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Implementation of Synthetic Aperture Radar Motion Compensation on FPGA

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ABSTRACT

Motion compensation is an important portion for any Synthetic Aperture Radar (SAR) processing having high resolution air borne sensors. Any deviation of the sensor platform from the ideal motion or known trajectory may degrade the image Quality and may also lead to improper Image formation. If this motion errors are known prior to the image formation one can correct them compensating the errors. This can be achieved with the help of Global Position System/Inertial Navigation Systems (GPS or INS), for every Transmitted pulse along the trajectory GPS or INS provides the deviated raw data which can be multiplied by the echo signal in order to remove motion errors. This paper presents the implementation of Motion error correction on Field Programmable Gate Array (FPGA) achieved through Very High Speed Integrated Circuit Hardware Description Language (VHDL) programming.

INTRODUCTION

Motion Compensation for airborne Synthetic Aperture Radar has always been important for high precision image formation. In general when the radar platform deviates from the ideal path the raw data may have an error which degrade the image hence this error needs be corrected and the deviation values are always traced by GPS/INS which provide the correction value for the every pulse to pulse. This paper presents the development and implementation of Motion Compensation digital hardware for motion correction, the module is designed using VHDL and the hardware used for implementation is Xilinx Virtex 5 ML506.

Figure below shows the block diagram of motion compensation, since the raw data provided by the sensor is in Inphase and Quadrature phase (IQ) format thus the complex multipliers are used and block RAM's are used to store the compensation Values for every pulse.

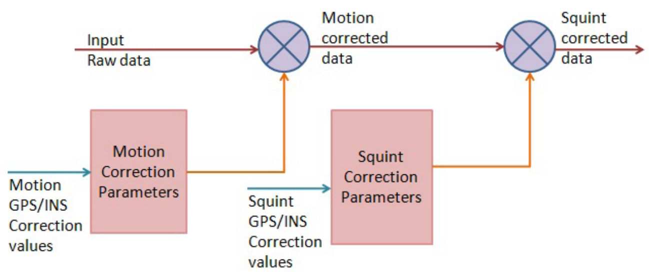

Figure1.Motion compensation block diagram

MOTION ERRORS

Motion errors are of two types ideal motion error and squint error figure below depicts the scenario of platform errors, the ideal path is assumed that the platform will always travel in straight line direction but in real time the platform may deviate From actual trajectory and hence the error occurs in the raw image data which degrade image.

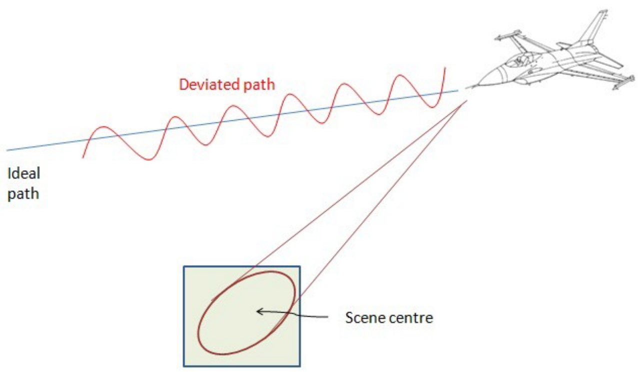

Figure 2. Motion errors

Translation motion causes platform displacement from the nominal, ideal path. This results in the target scene changing in range during data collection. This range shift also causes inconsistencies in the target phase history. A target

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at range R is measured at range R + ΔR which introduces a phase shift of

$$\phi\, m = (-2 * \Delta R * 2\pi)/\lambda$$

in the data .Fortunately if the motion is known (usually from an on board INS/GPS sensor), then the motion errors can be corrected.
The common method for compensating for the non-ideal motion involves two steps. First the corrections are calculated for a reference range, Rref , usually in the center of the swath. The phase correction

$$Hmc1 = \exp\,(j\ 4\pi\Delta Rref/\lambda)$$

is applied to the raw data.
The SAR data is range compressed. A second order correction is applied to each range according to the differential correction from the reference range. For each R; ΔR is calculated and the correction is formed.

$$Hmc2 = \exp\,(j4\pi\ (\Delta R - \Delta Rref)/\lambda)$$

IMPLEMENTATION OF MOTION COMPENSATION

In this paper, the hardware platform is based on Virtex5 sx5 FPGA from Xilinx Inc. The FPGA works at 240MHz and utilizes the Xilinx complex multiplier IP core and BRAM for error correction and restoring respectively as shown in the figure below

