TPM
Multi-Mission Production Functionality Porting to Linux

TPML Updated Mission Instrument Documentation JERS

[TN-UMID-JERS]

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1 PURPOSE AND SCOPE

This document contains an overview of the JERS mission/instrument characteristics. In particular, this document gives detail about the mission history and background, correction algorithm applied.

1.1 DOCUMENT STRUCTURE

This document consists of 5 main sections and they are:

Chapter 1	The current chapter.
Chapter 2	It contains the applicable and reference documents.
Chapter 3	It contains the mission history and background.
Chapter 4	Mission/instrument characteristics.
Chapter 5	Correction algorithm description.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

Document Title	Identifier	Internal Reference
TPML System requirements Document	TPML-TN-ACS-GS-0101 v1.2, 22-06-2007	[TN-REQ]
TPML Interface Control Document	TPML-ID-ACS-GS-0157 v1.8	[ICD]

2.2 REFERENCE DOCUMENTS

Document Title	Identifier	Internal Reference
JERS-1 to Ground Station Interface Description. Rev 2, 1 October 1990 NASDA	HE-88023	[JERS-ICD]
Map projections : theory and applications. Frederick Pearson.	-	[MAP]
Orbital mechanics. Vladimir A. Chobotov.		[ORB]
Operational algorithm to correct the along track and across track striping in the JERS-1 OPS images S Bizzi, O Arino, P Goryl - International Journal of Remote Sensing, 1996	-	[STRIP]

2.3 ACRONYMS AND ABBREVIATIONS

ACS	Advanced Computer Systems S.p.A.
EO	Earth Observation
GCP	Ground Control Point
G/S	Ground Segment
IFOV	Instantaneous Field of View
JERS	Japanese Earth Resources Satellite
LOS	Line Of Sight
LUT	Look Up Table
MSR	Microwave Scanning Radiometer
NASDA	National Space Development Agency of Japan
OPS	Optical Sensor
SAR	Synthetic Aperture Radar
TBC	To Be Clarified
TBD	To Be Defined
TM	Thematic Mapper

TOD	True Of Date
UTM	Universal Transverse Mercator
VTIR	Visible and Infrared Radiometer

3 MISSION HISTORY AND BACKGROUND

JERS-1 is an Earth Observation Satellite to cover the global land area for national land survey, agriculture, forestry, and fishery, environmental protection, disaster protection, and coastal monitoring, etc. focussing on observation around the word and resource exploitation.

It Was launched into a solar-synchronous sub-recurrent orbit at an altitude of 568 km with a recurrent period of 44 days by the H-I launch vehicle on February 11, 1992 from National Space Development Agency of Japan (NASDA) Tanegashima Space Center, and has been continuing to observe and collect data with a mission data recorder by the high performance Synthetic Aperture Radar (SAR) and Optical Sensor (OPS).

SAR is an active sensor which transmits microwave and observes characteristics, inequality, slope in th surface on the earth, etc. without being influenced by the weather day and night due to scattered waves from the Earth.

OPS can observe in seven bands from the visible region to short wave infrared band and is capable of stereoscopic observation by forward look.

Figure 3-1: JERS-1 satellite

- **JESR 1**
- **Launch Date**: February 11, 1992
- **Status**: out of service since 1998
- **Sensors**: SAR and OPS
- **Altitude**: nominally 568 km
- **Inclination**: 98°
- **Orbit**: polar, sun-synchronous
- **Period of Revolution** : 96 minutes; ~14 orbits/day
- **Repeat Coverage** : 44 days
- **Local Time at Descending Node**: a.m. 10:30

4 MISSION/INSTRUMENT CHARACTERISTICS

4.1 SYNTHETIC APERTURE RADAR (SAR)

Synthetic Aperture Radar is just like the radars used on ships and airplanes. It is an active microwave sensor that transmits in microwave and detects the wave that is reflected back by objects. SAR is completely different from passive optical sensors carried by Landsat or Japan's Marine Observation Satellite – 1/1b (MOS 1/1b). It enables high resolution, high-contrast observation, and accurate determination of topographic features, such as undulations and slopes, independently of weather conditions, even during fog or cloud cover.

