Single-FPGA Implementation of the Synthetic Aperture Radar Azimuth Pre-filter for On-board Data Reduction

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In this paper, we describe a Synthetic Aperture Radar (SAR) on-board data-reduction scheme which has been implemented on a single chip with low-mass and low-power consumption, by utilizing high-density Filed Programmable Gate Array technology. The objective of this filter, the Azimuth Pre-filter (AzPF), is to provide on-board data reduction which is directly applicable to many near-future multifrequency, multipolarization, meter-level resolution Earth-orbiting SARs which will generate unprecedented volumes of data, requiring multigigabit/s downlink capability at the high-latitude centralized receiving stations.

The AzPF takes advantage of data reduction in azimuth domain while introducing no degradation in the range domain. Thus the AzPF filter is applicable to many missions which can afford resolution reduction in the azimuth domain. Data reduction factor is selectable (1, 2, 4, 8, 16, 32), to allow for different reduction levels required for different periods within a mission. The benefits of the AzPF-based on-board data reduction are as follows.

- The rapid access to data is especially required for emergency situations (floods, earthquakes, etc.), and is highly desired by operational agencies.
- The users will have rapid access to lower-resolution data, from which they can quickly evaluate whether there is a need for the higher-resolution data already collected. If so, they will request such data. If not, the full-resolution data stored on-board or partially downlinked will be erased.
- This scenario is highly desired for large area mappings (e.g., Amazon basin, arctic circle, earthquake-prone areas), where lower-resolution data are routinely required on a large scale, and occasionally there is a need to study various sites at a high resolution to assess impact of dynamic events such as floods, fires, logging, earthquakes, and freeze/thaw events (arctic).
- Distributed ground stations have been considered by a number of missions being proposed (e.g., ECHO), and facilitate fast and wide-spread access to data.
- Azimuth pre-filtering will reduce data volume by a selectable factor (4 or more), enabling data downlink at lower data rates. This allows distributed ground receiving stations operated by groups of scientists or other user communities for fast access and analysis at lower-resolution. Full-resolution data could additionally be downlinked to the existing conventional central receiving stations.

This AzPF has been successfully implemented completely on a single two-million gate XILINX FPGA (XCV2000E-6) without no additional external chips. The filter first demodulates 8-bit offset video signal at 100 MHz sampling rate, then performs the azimuth per-filtering on the I/Q channels with each range line up to 8192 samples. The filter coefficients and the decimation factors are programmable. The filter design, performance evaluation, software modeling, FPGA design and challenges, and hardware implementation testing will be described in this paper.