ORFEUS

Joint MTU/ORFEUS Workshop
Southampton, 24/25 February 2010

What may ORFEUS mean for survey inspection quality and performance of commercial 'next generation' downward GPR?

G. Manacorda
Engineering Manager
IDS Ingegneria dei Sistemi SpA

2

Utility survey

- The term Utility Survey refers to the location, positioning and identification of buried pipes and cables beneath the ground
- A successful utility survey involves the combination of several techniques, the results of which are synthesised down to a single interpreted plot
- The techniques and methodologies used will primarily depend upon the required outcome for the survey, the site conditions and the type of pipes or cables being targeted

3

Expectations and Misconceptions

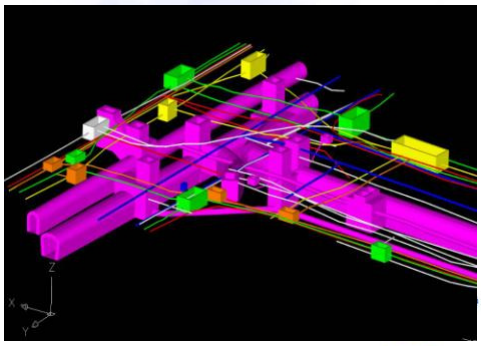
☒ There is a perception held by many that all buried pipes, cables and ducts can be detected and mapped irrespective of their size, duty, depth, location, material type, geology and proximity to other utilities

☑ A well designed and executed survey should be able to detect up to around 95% of utilities but it may not be possible to achieve a 100% detection rate.

4

"Well designed and executed…" Key aspects

- Equipment (hardware & software)
- Survey methodology & holistic approach
- Experienced, well trained site staff



GPR main advantages and limitations

☑ they can detect virtually anything that contrasts to the surrounding underground environment

☑ they are also effective in detecting larger, deep utilities through the use of lower frequency antennas

☑ they can work in areas with high ambient background noise (e.g. electric sub-stations)

☒ inspection range is limited when the soil is highly conductive (e.g. wet clay)

☒ in these soils, detecting any small (less than 20mm), non-metallic objects beyond a depth of 0.5 metres is extremely difficult

6

The ORFEUS project

- Collaborative research project with financial support from the EC
- Started on 2006, Nov. the 1st ending on 2010, Apr. the 30th
- 9 organizations involved

Orfeus objectives

- Provide a step change in the depth penetration and spatial resolution of GPR
- Design a prototype innovative GPR-based real-time obstacle detection system for Horizontal Directional Drilling
- To increase knowledge of the electrical behaviour of the ground
- Dissemination
  - Strong user input (requirement and evaluation phases)
  - Periodic user meetings (2 per year) to evaluate major achievements
  - Pan-European-field trial programme

8

The Orfeus downward radar

ORFEUS GPR

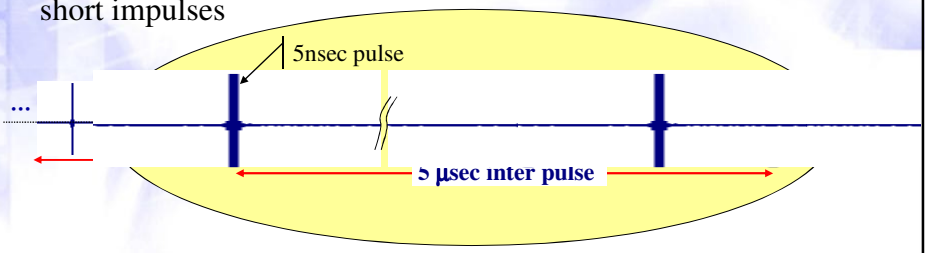
- Present market for surface GPR is dominated by impulsive systems
- Detection depth of a GPR is directly related to its dynamic range, defined as: $DR = \frac{\text{Maximum Power Received}}{\text{Minimum Detectable Power}}$
- Current S.O.A. pulse GPR have dynamic ranges that don't exceed 70dB, able to ensure at least 1m depth also in worst ground conditions
- In order to increase 50% detection depth (at lest up to 1.5m) an increase of dynamic range up to 105dB or more is required

