Data Processing and Calibration of SAR data in Japan

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Abstract

Japanese Earth Resources Satellite-1(JERS-1) will be launched from Tanegashima Space Center, NASDA by H-I rocket in Feb.,1992. The JERS-1 has two observation equipments: synthetic aperture radar (SAR) and optical sensor (OPS) which consists of visible, near-infrared and short-wave infrared radiometer. In order to evaluate parameters of SAR, to develop processing and calibration method and to evaluate the utility of SAR data in various fields of applications, NASDA conducted SAR-580 experiment by using variable parameter SAR mounted on Convair 580 owned by Canada Centre for Remote Sensing (CCRS) during October and November, 1983 in collaboration with many research organizations. As a part of this experiment, NASDA conducted calibration experiment in Tsukuba where several corner reflectors were set up. NASDA processed about 100 scenes of SAR-580 by newly developed auto-focusing method and evaluated SAR data from various points of view. Moreover, Communications Research Laboratory (CRL) participated in SIR-B experiment planned and conducted by JPL in collaboration with several agencies including NASDA.

In this paper, outline of data processing and calibration for SAR data in Japan are presented.

1. Introduction

Japanese Earth Resources Satellite-1 (JERS-1) is scheduled for launch in Feb.,1992 and will be launched by H-I rocket from Tanegashima Space Center, NASDA . Space segment of the JERS-1 is jointly developed by NASDA and JAROS and ground segment is developed by Earth Observation Center (EOC), NASDA. The JERS-1 has two observation equipments: synthetic aperture radar (SAR) and optical sensor (OPS). Main mission objectives of JERS-1 are to evaluate newly developed sensors and spacecraft and to collect data of the earth concerning resources exploration, geology, agriculture, forestry, land use, prevention of disaster, coastal monitoring, sea ice monitoring and others.

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In order to evaluate parameters of SAR, to develop processing and calibration methods, to evaluate utility of SAR data in various application fields and to study future advanced SAR, NASDA conducted SAR-580 experiment by using variable parameter SAR mounted on Convair 580 owned by Canada Centre for Remote Sensing (CCRS) in October and November, 1983 in collaboration with many research organizations. As a part of SAR-580 experiment NASDA conducted calibration experiment in Tsukuba Science City where several corner reflectors were set up. NASDA processed about 100 scenes of SAR-580 data and provided SAR-580 data to principal investigators who participated in SAR-580 data evaluation program in 1984-1986.

In this paper, data processing and calibration for SAR data in Japan are presented by focusing on SAR-580 data and JERS-1 data.

2. Outline of JERS-1 SAR data

2.1 Outline of JERS-1 SAR

Bread board model (BBM) of mission instruments of JERS-1 was developed by NASDA. Engineering model (EM) of mission instruments of JERS-1 is developed by Resources Remote Sensing System (RRSS) and Proto-flight model (PFM) will be developed by Japan Resources Observation System Organization (JAROS). On the other hand, Bus instruments of JERS-1 are developed by NASDA.

Table 1 shows the specifications of JERS-1 SAR. L band was selected by considering weight and power of payload and penetration through vegetation. It was confirmed in SAR-580 experiment and other experiments that L band penetrates vegetation such as trees deeper than C and X band. This is desirable for resources exploration.

2.2 JERS-1 data type and processing level

Ground segments of JERS-1 are developed by EOC, NASDA. Ground system for JERS-1 is under conceptual design in 1988. Basic design will begin in 1989. In order to develop processing system, it is necessary to define processing data volume, data type and processing level for JERS-1 data. In this case, both SAR data and OPS data should be considered. Table 2 shows tentative processing level of JERS-1 SAR data. Table 3 shows tentative data type of JERS-1 SAR data. Since the velocity of SAR is about 7km/sec and PRF is 1505.8-1606.0, sampling interval is about 4.5m. So, pixel size of 1 and 3 looks are defined as 3.125m and 12.5 m, respectively. Spatial resolution of SAR is 18m (3 looks) and 6m (1 look). Though there are many window function, typical window functions (Square, Riesz and Hamming) can be selected. Concerning output data type, both amplitude and logarithmic expression can be selected by considering dynamic range. Since the logarithmic expression provides quasi-normal distribution, this is desirable in case of land use classification by combining with optical sensor data and using maximum likelihood method.

