**FDTD METHOD FOR THE THEORETICAL ANALYSIS OF THE NETLANDER GPR.**
A. Reineix¹, B. Martinat¹, J.J. Berthelier², R. Ney², ¹IRCOM UMR 6615 CNRS (Electromagnetism Department 87060 Limoges Cedex – France, reineix@unilim.fr), ²CETP / IPSL 4, avenue de Neptune 94100 Saint Maur des Fossés (France, berthelier@cetp.ipsl.fr)

**Introduction:** This paper introduces an original theoretical way based on the FDTD method for the study of the GPR performances in the particular case of deep sounding applications. This particular version of the FDTD code has been developed for the NETLANDER GPR which will sound far deep regions into the Martian subsurface (about 2500 meters down from the surface). In such a case, the usual FDTD method would require too important computational resources, as a consequence an original model has been investigated to overcome this drawback. Some of the main tools developed for this study and some typical results obtained will be presented.

**Theoretical method:** The FDTD method [1] is now a well-known method in the electromagnetic domain, so its principle will not be recalled. The main improvement for the present application will be detailed in the following:

*Implementation of CPML:* The FDTD method allows to model the antenna and the ground down to 500 meters approximately in the whole computational volume. Thus, it’s possible to determine in the time domain the echoes diffracted by the different layers directly. To limit the computational volume, the PML (Perfectly Matched Layers) method developed by Berenger [1] is usually utilised. As it is used for absorbing diffracted waves in the vacuum, an extension has been made to take half-infinite lossy and conductive media into account. A CPML (Convolution PML) based on a convolution product recently developed by Gedney [2] has been implemented. Such a method allows to control the numerical parasitic reflection of the PML.

*Extrapolation Method:* In order to determine the magnitude of the signal diffracted by the deepest layers (-2500 m), a global computation would be too expensive in computational resources, and thus two different simulations have been made. The first one is a 3D-FDTD simulation and the second one is a 1-D FDTD simulation with a plane wave emitted from the surface which takes into account the attenuation due to the electromagnetic properties of the soil. The obvious interest of this 1-D simulation is a very large gain in CPU time. By using a very simple analytical calculation of the propagation losses (results 1D FDTD) and the geometric spreading in the far field region. The 3D method gives the gain and the effective surface of the antenna whereas the 1D method allows to compute the propagation losses on the direct and return trajectory. The total transfer function is the deduced from the coupling between the two approaches.

*Rough of interfaces and diffusive rocks:* The straight line to the plane interface is an ideal case. Some physical characteristics of the subsurface can decrease the performances of the GPR and damage the power budget. Two different causes of perturbations have been investigated: the roughness of the interface and the presence of diffusive rocks having a random distribution.

If the interface is limited to down 500 meters, the whole computation can be run in the same volume. In this case, a statistical approach has been investigated to give the power budget as a function of roughness or density of diffusion rocks.

For deep interfaces, the same methodology is employed with the difference that the reflection coefficients of the deep interfaces will be obtained from the computation of the RCS (Radar Cross Section) in a 3D-FDTD sub-volume around the diffusive rocks or around the non plane interfaces.

**Results:** Some typical results for the NETLANDER GPR will be now presented. To simplify the problem, the antenna will be modeled as a quasi continuously loaded resistive dipole (according to the Wu and King theory). The subsurface model is presented on figure (1).

![Figure (1) – model of the Martian subsurface](7013.pdf)
To validate the extrapolation method, the –400m interface will be considered. To have a reference case, the first simulation consists in considering the antenna and all the subsurface from 0 to –500 meters in the same computational volume. The transient current at the antenna level is a succession of wavelets which characterize the different reflections by the interfaces (figure(2)).

Thus, a transfer function is defined as the ratio of the current at the receiver level reflected back from the interface to the generator current. The transfer function computed by the direct computation and using also the extrapolation method from the –400 m interface gives a good agreement (figure(3)). A difference less than 3dB can be observed.

The computation for the –2500 meters layer would give a transfer function value about –200 dB.

To estimate the roughness effect on the power budget, some statistical rough profiles have been generated. The height of roughness is about 50 meters around –400 meters. The different results are presented on figure (4)

The figure 4 shows a difference of about 10 dB around the means values of the transfer function obtained for a plane interface in the [1-5] MHz bandwidth.

**Conclusion:** As the gain of CPU time is important, these new method allow us to run parametric simulations of the GPR in a modeled Martian environment with a good accuracy. These results are needed to help in the design of the instrument and to derive the convenient algorithm to analyse the data.

**References:**