	S.O.A Pulse GPR	→	**ORFEUS GPR**
Detection depth	1 meter (clay)	**+ 50%**	**1,5 meters (clay)**
Dynamic Range	70dB	**+ 35dB**	**105dB**

Limitations of pulse GPR

Dynamic Range of S.O.A Pulse GPR is ultimately limited by:

- low energy exploitable, due to low duty cycle of the received signals
- high noise figure, due to inherent noise in the generation of ultra short impulses



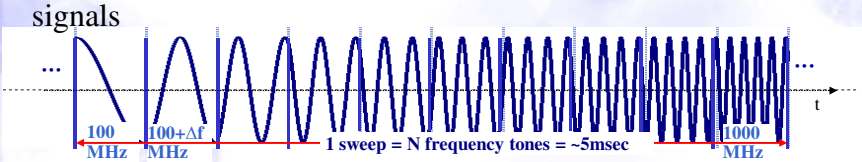
Only $1°/_{oo}$ of time is used to radiate e.m. energy

11

Stepped Frequency GPR

SFCW radar architecture promises to overcome such limitations :

- continous waveform allows 1000 times more energy to be radiated on targets and a more efficient signal acquisition process
- SFCW technology allows controlled synthesis of ultra wide band signals



but :

<u>developing a >100dB dynamic range, fast, cost-effective UWB SFCW radar is a challenging task</u>

12

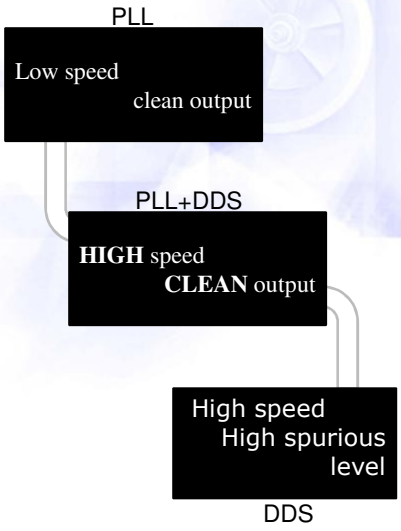
The SFCW technology

- Wide dynamic range
- Large bandwidth
- High time stability

The Orfeus SFCW Radar

Hardware setup - synthesizer

In order to improve the speed of the frequency generation a combined PLL+DDS technique has been used



Antenna system

Three different antennas have been used during the measurement campaign

15

The final setup

The complete radar system has been equipped in two different trolleys, because of the different antenna dimension

16

Validation of performance

The performance assessment has been done comparing the performance of the ORFEUS radar with a S.O.A. pulsed GPR.

