Restoration of Saturated SAR Data

Navneet Agrawal
Department of ECE, CTAE,
MPUAT,Udaipur (Rajasthan) INDIA

K.Venugopalan
Department of Computer Science
MLSU, Udaipur (Rajasthan) INDIA

ABSTRACT
Synthetic aperture radar (SAR) is an imaging technique, which provides high-resolution images. The high resolution in the range direction is achieved by using large bandwidth signals and that in the azimuth direction is achieved by synthesizing a large aperture antenna using platform motion. The unique data collection geometry of SAR system requires that huge amounts of raw data be processed before obtaining a viewable image. Therefore, performing some form of compression on SAR raw data provides an attractive option for SAR systems. Block Adaptive Quantizer (BAQ) has been a very attractive method for compression due to simplicity in its on-board implementation and less hardware complexity. Analog-to Digital Converter (ADC) is an integral part in this compression process. Since the SAR raw data has very wide dynamic range, the ADC gets saturated at higher average value of the input signal . The higher value saturates ADC causing loss of power. In the present paper we have suggested a technique to compensate this power loss and restoring the Gaussian nature of the SAR data.

Keywords
Synthetic aperture radar (SAR), A/D converter, saturated data restoration

1. INTRODUCTION
It is necessary to convert the received analog signals into digital raw data before Synthetic aperture radar (SAR) imaging. In this process of ADC the data are quantized. When the SAR data are out of range of ADC, it will lead to the phenomenon called ADC saturation. This saturation gives severe impact on radiometric accuracy due to power loss. By compensating the power loss [1] we can improve the radiometric accuracy and improve the image quality, measured backscatter and signal to distortion noise ratio (SDNR) in the brightest part of the data, while reconstruction. In the present paper we will be following the Rayleigh model for compensating the power loss. The algorithm is supported by various curves and the results have been derived for high resolution TerraSAR-X data set. Compression on the raw data provides an attractive option for SAR systems.

2. METHODS
Histogram for a random noise input (Raw) to a 3-bit ADC is shown in figure 1. The fundamental problem with the saturated data is that the data is no longer scattered in the tails of the distribution, but has been forced into the first and the last number of the digital range. In order to correct for the saturation power loss, the saturated data need to be restored to their prior location. For an individual data point, this is impossible because we have no way of knowing where the original value was. However, if a large enough samples are used, we can estimate the probability of finding a saturated data point at a given location in the distribution tails outside the saturation limits.

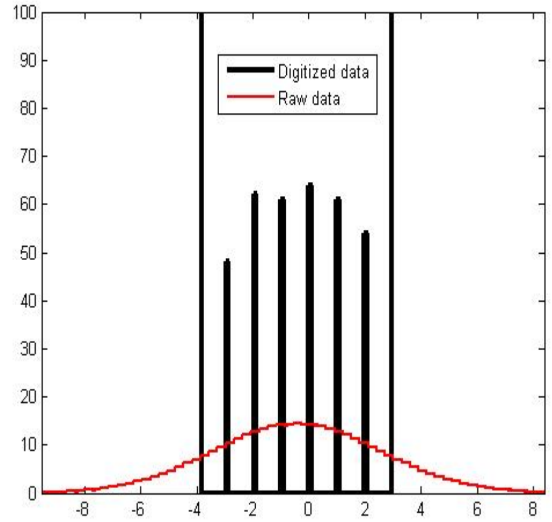


Fig. 1: Histogram of normal (random) noise input for both the analog and digitized case.

3. POWER LOSS COMPENSATION
The Saturated portion of the probability density function is divided into areas of equal probability and then we distribute one saturated value to each of these areas, where number of areas is equal to the number of saturated points. The percent of total values in the first bin of the ADC is the cumulative distribution function (CDF) up to and including the first bin.This is given by

$$\frac{X}{N} = CDF\left(\frac{V_s}{m}\right) \quad ...(1)$$

Where X/N is the ratio of the number of values in the first bin to the total number of values, Vs is the point at which the saturation begins i.e. -4 in the figure 1. And m is normalization constant.

