International Journal of Pure and Applied Mathematics
Volume 119 No. 12 2018, 1417-1426
ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
Special Issue
ijpam.eu

COMPRESSION OF SAR RAW DATA USING BLOCK ADAPTIVE QUANTIZATION

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Abstract

This paper focuses on synthetic aperture radar (SAR) raw data compression using field-programmable gate array (FPGA) technology. In particular, this paper centers around the locally available, ongoing compression for spaceborne SAR frameworks.SAR is an essential instrument for remote detecting of the World's surface, and creates huge amounts of information that require compression before downlink by means of a constrained limit channel. SAR framework configuration, including information displaying is analysed from the point of view of data compression, and algorithm usage prerequisites are determined. The improvement of a straightforward, yet adaptable, FPGA implementation of a block adaptive quantization (BAQ) compression algorithm is depicted, and the analysis of its performance is done.

Keywords: - *Synthetic Aperture Radar (SAR) ,Block Adaptive Quantization (BAQ),Field Programmable Gate Array (FPGA), Signal to Quantization Noise ratio (SQNR), Integrated Sidelobe Ratio (ISLR) Peak Sidelobe Ratio (PSLR)*

1. Introduction

Radar is a object identification syatem that utilizes radio waves to decide the range,angle, or speed of items which can be utilized to recognize aero planes, ships, shuttle, guided rockets, engine vehicles, climate conditions, and territory. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the object(s). Radio waves (pulsed or continuous) from the transmitter reflect off the object and return to the receiver, giving information.

Synthetic-aperture radar (SAR) is used to create 2D or 3D images of targets, like topographies. SAR captures the radar antenna motion over a target region to give better spatial resolution than traditional beam-scanning radars. The statistics of a block of data is estimated by the block adaptive quantizer (BAQ) algorithm and then scalar quantization is used to compress that block of data. The block statistics are downlinked with the compressed data to allow reconstruction of the signal. For spaceborne SAR, the raw data input signal is assumed to fit the complex Gaussian model. In the literature, the BAQ appears to be the de facto standard, against which all other algorithms are compared.

2. Literature Review

The block adaptive quantization (BAQ) was created by Kwok and Johnson of the NASA JPL (Kwok and Johnson, 1989) .As shown by its name, the BAQ algorithm exploits the gradually changing echo power in range from pulse-to-pulse to allow the block adaptation of the quantizer. This is proficient by the assurance of the insights for each block of information samples, which is utilized to modify the quantizer levels. Since the measurable appropriation of the real(I) and quadrature (Q) information samples is assumed to be zero-mean Gaussian with indistinguishable difference, the standard deviation is the main parameter important to portray the distribution.The decision of block size is a vital parameter in the BAQ algorithm. It is basically an trade off between the quantity of samples important to guarantee that the block will have a Gaussian distribution, and an endeavor to limit the block size to keep legitimate the stationary signal assumption. The BAQ agorithm is a non-uniform quantizer improved for a Gaussian probability distribution where the threshold values are adjusted on a block by block basis, and are obtained from the block variance.