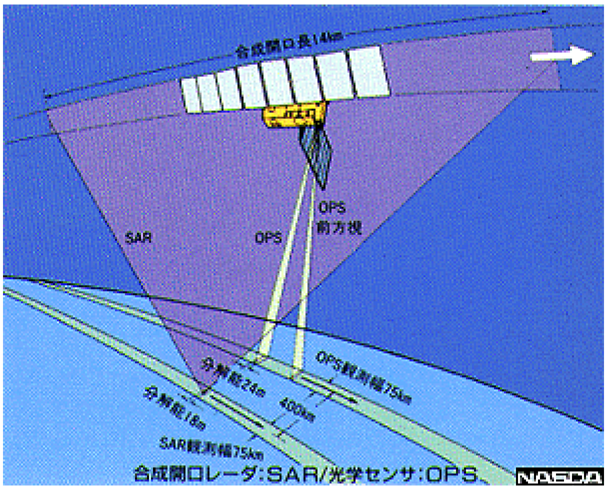


Figure 4-1: SAR instrument

Swath width	75 km
Resolution	18 m x 18 m
Observation Frequency	1,275 MHz
Off nadir angle	35 deg

Table 4-1: JERS SAR main characteristics

4.1.1 JERS-1 SAR Spatial Characteristics

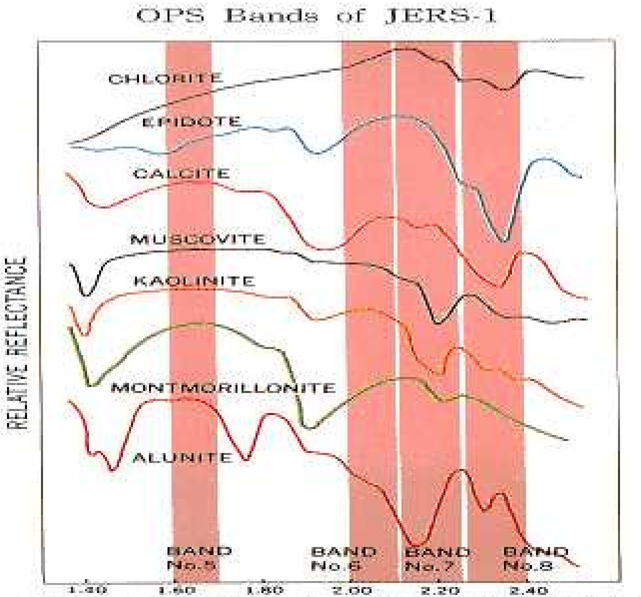
- Temporal Resolution: 44 days
- Image Size: 75 km X 75 km
- Swath: 75 km
- Programmable: no

4.2 OPTICAL SENSOR (OPS)

Optical sensor provides better ground resolution than MOS-1 MESSR. The OPS separates the light reflected from the ground into seven spectral bands from visible to short-wave infrared and employees CCD's. Detailed pictures from the satellite allow us to survey the earth resources, monitor sea status and obtain other information useful for an accurate earth monitoring.

Swath width	75 km
Resolution	18 m x 18 m
Observation bands	Visible near infrared band: 3 Shortwave infrared band: 4 Stereoscopic band: 1

Table 4-2: JERS-OPS main characteristics



BAND No.	WAVELENGTH(μm)	BAND No.	WAVELENGTH(μm)
1	0.52 — 0.60	5	1.60 ~ 1.71
2	0.63 — 0.69	6	2.01 ~ 2.12
3	0.76 — 0.86	7	2.13 — 2.25
4	0.76 — 0.86(STEREO)	8	2.27 — 2.40

Figure 4-4: The JERS-1 OPS band configuration and their effectiveness in mineral classification with SWIR relative reflectance pattern.

