Radar Data Compression and Matched Filtering using Digital Signal Processing Techniques

Chetan N. Mandaliya [1], B. Saravana Kumar [2], Ramesh B. Gameti [3], Dilip K. Kothari [4], Nilesh M. Desai [5]

[1,4] E & C Engg. Dept, Institute of Technology, Nirma University, Ahmedabad – 382 481, GUJARAT, INDIA

[2,3,5] MSDPD/MSDG/MRSA, Building No. 52, Room No. 26, Space Application Centre (SAC), Ambavadi Vistar P.O., Indian Space Research Organization (ISRO), Ahmedabad – 380 015, GUJARAT, INDIA

chetan.mandaliya08@gmail.com, nmdesai@sac.isro.gov.in

***Abstract*--Synthetic Aperture Radar is an imaging radar, used to generate microwave images of earth surface. SAR produces very huge amount of data, which is In Phase Modulated (I) and Quadrature Phase Modulated (Q) signals, treated as raw data. Raw Data can further be processed for Compression which is known as Range Compression. Because of limited on board storage and data rates, it is desired to compress the SAR data. For that Block Adaptive Quantization (BAQ suits SAR data the most. It consists of adapting the step size of a quantizer based on mean and variance of the input and then quantize each sample to the respected level of quantization. The another method is Block Histogram Equalization Quantization (BHEQ) in which samples are normalized to variance and same quantizer is used. In this paper matlab simulation results of Range Compression by matched filtering and deramping method, BAQ/BHEQ on Raw data are shown. Further comparison is done between standard and achieved values of Mean Square Error (MSE) and Signal to Noise Ratio(SNR).**

***Index Terms*--Synthetic Aperture Radar (SAR), Block Adaptive Quantization(BAQ), Block Histogram Equalization Quantization (BHEQ), Range Compression, Matched filtering, Deramping.**

I. INTRODUCTION

SAR is an imaging radar used to generate microwave images of earth surface. SAR find applications in various areas like Agricukture, Water resources' management Disaster (Flood) management, Forstery, Vegetation etc. SAR generates huge volumes of raw data with very high data rates. This places severe demands on the onboard Solid State Recorder storage as well as spacecraft to earth station downlink. This in turn restricts the extent of SAR instrument operation and consequently the global coverage. Because of limited onboard data storage and limited downlink bandwidth, it is necessary to compress the SAR data.

Generally for the radar operation different kinds of pulses are used, but for SAR operation Linear Frequency Modulated (Chirp) signal is used in place of pulse. Chirp signal improves range resolution with reduced peak transmitted power. The data produced by SAR is treated as Raw Data consisting of In phase (I) and Quadrature phase modulated signal (Q) components. When any chirp signal is correlated with its complex conjugate, an energy concentrated pulse is produced. This process is known as Range Compression and data we get after this process is known as Processed Data.

Because of Range Compression, the resultant output pulse can be considered as narrow width, high power pulse, thereby and hence resolution will be improved. Range Compression can be done by different signal processing methods viz. Matched Filtering and Demramping. In matched filtering two complex FFT operations, one complex multiplication and one complex IFFT is required whereas in deramping method, only one complex multiplication and a single complex FFT is required.

Currently the best scheme for SAR data compression is Block Adaptive Quantization (BAQ) which consists of adapting the step size of a quantizer based on mean and variance of the input and then quantizes each sample to the respected level of quantization. BAQ can directly be applied either on Raw Data it self or on the Processed Data.

Another scheme for quantization is Block Histogram Equalization Quantization (BHEQ), which is a variant of BAQ. In BHEQ, input samples are normalized to variance and same quantizer is used subsequently.

The sections below describe the Raw data compression and Range Compression methods, along with Matlab Simulation Results.

