 0 m, c) targets are behind obstacles. Testing of the control wire-line detector was done in three different scenarios.

8.1 *Detection distances achieved with NR-900EK3M EAGLE*

8.1.1 Targets at two heights

Targets	Detection distance H2 = 1.2 m	Detection distance H2 = 0, ground level
Half wavelength dipole & diode	>76 m	21 m
Half wavelength dipole with balun & diode	>70 m	23.5 m
Toy Car	11.5 m - 18.5 m	11 m - 14 m
IR sensor	20 m - 30 m	11 m - 23.5m
NOKIA1616+El.s.	14 m - 22m	12.5 m - 17 m
Meteo station	12 m -13.5 m	9 m
Remote Control	18.3 m - 20 m	16.5 m - 17 m
Nokia5130c	10.5m - 11m	7 m
Nokia5130c+El.s.	18 m - 20 m	16 m - 17.5m
Light switch	1.7m	

8.1.2 Targets behind the obstacle

Targets	Detection distance
IR sensor	4 m - 11.5 m
NOKIA1616+El.s.	8 m

The tests conducted in Cerovac lead to a similar conclusion that was derived in (Hong 2014), but in general, larger detection distances were achieved. The achieved detecting distances of the calibrating half wavelength dipole with diode and with balun and diode are 76 m and 70 m respectively, whereas in (Hong 2014) it was 45 m. For considered dipoles on the ground detecting distances of 21 m and 23.5 m respectively, were achieved, whereas in (Hong 2014) it was 6 m to 8 m.

8.2 *Detection distances achieved with NR-2000*

8.2.1 Targets at two heights

Targets	Detection distance H2 = 1.2 m	Detection distance H2 = 0m, ground level
Toy Car	3.5 m - 5.9 m	5 m - 7 m
IR sensor	12m - 16 m	8.6 m - 14.8 m
NOKIA1616+El.s.	3 m - 4.8 m	3.5 m - 6.3 m

8.2.2 Targets behind the obstacle

Targets	Detection distance
Toy Car	0.8 m - 3.4 m
IR sensor	2.7 m - 11 m
NOKIA1616+El.s.	0.8 m - 2.8 m

8.3 *Detecting performances achieved with NR-12C*

8.3.1 The testing of the NR-12C showed that it has ability to detect a twenty meter long wire-line and a welded metallic grid 1 x 1m embedded inside a ditch at depths from 5 to 30 cm, at the distance of 168 cm from the beginning of the wire and at the distance of 100 cm before the end of the wire.

8.3.2 The testing of the NR-12C showed that it has ability to detect a wire under water, placed on the bottom of a ditch. The operator was able to follow the signal of the embedded wire and also the wire positioned under water. The last detection of the wire signal was at a distance of 160cm from the one end of the wire and 20cm from the other.

8.3.3 The testing of NR-12C showed ability to detect a wire in real working conditions. A 55 m long wire-line was embedded at 5 cm depth, laid on the ditch bottom in the water and on the ground surface with dense vegetation. The operator successfully followed the wire-line, and determined the first and the last wire-line response.
The tests in Cerovac lead to a similar conclusion that was derived in the test conducted in Tolemaida, Colombia (Fernandez Gonzales 2012).

9 REFERENCES

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10 ACKNOWLEDGEMENT

The Radar laboratory of the University of Applied Sciences Zagreb (Tehničko veleučilište Zagreb) supported the testing and the measurements' preparation, the multisensor measurements of selected improvised explosive device targets, and made the half-wave dipoles with diodes.

11 ANNEX

11.1 *Specific electric conductivity of soil samples at NLJD lane in Cerovac test site*

	AGRONOMSKI FAKULTET SVEUČILIŠTA U ZAGREBU Analitički laboratorij Zavoda za Opću proizvodnju bilja ISPITNO IZVJEŠĆE	Svetošimunska cesta 25 10 000 Zagreb • 385 1 239 4090

Zagreb, 31. svibnja 2016. g.

gđa. Tamara Ivelja, Tehničko Veleučilište u Zagrebu, Vrbik 8, Zagreb, OIB: 08814003451

Dana 24.05.2016. g. u laboratorij je primljeno 5 **nepripremljenih uzorka tla.**

Analize su provedene u skladu s dolje navedenom metodom.

Br. analize	Vrsta ispitivanja	Matriks	Prema propisu
1.	Priprema uzorka za fizikalne i kemijske analize sušenje/mljevenje/prosijavanje/homogeniziranje	tlo	HRN ISO 11464:2004
2.	Kakvoća tla-Određivanje specifične električne vodljivosti, EC (w/v=1:5)	tlo	HRN ISO 11265:2004

Točnost analiza kontrolirana je pomoću RM: ISE 882, 879 i 910, Wepal i zadovoljavajuća je (recovery < 5 %).
Preciznost analiza kontrolirana je ponavljanjem analize uzoraka (3 puta) i zadovoljavajuća je (RSD < 5 %).

Rezultati su iskazani u zrakosuhom tlu (nije dodatno sušeno na 105 °C do konstantne mase).

Rezultati analiza:

Broj uzorka	EC [µS/cm]
1	106,0
2	105,7
3	106,0
4	106,1
5	105,4

Voditelj Analitičkog laboratorija
Zavod za Opću proizvodnju bilja
Doc.dr.sc. Željka Zgorelec, dipl.kem.ing.

	Funkcija/Titula	Ime i prezime	Datum	Potpis
Izradio	Analitičar /mag.ing.agr.	Marija Ćaćić	31. svibnja 2016.	