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Image resolution enhancing in the MARSIS experiment

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MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) is a low frequency, pulse-limited radar sounder and altimeter selected by ESA as a payload of the Mars Express mission. Synthetic aperture technique is required to reduce the wide ground footprint (due to the low operating frequency and the small allowable antenna dimensions) and, thus, the unwanted echo from other surface objects.
MARSIS primary objective is to detect, map and characterize subsurface material discontinuities in the upper crust of Mars. These may include boundaries of liquid water-bearing zones, icy layers and geologic structures. Past studies have shown polar caps stratifications, in terms of depth structure and composition, ground ice abundance and seasonal variations (thickness of seasonal deposits, thermal effects).
MARSIS is the first instrument able to detect what lies beneath the surface of Mars. MARSIS operates with a very high fractional bandwidth: 1MHz bandwidth allows a vertical resolution of 150 m in free space which corresponds to a lower resolution in the subsurface, depending on the electromagnetic wave propagation speed in the crust. The centre frequency of the pulses transmitted by MARSIS can be set to 1.8 MHz, 3MHz, 4 MHz and 5MHz. On day side operations, it operates only in 4MHz and 5MHz due to the ionosphere plasma frequencies of Mars that reflects all the frequencies lower than 4 MHz. All the four carrier frequencies are available for subsurface sounding on night side.
This paper propose a modified version of the well known stepped frequency processing to improve the vertical resolution of MARSIS in order to allow the detection of thinner interfaces that could not be discriminated by the present processing because of its coarse vertical resolution. In fact, range resolution in SAR images is inversely proportional to the transmitted signal bandwidth. Since there is a limit in the transmitted bandwidth that can be supported by the radar hardware, there is a limit in range resolution that can be achieved by processing the SAR data in conventional way. However, if the frequency band of the received signal is widened with a group of sub-pulses, close in frequency (e.g. 3Mhz and 4 MHz), and properly combined, the composite signal increases the bandwidth and hence the improvement in range resolution can be achieved.
The algorithm proposed modifies the standard stepped frequency processing introducing ionosphere effects compensation necessary for a correct data processing . Thanks to improved data set it will be possible to have either a deeper knowledge of the subsurface stratifications as well as additional information about the nature of the volume scattering useful in the data inversion process (estimation of the materials composing the surface and the subsurface by the estimation of the dielectric constants).