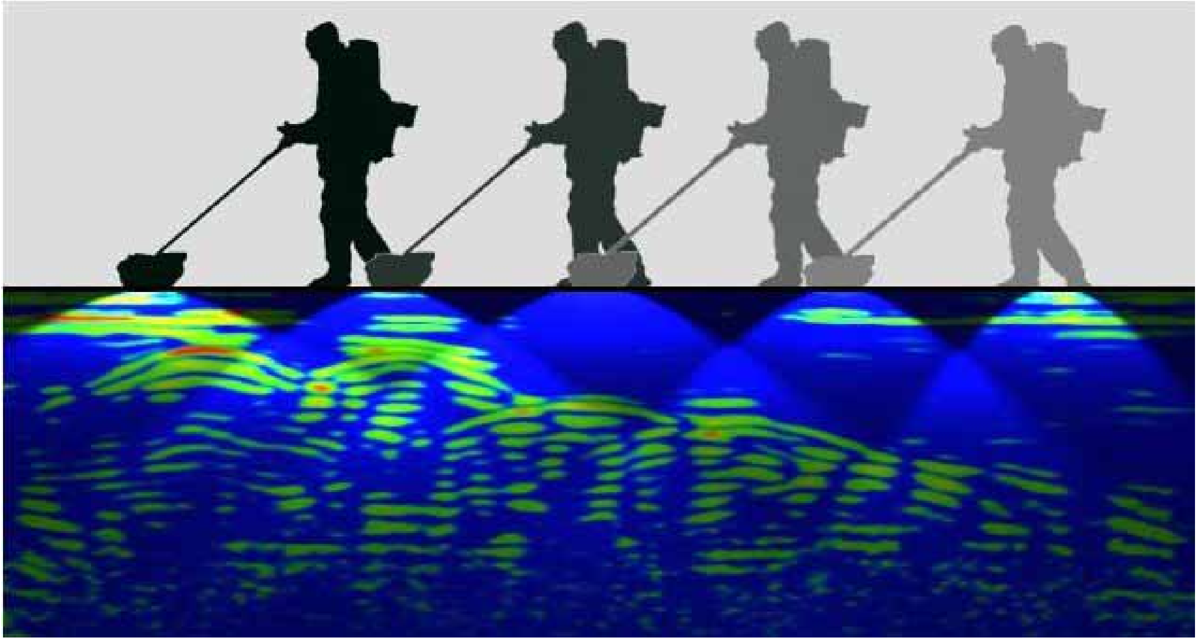
Optimised Radar to Find Every Utility in the Street



Bore-head Radar Development Report

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1 Introduction

1.1 Identification of the Contract

Contract name: ORFEUS

Customer and Contractors:

contract signed between the European Community, represented by the Commission of the European Communities, and

- OSYS Technology (UK), (OSYS)
- IDS INGEGNERIA DEI SISTEMI S.p.A (Italy), (IDS)
- GAZ DE FRANCE (France), (GdF)
- TRACTO-TECHNIK (Germany), (TT)
- UKWIR Ltd (United Kingdom), (UKWIR)
- EUROGAS-GERG (Belgium), (GERG).
- TECHNISCHE UNIVERSTIET DELFT, (TUD)
- UNIVERSITA DEGLI STUDI DI FIRENZA, (UNIFI)
- VYSOKE UCENI TECHNICKE V BRNE (BUT)

Contract number: FP6-2005-Global-4-036856

Contract signature date: 19-12-2006

Contract start date: 01-11-2006

Contract termination date: 31-10-2009

1.2 Purpose of the Contract

This project addresses the requirement for advanced technologies for locating, maintaining and rehabilitating buried infrastructures (area II.3.3). Specifically, it fulfils the requirement for locating buried assets. This project will use innovative techniques to provide a clear advance in the state of the art in Surface Radar. It will also prototype an innovative GPR-based real-time obstacle detection system for steerable bore- heads of Horizontal Directional Drilling (HDD) pipe and cable laying systems so that they can operate more safely below ground. This will require that new antenna designs be developed to provide a look-ahead capability and robust systems to be designed to protect against the hostile mechanical environment. In order to pursue these two objectives, an increased knowledge of the electrical behaviour of the ground, by means of in-situ measurements to enhance understanding of the sub-soil electrical environment and to provide information for scientifically based antenna design.