Band Number	µm	Resolution
B1	0.52-0.60	18 m X 18 m
B2	0.63-0.69	18 m X 18 m
B3	0.76-0.86	18 m X 18 m
B4 (stereo)	0.76-0.86	18 m X 18 m
B5	1.60-1.71	18 m X 18 m
B6	2.01-2.12	18 m X 18 m
B7	2.13-2.25	18 m X 18 m
B8	2.27-2.40	18 m X 18 m

Table 4-3: JERS-OPS spectral characteristics

4.2.1 JERS-1 OPS Spatial Characteristics

- Temporal Resolution: 44 days
- Image Size: 75 km X 75 km
- Swath: 75 km
- Programmable: no

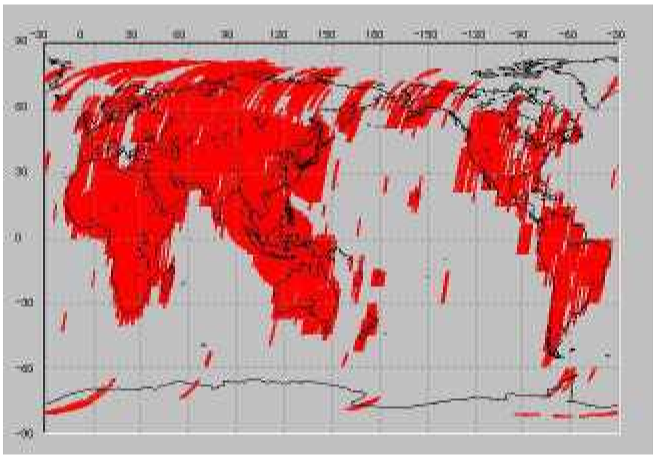


Figure 4-4: The areas covered by OPS observations during the operation of JERS-1 (11.Feb.1992~12.Oct.1998), are shown in red area of following chart.

5 CORRECTION ALGORITHM DESCRIPTION

5.1 RAW DATA FORMAT AND ACQUISITION CHARACTERISTICS

A detailed description of the JERS OPS and SAR raw format and the related acquisition characteristics can be found in [JERS-ICD].

In more detail:

- Data format, OPS section 3.7 and SAR section 4.3;
- Acquisition characteristics section 2.

5.2 GEOMETRIC CORRECTION

In this section we describe the geometric corrections of the optical sensors (OPS). The Synthetic Aperture Radar instrument is not part of the TPML project; therefore the relative processing algorithms are not handled here.

5.2.1 Overview

Remote Sensing data includes two types of geometric errors or distortions, that is, internal error and external error. The internal error is mainly resulted from the geometric characteristics or performance of sensor, therefore, it can be corrected systematically only if the calibrations data or parameter for correction can be given.

On the other hand, the external error is resulted from the altitude of the platform and the geometric configuration of the objects. The distortions resulted from the altitude such as the variations of three axes, that is, roll, pitch and yaw, the velocity or the altitude can be corrected systematically only if these variations can be precisely measured on board.

5.2.2 Processing levels

The JERS-OPS IPF produces only the Level 2 product. he Level 2 geometric corrections of systematic effects (panoramic effect, Earth curvature and rotation) are handled. Internal distortions of the image are corrected for measuring distances, angles and surface areas. In the following table are reported the principal systematic effects managed by the processor.

Satellite Orbit	Satellite position and velocity and estimated error
Satellite Attitude	Satellite attitude variation and measurement error
Rotation of the earth	Skew effect by rotation of the earth
Shape of the earth	Curvature of the earth

Band-to-band registration	Deviation of CCD sensor mounting position Focal length difference between bands
Image distortion	Distortion of optical system Deviation of CCD sensor mounting position
Alignment	Deviation of sensor optical axis