Table 1 Specifications of JERS-1 SAR

Altitude	568 km
Transmit Frequency	L band (1.275 GHz)
Polarization	H-H
Swath Width	75 km
Off-nadir Angle	35 degree
Incident Angle	38.7 degree (Center of Swath Width)
Transmitted Pulse	
Type	linear down chirp
Bandwidth	15 MHz
Initial Frequency	1282.5 MHz
Pulse Length	35 sec
Sampling Rate	17.1 MHz
Pulse Repetition Frequency (PRF)	1505-1605 in 25Hz incriments (1505.8, 1530.1, 1555.2, 1581.1, 1606.0)
Noise Equivalent	-20.5 dB
Signal to Ambiguity (S/A)	>14 dB
Raw Data Bit Precision	3I/3Q
Raw Data Rate	30x2 Mbps

Table 2 Tentative processing level of JERS-1 SAR data

Level 0:	Raw data
Level 1:	Basic image (Range and Azimuth Compression)
Level 2:	System corrected (Bulk) image (Radiometrically and geometrically corrected image)
Level 3:	Precisely corrected image by using GCP.
Level 4:	Precisely corrected image by using Digital Terrain Model (DTM)

Remarks: Main product is level 2.

Table 3 Tentative JERS-1 SAR data processing types

Map projection method:	UTM (Universal Transverse Mercator) SOM (Space Oblique Mercator) PS (Polar Stereo)
Resampling method:	Nearest Neighbor (NN) Cubic Convolution (CC)
Frame Size	75km x 75km (level 0: 75km x 90km)
Pixel Size	3.125m (1 look), 12.5m (3 looks)
Window Function	Square, Riesz, Hamming
Output Data Type	Amplitude/Logarithmic expression
Recording Format (CCT)	Super structure (Based upon CEOS WGD SAR format standardization)
Recording density(CCT)	6250 BPI, 1600 BPI
Number of Tracks (CCT)	9

3. Data processing flow of SAR data

3.1 SAR-580 data

NASDA collected SAR data over 8 test sites (Tsukuba, Hiratsuka, Off-shore of Hiratsuka, Mt.Fuji, Oshima, Miyakejima, Akita (Futatsui) and Shizukuishi/Kosaka) in Oct.28-Nov.4, 1983 by using Convair 580 with variable parameter SAR which are chartered from CCRS based upon the arrangement between CCRS and NASDA which were concluded on Aug.23, 1983.

NASDA processed about 100 scene of SAR data in 1984 by newly developed auto-focusing method. Fig.1 shows the data processing flow of SAR-580 data. There are two methods for auto-focusing: (1)to employ the relationship between target positional shift and processing parameter error (2)to employ the relationship between image contrast in the processed image and processing parameter error. The first method was used for our program. Main feature of this program is to employ auto-focusing method both in range and in azimuth direction. The feed back loop of auto-focusing converges within 2-3 repetitions.

3.2 JERS-1 SAR data

Since JERS-1 has mission data recorder (MDR), it is possible to collect SAR data and OPS data all over the world excluding some of arctic and antarctic region (SAR:86.015°N-90°N, 78.661°S-90°S, OPS:82.338°N-90°N, 82.338°S-90°S). If only land and coastal region is observed, about 30000 scenes are obtained. JERS-1 data will be received by Earth Observation Center (EOC) in Hatoyama, by Fairbanks ground station and Gatineau ground station in Canada. Data will be dumped at Fairbanks ground station. There may be other foreign ground stations to receive JERS-1 data within limited power and stored command number for spacecraft.

Minimum requirement of observation by JERS-1 is to observe land and coastal area in the world once during two years for SAR and twice during two years for OPS.

Fig.2 shows the data processing flow for JERS-1 data. In order to get high quality image, it is necessary to introduce auto-focusing method even to spaceborne SAR data processing. In case of JERS-1 SAR data processing, this auto-focusing method will be applied to azimuth direction by using relationship between target positional shift and processing parameter error. In principle, it is impossible to apply this method to very flat area such as calm ocean.

Processing level of JERS-1 SAR data will be explained as follows:

(a) Level 0: Raw data

Radar hologram data including data and parameters required for processing such as orbital data, attitude data, on-board calibration data, PRF, Sensitive Time Control (STC).

(b) Level 1: Basic image

Range and azimuth compressed image by using FFT accompanied by look processing (1 look and 3 looks) and auto-focusing. 1 look image is superior to 3 looks image in obtaining higher spatial resolution and detailed information.

(c) Level 2: System corrected image (Bulk image)
Geometrically and radiometrically corrected image. Geometric correction includes conversion from slant range coordinates to ground range coordinates, resampling. Radiometric correction includes STC compensation, antenna pattern compensation, incidence angle compensation, receiver gain compensation. (Position error: ±1km)
(d) Level 3: Precisely corrected image
Precisely corrected by using GCP. By using GCP and map coordinates, antenna position is estimated and by using orbital data and attitude data precisely corrected image is obtained. (Position error: spatial resolution)
(e) Level 4: Geocoded image
Position error due to terrain relief is eliminated by using digital terrain model (DTM).

