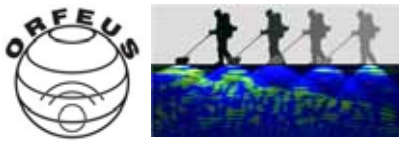
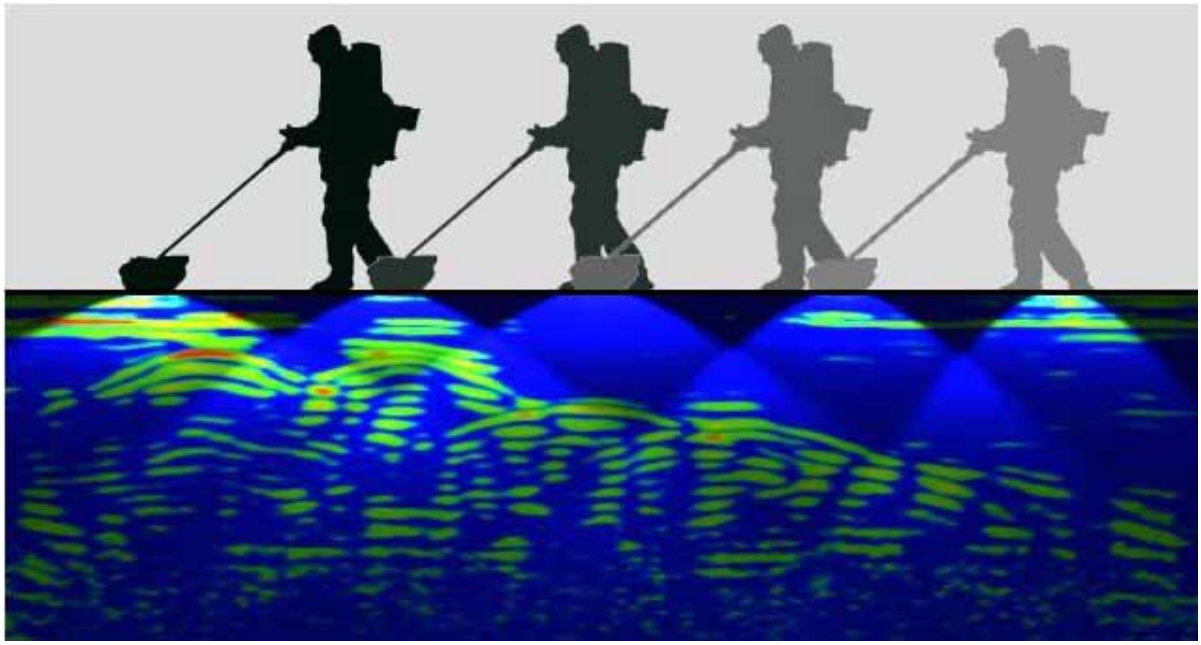


036856 / (STREP)

Optimised Radar to Find Every Utility in the Street



Bore-head Radar Specification

CONTENTS

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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 specifications for the bore-head radar prototype. These have been developed from the analysis of the performance requirements included in the contract and in the following documents issued by the end-user group:

- Document D2 - Bore-Head GPR User Requirements
- Document D6a – Requirements summary for Bore-Head Radar

2 Executive Summary

This document reports on the analysis of the ORFEUS bore-head radar project proposal requirements, on the basis of which the EC awarded the contract. The End-User requirements, as described in Deliverable D2 (Bore-head GPR User Requirements Specification) and Deliverable 6a (Requirements Summary for Bore-Head Radar) were also analysed and considered in the specification of the system being developed within the work-package 2000 of the project.

The system specification sets the standard to which the final system design is required to perform and was developed from an exhaustive and accurate analysis of all the requirements. It describes the ideal design for the optimum performance of the system given the current state of the technology and realistic estimates of the environment in which it will operate.

In the following paragraphs, the main system performance parameters are first specified and a possible architecture identified; then, sub-system specifications are defined. Each paragraph includes also a description of the interfaces between the sub-systems.

There are several critical issues to be resolved during the development of the radar; most of them relate to the design of an antenna that must fulfil several severe requirements, in terms of dimensions (due to the restricted space available in the HDD equipment), direction of look capabilities, sensitivity to small targets and penetration depth.

A further significant issue is the data processing methodology; in fact, the working principle of this system is quite different from standard GPRs and the form of display needed is different from those that have been developed over a number of years for interpreting data obtained from surface based radars. Moreover, the information presentation system must be as simple as possible so that the data can be correctly interpreted by unskilled operators.

Therefore, it is likely that some design compromises must be accepted. In addition it is possible that some end-user requirements, that significantly exceed the state-of-the-art, may not be satisfied (at least during this project). This, however, should not prevent the “prototype system” from being a useful tool for the end-user.

Conclusion

This report is the reference document for the development phase of the ORFEUS bore-head radar. A system architecture is proposed together with the description of the main sub-systems and their associated specifications.

3 Bore-head Radar System Specification

This chapter develops the Bore-Head GPR requirements detailed above into a set of system and sub-system technical specifications hereafter referred to as the 'system specification'.

