Requirements of processing parameters for Multi-Satellites SAR Data Focusing Software

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Abstract: SAR (Synthetic Aperture Radar) signal data need a focusing procedure to make the information available to the user. In recent SAR systems, various sensing modes and mission operations are applied to acquire high-resolution SAR images. Therefore, in order to develop generalized focusing software for multi-satellites, a regularized parameter configuration that sufficiently represents sensor and platform characteristics of the SAR system is required.
The objective of this paper is to introduce the consideration of parameter definition for developing a generalized SAR processor and to discuss the flexibility and extensibility of defined parameters. The proposed parameter configuration can be applied to a SAR processor. Experiments based on real data will show the suitability of the suggested processing parameters.

Keywords: SAR, focusing, generalized processing parameters

1. Introduction

SAR is an active microwave instrument that performs high-resolution observation under almost all weather conditions. SAR image has been used in many application areas and depending on objective of the users, the type of SAR data has been varied.

In the previous research, SAR processor that performs data importing, focusing and geometric-correction, was developed [1][2]. The developed SAR processor handled raw SAR signals that were acquired from JERS-1 and ERS-1/2 satellites. However, recent SAR systems have been improved dramatically to handle various high-resolution SAR images. Those systems adopt various sensing modes, specially designed antennas, and mission operations. Therefore, SAR processors should be flexible and extendable to cope with those different characteristics of SAR systems.

The objective of this paper is to introduce generalized processing parameters of a SAR processor that can be easily extendable for other types of radar signals.

Section 2 will introduce several aspects to be considered for defining processing parameters. The practical consideration of development process will be presented in section 3. Conclusion and future works are followed in section 4.

2. Parameter Definition

The civilian SAR mission started the operation from 1978 by SEASAT. Since then, several missions have been considerable increase in orbital SAR activity, such as ALMAZ, ERS, JERS, SIR-C/X, RADARSAT, ENVISAT and so on. Those systems have own characteristics and mission operations. [5] briefly summarized the characteristics of commonly used commercial satellites. As examined in [5], the processing parameters for a multi-satellite SAR processor should handle those various sensor features and mission characteristics. That is, an optimized SAR processor can be defined by SAR system parameters, geometry parameters and image quality parameters. While system and geometry parameters depends on physical design of sensor and flight mission, the image quality parameters which are spatial resolution, signal-to-noise ratio, radiometric resolution, ambiguity ratios and height errors is defined by the evaluation of SAR products. Because the image quality evaluation on SAR products were already defined in other research [3][4]. In this paper, we focused on SAR processing parameters for multi-satellites SAR processor which can be categorized as follows.

- System parameters
  - General parameters
  - Sensor parameters
  - Platform/Orbit parameters
- Geometry parameters
- Processing parameters

1) System Parameters

The System parameters describe general aspects of SAR system and flight mission operation. Thus, these are divided into three parts: general parameters, sensor parameters and platform/orbit parameters.

General parameters: These parameters defined basic and common features of SAR image products. Table 1 describes those parameters. These parameters are essential requirements and should be followed only types of SAR products to provide visual inspection and accessibility in applications.

Table 1. General parameters

parameters	description
nmrPixelsPerLine	number of pixels per line
nmrLines	number of lines
nmrBytesPerPixel	number of bytes per pixel
nmrSpectralBands	number of spectral bands
bandInterleaving	inverleaving indicator (BIP/BIL/BSQ)

Sensor parameters: The sensor parameters contain SAR sensor characteristics. These parameters define the chirp and receiver characteristics, ADC configuration, raw data structure, and antenna pattern. Generally, the sensor parameters describe static parameters for a particular sensor or beam mode. A beam is characterized by its nominal incidence angle, nominal swath width and nominal spatial resolution. Because these parameters are more related to processing parameters, they are defined in processing parameter category. Other parameters are listed in the sensor parameters (see Table 2).