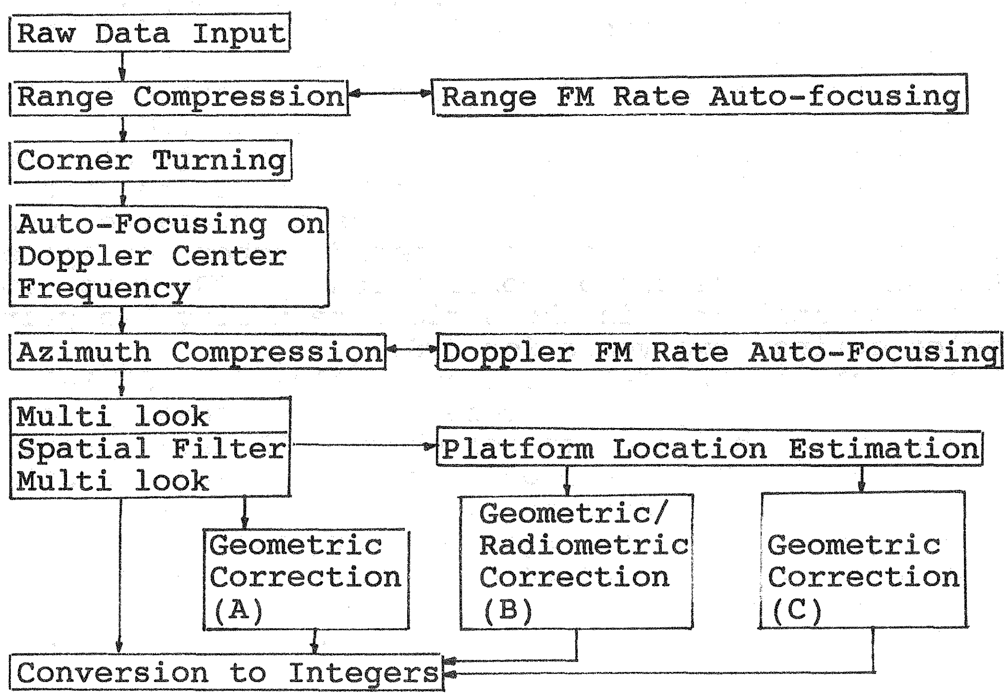


Fig.1 Data processing flow of SAR-580 data

Note 1. JERS-1 SAR simulation software is included.
2. Geometric correction (A): The multi-look image is converted from slant range coordinates to ground range co-ordinates and resampled to adjust image pixel spacing.
3. Platform location estimation: Using the GCP coordinates of the multi-look image and the map, platform position is estimated as an approximate function.
4. Geometric and radiometric correction (B): The results of the platform location estimation are used to correct for geometric distortion in the image data. The data is projected onto the map co-ordinates and radiometric distortion is corrected.
5. Geometric correction (C): Geometric distortion is corrected for terrain relief, using digital terrain model.