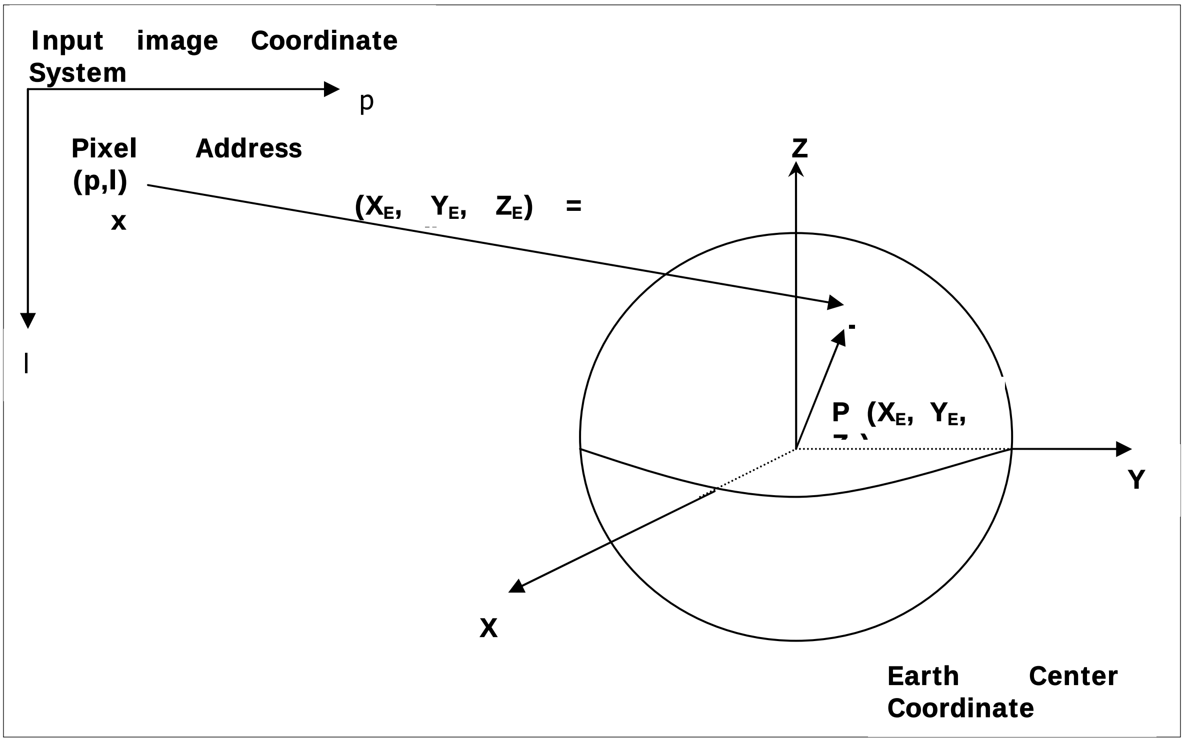
.

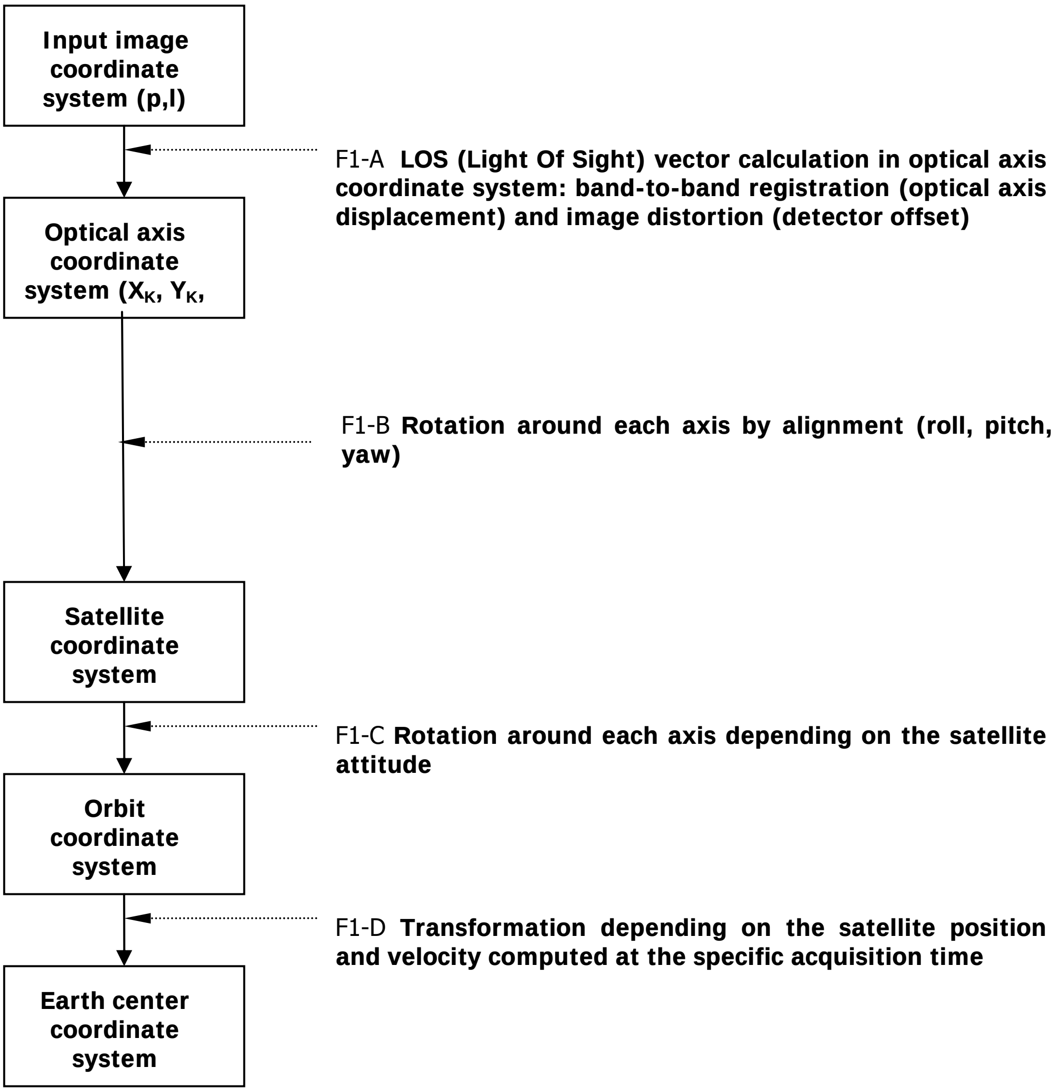
5.2.3 Transformation from Input Coordinate to Output Coordinate

