FDBAQ A NOVEL ENCODING SCHEME FOR SENTINEL-1

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1. INTRODUCTION

Raw SAR data compression has been applied for the first time in the NASA Magellan mission to Venus from 1989 to1994 [1]. Also the ASAR data from the ENVISAT satellite is transmitted in a raw compressed format [2]. The type of compression applied in these cases has been called Block Adaptive Quantization (BAQ). Raw SAR data compression is not lossless. The digitization and coding process introduce additional noise and effects on the SAR images to be processed. Until today most space SAR sensors have been built to fulfill scientific or technology demonstration objectives. But the coming years will show a trend towards more and more operational use of remote sensing data. This will have its impact on the user and the system requirements imposed on on-board data compression.

2. GMES SENTINEL-1

The global Monitoring for Environment and Security (GMES) space component relies on existing and planned space assets by European States, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and the European Space Agency (ESA), as well as new complementary developments by ESA. The new developments are implemented in terms of five families of satellites called Sentinels. The Sentinel-1 mission is an imaging synthetic aperture radar (SAR) mission at C-band designed to supply all-weather day-and-night imagery to a number of operational Earth observation based services. Three priorities (fast track services) for the mission have been identified by user consultation working groups of the European Union: Marine Core Services, Land Monitoring and Emergency Services. These cover applications such as: monitoring sea ice zones and the arctic environment, surveillance of marine environment, monitoring land surface motion risks, mapping of land surfaces: forest, water and soil, agriculture, mapping in support of humanitarian aid in crisis situations. Sentinel-1 has been designed to address medium resolution applications. It includes a main mode of operation that features a wide swath (250 km) and a medium resolution (20 m x 5 m, azimuth x range). The two-satellite constellation offers six days exact repeat and the conflict-free operations based on the main operational mode allow exploiting every single data take. An extensive ground segment is required with several ground stations receiving instrument data from the satellite at a rate of 520Mbit/sec, with cumulative processing capacities above 500 GHz, with archiving requirements exceeding 10000 Terabytes, and with a data dissemination exceeding current systems by one order of magnitude. In order to fully satisfy the GMES service requirements the Sentinel-1 ground segment is required to facilitate coordinated mission planning and data exchange with other GMES contributing missions. The ground segment needs to guarantee a Quality of Service to the user in line with the operational nature of GMES, ensuring that the data products are accurate, complete and provided on time.

3. FDBAQ PRINCIPLE

FDBAQ is designed to provide a variable bit rate coding that increases the number of bits to be allocated to the bright scatterers. In other words, the actual Clutter level of the raw data determines the number of allocated bits. The quantization of raw data introduces a quantization noise power that dependents upon the input signal, clutter and thermal noise, and the quantizer performances. An important ratio is the Clutter to total (quantization and thermal) Noise ratio, CNR. In general by tuning the bite rate it is possible to balance the contribution of the quantization noise and the thermal noise, hence increasing the rate according to the Clutter to Thermal Noise Ratio (CTR). In the general SAR case, the received clutter power is depending on target backscatter (that itself depends on e.g. wavelength, incidence angle, and polarization), acquisition geometry and system parameters (transmitted power etc), the behavior being modeled by the RADAR equation. In particular,

there is a systematic variation of CTR with range that is mainly due to the antenna pattern, with minor contribution from spreading loss and incidence angle variation that can be taken into account in the design of the FDBAQ quantizer.
The CNR at each range is uniquely related to the ratio between the received clutter power, which depends on the target and the range, and the thermal noise power. For the purpose of optimization and performance evaluation, it is more simple to calibrate the raw data, e.g. to compensate for the systematic variations with range, due to spreading loss, antenna pattern and incidence angle variation, so that the clutter would represent the backscatter coefficient of the scene. The range varying CNR leads the use of a VBR quantizer, where a larger number of bits is used for the strongest scatterers.
Notice that the FDBAQ quantizer measures the local clutter power by exploiting raw data in blocks of a few hundred samples, like any other FBAQ. However, the quantizer needs also the knowledge of the NESZ that is not measured on board, but assumed known (e.g. estimated using on ground instrument characterization). The principal difference between the FDBAQ and the FBAQ is that the number of bits per sample is selected according to the local CNR and some criteria. The idea is the minimization of the total error related to the total bit-rate.

4. ENVISAT GM MOSAIC

A 16 bit GM ENVISAT Mosaic has been used for the simulation of FDBAQ performances. Such mosaic, if properly calibrated, can give an estimate of the mean radar backscatter, which is used for the computation of the bit rate. The available GM world mosaic is not absolutely calibrated, so that the read values do not represent the radar backscatter coefficient. Therefore, an empirical estimation of the calibration constant has been performed. The rain forest C-band backscattering model is known to be independent from the incidence angle. Such value has been estimated computing the mean power of a single, absolutely calibrated GM image over a rain forest region. Then, the mean mosaic power over the same rain forest region has been evaluated too and the calibration constant has been estimated. The calibration procedure has been validated recurring to other GM level-1 images, over different ground areas. Such analysis shows that if the same calibration procedure is repeated over different homogeneous ground areas, obtained results are consistent. The backscattering coefficient difference, regarding the estimate over South America, is 0.2 dB.

5. SIMULATION RESULTS

The simulation carried out calculates performances in terms of CNR and bit rate by using synthetic Sentinel-1 acquisitions along the orbit. The simulation assumes the nominal Sentinel-1 orbit and swaths, and estimates the ground backscatter by using a Global Monitoring ENVISAT/ASAR Mosaic covering almost the entire world. These mosaics are normalized after processing, therefore a renormalization and calibration is needed in order to use this data for simulation purposes. The aim of the simulation is to estimate a range and azimuth varying bit-rate and assign, to each portion of illuminated ground, a figure of merit related to the total noise power (sum of the thermal noise power and the quantization noise power). A number of different areas have been analyzed, ocean, ice and land where the bit rate was selected in order not to exceed a -22 dB level for the total noise power. The resulting data rate for the downlink was evaluated.

6. CONCLUSIONS

The FDBAQ quantizer has been introduced and a method for the evaluation of FDBAQ performances has been presented. The FDBAQ theoretical performances have been evaluated and different TOPSAR IW simulations using Sentinel-1 orbits and parameters have been performed. The FDBAQ simulator exploits an ENVISAT ASAR GM world-wide mosaic, absolutely calibrated and compensated for the expected variation of backscatter with incidence angle, in order to retrieve an estimate of the on-ground reflectivity. This information, together with the a priori information on range-varying NESZ are used to compute the number of quantization bits for each 1 x 1 km pixel on the earth. The obtained results lead to the following conclusions. FDBAQ satisfies the requirement of an average bit rate of 260 Mbit/s. A figure of merit (Total Noise Power) has been evaluated, showing that IW1 sub-swath is always more noisy then IW2 and IW3

6. REFERENCES

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