BISTATIC DEEP SOUNDINGS WITH THE HF GPR TAPIR IN THE EGYPTIAN WHITE DESERT.
V.Ciarletti, A. Le Gall, J.J. Berthelier, C. Corbel, F. Dolon, R. Ney, CETP/IPSL 10-12 avenue de l'Europe,78140 Vélizy, France, ciarletti@cetp.ipsl.fr

Introduction: In the frame of the NetLander mission, the Centre d'étude des Environnements Terrestre et Planétaires (CETP) has developed an impulse ground penetrating radar (GPR) operating at very low central frequencies from 2 to 6 MHz [1]. This instrument, named TAPIR (Terrestrial And Planetary Investigation Radar), aims at exploring the geological features in the deep Martian subsurface and at the detection of liquid water underground reservoirs. This GPR was designed to retrieve, from a single fixed location, both the distance and the direction of the reflecting structures. This can be achieved by determining the propagation vector of reflected waves, through measurements of two horizontal electrical and three magnetic components of the reflected waves. This direction information is essential not only to characterize the sub-surface structures but also to discriminate between the echoes coming from the subsurface and those due to the surface clutter, In-situ measurements on well documented soils that are analogues of the expected Martian soils are crucial to validate the performances of the instrument. In 2004, ground tests were successfully carried out on the Antarctic continent with a mono-static GPR prototype [2]. In November 2005, an updated version of the instrument working either in monostatic or in bi-static mode was tested in the Egyptian White Desert. Complementary sounding investigations were jointly conducted on the same site by research teams from the LPI (Lunar and Planetary Institute) [3] and the SwRI (Southwest Research Institute) [4]. They will provide independent information which will help the interpretation of our GPR data.

TAPIR operating modes: The mono and bi-static operating modes of TAPIR are illustrated in figure 1. The Tx/Rx GPR with both transmission and reception allows mono-static measurements. It can also be used as the transmitting GPR for bi-static measurements. In this case, the Rx GPR is only used for reception. 70 m loaded dipoles antennas laid on the surface are used for transmission and measurement of the reflected electric field. A single magnetic antenna, which can be successively positioned along 3 mutually orthogonal directions, provides 3 independent orthogonal magnetic components. Rotating the transmitting electric antenna by 90°, allows to vary the polarization of the transmitted signal, which will provide additional information on the reflectors. TAPIR is also able to perform passive measurements of the HF background noise and to measure the electric antenna self-impedance. Electromagnetic parameters of the shallow subsurface (electric permittivity and conductivity) can be derived from this last measurement.

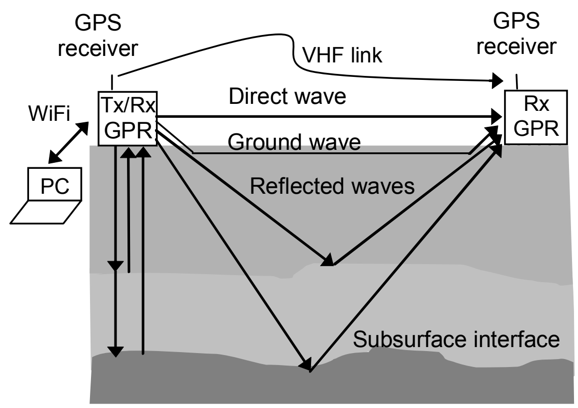

Figure 1: Principle of operation

Besides offering an obvious interest for subsurface tomography, the bi-static configuration makes it possible to get rid of interferences due to the coupling between the transmitting and receiving antennas and thus to reduce the radar blind zone which prevents from detecting shallow targets in a mono-static configuration. Figure 1 schematically indicates the principle of operation of the bi-static mode. A very accurate synchronization between the two radars is necessary to achieve bi-static measurements. This is obtained by using the 10 MHz clock provided by the GPS system. This has enabled us to perform stackings up to 2^{31}.

Data analysis: This paper essentially deals with bi-static observations made on the Abou Saied limestone Plateau approximately 30 km west of the Farafrah Oases (600km southwest of Cairo). The subsurface of Abou Saied Plateau is horizontally layered [3]. Measurements of the ambient electromagnetic noise have shown that this site is quite favorable in the HF band. Full polarimetric measurements have been performed at 4 MHz for two different distances between the radars (45m and 95m). The pulse duration was set to 500 ns in order to ensure a reasonable resolution range.

