# Mars Ionosphere preliminary impact analysis on SHARAD radar signal

**G. Alberti (1), D. Biccari (2), S. Dinardo (1), S. Mattei (1), R. Orosei (3), C. Papa (1), R. Phillips (4), G. Picardi (2), A. Safaenili (5), R. Seu (2)**
(1) CO.RI.S.T.A (Consortium for Research on Advanced Remote Sensing Systems), Viale Kennedy 5, I-80125, Naples, Italy
(2) INFO-COM, University of Rome La Sapienza, Via Eudossian 18, I-00184, Rome, Italy
(3) INAF-IASF (Istituto Nazionale di Astrofisica, Istituto di Astrofisica Spaziale e Fisica Cosmica), CNR, Via del Fosso del Cavaliere 100, I-00133 Rome, Italy
(4) Washington University in St. Louis, Campus Box 1169 One Brookings Dr. St. Louis, MO 63130, USA
(5) Jet Propulsion Laboratories, California Institute of Technology, Pasadena, CA 9 1 109, USA


Mars Reconnaissance Orbiter Pictorial View
Courtesy NASA/JPL-Caltech

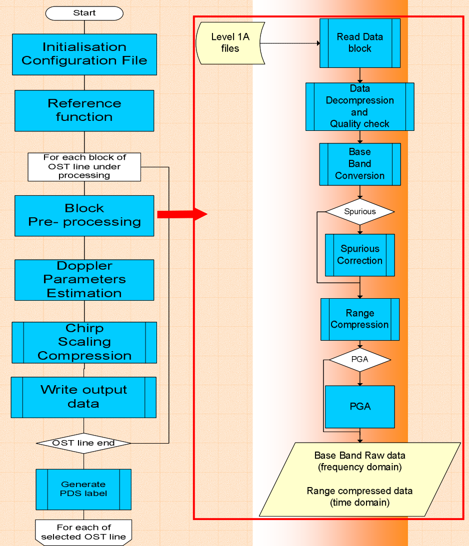
**SHARAD is the sub-surface sounding radar provided by the Italian Space Agency (ASI) as a facility instrument to NASA's 2005 Mars Reconnaissance Orbiter (MRO). SHARAD is a wideband low-frequency nadir-looking pulse limited radar sounder transmitting at a centre frequency of 20 MHz within 15-25 MHz spectral range. The transmitted waveform is a 10 MHz bandwidth chirp linearly modulated in frequency. The transmitted pulse bandwidth provides a theoretical range resolution of 15 m in free space propagation. Horizontal resolution is 300-1000 m along-track, and is achieved by means of a focused synthetic aperture processing. Horizontal resolution across-track is 1500-8000 m, depending on spacecraft altitude and terrain roughness.**
**SHARAD has been launched on August '05 and has started its nominal observation phase since November '06.**
**The primary objective of the SHARAD investigation is to map, in selected locales, dielectric interfaces to depths of up to one kilometer in the Martian subsurface and to interpret these interfaces in terms of the occurrence and distribution of expected materials, including rock, regolith, water, and ice.**

**The SHARAD instrument is functionally composed by two building blocks:**

- **The transceiver, composed by two units (named RDS and TFE) located in the SHARAD Electronic Box (SEB)**
- **The antenna which is 10 m foldable dipole parallel to the surface to the direction of motion.**

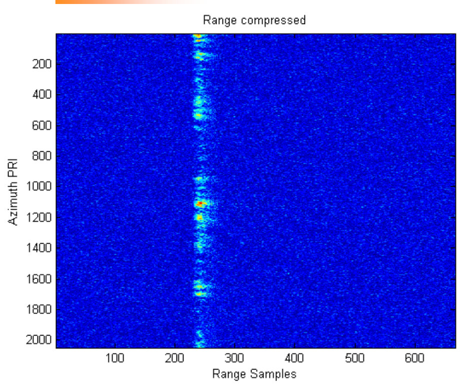
**The RDS implements both digital (including digital chirp generation) functions in the DES and the analogue, receiving functions in the RX. Key elements for the radar design are represented by the identified centre frequency, 20 MHz, the bandwidth of the radar pulse equal to 10 MHz, and the requested spatial resolution which is expected to be better that 1000 m in the along-track direction and 7000 m in the cross-track direction. The selected frequency is be able to penetrate Mars surface and will be used to estimate the dielectric properties. But, the need to penetrate Martian surface requires radar operation at a MHz frequency regime which make ionospheric distortions unavoidable.**