1.3 Purpose of this document

This document provides the development report for the bore-head radar prototype.
The design and development of all the system components were executed basing on the specifications included in following document:

- Document D7 - Bore-Head Radar Specifications

2 Executive Summary

This document describes the development of the main sub-systems of the bore-head GPR, whose specifications have been detailed in the project deliverable D7.
Fig. 2-1 sketches the architecture of the system to be implemented in the drill-head including main sub-systems and I/O interfaces to the control computer; it was judged suitable for matching the contractual and most of the end-user requirements.

According to this working hypothesis, the system integrates

- a transmitting and receiving GPR antenna hosted in the drilling head to look-ahead
- a transmitting and receiving GPR antenna hosted in the drill rod to provide the side looking capability
- a multi-channel timing circuit for controlling the antennas
- an A/D conversion board and the interface to the control computer
- the power supply module for generating all the voltages needed by the electronics.

Thus, the development of the bore-head GPR has focused on the following sub-systems:

- Antenna
- Antenna transmitter
- Antenna receiver
- Radar Electronics (including the timing circuit, the A/D conversion and PC interface modules)
- Data processing and display

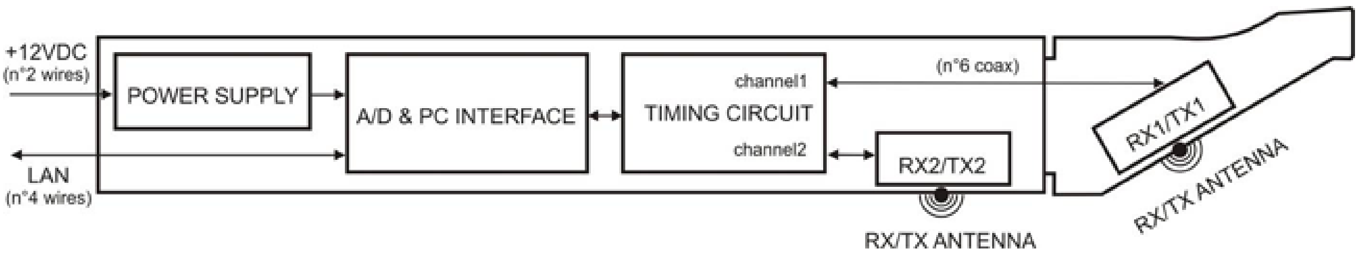

Fig. 2-1: Bore-head GPR system architecture

Further activities have identified and investigated a suitable material for protecting the antenna, on the vibration damping mechanism for protecting the electronics, on the power supply method, and on means of transferring the data to the computer at the operator seat.

Conclusion

This document reports on the activities executed within tasks 2200.2, 2200.3 and 2200.4 of ORFEUS work package 2000.
Design and development of all the sub-systems was completed; future activities will, therefore, be focused on the integration of such devices into the drilling rig to complete the development of the bore-head GPR.

3 Foreword

The design and development of the bore-head GPR sub-systems has required a substantial effort; the activities lasted for more than one year and only the major results are reported in this document.

With the exception of data processing and visualisation software, development has been fully completed; the main reason for the exception is that the decision on the most suitable methodology for processing and displaying the data collected by the system is dependent upon of the availability of some data sets and this obviously requires the conclusion of the system integration. Therefore, activities on this issue will continue in the next period.

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4 Development report for the antenna sub-system

As already introduced in D7, the antenna is the radiating element of the bore-head GPR (i.e. excluding the transmitting and receiving electronics).

D7 also reports on the antenna arrangement suitable for matching the end-user requirements; according to that hypothesis (Fig. 4-1), the antenna for the monitoring area in front of the bore-head is integrated in the steering surface, while the lateral area is covered by a separate antenna built into the lateral surface of the cylindrical housing behind the bore-head.

This arrangement allows for the optimal alignment with respect to the surveyed area. By this antenna configuration, the "blind area" in front of the bore-head[1], can be minimised or, possibly, entirely avoided.

Thus, one antenna needs to be accommodated in the steering surface and sufficient space remains for other facilities (such as drilling fluid channels).