The mapping from the input coordinate to the output coordinate is made by using four coordinate transformations reported in the following table.

Name	Description
F1	Convert the line pixel from input coordinate system to coordinate values in the Earth Center Coordinate.
F2	Convert the Earth Center Coordinate into longitude and geodetic latitude.
F3	Convert the longitude and geodetic latitude into map coordinate system (UTM).
F4	Convert the map coordinate system into pixels and lines on the output coordinate system.

5.2.3.1 F1: Convert pixel addresses on the input coordinates into scan point on the earth center coordinates


Input image Coordinate System
p
Pixel Address (p,l)
x
l
(X_E, Y_E, Z_E) =
Z
P (X_E, Y_E,
Y
X
Earth Center Coordinate



F1-A **LOS (Light Of Sight) vector calculation in optical axis coordinate system: band-to-band registration (optical axis displacement) and image distortion (detector offset)**

F1-B **Rotation around each axis by alignment (roll, pitch, yaw)**

F1-C **Rotation around each axis depending on the satellite attitude**

F1-D **Transformation depending on the satellite position and velocity computed at the specific acquisition time**

STEP F1-A

(l,p) -> (l + Δl, p + Δp) due to detector offset (D) and optical axis offset (OA): $\Delta l = \Delta l^{D} + \Delta l^{OA}$ and $\Delta p = \Delta p^{D} + \Delta p^{OA}$

Band-to-band registration/optical axis offset: It's the deviation between the central pixel of CCD and its ideal center (indicated in the number of pixel).

"Displacement from Ideal Optical Axis" and Image Distortion/Detector Offset are the displacement of each pixel from its ideal position and are defined in the JERS 1 Data User Handbook [JERS-DUH].

Now, we are able to compute the across_angle and along_angle for each (l,p) point of the input space coordinate:

$$\text{across\_angle} = -\ \text{IFOV}(\text{system, band}) \times (p + \Delta p - \text{centrePixel})$$
$$\text{along\_angle} = \text{IFOV}(\text{system, band}) \times \Delta l$$

where IFOV is the instantaneous field of view.

