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Calibration and Quality Evaluation of SAR Sensors

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Abstract - *Synthetic Aperture Radar (SAR) is an active microwave imaging radar used to image the earth's surface in day and night, regardless of the weather conditions and its surface penetration capability makes it possible to extract information about crops, vegetation, forests, snow cover and geographical features. This paper discusses the need for calibration of SAR sensors and different sensor parameters which are evaluated and monitored to obtain reliable and high quality SAR data products.*

Key Words: ***Synthetic Aperture Radar***, ***Sensor, Data Quality Evaluation, Calibration, Quality Parameters***

1. INTRODUCTION

Synthetic Aperture Radar (SAR) has emerged as an important source of high resolution satellite imagery useful in earth observation. It can image the earth's surface in day and night, regardless of the weather conditions and owing to its surface penetration capability; it is possible to extract information about crops, vegetation, forests, snow cover and geographical features [1]. SAR is an active imaging microwave radar mounted on a moving platform. It provides high resolution images by synthesizing a virtual aperture using the forward motion of the platform [1][2]. Unlike the optical imaging system, SAR data needs pre-processing which is performed on ground to obtain image [2][9]. Accurate interpretation and analysis of SAR data is very important to extract the geophysical properties from the observed data. Also, the accuracy and consistency is important to ensure the quality of the data products derived from these observations. Calibration is an important process to ensure that the data products meet the requirement of scientific utilization [1]. Calibration is important to characterize the performance of an instrument and obtain reliable output. It is the process in which the accuracy of any instrument is compared with a reference or known standard. This paper discusses the different calibration processes and quality parameters to evaluate and monitor SAR sensor performance.

2. CALIBRATION OF SAR SENSORS

The main objective of the calibration is to ensure the success of any remote sensing mission. The calibration of SAR sensor is performed prior to the launch as well as post the satellite launch for obtaining reliable data, The preflight calibration as well as the in flight calibration is important to characterize the end-to-end performance of the SAR system. So the calibration of SAR sensor can be categorized as internal calibration and external calibration.

2.1 Internal Calibration

Internal calibration is the characterization of the SAR instrument to measure any drift in the amplitude or phase of system components. The SAR sensor is generally well calibrated prior to the launch but there may be degradation due to component ageing, temperature or exposure to UV radiation. These effects change the characteristics of the sensor and may be subject to further degradation.

The preflight calibration of SAR sensor is performed prior to the launch under controlled environment [7]. The performance of the instrument is observed and modeled by subjecting it to stress before it is exposed to the harsh orbital conditions [3][7].

For the purpose of internal calibration, the SAR sensors are provided with dedicated onboard calibration facility. The onboard calibration is carried out with the predefined internally generated calibration signal at regular period to check sensor performance. The onboard calibration data is compared with the preflight conditions to check for any variations. The onboard calibration facility have been provided for the different spaceborne sensors like Sentinel-1, TerraSAR-X, ENVISAT, RISAT-1 and ERS SAR missions. These SAR sensors have an active phased array antenna which electronically shapes the beam patterns. They have number of radiating sub-arrays known as Transmit-Receive Modules (TRM). The individual performance and health of the TRMs are monitored with the help of internal calibration. The internal calibration is performed regularly to keep tab on instrument status.

2.2 External Calibration

External calibration is the radiometric calibration performed to ensure that the backscattered signal represents the geophysical properties of the earth's surface faithfully. It is done by deploying target with known radar properties on the ground. They are passive corner reflectors used as point targets like trihedral corner reflectors. The invariant sites on Earth, like rain forest or vegetation free surface with stable climate and stable topography are also used for calibration.

3. DATA QUALITY EVALUATION

Data quality evaluation is important with respect to the accurate data products for users and obtaining correct relationship between radar backscatter and geophysical parameters.

For a SAR signal, the raw data must be processed on ground to generate an image. The SAR data product is generated from this raw data, so its analysis is very important. The SAR data is the coherent sum of many independent reflections from multiple point targets in a given resolution cell. So the SAR data is considered to be Gaussian with zero mean. The raw data needs to be evaluated before any further processing steps [1][12].

The quality of raw data is based on the statistical analysis carried out on the raw SAR data. The quality parameters are evaluated for I and Q channel data (i.e. assuming quadrature modulation) for mean, stability of standard deviation, gain imbalance, phase imbalances and uniform phase distribution [4].

The other image quality parameters which can be derived are using the corner reflectors as point targets and measuring their impulse response function. The quality parameters which are evaluated are the Background to Peak ratio (BP), Peak Side Lobe ratio (PSLR), Integrated Side Lobe ratio (ISLR) [13].

The long term stability and performance of SAR system was evaluated using the level-0 data, i.e., raw data [4]. The parameters monitored for the echo data were statistics in terms of bias of I and Q channel data, power imbalance, phase imbalance, antenna pattern in elevation for qualified swath, Doppler centroid estimation and chirp phase and amplitude stability. The antenna pattern was observed for 3 dB compressed swath from range uncompressed raw data for homogeneous and non- homogeneous targets. The trend analysis for the quality parameters was prepared to check the stability and monitor if the values are within system specifications.

Similarly, the consistency of the backscattered values was measured by monitoring the SAR sensor parameters for different beam and polarization [13]. Trihedral corner reflectors were used as point targets to measure the impulse response in both azimuth and elevation direction. The observed Radar cross section is compared with the theoretical RCS for the purpose of absolute calibration. The quality parameters were calculated for multiple corner reflectors on multiple occasions in different beams. The multiple analysis ensures that the system is consistent.

The image quality analysis for RADARSAT-1 for single beam as well as ScanSAR mode was performed [9]. The quality was monitored periodically using impulse response function, radiometry using images of Amazon Rainforest. The routine exercise helped in the correction of elevation beam patterns and generation of recalibrated beam pattern to achieve improved radiometric accuracy.

Similarly, during the initial phase there were inconsistencies for TRM of RISAT-1 satellite which were observed in onboard calibration [6]. There was large deviation in the value of gamma-naught due to uncompensated antenna pattern. So by analyzing the onboard calibration data, phase drift was corrected and antenna pattern was correctly derived.

4. CONCLUSION

Calibration and data quality evaluation is an important aspect for maintaining the consistency and quality of any SAR data products. The calibration and quality is assessed to evaluate and monitor the sensor performance and radiometric stability. These measurements need to be calculated at regular interval throughout the mission lifetime. Calibration and data quality evaluation thus plays an important role in the post launch operational capability of the SAR sensor, stability and health of the sensor.

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