The system specification defines the standard to which the final system design must perform, and is derived from a complete and accurate analysis of all the end-user requirements. It is the reference for the optimum performance of the system, and takes account of the current state of the technology and realistic estimates of the environment in which the system will operate.

Some of the specifications below were estimated from existing knowledge of surface GPR and others from calculations and simulations.

As a reference, Fig. 3-1 illustrates a generic architecture for GPR systems that applies regardless of the particular implementation scheme. The scheme chosen for the ORFEUS, bore-head GPR will have a similar design and shall be characterized by analogous parameters, as specified below.

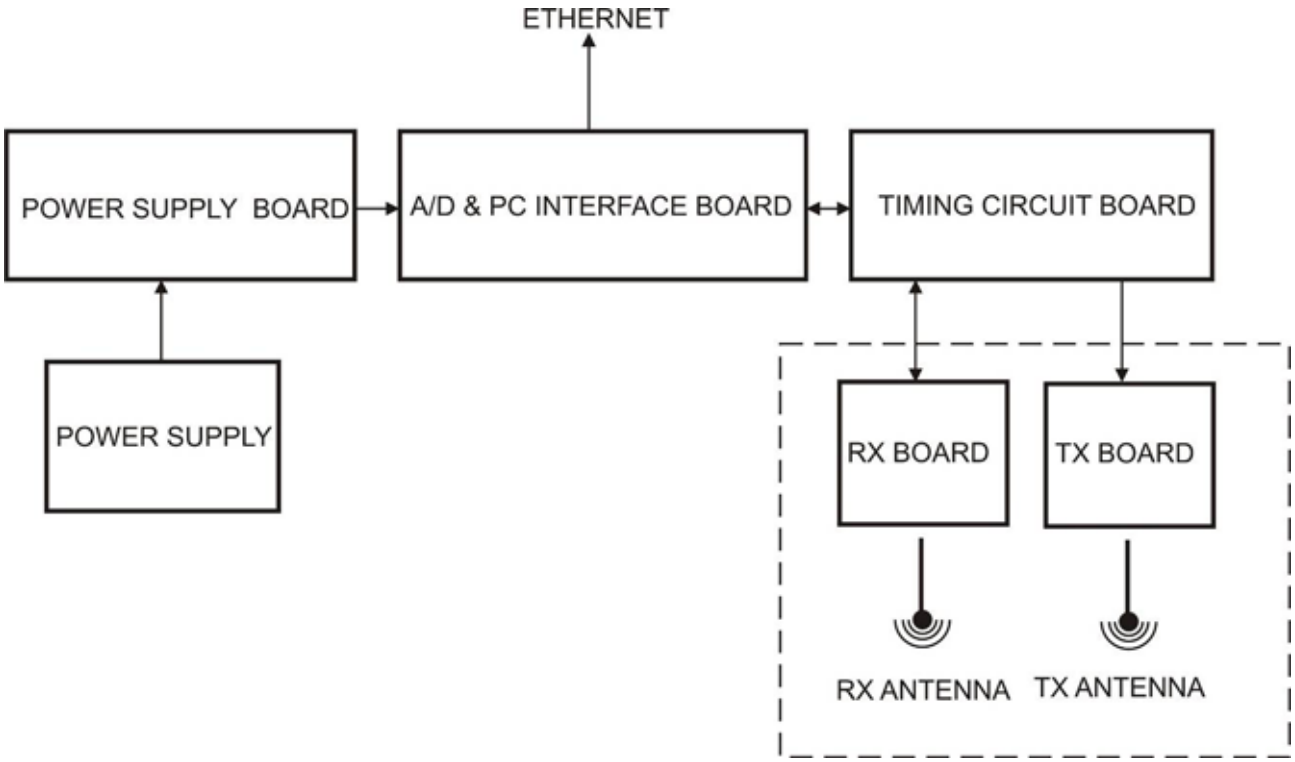

Fig. 3-1: System architecture of a GPR

3.1 System main specification

System mission:	To produce advance warning of obstacles present in the vicinity of the pilot bore
System directional detection capabilities:	ahead and in the azimuth plane with respect to the drilling direction
System technology:	Impulsive Ground Penetrating Radar
Sensing device:	Ultra Wide Band GPR antenna
System main composition:	Underground Sensing Apparatus (USA) and Data Logger (DL)
Dimensional constrains (USA):	The underground equipment must be implemented in or behind the drilling head
USA interface to DL:	Ethernet connection (4 wires) to send out digital data
USA power consumption:	< 1.3 A @ 12 VDC
USA power supply:	By local generator or batteries or from the surface (2 wire)
DL composition	Laptop computer with LAN interface
DL software modules	USA control and programming module, data storage module, data processing and display module
System minimum dynamic range:	40 dB
System clutter decay rate:	> 4dB/nsec
Environmental:	all the sub-systems of the underground equipment, including connections, must be protected against ingress of dust and water to te requirements of IP65.
Mechanical:	all the sub-systems of the underground equipment must be protected with proper vibration damping mechanism to avoid failures of the electronics
Working temperature (USA only):	-15°C – 60°C

Fig. 3-2 sketches a possible composition of the bore-head radar to be implemented in the drill-head including main sub-systems and I/O interfaces to the control computer.
According to this hypothesis, the system shall integrate

- 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.