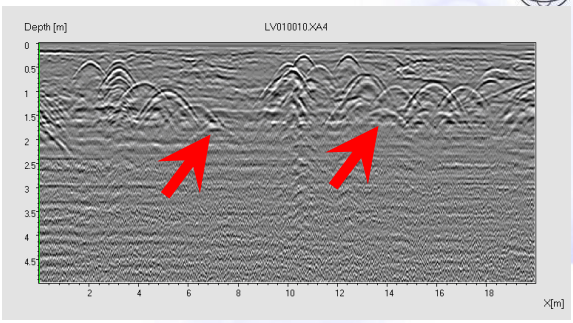
DetectorDUO

- Pulsed GPR
- Equipped with 2 antennas
  - 250 and 700 MHz center frequency

17

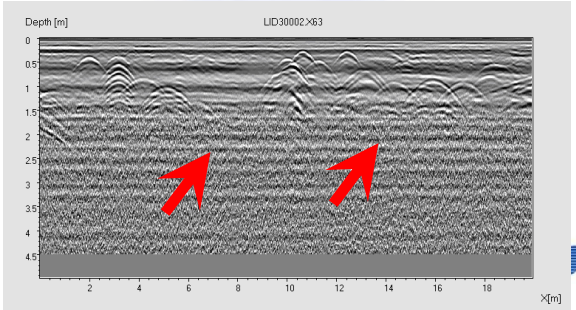
Better penetration depth

Orfeus GPR

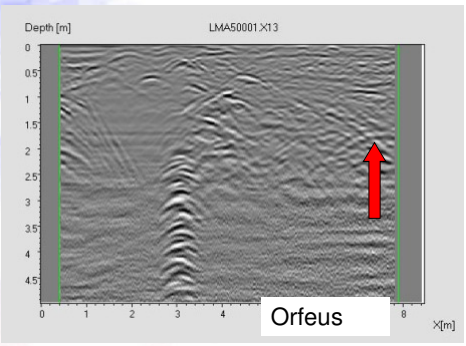


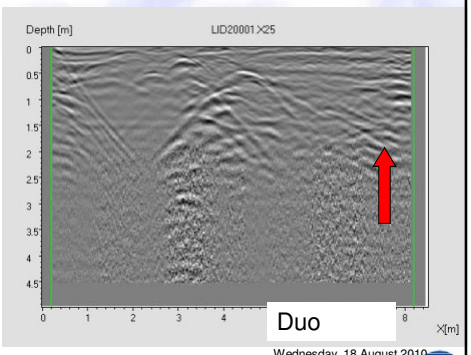
GPR Test site: Test - # 1

Pulsed GPR



Better penetration depth

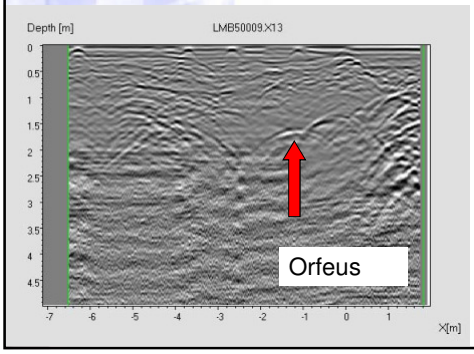


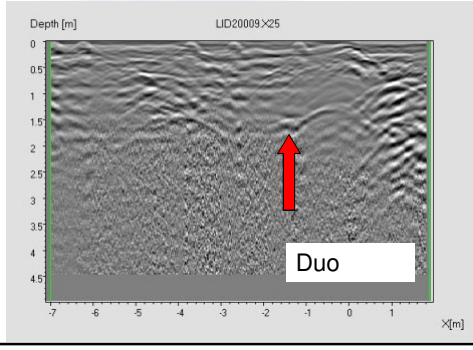


Wednesday, 18 August 2010

19

Better penetration depth



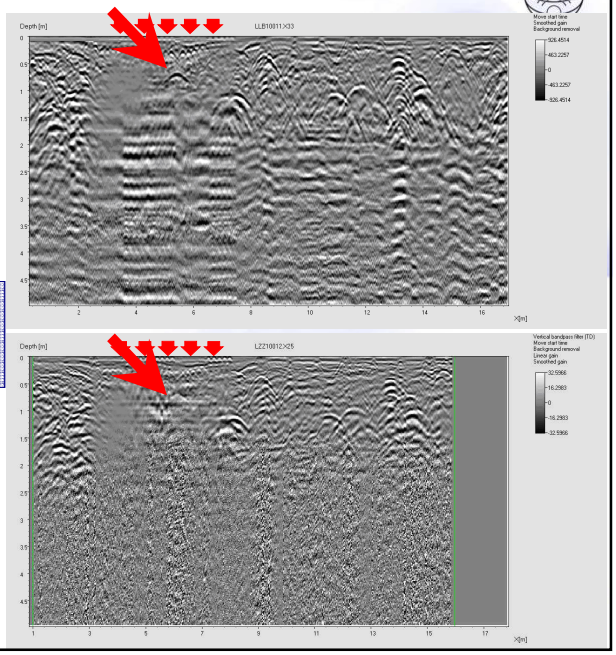


Better sensitivity to small targets

Orfeus GPR

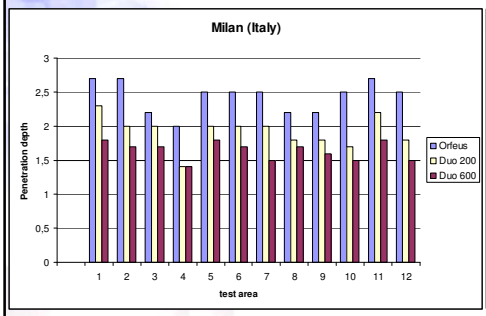
GPR Test site: Test - # 2

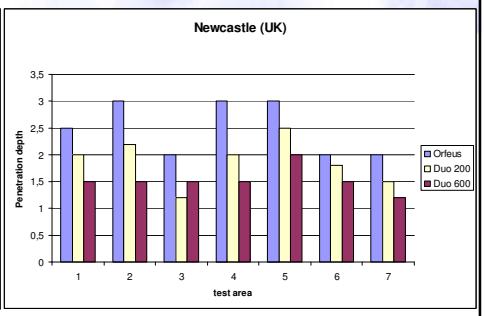
Pulsed GPR



Main findings from the trial period

- Penetration depth is increased by more than 30% (average value) with respect to pulse systems