In general, the percentage of total values up to the ith point of the distribution is the CDF at that point. So

$$\frac{i}{N} = CDF\left(\frac{V_i}{m}\right) \quad ...(2)$$

If we take the inverse of equations 1 and 2 and then rearrange, we get

$$\frac{V_i}{V_s} = \frac{CDF^{-1}\left(\frac{i}{N}\right)}{CDF^{-1}\left(\frac{X}{N}\right)} \quad ...(3)$$

Where CDF^{-1} is the inverse of the cumulative probability density functions. Equation 3 is used to distribute the i^{th} saturated value to the location V_i. The CDF^{-1} can be provided in a look up table calculated for a given sample.

4. RAYLEIGH MODEL AND DATA RESTORATION

For a certain range of the ADC, power loss $P_{A/D}$ can be described by clutter distribution [6]characteristics

$P_{A/D} = h(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \ldots \alpha_i ; N \text{ bits})$

Where α_i is clutter distribution characteristic parameter and N is the ADC quantization level. The restoring of the data is done following the procedure given below:

1) Establishing the statistical model of the raw data.
2) Building a theoretical model for $P_{A/D}$
3) Analyzing the statistical characteristics of the raw data and calculating α_i
4) Achieving $P_{A/D}$ by using theoretical model established through step 2) and α_i .

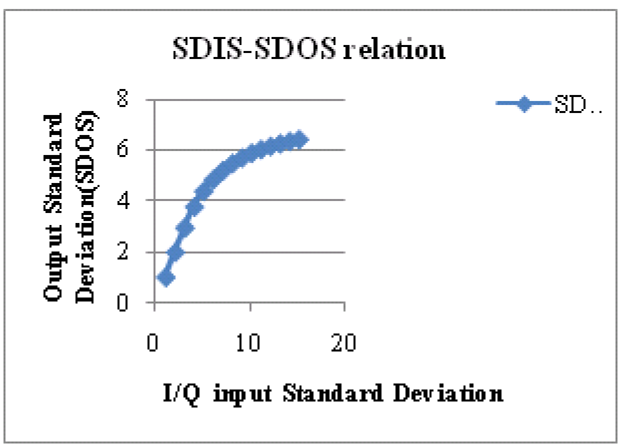
The saturation S and the power loss L is defined as

$$S = \frac{N}{M} \quad ...(4)$$

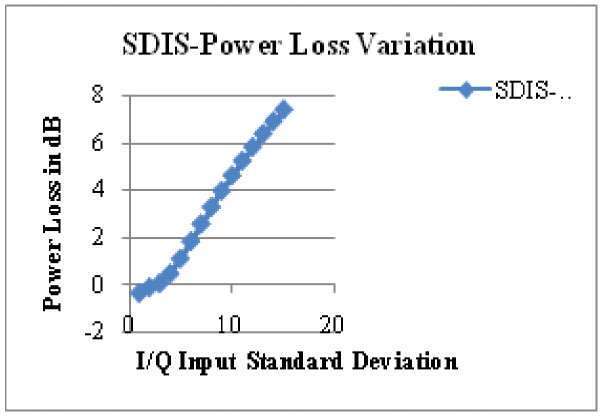
and

$$L = 10 \log \frac{P_i}{P_o} \quad ...(5)$$

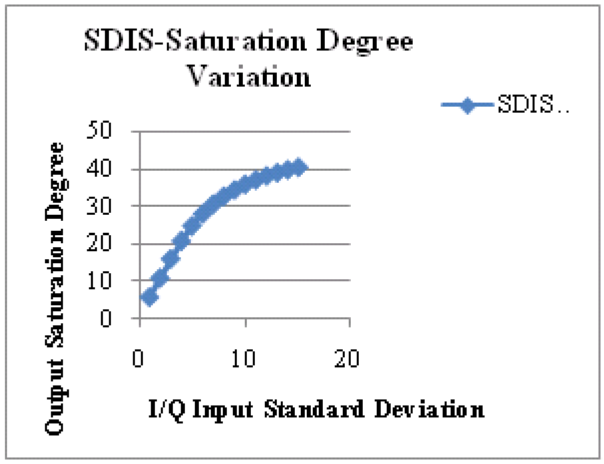
Where M is the total number of samples and N is the number of saturated samples, Pi is the input power and Po is the output power [2].For a certain input standard deviation, we calculate the saturation degree, loss and the output standard deviation. Then we establish the relation [4] among these findings and get the following resultant curves.



