SURFACE CLUTTER SUPPRESSION USING COHERENT PROCESSING OF RADAR SOUNDER DATA FROM REPEATED GROUND TRACKS.

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Introduction: One of the major problem for subsurface planetary investigation using radar sounding technique is caused by off-nadir surface ambiguous returns that can be received synchronous to subsurface nadir signal of interest. Herein we coherently process radar sounder data from repeat ground track orbits in order to detect/suppress the unwanted off-nadir returns. We demonstrate that under certain conditions, data from radar sounder preserve coherence of phase and coherent integration can be performed. We present results applied to a pair of observations acquired from the SHAllow RADar (SHARAD) currently orbiting Mars. This technique has been tested in the framework of the SWIM project [1].

Beamforming theory for multi-orbit data: The repeated passes coherent processing here adopted is based on the beamforming theory of antennas array. Data acquired at different epochs over the same region, and in an optimal geometry configuration, can be processed coherently in order to apply SAR techniques in the across track direction. For each radar observation, the correspondent adjacent tracks can be considered as elements of the array system [2]. Signal phase which is usually deterministic in the case of a real array, can be estimated for repeated passes radar acquisitions using the first return of each observation [2]. This is the case of no sloped and moderate roughness surface, where the first return corresponds to the nadir direction and the phase estimation can be easily performed from the first peak return. In case of substantial roughness and sloped terrains, the co-registration of products and identification of nadir returns become challenging. In this work we present results applied to the simple case of two adjacent tracks acquired over relatively moderate rough and no sloped terrain. The last information can be derived from Digital Elevation Model (DEM) such as the one obtained from Mars Orbiter Laser Altimeter (MOLA). The processing of two tracks allows up to 3 dB of increase in SNR for nadir returns, while off-nadir clutter can suppressed based on angle of arrival and array configuration. Due to the reduced number of element the synthetic array pattern can show grating lobes (i.e. angular ambiguities) which enhance clutter in regions synchronous with specific depths. For each different scenario a maximum depth defined from a non–ambiguity zone can be calculated based on the array configuration.

Data Coherence: Data coherence is necessary in order to apply coherent processing. Degradation of coherence is a well know problem for radar interferometry system due to several factors such as: baseline decorrelation, temporal decorrelation and atmosphere/ionosphere decorrelation. Herein we discuss this factors for the of SHARAD radar.

Baseline decorrelation: The effects of the baseline decorrelation (i.e. decorrelation due to the physical distance between antennas/observations) has been widely studied in SAR interferometry [3]. Using similar approach for interferometry, we derived a maximum distance (i.e. critical baseline) for the case of SHARAD of approximately 700m.

Temporal decorrelation: Temporal decorrelation is mainly caused by the change of the surface with the time and is one of the main cause of decorrelation for radar operating on Earth. However on Mars, the effects of the weather/atmosphere is weaker than Earth due to the different environment. Particular attention should be paid for those observations acquired at poles, where seasonal CO_2 accumulation occurs.

Decorrelation due to the ionosphere: Ionosphere is a severe problem for space-born radar sounding applications due to the nature of plasma medium which reflects, distorts and attenuates EM waves below or in proximity of the plasma frequency. On Mars, precedent studies have demonstrated that plasma frequency generally varies from 700 KHz up to 4 MHz according to solar illumination (i.e. Solar Zenith Angle(SZA)) [4]. For multi-orbit processing, time and space varying ionospheric condition can decrease coherence of data and thus radar observations acquired during the minima peak of plasma frequency daily oscillation (i.e. night time observations) are preferred. Based on the coherence analysis of various SHARAD radar products, we find that observations acquired at the equatorial region and middle latitude of Mars during night time, result in a better correlation and low distortion.

SHARAD Dataset and Area Selection: SHARAD radar on board of MRO mission is an instrument working at HF frequency band and is currently operating on sounding the internal structures on Mars [5]. The radar is characterized by a carrier frequency of 20MHz and a bandwidth of 10MHz which allows to achieve a free space vertical resolution of 15 meters. In our work we use the L1B complex format products available at the PDS node. In order to test our processing we selected few example of optimal configuration of a two-pass orbits acquired in favorable condition (i.e. SZA and moderate horizontal baseline). Here we show products

RDR0585801 (October 26th 2007) and RDR0621402 (November 23th 2007) acquired over Elysium Planitia, located at 164.0°E and 2.5° N, 154.0°E and 2° N respectively (See upper panel Fig. 2). The two products have a temporal baseline of approximately 4 weeks and an horizontal baseline of 160 m.

