A SIMPLIFIED ANALYTICAL FORMULATION OF THE NETLANDER IONOSPHERE AND GEODESY EXPERIMENT ORBITER/LANDER OBSERVABLE

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The NetLander Mission that will be launched to Mars in 2007, will deploy a network of four similar micro-stations on the planet surface to observe the atmosphere and the internal structure of Mars by means of nine geophysical instruments, including the NEtlander Ionosphere and Geodesy Experiment (NEIGE). The geodesy part of this experiment consists in analysing the Doppler shifts of a radio-signal transmitted between (1) the landers and the orbiter (data relay) and (2) the orbiter and the Earth in order to obtain the Mars orientation parameters. By monitoring the polar motion, variations in the rotation rate or in the length-of-day (lod), precession and nutations, we will be able to obtain information about the Martian internal structure. See Dehant, Barriot et al, 2002, this issue.

The NEIGE Doppler observable q between the data relay orbiter and one lander on Mars' surface can be analytically modeled in a simplified way by looking at the instantaneous projection of the velocity difference between the satellite and the lander on the satellite-lander line. The hypotheses used are: (1) an instantaneous propagation, (2) no ionospheric perturbation of the signal, (3) no gravity field and no other forces acting on the satellite. The expression for the Doppler observable has been linearized in the first order in the small quantities X, Y and ξ which are linked to the geophysical rotation parameters.

We have to express the lander and satellite coordinates and velocities in the same frame. In order to go from a Martian Reference Frame to an Inertial Reference Frame, we use the rotation matrix $\mathbf{M}$ depending on the five Martian Orientation Parameter (MOP): nutation and precession, polar motion and sidereal time. This matrix can be divided in two parts $\mathbf{M} = \mathbf{M_{Reg}}\, \mathbf{M_\infty}$:

- a regular matrix $M_{Reg} = R_z(-\psi_R) R_x(I_R) R_z(-\phi_R)$ that includes all the constants and linear contributions of each rotation angle I_R (the obliquity), ϕ_R (the rotation angle) and ψ_R (the precession angle) and
- an infinitesimal matrix M_∞, which includes the periodic irregularities: the polar motion (x_P, y_P), the nutations (δI, $\delta\psi$) and the variation of the length-of-day ($\delta\phi$).

This infinitesimal matrix can be expressed using three parameters (X, Y, ξ) only, instead of the five MOP. The link between X, Y, ξ and the MOP is :

$$\begin{aligned} X &= x_P + \sin I_R \,\cos\phi_R\, \delta\psi - \sin\phi_R\, \delta I \\ Y &= y_P + \sin I_R \,\sin\phi_R\, \delta\psi + \cos\phi_R\, \delta I \\ \xi &= -\cos I_R\, \delta\psi - \delta\phi \end{aligned}$$

This formulation in X, Y, ξ gives simpler expressions for the matrix $\mathbf{M}$, for the rotation vector and finally for the Doppler observable q. We considered a precessing orbit for the data relay (J_2 term).

There are lander-orbiter configurations for which visibility is not possible. For example, if the lander latitude is larger than 27° and for a circular equatorial 400 km orbit, the orbiter is always under the lander horizon. The effect of such configurations can be seen on the upper left corners of the graphs in Fig. 1 where the contribution is strictly equal to 0.

The expression of the Doppler observable as function of X, Y and ξ allows us to understand how the geophysical information appears in the signal. We have studied different lander locations and changed the orbital parameters of the data relay, in order to see how the signature in the Doppler observable of the geophysical phenomena under study can be maximized (accounting for the visibility/non-visibility of the lander by the orbiter).

The quantities plotted in Fig. 1 are the contributions to the Doppler observable of different (or all) geophysical parameters. These contributions have been computed by evaluating the difference between the Doppler observable with and without the geophysical contents (the perturbations on the MOP models are: for nutations, changes on the transfer function parameters corresponding to perturbation up to 12 mas, for polar motion, to 50 mas perturbation, for UT, to 300 mas perturbation). We have scaled the results by 0.1 mm/s, which is the nominal precision of NEIGE. The configurations that maximizes the 3 geophysical effects (Nutation, UT and

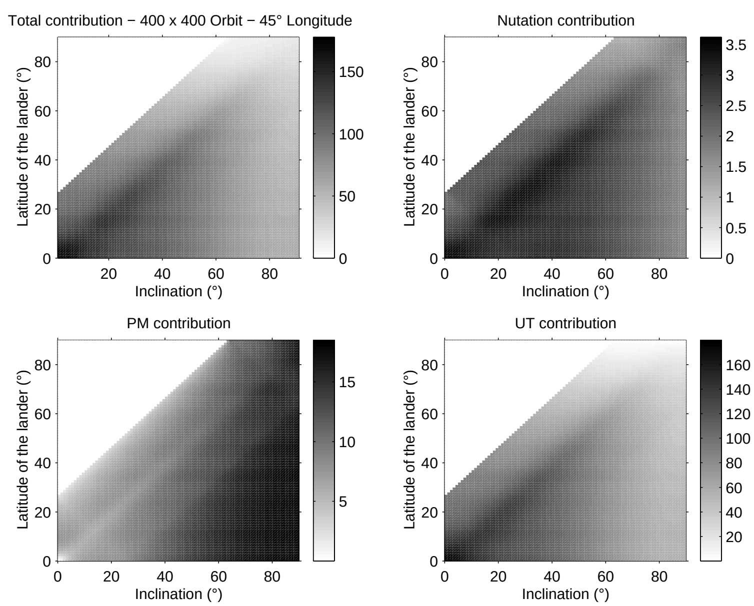

Figure 1: Total contribution (upper left graph) to the Doppler Observable and Nutation (upper right), Polar Motion (PM, lower left) and Sidereal Time (UT, lower right) contributions as function of the orbiter inclination and the lander latitude. The statistical quantity plotted is the quadratic mean of the temporal series when there is visibility (0.1 mm/s). The orbit is a circular 400km-high orbit

PM) are different. But the NEIGE experiment focuses rather on nutation and UT, which have similar signatures on the Doppler signal. The local maxima for the nutation contribution are reached if the lander latitude is almost equal to the orbit inclination, while the maximum for the PM contribution occurs for a large orbit inclination. The best configuration to get a large UT signature corresponds to both lander latitude and orbit inclination below 10 $^\circ$. These graphs are independent of the lander longitude.