(a)



(b)



(c)

Fig. 2 (a,b and c): SDIS, SDOS , Power loss curves

From the figures 2, it is deduced that there is a certain relation between standard deviation of ADC output and the power loss. This is established as figure 3.

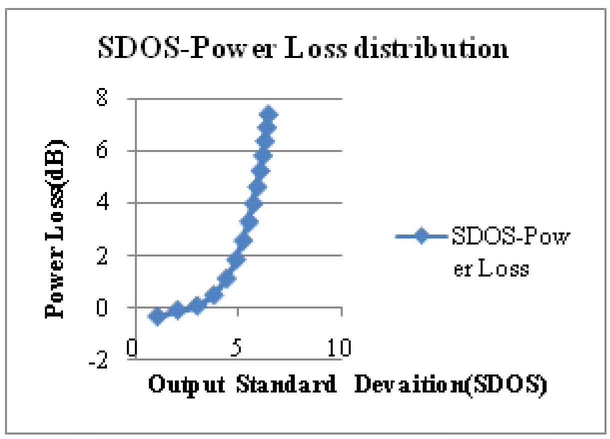


Fig. 3: Theoretical model curve for the relationship between output standard deviation and power loss.

5. SIMULATION RESULTS

The data selected to carry out the experiments are in the form of images from TerraSAR-X satellite and have been verified on MATLAB® 7.0 platform.

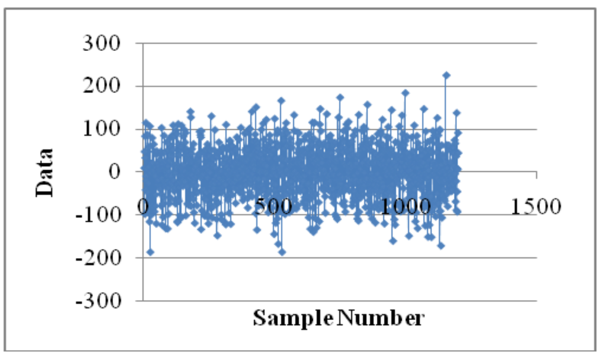
Table 1: Various Parameters for 4-bit Quantizer

Mean Value	SDIS	SDOS	Saturation Degree (%)	Power loss(dB)
0.7988	1.0051	1.0433	5.8053	-0.3239
1.5977	2.0103	2.0293	10.9187	-0.0819
2.3965	3.0154	2.9855	16.0460	0.0865
3.1954	4.0205	3.7987	20.7860	0.4929
3.9942	5.0256	4.4168	24.7340	1.1216
4.7930	6.0308	4.8774	27.9013	1.8437
5.5919	7.0359	5.2317	30.4800	2.5736
6.3907	8.0410	5.5110	32.5907	3.2816
7.1896	9.0461	5.7309	34.3087	3.9649
7.9884	10.0513	5.9147	35.7707	4.6057
8.7873	11.0564	6.0619	36.9800	5.2200
9.5861	12.0615	6.1869	38.0307	5.7985
10.3849	13.0666	6.2884	38.8840	6.3525
11.1838	14.0718	6.3798	39.6633	6.8709

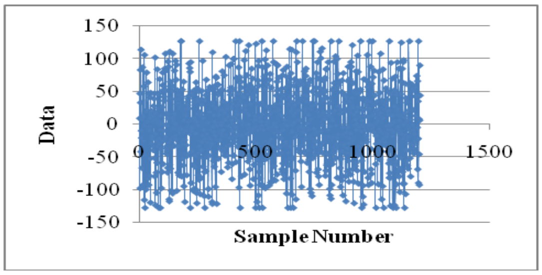
Typical parameters using Rayleigh model for saturated SAR data power loss compensation are summarized in table 2.