Thus, the LOS in the optical axis coordinate system is:

$$X_K = \sin(\text{across\_angle}) \times \cos(\text{along\_angle})$$
$$Y_K = \sin(\text{along\_angle})$$
$$Z_K = \cos(\text{across\_angle}) \times \cos(\text{along\_angle})$$

STEP F1-B

Rotation around each axis by alignment (roll, pitch, yaw) in order to align the JERS instrument to the spacecraft.
The rotation angle ω around X axis is the roll angle, the rotation angle φ around Y axis is the pitch angle and
the rotation angle κ around Z axis is the yaw angle.

$$r_S = R_Z(\kappa)\, R_Y(\varphi)\, R_X(\omega)\, r_M$$

$$\mathbf{R}_x(\omega) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{pmatrix} \qquad \mathbf{R}_y(\varphi) = \begin{pmatrix} \cos\varphi & 0 & -\sin\varphi \\ 0 & 1 & 0 \\ \sin\varphi & 0 & \cos\varphi \end{pmatrix} \qquad \mathbf{R}_z(\kappa) = \begin{pmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

STEP F1-C

Rotation around each axis depending by the attitude in order to align the spacecraft to the Orbit Coordinate System. The attitude rotation angles are sampled each second and provided by the satellite telemetry.
The rotation angle ω(t) around X axis is the roll angle, the rotation angle φ(t) around Y axis is the pitch angle and the rotation angle κ(t) around Z axis is the yaw angle.

Note that the yaw angle is not determined; therefore we assume it set to zero.

$$r_O = R_Y(\varphi(t))\, R_X(\omega(t))\, r_S$$

$$\mathbf{R}_x(\omega) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{pmatrix} \qquad \mathbf{R}_y(\varphi) = \begin{pmatrix} \cos\varphi & 0 & -\sin\varphi \\ 0 & 1 & 0 \\ \sin\varphi & 0 & \cos\varphi \end{pmatrix} \qquad \mathbf{R}_z(\kappa) = \begin{pmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

In order to accomplish this step it is required to know for each line of the input space the corresponding acquisition time.

STEP F1-D

Given the LOS vector r_O in the Orbit Coordinate System, this step computes the intersection of the line of sight with the earth surface and compute this intersection in the Earth Centred Coordinate System (ECEF).

This transformation depends on the satellite position and velocity computed at the specific acquisition time (via orbit propagator or via interpolating functions) that defines the Orbit Coordinate System.

The definition of the orbital co-ordinate frame is as follows:

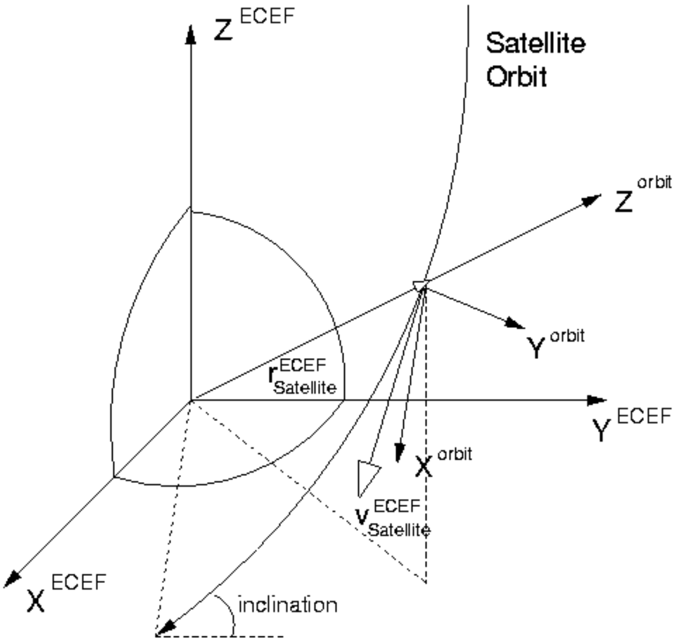
- Origin at the position of the barycentre of the satellite
- ZOrbit pointing from the earth center of mass (origin of ECEF co-ordinate frame) to satellite center of mass
- YOrbit directed along the normal of the actual orbital plane, which is pointing to the actual angular momentum of the satellite motion in orbit
- XOrbit completes the right handed triad

$$\mathbf{e}_z^{ECEF} = \frac{\mathbf{r}_{Satellite}^{ECEF}}{\left|\mathbf{r}_{Satellite}^{ECEF}\right|}$$

$$\mathbf{e}_y^{ECEF} = \frac{\mathbf{r}_{Satellite}^{ECEF} \times \mathbf{v}_{Satellite}^{ECEF}}{\left|\mathbf{r}_{Satellite}^{ECEF} \times \mathbf{v}_{Satellite}^{ECEF}\right|},$$

$$\mathbf{e}_x^{ECEF} = \mathbf{e}_y^{ECEF} \times \mathbf{e}_z^{ECEF}$$

where $\mathbf{r}^{ECEF}_{Satellite}$ is the actual satellite position and $\mathbf{v}^{ECEF}_{Satellite}$ the actual velocity of the satellite expressed in the ECEF co-ordinate frame. It is noted, that the velocity vector is not collinear with the x-axis of the orbital co-ordinate frame.