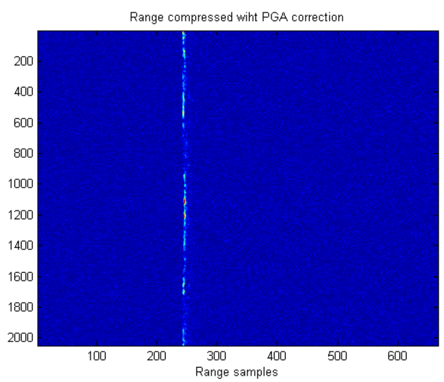
**To accomplish SHARAD data processing, a specific software tool has been designed and implemented by Co.Ri.S.T.A. within the SHARAD Ground Data System (GDS) development activities funded by the Italian Space Agency.**
**The SHARAD Ground Data System (GDS) is the element of the Internet-distributed architecture defined for controlling and monitoring the instrument, and for receiving and processing the down linked Science Data.**
**The Level 1B (L1B) Tool is the GDS software devoted to basically accomplish Range and Doppler processing in order to produce radargrams of Mars sub-surface. It generates as output Level 1B data files formatted according to PDS formatting specifications.**
**In Level 1B Tool, the range processing of each sampled pulse echo is performed by computing the complex conjugate of the FFT of the discretely-sampled transmitted signal (which is called filter or reference function), by multiplying it by the FFT of the pulse echo, and then by performing the IFFT of the result: because of the properties of Fourier transform pairs, this is equivalent to the computation of a correlation in the time domain.**
**As far as Doppler processing is concerned, we have to notice that SHARAD is quite different from a classic SAR (Synthetic Aperture Radar), because Doppler bandwidth and centroid are strictly dependent on surface scattering. In particular Doppler bandwidth is a direct consequence of surface roughness, while surface slope affects tightly Doppler centroid. This has lead to design the tool in order to perform an accurate Doppler parameters estimation (centroid and bandwidth) before starting processing chain. Moreover, realignment of each range line before Doppler parameters estimation and range Doppler processing has been faced to remove very high variability of receiving window position.**
**The Chirp Scaling Algorithm has been adopted to perform data processing. Depending on Doppler bandwidth of the received signal, this algorithm can provide a maximum full resolution of 300 meters by compensating range migration effects. Since a 55dB in signal dynamic is requested, each source of distortion (Mars ionosphere, on board noise) is compensated by the tool.**




**Moreover, it is worth notice that the need to penetrate Martian surface requires radar operation at a MHz frequency regime which make ionospheric distortions unavoidable. This will result in a signal phase distortion across the spectrum of the received radar pulses which may cause severe degradation of the instrument performances in term of SNR and pulse spreading and therefore in sub-surface interface resolving capabilities. These undesired effects on the radar signals have been removed making use of Phase Gradient Autofocusing (PGS) algorithm. PGA method enabled the tool to estimate range-independent phase error functions (PEFs) due to the unknown components and correct for them.**

**SHARAD has been launched on August '05 and has started its nominal observation phase since November '06, following commissioning activities during which antenna system has been successfully deployed. The instrument is now fully operative and is properly collecting data from Mars surface.**
**Since then, Level 1B Tool has been intensively used.**
**PGA method has been often applied to SHARAD data showing clear improvements in range compression.**




**Taking advantage of PGA phase estimation, a non linear least-squared fitting (Trust-region method) has been applied to the estimated phase values according to the following law:**

$$\varphi(f) = 2\pi\tau_0\sqrt{f^2 - f_p^2} - 2\pi\Delta\tau f - K$$

**By using this method, plasma frequency and ionospheric delay of Mars ionosphere have been evaluated.**
**The estimated values seem to be in accordance with measurements acquired by MARSIS on board MEX mission.**