Table 2: Typical simulation results

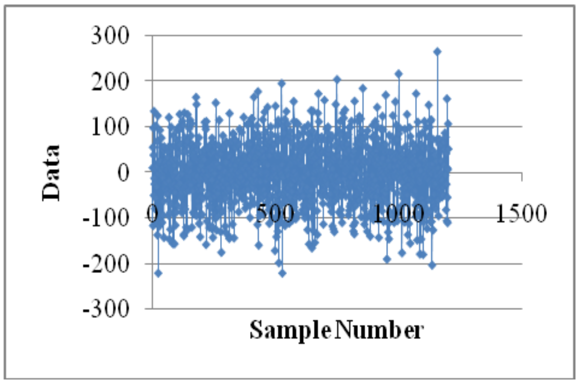
Simulated Output	Saturation	2.10	9.6	16.3	25.2	30.1	44.3
	SDOS	3.32	4.16	4.45	4.58	5.9	5.67
Power loss(dB)		0.02	0.43	1.10	4.42	6.22	5.26
Power (in dB) compensated by Rayleigh Model		0.21	0.73	0.99	1.26	1.78	3.54



(a) Original data

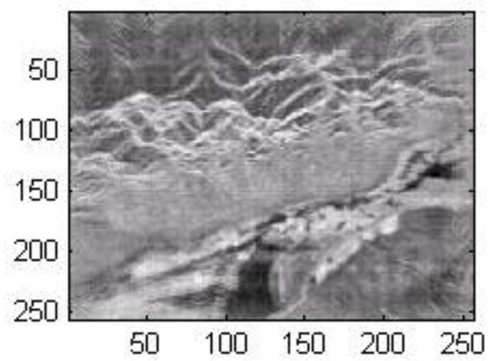


(b) Data with 8 bit ADC

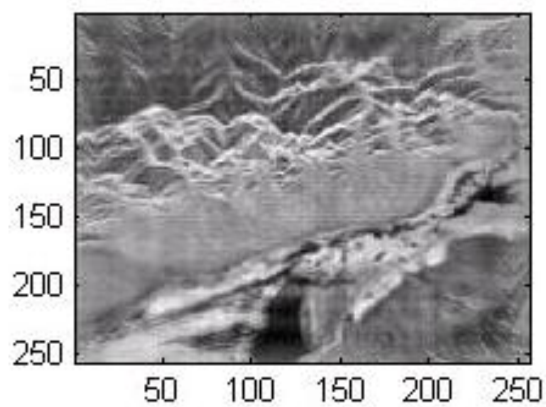


(c) Restored data with compensation

Fig. 4(a,b,c): Original and Restored data with gain compensation



(a) Image before Compensation



(b) Image after compensation

Fig. 5(a&b): Relative image quality before and after saturation compensation

6. CONCLUSION

The paper studies the ADC saturation based on the data field and extended the Rayleigh model. Using the established relation, we can compensate the loss of power due to saturation of ADC. It is concluded that compared with using an 8-bit ADC quantizer, saturated SAR raw data restored using the optimal gain value, is much closer to the real data. When the data volume is much larger, the data are divided into blocks to get better effects during implementing data correction. The minimum block size is selected in order to guarantee a Gaussian statistic within a block; the maximum block size is limited by the fact that the signal power should be approximately constant in the block. The proposed algorithm is evaluated on a set of simulated SAR raw data of dimensions 256 x 256. The performance is evaluated using SNR, PSNR and MSE criteria also. The power normalization is performed on the compressed image to ensure same power as in the original image since quantization operation in general is not a power conserving operation.

7. REFERENCES

[1]. P.S.Cooper,"ADC saturation effects and pointbtarget calibration," Proceedings of CEOS SAR calibration Workshop, 28-30 september 1994, pp38-50.

[2]. P.J.Meadows and P.A.Wright,"ERS-1 SAR analogue to digital converter saturation," in Proceedings of CEOS SAR Calibration Workshop,28-30 september 1994,pp24-37.

[3]. J.Nicoll,R.Gens and P.Denny,"Pre-processing compensation for saturation power loss in SAR data," in Proceedings of IEEE International Geoscience and Remote Sensing Symposium,IGARSS 2002,vol.5.pp.2744-2746.

[4]. H. DonghuiH. ,Zhou. and H.Wen, "Correction method for saturated SAR data to improve radiometric accuracy," in Proceedings of IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2005,pp.3344-3347.

[5]. J. Max, "Quantization for minimum distortion," IEEE Transactions on Information Theory, vol. IT-6, pp.7-12, 1960

[6]. M.Shimada,M.," Radiometric correction of saturated SAR data",in IEEE Transactiuons on Geoscience and Remote sensing,vol.37,no.1,pp.467-478.1999