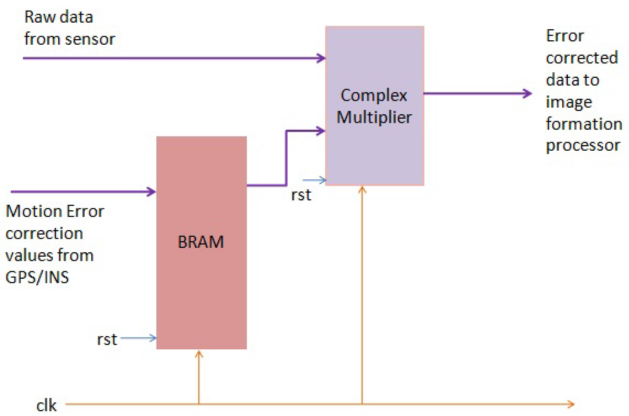

Figure 3. Motion correction Implementation

RESULTS

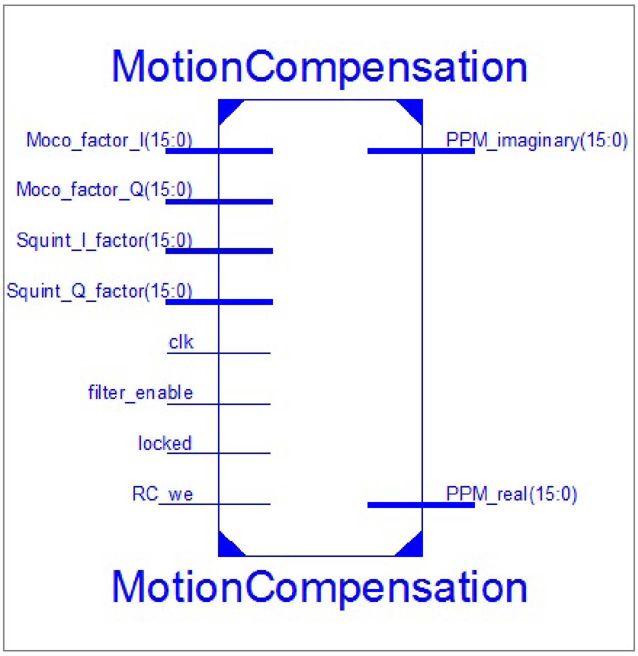

Figure 4.Top level Module of Motion compensation

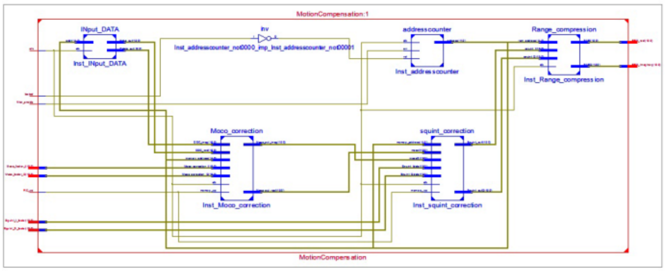

Figure 5. Schematic view of motion compensation

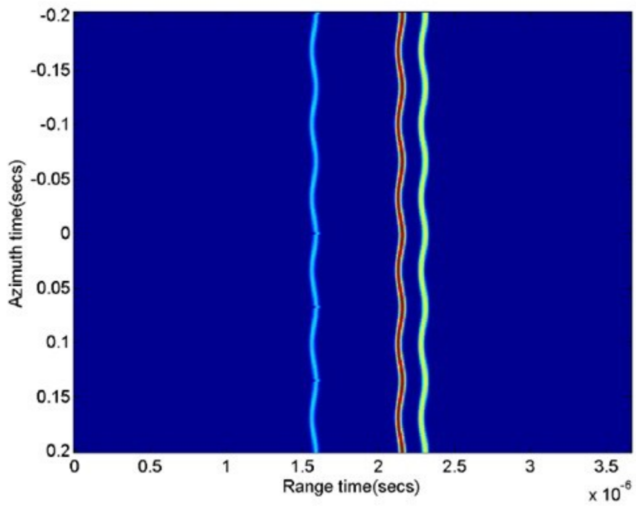

Figure 6. RAW data before motion compensation

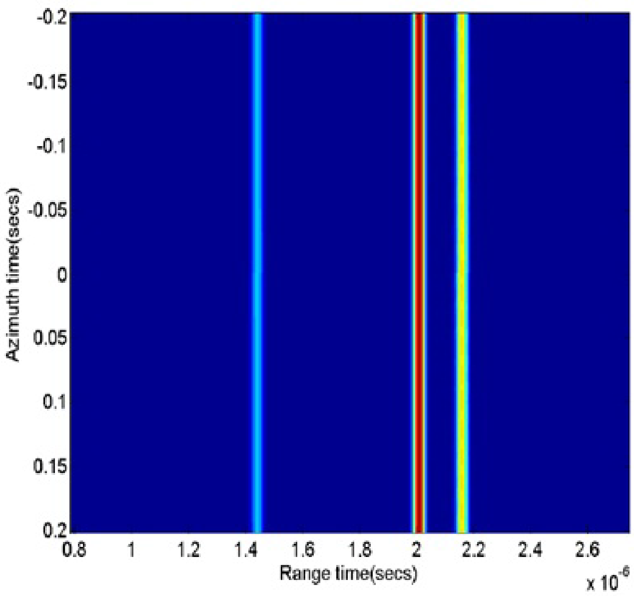

Figure7. RAW data after motion compensation

CONCLUSION

In this paper, we researched an efficient method for motion compensation, by using Xilinx Ip cores. hence the raw data used for image formation can be made error free before sending it for image formation in order to avoid the degradation of image.

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