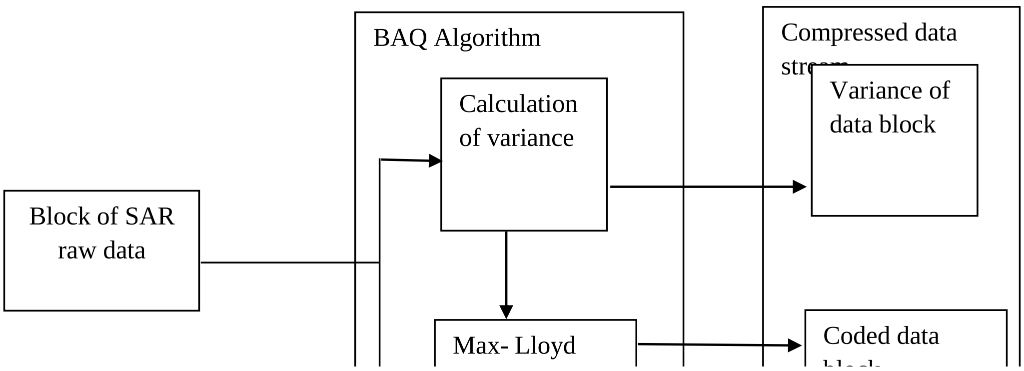


Fig 1: Block Diagram Of Standard BAQ Algorithm

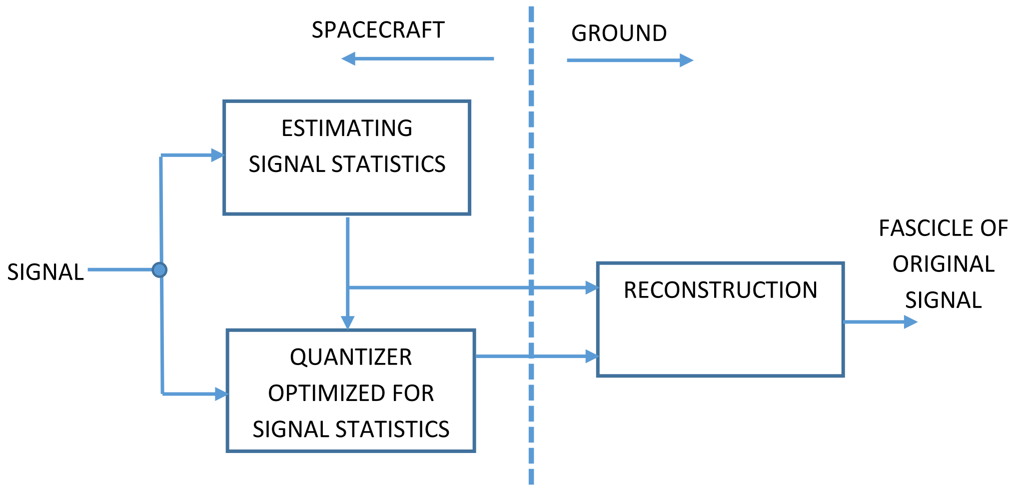
The raw data is divided into small blocks. The block size is chosen so as to guarantee Gaussian statistic distribution within a block and the the maximum block size is constrained by signal power, which ought to be constant all through the block.The standard deviation of each block is evaluated by the following equation.

$$\text{Mean } |I| = Mean|Q| = 127.5 - \sum_{i=O}^{127} \text{erf}\left(\frac{i+1}{\sigma\sqrt{2}}\right) \quad \text{-----------------(1)}$$

Where I and Q are the real and imaginary part of the samples. For the ideal working point, the threshold values are corresponding to the standard deviation of every block of data. The standard deviation of every block is transmitted and utilized for the decompression of the information .For every block, the response levels of a non-uniform quantizer are scaled by the standard deviation.

3. **Research Objectives**

The goal of adaptive quantization is to provide effective data compression of a signal source with time-varying parameters. An adaptive quantizer estimates the statistics of the source and attempts to match the quantizer to the



observed in time-varying statistics.

Fig 2: Prospective BAQ block diagram

In the approach taken to design the adaptive quantization scheme, the model shown in Fig 2 was used. The statistics of a block of incoming data samples are estimated and a quantizer which is optimized for that source model is selected for quantization of that block of data. An understanding of the source statistics is therefore paramount in the design of an optimal quantizer. The reconstruction of the data samples is also an issue in the efficient mechanization of the quantization scheme. In a data rate limited system, the selection of the number of levels of quantization is a trade-off between the range resolution (or pulse bandwidth) and performance of the quantizer (quantization noise). The range bandwidth determines the sampling rate of the echo returns and therefore affects the data rate. In addition, the performance of the quantizer affects the noise in the digital data and therefore, the image quality.

4. COMPRESSION ALGORITHM

Lossless compression removes redundancy from a dataset in such a way that the original information content can be recovered after compression. The entropy of a dataset gives an indication of the potential for lossless compression. The entropy *H(X)* of a discrete random variable X is defined by

$$H(X) = -\sum_{x} p(x)log_2(p(x)) \qquad \text{------------------(2)}$$

and is the number of bits on average required to describe *X.* Typical SAR raw data has high entropy relative to the number of bits used to quantize the analog signal, and thus the potential for lossless compression is limited. In addition, SAR data exhibits low sample-to-sample correlation, a lack of systematic patterns and a relatively high bandwidth compared to the sampling rate. Therefore in order to achieve data rate reduction in SAR data, lossy compression is necessary.

Lossy compression can achieve the required data rate reduction, but does so at the expense of information content. However, due to the relatively low SNR levels of satellite SAR data (between 5dB and 15dB), a moderate amount of added noise due to lossy data reduction will not have a significant impact on image quality.

A variety of lossy compression algorithms for compressing SAR data can be found in literature, but most commonly implemented is the Block Adaptive Quantization (BAQ), which uses scalar quantization to achieve lossy compression. Scalar quantization is the mapping of each observed value to the nearest approximating value in a predetermined finite set of allowed values.Lossy compression is achieved by mapping M input levels to N output levels, where M>N. Various ways to measure quantizer performance are

- RMS phase noise
- Signal to Quantization Noise ratio (SQNR)
- Integrated Sidelobe Ratio (ISLR)

- Peak Sidelobe Ratio (PSLR)
- Visual comparison of processed images

5. SAR DATA ACQUISITION

Radar echoes are down converted from Ku band to an IF of 1750 MHz in analog receiver and ADC which is operating at 1GHz, samples the analog signal to 12 bit wide samples.