- In the worst case (Newcastle Upon Tyne-UK) a peneration of 2 m was anyway achieved
- Resolution better than a 600 MHz pulse system

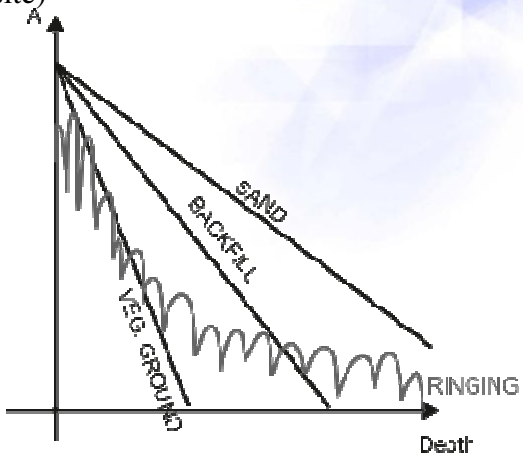




22

Future researches - 1

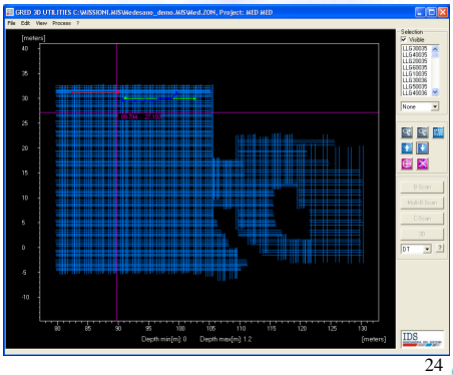
- The 105 dB clutter free dynamic range guaranteed by the radar is reduced by the antenna internal ringing.This ringing can decrease the system performance in very attenuative soils (like in the Newcastle test site)



23

Future researches - 2

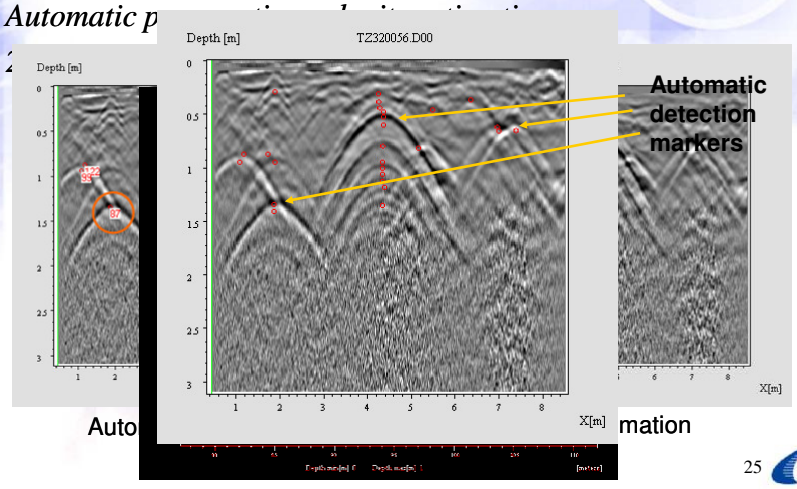
- The further research that may be addressed is the implementation of a multi-scan line system or of a high density array system. These architectures (already available in pulse GPRs) enable the collection large densely sampled data sets in a relatively short time