Measurements on both electric and magnetic antennas show evidence of echoes. The first one, which is by far the strongest, is caused by the direct wave propagating horizontally from the Tx GPR to the Rx GPR. The observed delay corresponds to the calculated propagation time. The following echoes corresponding to reflections are more than 50 dB weaker but still noticeable. Figure 2 gives an example of co-polar signal measured on the electric antenna at 4 MHz for a 500 ns pulse.

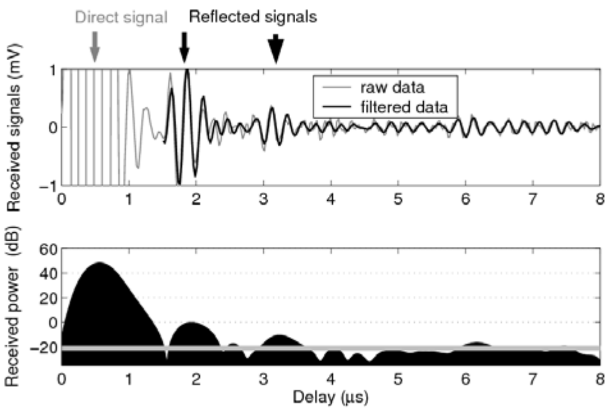

Figure 2: TAPIR signal strength versus time delay.

The reflected signals are clearly visible on the top figure's linear scale (appropriately enlarged), whereas the bottom figure, in logarithmic scale, also enable to show the direct signal.

For a given configuration, the five measured components (the two electric and three magnetic ones) of the received waves show satisfying consistency. They can be used to determine the direction of arrival of the received signals and to find out more accurately the propagation path of the reflected signals.

Some co-polar measurements have also been performed for central frequencies ranging from 2 MHz to 6 MHz giving the opportunity for a multi-frequential analysis. Figure 3 gives an example of co-polar measurements at 3 and 5 MHz. As expected, the higher frequency leads to weaker echoes; the available data will be used to deduce the variation with frequency of the attenuation in the subsurface.

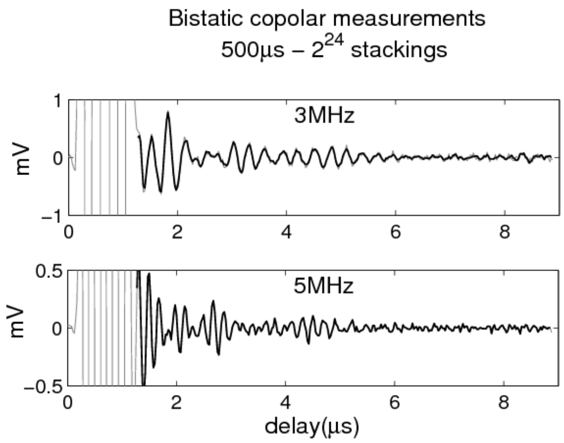

Figure 3: Co-polar bi-static measurements at 3 and 5 MHz with a 500 ns pulse duration and 2^{24} stackings.

Moreover, the comparison between data acquired for the two GPR separations (45m and 95 m) also shows good consistency. Besides, electric antenna self impedance measurements were performed giving access to an evaluation of the geoelectrical parameters of the superficial subsurface.

A more detailed analysis of the observations is in progress but even at the present preliminary stage of data reduction we have already obtained several valuable results. In particular the operation of TAPIR in a bi-static configuration has been validated. It does appear of high interest in the case of a planetary mission such as the ESA EXOMARS mission with a fixed lander (the so called GEP, Ceophysical and Environmental Package) and a rover.

Acknowledgements: Support for the CETP participants was provided by CNES.

References: [1] Berthelier J.J. et al., *JGR–Planets* (2003) doi:10.1029/2002JE001867.

[2] Berthelier J.J. et al. (2005) *GRL, 32,* doi: 10.1029/2005GL024203.

[3] Clifford et al. (2006) these abstracts.

[4] Dinwiddie et al. (2006) these abstracts

.