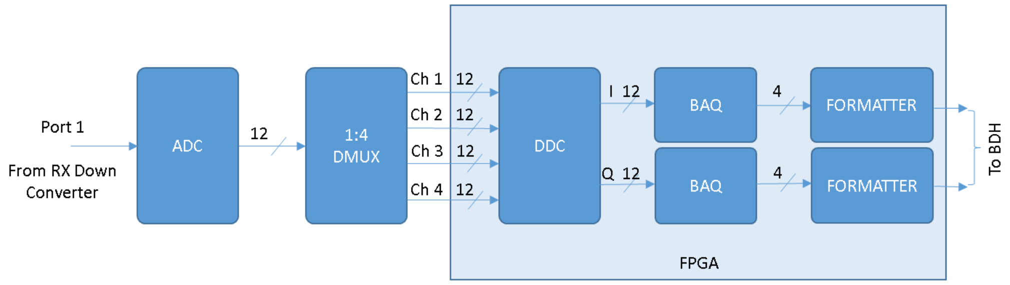
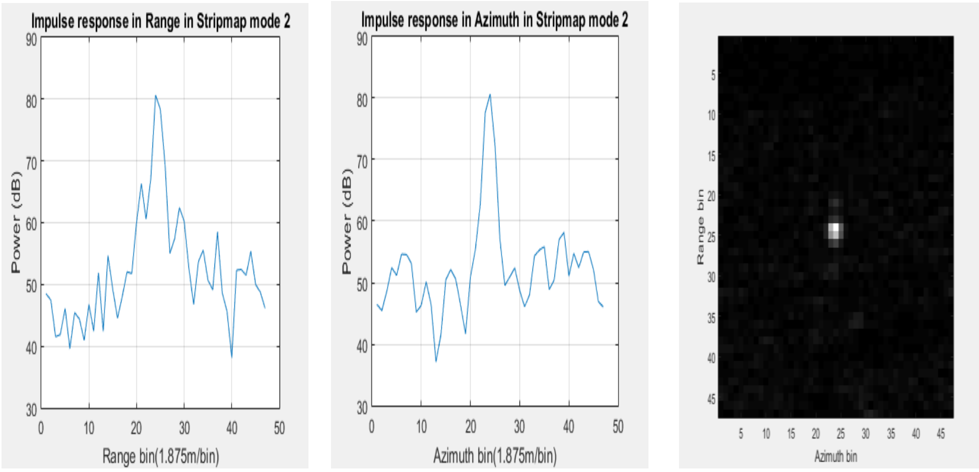


Fig 3 : SAR Data Acquisition

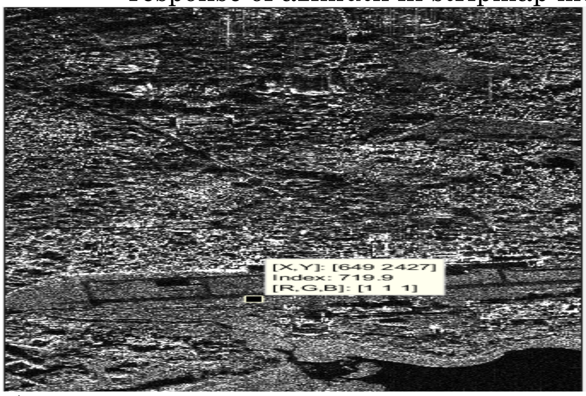
There are two parallel chains each for vertical and horizontal polarizations. ADC output is provided to a 1:4 DMUX for reducing input data rate to the FPGA. Digital down conversion and filtering is carried out in each of the four channels and decimated In phase and quadrature phase signals with 12 bit wide samples are passed onto block adaptive quantization modules to reduce the sample width to 4bits per sample. 32 range lines are considered as one batch since block size considered for BAQ is 32x32. With a sampling frequency of 250MHz, transmit pulse width of 33uS and imaging swath of 5km, 250e6x (33e-6+33e-6) x32=528000 samples will be generated and when it is further divided into blocks of 32x32 samples, 520 blocks will be formed. On a raster scan basis, all the blocks of the batch will undergo BAQ compression. Compression can be done on different blocks in parallel. No. of parallel compression modules will be dictated by hardware resource availability and data rate requirements.Compression related information used for decompression and other radar metadata are attached along with compressed IQ data in the formatter and finally provided to satellite Baseband Data Handler (BDH).

6. SIMULATION RESULTS

BAQ encoding is actualized by separating the SAR raw informational set into information blocks of little size.For each block standard deviation esteem is calculated.



a) Impulse response of range in stripmap mode 2 b) Impulse response of azimuth in stripmap mode 2 c) image obtained



d) particular zoomed image of BAQ model

6.1 SIMULATION IN FPGA

FPGA technology is suitable for the implementation of signal processing in space applications, especially given that most of the space-based systems are highly specialized and custom-built. Radiation-hardened, high-reliability versions of FPGAs are widely-used in space. In addition, FPGA features include multiple clock domain support and a large number of 10 pins, thus allowing various radar functions (e.g., pulse generation, timing and control, filtering, data compression) to be implemented on the same chip.