Table 2. Sensor parameters

parameters	Description
sensorMode	sensor identifier
downChirpFlag	chirp direction flag
antennaLength	length of antenna (m)
antennaWidth	width of antenna (m)
beamMode	beam mode
azimuthBandWidth	bandwidth in azimuth (Hz)
rangeBandWidth	bandwidth in range (Hz)
wavelength	radar wavelength (m)
pulseRepetitionFreq	pulse repetition frequency (Hz)
chirpDuration	chirp duration (sec)
chirpBandWidth	chirp bandwidth (Hz)
chirpSamplingRate	chirp sampling rate (Hz)
elevationBeamWidth3 DB	elevation beam width (3 DB width) (deg)
azimuthBeamWidth3D B	azimuth beam width (3 DB width) (deg)
rangeGateEarlyEdgeSt artTime	range gate delay at early edge at the start of the image (sec)
rangePulseAmplitude Coeff	nominal range pulse (chirp) amplitude coefficient
rangePulsePhaseCoeff	nominal range pulse (chirp) phase coefficient

Platform/Orbit parameters: The platform/orbit parameters describe the platform information and general shape and orientation of a satellite's orbit, respectively. The orbit parameters contain the time, velocity and altitude of a scene center, platform position and velocity information. These values are used in the camera Model for Doppler parameter estimation or geometric correction.

These parameters are usually acquired from the ancillary data. However, that can be calculated by using the orbit propagator, if these parameters are not provided from them [10][11]. Table 3 describes the orbit parameters.

Table 3. Platform and orbit parameters

parameters	description
satellite	satellite name
yawSteeringFlag	yaw steering applied flag
sceneCenterTime	scene center time (UTC)
sceneCenterVelocity	scene center velocity (m)
sceneCenterAltitude	scene center altitude (m)
orbitDirection	orbit direction indicator (ASCENDING/ DESCENDING)
position vector	position of the SAR platform (m) at the specific time
velocity vector	velocity of the SAR platform (m/sec) at the specific time

2) Geometry parameters

The geometry parameters define the geometric information of the image at the time of acquisition. These parameters allow latitude and longitude information to be calculated for each pixel in image. The geometry parameters, such as geodetic information of the image, map projection, datum and ellipsoid, will be calculated based on processing levels.

Table 4. Geometry parameters

Parameters	description
sceneCenterLatitude	processed scene center geodetic latitude (deg)
sceneCenterLongitude	processed scene center longitude (deg)
sceneCenterOrientatio nAngle	processed scene center true heading (deg)
cornerLatLong	processed scene corner latitude and longitude (deg)
datum	datum designator
mapProjection	map projection designator
zoneNumber	UTM zone number
ellipsoid	ellipsoid designator
ellipsa	ellipsoid semi-major axis
ellipsb	ellipsoid semi-minor axis
resamplingKernel	resampling designator
offNadirAngle	incidence angle at scene center (deg)
pixelTimeDirection	time direction indicator along pixel direction
lineTimeDirection	time direction indicator along line direction

3) Processing Parameters

The SAR processor includes various processing steps, such as raw data correction, range compression, range migration correction, azimuth compression. The detail explanation of processing steps can be founded in references [1][2]. While system and geometry parameters are defined according to physical sensor characteristics and orbital mission, processing parameters are defined by requirement of modules inside the SAR processor.

Since processing starts from importing input raw signals, it also considers the format of raw signals. Although almost every SAR data are provided and formatted in CEOS, the detailed formats in CEOS are different according to the providers. For example, ERS has different parameters for each PAF (Processing and Archiving Facilities) because each of the PAF's choose to implement the CEOS leader file differently and create their own complex data sequence [6]. In case of JERS-1 data is characterized by possible large amounts of squint that can lead to Doppler centroid that are several multiples of the PRF [7]. For RADARSAT-1, these bytes contain the spacecraft telemetry and replicas of the transmitted chirp. The telemetry contains information on the radar state, time, and spacecraft attitude. The raw data IQ samples are in 2's complement form, rather than the offset binary format favored by all other space-borne SARs, and the decoding program rapidly converts the RADARSAT-1 data into offset binary format. Like JERS-1, RADARSAT-1 data is characterized by possible large amounts of squint that can lead to Doppler centroid that are several multiples of the PRF [8][12][13][14]. ENVISAT ASAR imaging mode data are stored as records in the file with each record corresponding to an echo. Each echo consists of a header consisting of timing and error information and radar parameters followed by a set of packets containing the echo samples. These echo samples are stored using block floating point quantization [9].