The detailed specifications of the sub-systems are given within next paragraphs.

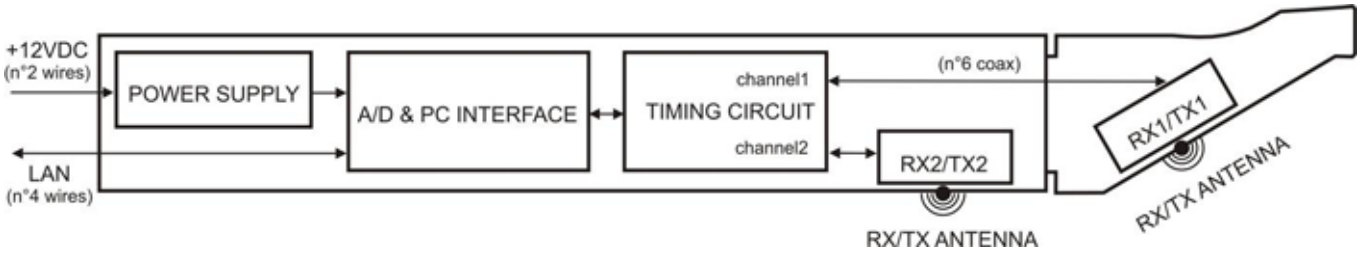

Fig. 3-2: A possible System architecture

3.2 Sub-systems specification

3.2.1 Antenna

Technology:	Ultra Wide Band (UWB) dielectrically loaded dipole
Dimensions (radiating dipole) (LxW):	< 40x35 mm
Antenna bandwidth (-10 dB):	> 1 GHz
Antenna working centre frequency:	≤ 2 GHz
Antenna position:	in front of the bore-head and/or on the drilling rig
Antenna dipoles orientation:	Parallel, broadside
Antenna directional capability:	side-looking and forward-looking
Antenna-3 dB beamwidth in E plane:	< 90°
Antenna -3 dB beamwidth in H plane:	< 120°
Antenna impedance:	about 100 Ω
Dimensions of each radiating element (electronics included) (LxWxH):	<40x35x30 mm
Dielectric window permittivity	in the range 3 to 5
Dielectric window loss tangent	in the range 0.0001 to 0.001
Interface with other sub-system:	Soldered onto TX/RX electronics

3.2.2 Antenna transmitter electronics

Technology:	Surface Mounted Device (SMD)
Dimensions of TX board (LxW):	< 20x30 mm
.....	
Pulse repetition frequency (PRF):	400 KHz
Pulse generation technique:	Avalanche transistor
Pulse rise time:	< 150 psec
Jitter (rms)	< 5 psec
Pulse amplitude (peak to peak, at the antenna feed point):	>50 V (measured over a 100 Ω impedance)
Power consumption:	< 1W
Interface with other sub-system:	2 Coaxial cables to the antenna timing circuit

3.2.3 Antenna receiver electronics

Technology:	Surface Mounted Device (SMD)
Dimensions of RX board (LxW):	< 20x30 mm
.....	
RF Sampling frequency:	400 KHz
Sampling technique:	diode sampling gate
RF max input voltage:	0.2 V (peak)
Sampler aperture width:	< 400 psec
Bandwidth:	> 2.5 GHz
RF noise figure:	< 20 dB
Power consumption:	< 0.6 W
Interface with other sub-system:	4 Coaxial cables to the antenna timing circuit

3.2.4 Radar timing circuit, A/D conversion and PC interface

Technology of the timing circuit:	Digital generation of triggers by means of DDS (Direct Digital Synthesizer) circuits
Dimensions of the whole board (LxW):	< 600x35 mm
PRF:	400 kHz
Range:	20 ns
Sample per trace:	256
Audio sampling clock:	200 kHz
A/D sampling depth:	16 bit

Total scan rate (2 channels):	< 3 msec
Maximum throughput:	3 Mbit/s
Minimum angular resolution:	3.6° (at the maximum head rotation frequency, i.e. 200 rpm)
Power supply section	Capable to supply 1A@5VDC, 250mA@+12VDC, 250mA@-12CDC, 40mA@150VDC
PC interface section	Ethernet 100 Mbit TCP/IP interface to the computer (4 cables)
Total power consumption	<10 W

3.2.5 Data Processing and Diplay

Data processing:	Basic data processing algorithms (band-pass filter, background removal, gain function, horizontal filtering, etc.)
Target detection module:	Single threshold detection, correlation of detections
Data display	Visualisation of plots in a 3D volume according to the position of the drilling head, rotation angle and distance from the radar
Computational load	Capable of providing a display of the plot within 1 sec after the detection
Interface with other sub-system	HDD equipment control computer that provides the position of the drilling head in the hole with few centimetres (<5 cm) accuracy