24

Densely sampled data set and advanced imaging techniques

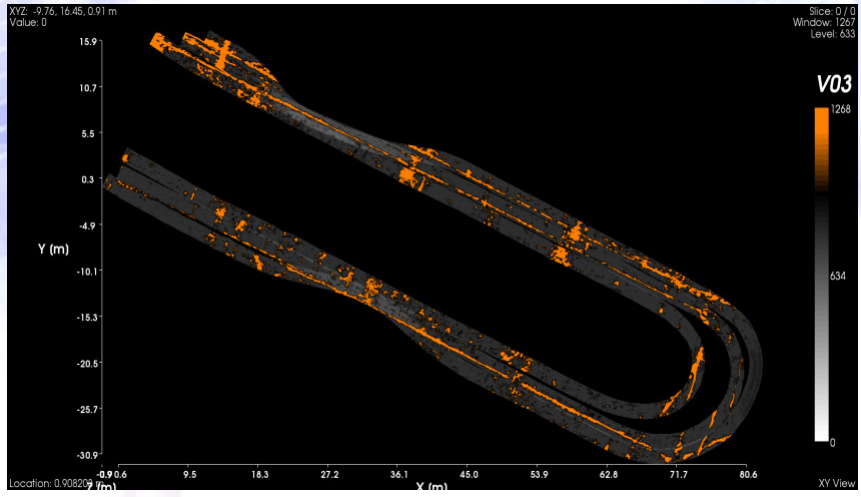
- *Automatic target detection*
- *Automatic p*
-



Auto mation

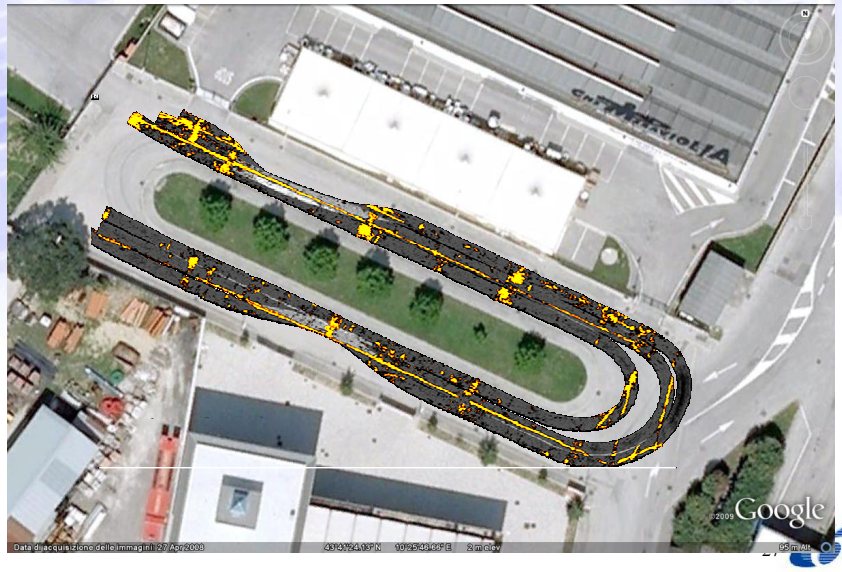
25

Densely sampled data set and advanced imaging techniques



26

3-D view of surveyed area



Conclusion

- ORFEUS project addresses the requirement to improve the technology used to locate utilities' buried infrastructure
- A single scan line downward SFCW GPR is available. Its performance have been validated through a pan-European field trials programme and were found exceeding the ones owned by state-of-the art equipment
- Further researches should address other aspects to increase the reliability of utility surveys, allowing a better management of buried assets and, as a result, significantly easing their rehabilitation and/or replacement

28

Acknowledgements

The ORFEUS project is supported by the European Commission's 6th Framework Program for Community Research ("Thematic Priority" area of sustainable development, global change and ecosystems), managed by Directorate General for Research under the contract n° FP6-2005-Global-4-036856 and would not have been possible without the support of the Commission

29