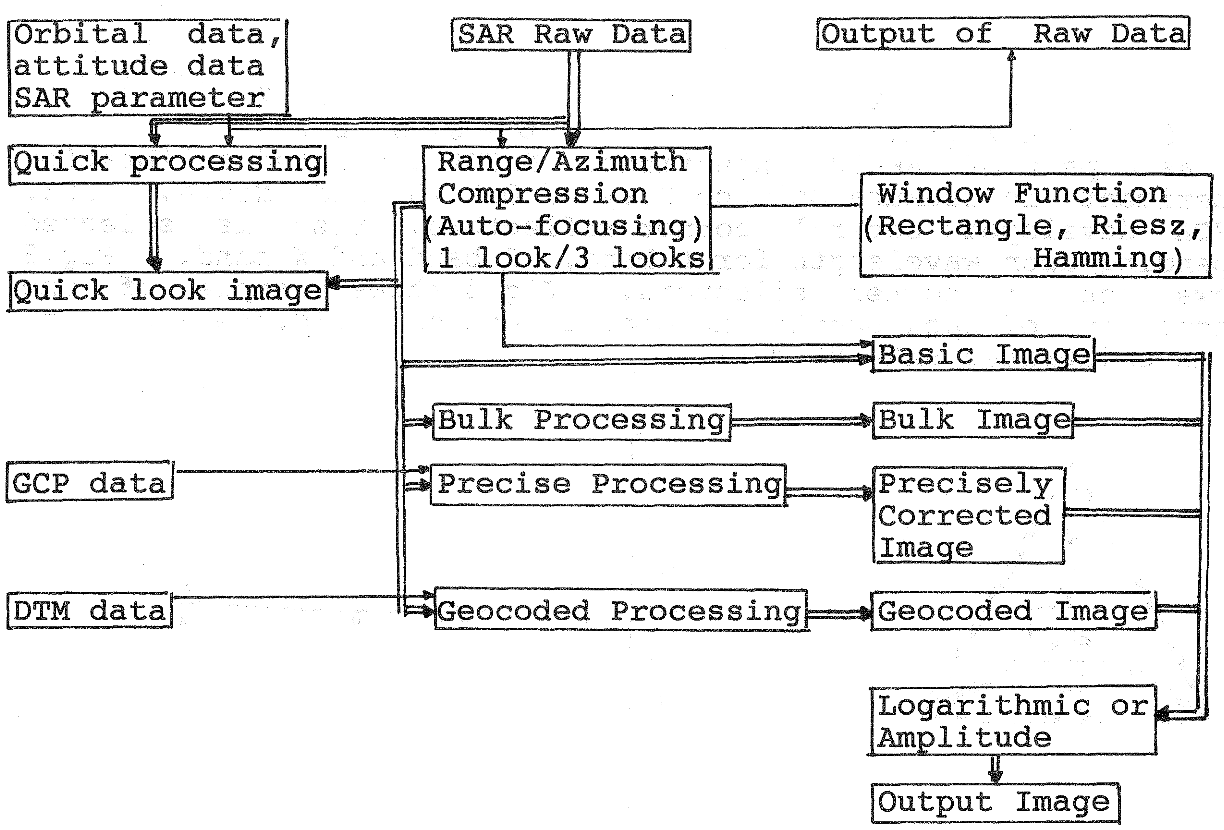


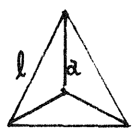
Fig.2 Data processing flow of JERS-1 SAR data

4. Calibration flow of SAR data

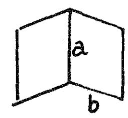
4.1 SAR-580 data

Table 4 Type of corner reflectors

Type	Size ℓ	Number	Testsite
INTERA corner reflector	1725mm	3	Tsukuba Science City
NASDA corner reflector A	1049mm	1	ditto
ditto B	822mm	4	ditto
ditto C	502mm	1	ditto
ditto D	376mm	1	ditto
ditto E	141mm	1	only for test
INTERA corner reflector	287mm	3	Tsukuba Science City
ERSDAC corner reflector	714mm	5	Oshima
ISAS corner reflector (Dihedral corner reflector)	150mm/ 177mm	4	Tsukuba Science City



$\sigma_c = 4\pi a^4 / (3\lambda^2)$



$\sigma_c = 8\pi a^2 b^2 / \lambda^2$

As a part of SAR-580 experiment, NASDA conducted calibration experiment in Tsukuba Science City on Oct.28 and Nov.4, 1983. NASDA developed several corner reflectors. Size is selected depending upon wavelength for L band, C band and X band. Fig.3 shows one of corner reflectors. Fig.4 shows example of the dependency of back scattering coefficient on incidence angle by using calibrated SAR-580 data.