Multiorbit Coherent Processing: Before applying beamforming technique, radar products must be co-registered. In our work, we use a two steps procedure to realize co-registration. First, we use the cross correlation of the power profile in order to estimate the azimuthal off-set (see Fig 1 upper panel). Second, we estimate the range off-set by measuring the time-delay from the first surface return of the interpolated radargrams.

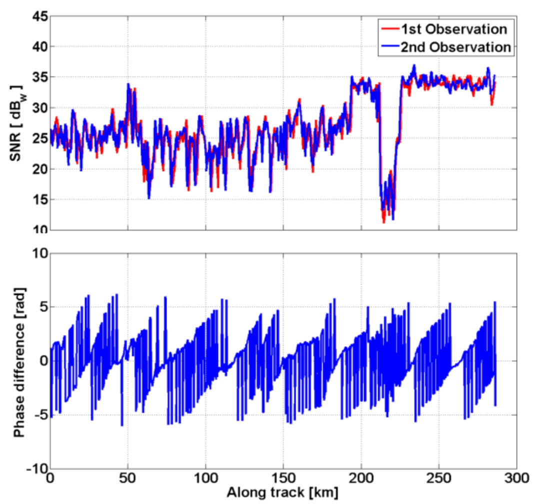

Figure 1. (a) Received power profile for the selected observation. (b)Unwrapped phase difference between observations

After co-registration, the follow step is the phase calibration. The phase values are measured for each individual echoes directly over the maxima peak. For each radargram a vector of estimated phases is generated and the difference of the two vectors (delta phase) is used for calibrating each orbit (see Fig. 1 lower panel). The processing is finally performed by coherently summing the two products after delta phase compensation. Figure 2 shows the standard product (Fig. 2 upper radargram), the nadir beam steering product (Fig. 2 middle radargram) used for suppress clutter and enhance subsurface nadir signals and null steering product (Fig. 2 bottom radargram) in which nadir returns are suppressed and off-nadir clutter is enhanced. Figure 3 shows waveforms before and after processing. Note that nadir returns are improved by up to three decibels. Final products are still available in complex format and can be further processed for example using super resolution techniques [5].

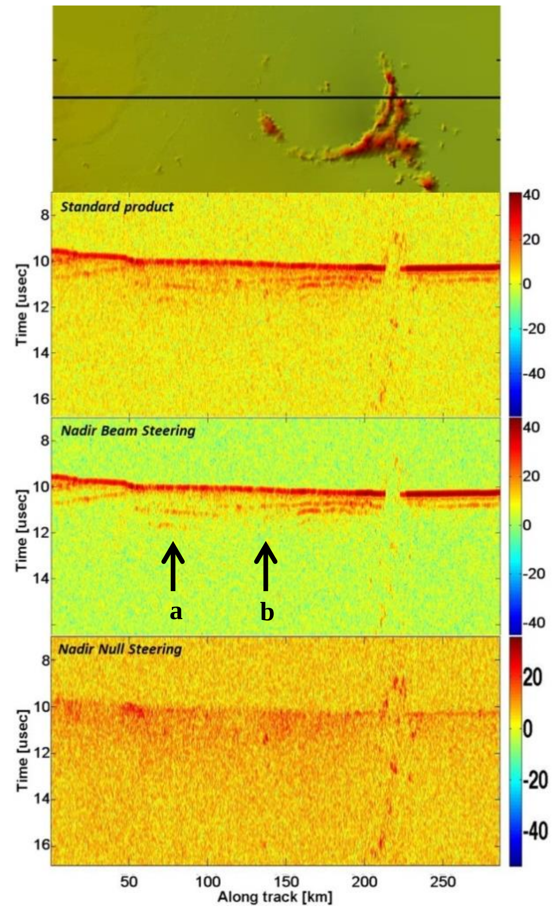

Figure 2 (upper panel) MOLA shaded relief along with ground tracks and the two radar product. (lower panel) Standard product, Beam steering for clutter suppression and null steering for clutter detection.

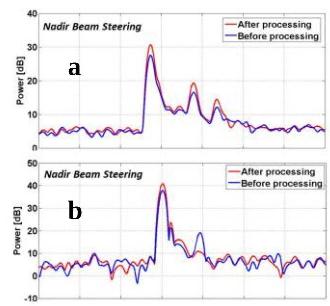

Figure.3 Radar waveforms before (blue) and after (red) processing over the regions pointed by arrows . Products show up to three dB in SNR improvement for nadir returns.

References:

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