5.2.3.2 F2: convert the coordinate values in the earth center coordinate system into longitude and latitude values (geodetic)

See [ORB] for a detailed description of the mathematical steps.

5.2.3.3 F3: convert longitude and latitude values (geodetic) into points on the map coordinate system (UTM)

This step is implemented by any Projection Transformation package. See [MAP] for a detailed description of the mathematical steps.

5.2.3.4 F4: convert the coordinate values on the map coordinate system into pixels and lines on the corrected output image coordinate system

Defining the Frame

The first step in the gridding process is to determine the geographic extent of the output image to be generated by the resampler. This geographic extent of the output image space is referred to as the output space "frame", and is specified in output image projection coordinates.

For JERS OPS instrument we consider only the path oriented product in Universal Transverse Mercator (UTM) projection. The frame is a preset number of lines and samples based on the OPS scene size and the maximum rotation needed to create a path oriented product.

For a pixel size of 18 meters, a rectified image in the UTM projection is approximately 4000 lines by 4000 + 3-5 % samples in size. The number of pixel of the output image must be determined in order to avoid the missing of any portion of the input image for all the admitted rotation angles.

Path Oriented Framing and Rotation

A path oriented projection is basically a rotation from a typical "map-north" up projection that better represents the near polar orbit of the JERS-1 satellite (nominal inclination angle of 98 degrees). The path oriented projection also does a better job of maintaining the scan line to the output space line.

The first step in generating a path oriented projection is to calculate the center location in the output space that the frame is to be rotated about. The scene centre is computed by another task which goes before the geometric correction task.

The frame is centered in the output projection space at this projection coordinate and will be rotated about this point.

$$(SC\_Lat, SC\_Long) \rightarrow (center\_proj\_x, center\_proj\_y)$$

To this scene center point it is associated the output coordinate $(center\_pixel, center\_line) = (number\_pixels/2, number\_lines/2)$

Given a point in the standard UTM projection, first it is rotated by the rotation angle φ:

$$proj\_x' = delta\_x * \cos(angle) + delta\_y * \sin(angle) + center\_proj\_x$$
$$proj\_y' = -delta\_x * \sin(angle) + delta\_y * \cos(angle) + center\_proj\_y$$

where $delta\_x = proj\_x - center\_proj\_x$ and $delta\_y = proj\_y - center\_proj\_y$

The corresponding output coordinates are given as follows:

$$output\_pixel = (proj\_x' - center\_proj\_x)/pixel\_size + center\_pixel$$
$$output\_line = (proj\_y' - center\_proj\_y)/pixel\_size + center\_line$$

The rotation angle φ (grid heading angle) is the sum of the scene heading angle and the UTM convergence angle.

The UTM convergence angle is computed as follows:

1. First, convert the scene center lat/long to map projection X1, Y1 and moving to a point slightly north of the scene center. This is done by adding 1 microradian (0.2seconds) to the scene center latitude and projecting this point to X2, Y2.
2. Next, the azimuth of this line is computed in grid space as the arctangent of the X difference (X2-X1) over the Y difference (Y2-Y1). This is the grid azimuth of geodetic north at the scene center.

5.2.4 Auxiliary Files

The JERS-1 OPS IPFs are able to read the following auxiliary file:

- State Vector file in ACS format defined in [ICD].

5.3 RADIOMETRIC CALIBRATION

For JERS OPS we apply a **statistical calibration.** The statistical calibration computes the LUTs making a statistical analysis on the scene data for any band. Histograms of any detector of any band will be computed and they are used to select the reference detector for each band. The detector with the highest gain value is considered as reference and the LUTs are computed respect to it.

A detailed Description of the algorithm can be fond in [STRIP].

End of Document