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Optimised Radar to Find Every Utility in the Street

Deliverable D13: Surface GPR Development Report

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EXECUTIVE SUMMARY

This document reports the design, development and schedule of the ORFEUS surface GPR. The inputs are the system specifications reported in D8 “Surface GPR Specification”. A new issue introduced in the present document is the division of the surface GPR development in four phases. The overall goals of the ORFEUS surface GPR development have not changed, yet the new approach to the first phase of the development deserves a remark. The analysis, simulations and measurements performed during the development demonstrated the possible advantage of Invariant solutions (supplying good performance in most kind of ground) if compared to Adaptive ones (supplying the capacity to adapt the sensor characteristics to the ground variations).

For this reason the output of the first phase of the development will be an Invariant prototype which will employ:

- the Range Gating technique instead of the Adaptive ABC;

- an Invariant Antenna instead of the Adaptive Antenna.

Adaptive solutions will be selected and developed respectively in the second and in the third phase of the project after having tested the first prototype and having estimated its performance. A clear description of the development phases can be found in chapter 9 - Time schedule.

This document addresses the following items:

1. System composition and architecture:

- *Adaptive Antenna (to be developed by TUD)*:
    - ANT Adaptive Antenna

- *Adaptive Radar Front End (to be developed by UNIFI)*:
    - RAD FMCW Radar
- *Radar Control and Signal Processing (to be developed by IDS)*:
    - DLOG: Data Logger
    - ACU Acquisition and Control Unit
- *Integration items (to be developed by IDS)*:
    - M&SW Mechanics and Survey Wheel.
    - POW Power Supply.

2. Acquisition Modes

- The system can implement several different acquisition modes, in order to allow the testing of various acquisition approaches and parameters.
- The main objectives of different Acquisition Modes are to test calibration strategies, different kind of adaptivity, comparison between adaptive and not adaptive performance or test purposes.
- The Acquisition Modes are programmed by a configuration file (called “sequencer”) which defines a sequence of “sweep acquisitions”; each sweep acquisition (called “Sub Mode”) is characterised by different parameters of the HW and SW radar components;
- The main parameters that characterise Sub Modes are:
    - Waveform: stepped frequency (for acquisition) or CW (for test)
    - Gating: gating off, gating on, gate parameters
    - Calibration: calibration or acquisition
    - ABC: ABC off, ABC on, ABC parameters.

This approach guarantees a high level of system configurability and testability.

3. Adaptive Antenna

- The requirements for the antenna are demanding, combining a wide bandwidth, good matching, low antenna coupling, reduced dimensions and capacity to operate well in many types of ground.
- A good solution that operates with excellent performance in the most significant types of ground was found to be an “Invariant Antenna” solution, i.e. an antenna with performance relatively independent of ground type. The “Invariance” concept was proposed and developed as a good alternative to the “Adaptive” one.
- An invariant antenna based on a resistively loaded bow-tie dipole was designed and simulated, and demonstrated to be able to satisfy all the requirements for the ORFEUS Surface GPR
- An adaptive antenna solution was however also studied.

4. Adaptive Radar Front End

- The design of the radar front end confirmed the difficulty of fulfilling the requirements; a huge design effort was needed to achieve the required performance.
- The radar front end architecture consists of five modules: Transmitter, Receiver, Calibration, ABC (Active Background Canceller) and Range Gating.
- The Transmitter module integrates the Frequency Synthesizer based on DDS technology. In order to reduce spurious responses by DDS, a mixed solution DDS + PLL was designed and developed.
- The ABC was designed and a prototype was developed demonstrating the capability to achieve a dynamic range reduction of over 40dB in a laboratory environment. Analysis and simulations, taking horizontal variations of the ground e.m. characteristics into account, demonstrated the dependence of the cancellation on the ground itself, which limits the effectiveness of this technique.
- An alternative approach is based on a suitable Range Gate both in the Transmitter and in the Receiver part of the equipment. Such approach was analysed, simulated and tested in laboratory conditions demonstrating:
    - the achievement of a better cancellation performance (if compared to the ABC)
    - and to be less sensitive to ground characteristics.

5. Radar Control and Signal Processing, Integration items

- The Radar Control and Signal Processing sub-system is composed of:
    - The Data Logger, which is a rugged PC containing the MMI Interface, the Data Display functions and the data storage capabilities. The Data Display functions were designed to be the same as those of a standard GPR pulse system, in order to allow an on-site comparison between the performance of the ORFEUS Surface radar and of a state of the art commercial pulse GPR.
    - The Acquisition and Control Unit, which is based on a Texas DSP with several HW interfaces:

      i. two 24bit I/Q Analog to Digital Converter, to acquire both IF and BB radar signals,

      ii. one 24 bit I/Q Digital to Analog Converters, for real time control of system adaptivity

      iii. one Ethernet Adapter to allow efficient communication with the Data Logger.
- A simulation framework was developed to allow:
    - Simulation of ground backscatter, antenna coupling and target response
    - Simulation of radar effects (noise, frequency response, dynamic range, ABC, Range gate)
    - Simulation of the signal processing which will be integrated in the ACU and DLOG.
- Integration items were designed to allow:
    - The mechanical integration of the three sub-systems
    - The measurement of the radar position on the ground by means of a Survey Wheel.
    - The availability of Power Supply.

6. Revised Time schedule.

The development was divided in three steps (Phases)

- Phase 1 – Non-adaptive prototype
    - A first prototype will be developed and integrated. This will be a non adaptive version of the Surface radar and will be developed, integrated and tested in Pisa.
    - It will implement DDS + PLL Frequency Synthesiser, Range Gate and Invariant Antenna solutions.
    - The integration will end in September 2008, and the test within December 2008.
- Phase 2 – Trade-off Analysis
    - This phase will include ABC development and testing: a trade-off will be analysed between ABC and Range Gate technologies. Moreover a solution for the Adaptive Antenna will be studied and a trade-off will be analysed between Adaptive and Invariant Antenna.
    - The trade-off decision will be made at the end of September 2008. It will be decided whether to integrate ABC adaptivity or Range Gate adaptivity into the second prototype. It will be decided whether to integrate an Adaptive Antenna or an improved Invariant Antenna into the second prototype
- Phase 3 – Integration of the second prototype will end in February 2009, and tests in June.
    - The ORFEUS Surface GPR (second prototype) will be ready for the final tests at the GdF Paris test site.

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