The processing parameters in table 5 contains algorithm to be used for processing and the values produced during the processing. The optimum algorithms for each SAR sensor are predefined in the processing parameters, however it can be changed.

Table 5. Processing parameters

parameters	description
focusingAlgorithm	focusing algorithm designator
processingLevel	product processing level
biasRemovalAlgorithm	raw data correction algorithm designator
biasI	bias for I-component
biasQ	bias for Q-component
gainI	gain imbalance for I-component
gainQ	gain imbalance for Q-component
nmrLooks	number of looks in azimuth
gsdAlongLine	line spacing (m)
gsdAlongColumn	pixel spacing (m)
dceAlgorithm	Doppler frequency centroid estimator designator
dceNmrSections	internal processing parameter of spectrum analysis (DCE)
dceNmrAvgLines	internal processing parameter of spectrum analysis (DCE)
dceAvgLineGap	internal processing parameter of spectrum analysis (DCE)
dreAlgorithm	Doppler frequency frequency estimator designator
dopplerFreqALEarly	along tack Doppler frequency centroid at early edge of image
dopplerFreqACEarly	cross tack Doppler frequency centroid at early of image
dopplerFreqRateALEarly	along tack Doppler frequency rate at early edge of image
dopplerFreqRateACEarly	cross tack Doppler frequency rate at early edge of image
azimuthWeightingFunction	weight function designator in azimuth
rangeWeightingFunction	weight function designator in range
rangeMigrationFlag	range migration applied flag
optimalFFTSize	FFT size
blockOperationSize	data I/O block size

3. Practical Consideration

Beside the processing parameters, the SAR processor needs to consider the processing steps in practical. Because of the amount of SAR signal and various hardware limitations, the following practical aspects should be considered.

- Signal Data Set
- Input Data Correction
- Corner Turning

If the SAR processor should handle huge amount of raw SAR signals operationally, then these considerations are more valuable than others.

Signal Data Set: The signal data appears as an array of complex numbers which are sampled in azimuth by the inter-pulse period of the radar and sampled in slant range by the ADC converter. Since the SAR processor needs to handle these complex numbers efficiently, the SAR processor usually operates on blocks of input data, producing a single frame of output imagery. These block processing or parallel processing can provide performance throughput.

Input Data Correction: The raw data correction is already defined processing step of the SAR processor. Beside the defined statistical parameters and correction modules for bias, gain imbalance and orthogonality of two channels, other practical considerations such as dynamic gain adjustment or gain look-up tables can be applied for efficiency of the processor. The gain look-up table also allows correction for systematic gain variances due to radar parameter variation. Moreover, radiometric calibration can be also included in the look-up table.

Corner Turning: The corner turning is transposition of the array to accept column operations. SAR processors have to be designed with the sequence of operations selected to minimize the required corner tuning manipulations unless the processor is able to take advantage of a large corner turning memory or RAM.

4. Conclusions

We described the characteristics of SAR data related to each satellite and analyze the requirements of processing parameters. Based on our parameter definition, a SAR processor can be implemented to have extendibility and flexibility. Our SAR processor has been developed using the parameter definition, so that a SAR processor for new SAR sensors can be easily integrated with the existing SAR processor.

The SAR Processor takes raw signal data from JERS-1 and ERS-1/2, and generates various SAR image products. Recently, we are extending the processor to handle RADARSAT-1 and ENVISAT.

The Fig. 1 and Fig. 2 show the ERS-2 and RADARSAT-1 result images according to processing steps.