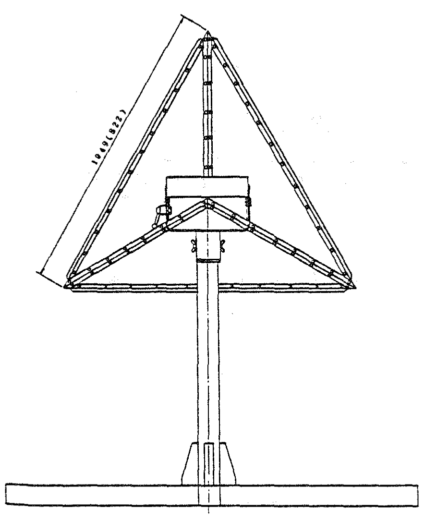


Fig.3 Example of corner reflector

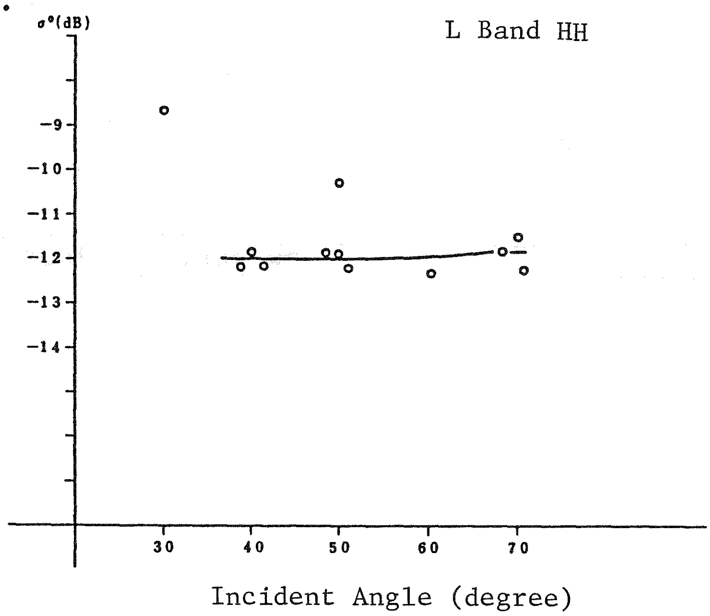


Fig.4 Dependency of on incidence angle in case of field in Tsukuba

4.2 JERS-1 SAR data

Calibration of JERS-1 SAR data is essential in various field of application such as land use, monitoring of vegetation. Fig.5

shows calibration flow of JERS-1 SAR data.

Raw Data
↓
Range Compression
↓
Corner Turn
↓
Azimuth Compression
↓
Relative Calibration
↓
Calculation of 6° for Corner Reflectors/Transponders
↓
Calculation of Spot Area for Corner Reflectors/Transponders
↓
Absolute Calibration

Fig.5 Calibration flow of JERS-1 SAR data

In Japan, there are very few testsites for space borne SAR calibration because very few flat and uniform area exist. Therefore, it is necessary to develop special method for calibration which can be utilized in Japan.

If transponder set near lake or pond has delay time such as 5-6 μ sec between receiving and transmitting, point target appear in the lake or the pond. Since back scattering coefficient of the lake or pond is sufficiently small, it is easy to calibrate SAR data.

5. Evaluation program

Before SAR-580 experiment, committee was held 4 times and flight course and content of experiment were studied. As part of SAR-580 experiment,evaluation program was made and processed SAR-580 data were provided to principal investigators who participated in this program. All fruitful results were presented at SAR-580 experiment symposium in Tokyo on Sep.25, 1986.

The evaluation theme of SAR-580 data is as follows:

(a)Joint Research Organization

National Research Center for Disaster Prevention	On detection of ocean waves Analysis of urban land use utilizing SAR-580 image Possibility for interpretation on landslide landform

National Institute for Environmental Studies	Soil moisture measurement using SAR-580 data
Forestry &Forest Product	Evaluation of SAR-580 data on forest type classification
Tokai University Research and Information Center	An optical image display method and effectivity for land cover classification using SAR data
Earth Resources Satellite Data Analysis Center(ERSDAC)	Geologic analysis of SAR-580 data

(b)Cooperative organization

Institute of Space and Astronautical Science (ISAS)	Studies on microwave signature
Meteorological Research Institute	Investigation on reflectivities of radar antenna reflection measured by SAR SAR imageries obtained in the sea areas around the Oshima and Miyake islands Inspection of ground surface state of Oshima and Miyakejima volcanoes with SAR-580 images
Geographical Survey Institute	Feasibility study of SAR image interpretation for planimetric objects
Department of Computer Science, Iwate University	Investigation of correspondency between Images in SAR-580 data and characteristics of land cover objects
Science Information Processing Center, University of Tsukuba	Image processing of synthetic aperture radar (SAR-580) data
Remote Sensing & Image Research Center of Chiba University	Evaluation of SAR-580 imagery
Kanazawa Institute of Technology	The classification of the ground cover types on the rugged terrain by the SAR-580 data
College of Engineering, Hosei University	Fundamental study for verification of classifying SAR images by checking the objects in field
Toba National College of Maritime Technology	Sea surface phenomena investigation using the SAR data
Remote Sensing Technology Center of Japan (RESTEC)	Detection of terrain height from stereo SAR image and optically processed images Accuracy of land cover classification by SAR image

CRL participated in SIR-B experiments planned and conducted by JPL in collaboration with several agencies including NASDA in Oct.,1984 and it was found that a simulated oil slick area over sea was clearly detected (Ref.8).

6. Conclusion

EOC, NASDA is developing JERS-1 ground system (Conceptual design). Processing level and format was studied in the committee on JERS-1 ground system. Considering user requirement and capability of spacecraft, basic and detailed design will begin from 1989.

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