II. SAR RAW AND RANGE COMPRESSED DATA

The original data received from SAR is treated as Raw Data. As discussed above, for SAR operation Chirp signal is used rather than pulse. Chirp is used because of two reasons. If we want high resolution then transmitted pulse width should be low but at the same time transmitted power should be high to have desirable SNR. Both the problems can be overcome by chirp signal. When a chirp signal is correlated with it self, it produces a high energy narrow pulse. Hence Chirp signal is used in SARs. For simulation in matlab, parameters taken are, for chirp bandwidth 30 MHz, Sampling rate 41.67 Mhz, sending window time 80 µs and receive widow time 187 µs. In figure 1 and 2, sent and reference are shown respectively.

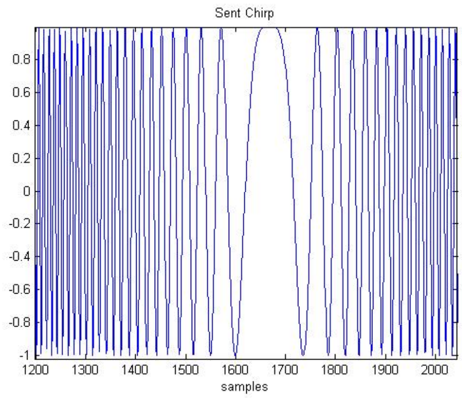

Fig.1. Transmitted Chirp

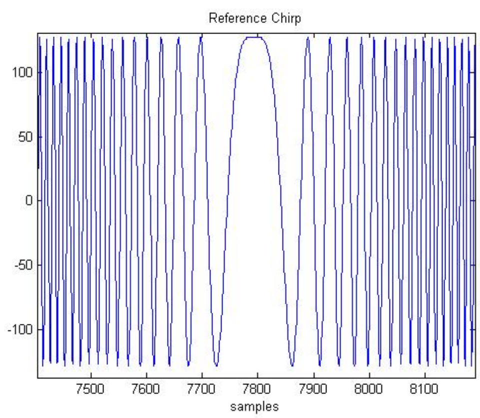

Fig.2. Reference Chirp

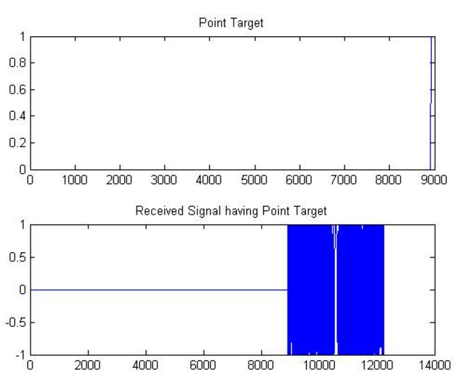

Fig.3. Point Target and Received Chirp

For convenience a single point target is taken. In figure 3 position of point target and reference chirp including that point target is shown.

Range compression is done to achieve high range resolution. Basically range compression is done by correlating the received chirp with its complex conjugate. Range compression produces a high power narrow width pulse and hence desired resolution can be achieved. There are two types of Range Compression. One is matched filtering and the other is deramping. Matched filtering is done in three steps, first FFTs of received chirp and its complex conjugate are taken, second complex multiplication of these two and third inverse fft is taken at last. Deramping is done in two steps, first complex multiplication of received chirp and its complex conjugate, second fft of the product. Hence, Deramping is faster than Matched Filtering.