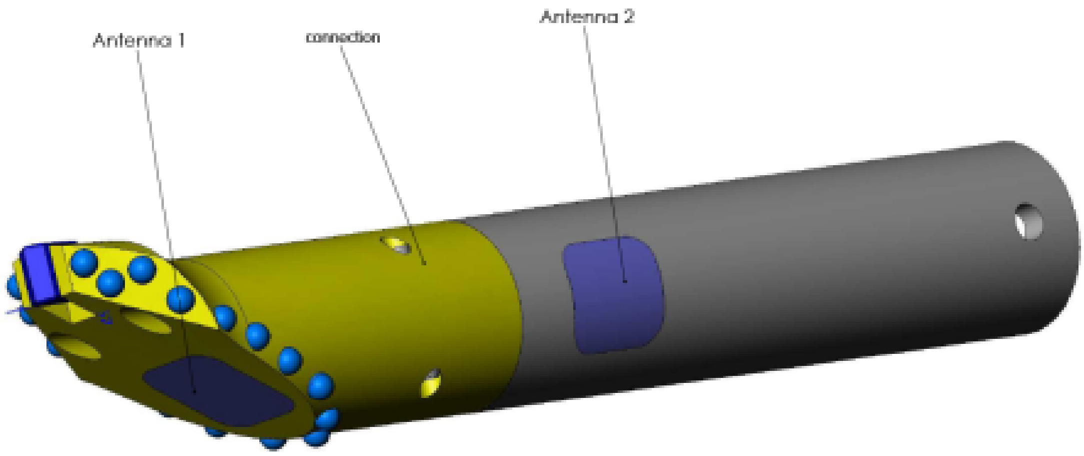

Fig. 4-1: One antenna (look-ahead) integrated in the steering surface, one antenna integrated in the lateral surface area of the cylinder behind the steering surface of the bore-head (looking sideways)

However, the development of such an antenna is one of the most critical issues of the project; there are severe dimensional constrains (due to the limited available space in the drilling rig) that have forced the choice of the technology and the design; moreover, these constrains also affect some performance parameters (especially on the beamwidth).

The development has required an intensive use of electromagnetic prediction tools.

Finally the antenna prototype performance has been tested and measured.

[1] i.e. the area directly in front of the bore-head which cannot be covered by the radar.

5 Development report for the antenna transmitter

The main purpose of the transmitter circuit is to generate a very fast rise time pulse (in the order of 100 psec); its amplitude should be large enough to produce the required electromagnetic radiated power (usually a 50 V peak-to-peak amplitude is sufficient).

From the electronics point of view, the solution is not trivial because it requires both fast switching and high-power components; the circuit implemented for the bore-head GPR uses an avalanche transistor (working in break-down mode) and step-recovery diode to decrease the rise time of the generated pulse.

This pulse excites the dipole to produce the desired waveform travelling in the ground.

In order to check the performance of the circuit against the required specification, several laboratory measurements were performed.

In detail, following characteristics were evaluated:

- Power consumption
- Pulse rise time
- Pulse amplitude (peak to peak at the antenna feed point measured over a 100 Ω impedance)
- Jitter (rms)

All these measurements were well matched to the relevant specifications.

6 Development report for the antenna receiver

The receiver is implemented using the same technology as in high frequency time domain sampling oscilloscopes to down-convert the radio frequency received signal from the nanosecond time regime to an equivalent version in the millisecond time regime.

Obviously, as the amplitude of the received signal can be very small (microvolts), and the design of the electronics must be designed so that the dynamic range is maintained. The bandwidth of the receiver is also an issue as, especially in the ORFEUS bore-head radar where very high frequency signals are generated and received.

The circuit was tested and found fully matching the relevant specifications included in deliverable D7.

7 Development report for the timing circuit, A/D conversion and PC interface

The control electronics includes the timing circuit (that generates the triggers for the transmitter/receiver), the A/D conversion module (that digitises the received signal, once it has been converted into audio frequencies as explained in the previous chapter), and the PC interface (i.e. the section assuring the bi-directional communication with the control computer at the drilling operator seat).
Finally, the control electronics also supplies the power for the transmitter/receiver.

All these sections of the board were tested against relevant specifications and found fully matching those requirements.

8 Conclusion and future activities

This document reports on the activities executed within tasks 2200.2, 2200.3 and 2200.4 of ORFEUS work package 2000.

With the only exception of Data processing and visualisation tools, design and development of all the sub-systems have been completed; those have been found performing well and fully matching the relevant specification.

However, it is possible that the review of the design of some components will be required; for instance, the antenna performance might change when integrated in the drilling head and an adjustment could be needed.

Future activities will, therefore, be focused on the integration of the subsystems into the drilling rig to complete the development of the bore-head GPR. This includes the verification of the antenna performance, the design of the vibration/shock absorbing method, the implementation of the connection amongst the various sub-systems, the minimisation of possible interferences between the bore-head radar and the drilling rig locating system.

In the meantime, as soon as some meaningful data sets will be available, activities on the data processing and visualisation methodology shall continue.