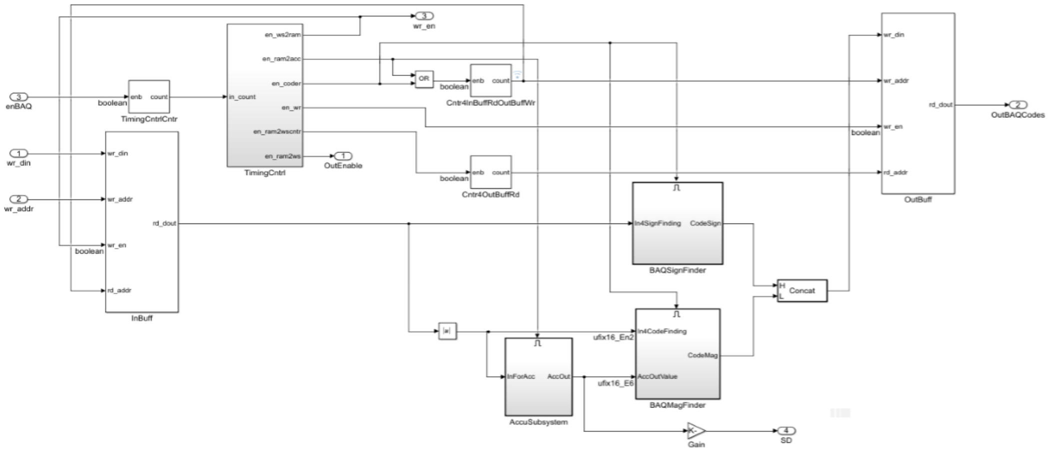


FIG 4 ：Simulink model

6.2 IMPLEMENTATION RESULTS

FPGA implementation is obtained by HDL coder which is used to generate portable,synthesizable,verilog and vhdl codes from matlab functions, simulink models and state flow charts. The generated hdl code can be used for FPGA programming. It provides an traceblity between Simulink model and generated vhdl and Verilog code enabling code verification for high integrity applications

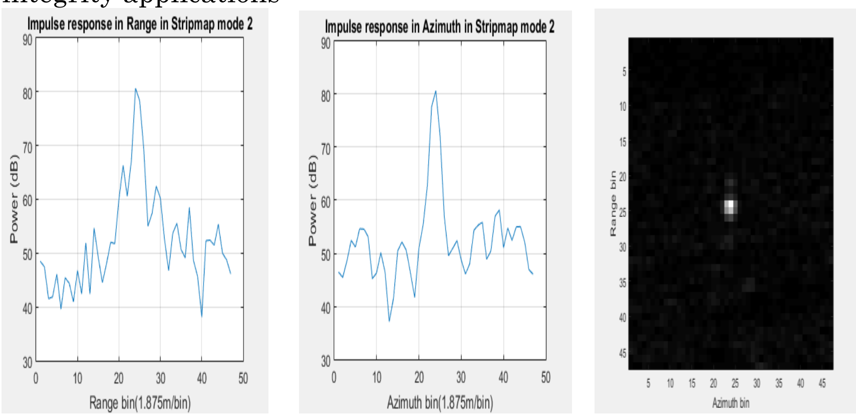
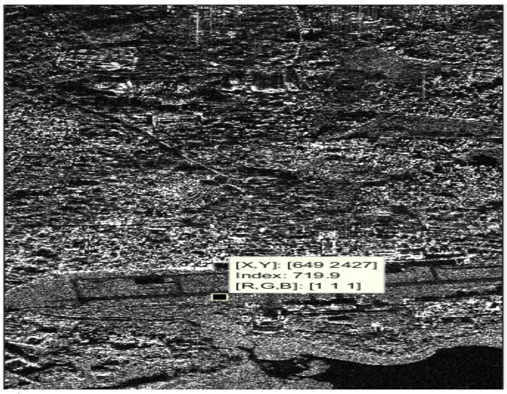


FIG 5. a) Impulse response of range in stripmap mode 2 b) Impulse response of azimuth in stripmap mode 2 c) image obtained .



d) zoomed image obtained in FPGA implementation

7. DISCUSSIONS AND CONCLUSIONS

The paper described the simulation of BAQ process and its FPGA implementation including the development of a practical test bench suitable for further radar development. The combination of Matlab, Simulink and HDL Coder provides an efficient method for developing, testing and implementing digital designs.The standard BAQ algorithm utilizes a small percentage of the available resources of modern FPGAs, and thus there is significant scope for more advanced compression algorithms and/or more radar functions on a single FPGA chip.

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