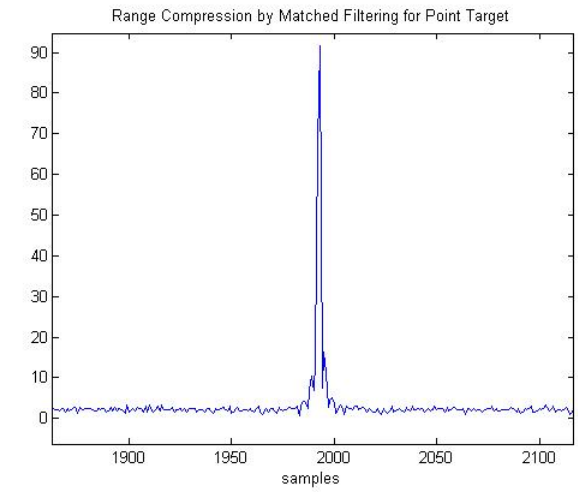

Fig.4. Range Compression by Matched Filtering

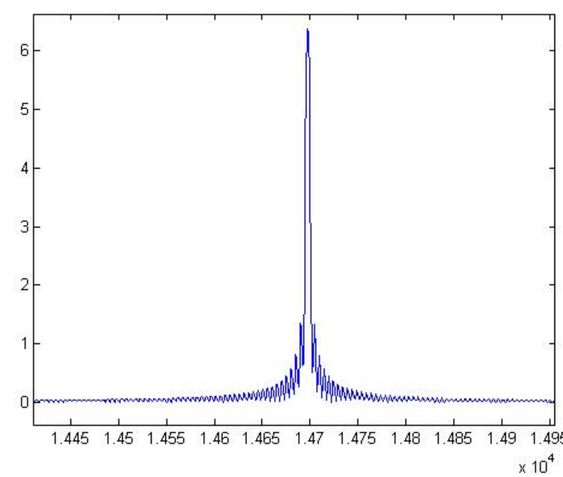

Fig.5. Range Compression by Deramping

III. BAQ Simulation Results and Comparison with Standard Values

SAR signal data can be modeled as Gaussian distributed random variable with a slowly varying RMS value. As discussed above, because of limitations in downlink bandwidth and onboard storage compression is essential. BAQ is used for this purpose. In BAQ, the RMS value is estimated from the average of the magnitude of the input I/Q samples in the block. Then after quantization is used.

BAQ was applied on the data having Gaussian distribution and Laplacian distribution. Further, the results were matched with standard results and comparison is done between standard and obtained values for Mean Square Error and Signal to Noise Ratio. In table 1 & 2 comparison is shown and in figure 6 input output mapping of the quantizer for Gaussian distributed signal is shown.

TABLE I
RESULTS AND COMPARISON OF BAQ ON GAUSSIAN DISTRIBUTED DATA

Mean 0, Variance 1		
Encoded input(bits)	**Designed Gaussian Quantizer(SNR(dB)/ MSE)**	**Standard Values(SNR(dB)/ MSE)**
2	9.1002/0.1365	9.3003/0.1175
3	14.3492/0.0387	14.616/0.0345
4	20.5377/0.0087	20.222/0.0095
5	26.53/0.0023	26.012/0.0025
6	31.91/0.00065	31.9094/0.0006

TABLE II
RESULTS AND COMPARISON OF BAQ ON LAPLACIAN DISTRIBUTED DATA

Mean 0, Standard Deviation 1		
Encoded input(bits)	**Designed Laplacian Quantizer(SNR(dB)/ MSE)**	**Standard Values(SNR(dB)/ MSE)**
2	7.4413/0.1806	7.5401/0.1762
3	11.8026/0.0648	12.638/0.0545
4	18.2720/0.0149	18.133/0.0154
5	24.1703/0.0038	23.87/0.0041
6	29.8393/0.0011	29.7430/0.011