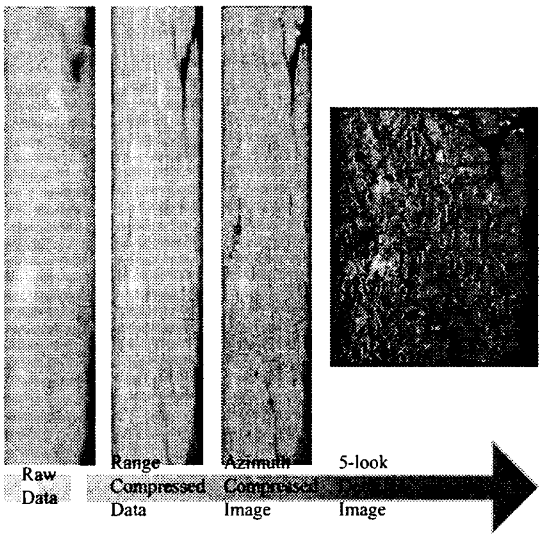

Fig. 1. Processing results (ERS-2, Dajeon)

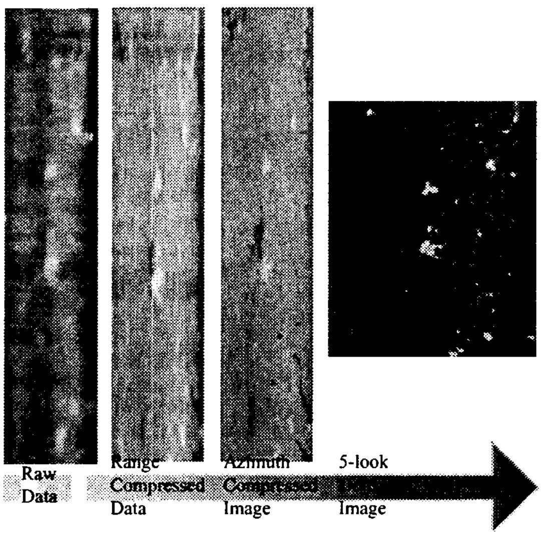

Fig. 2. Processing results (RADARSAT-1, Dajeon)

Reference

[1] S. Kwak, Y. Lee, D. Shin and W. Park, 2003, SAR Processing Software for Ground Station, *International Symposium on Remote Sensing*, pp.504-506

[2] S. Kwak, Y. Lee, D. Shin and W. Park, 2004, Synthetic Aperture Radar : From Signal To Image, *KEM (Key Engineering Matrials)*, on press.

[3] Y. Lee, S. Kwak, D. Shin and W. Park, 2003, Quality Analysis of SAR Image, *International Symposium on Remote Sensing*, pp.507-509.

[4] Y. Lee, K. Kim, S. Kwak, D. Shin, S. Jeong and K. Kim, 2004, Evaluation of SAR Image Quality, *International Symposium on Remote Sensing*, on press.

[5] J.C. Curlander, R.N. McDonough, *Synthetic Aperture Radar : Systems and Signal Processing*, Wiley.

[6] *ERS SAR.RAW CCT and EXABYTE Format and Specification*, ER-IS-EPO-GS-5902.1 3.0, August, 1, 1998.

[7] *User's Guide for JERS-1 SAR Data Format*, National Space Development Agency of Japan.

[8] *Radarsat Data Product Specification*, RSI-GS-026, 3.0, May, 8, 2000.

[9] URL : *ASAR Product Handbook*, Available at : http://envisat.esa.int/dataproducts/asar/CNTR.htm

[10] D. Shin and Y.R. Lee, 1997, *Geometric Modeling and Coordinate transformation of Satellite-Based Linear Pushbroom-Type CCD Camera Image*, Korean Journal of Remote Sensing, 13(2) : 85-98.

[11] D. Shin and W. Park, 2002, *Forward Mapping of Spaceborne SAR Image Coordinates to Earth Surface*, Korean Journal of Remote Sensing, 18(5) : 273-279.

[12] R. Bamler, H. Runge, 1991, *PRF-ambiguity resolving by wavelength diversity*, IEEE Trans.on Geoscience and Remote Sensing Society, 29(6) : 997-1003.

[13] F. Wong, I.G.Cumming, 1996, *A Combined SAR Doppler centroid estimation scheme based upon signal phase*, IEEE Trans.on Geoscience and Remote Sensing Society, 34(3) : 696-707.

[14] F.K. Li, W.T.K.Johnson, 1983, *Ambiguities in Spaceborne Synthetic Aperture Radar Systems*, , IEEE Trans.on Aerospace and Electronic Systems, AES-19(3) : 389-397.