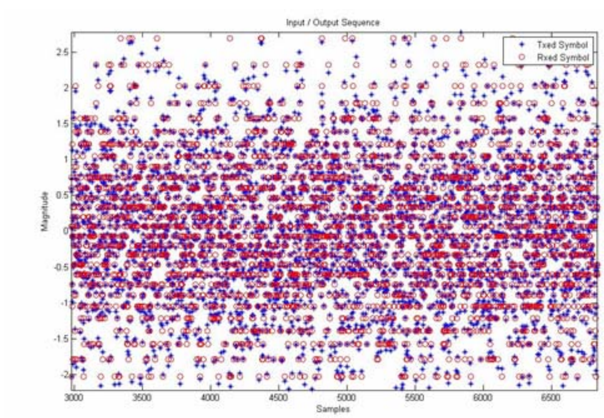

Fig.6. Input Output Mapping of Quantizer for Gaussian distributed signal

IV. BHEQ AND ITS SIMULATION RESULTS

BHEQ is a variant of BAQ. In Block Histogram Equalization Quantization, histogram is equalized to uniform distribution and then uniform quantizer is applied on the data. Here, it is assumed that input data is Gaussian Distributed. After having input, Cumulative Distribution Function (CDF) of the input is found and its inverse is taken. This results in to uniform distribution. Now uniform quantizer is applied on the uniform distribution which we got after CDF inversion.

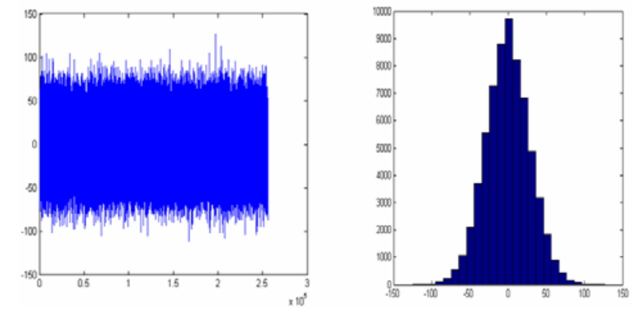

Fig.7. Input data and its histogram

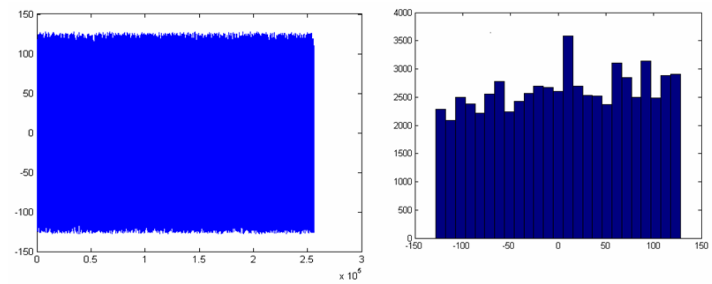

Fig.8. Input data after CDF inversion

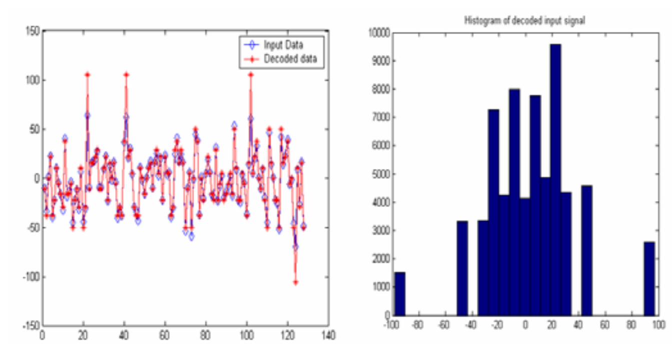

Fig.9. Input output mapping and its histogram after quantization

V. FUTURE SCOPE

Here, BAQ is applied on raw data only, which can be applied to Range Compressed data for better performance and more compression. That can also be implemented in hardware via xlinx for real time applications. The effort can be made to have a generic algorithm which can calculate optimum threshold levels for any kind of input distribution.

VI. CONCLUSION

SAR generates a huge volume of data, in view of wide swath and / or high resolution operation. Raw SAR data compression helps to reduce these data volume and also limits the overall data rates and satellite to earth station downlink within the limits of X-Band data link (max. 640 Mbps). Similarily, onboard SAR processing which involves basically range compression, also helps in further reduction of data volume by 10-20%. In this paper, Matlab Simulation Results of Range Compression for two methods viz. Matched Filtering and Deramping as well as BAQ/BHEQ compression on Raw Data are shown. Further, the compression performance is compared with respect to Mean Square Error (MSE) and Signal to Noise Ratio (SNR).

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