KOMPSAT-2 Image data Manual

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Abbreviations and Acronyms

CAP	Catalogue And Product generation S/W
DSM	Direct Sensor Modeling
EFL	Effective Focal Length
FOV	Field Of View
GSD	Ground Sample Distance
IRPE	Image Reception and Processing Element
KARI	Korea Aerospace Research Institute
KGRS-2	KOMPSAT-2 Grid Reference System
KGS	KOMPSAT-2 Ground Segment
KOMPSAT-2	KOrea Multi-Purpose SATellite
LEOP	Launch and Early Operations Phase
LOD	Line-Of-Detector
LOS	Line-Of-Sight
MCE	Mission Control Element
MS	Multi-Spectral
MSC	Multi-Spectral Camera
MTF	Modulation Transfer Function
PAD	Precision Attitude Determination
PAN	Panchromatic
PDTS	Payload Data Transmission Subsystem
POD	Precision Orbit Determination
PSS	Pass Scheduling System
RAS	Receiving and Archiving System
RFM	Rational Function Model
RPC	Rational Polynomial Coefficients
SNR	Signal to Noise Ratio
TDI	Time Division Integration

1. Introduction

The KOMPSAT-2 Image data Manual was designed and produced by KARI. This document intends for users of data supplied by KOMPSAT-2, and includes basic information about the KOMPSAT-2 system, processing & specification of KOMPSAT-2 imagery data and a brief overview & evaluated values of the theoretical concepts of image quality.

2. The KOMPSAT-2 System

2.1. Mission

The KOMPSAT-2 system allows the acquisition of PAN images at spatial resolution of 1 meter and MS images of 4 meters from space. The mission objectives of the KOMPSAT-2 System are to provide the following capabilities in the field of earth observation.
The KOMPSAT-2 system provides 1) surveillance of large scale disasters and their countermeasures, 2) acquisition of independent high resolution images for GIS, and 3) composition of printed maps and digitized image maps on domestic and overseas territories to users.
Images of the KOMPSAT-2 system may be used for balanced development of world territories and survey of natural resources. Also, KOMPSAT-2 will continue to support satellite earth observation activities that have been served by the KOMPSAT-1 system.

2.1.1. Overview

The Second KOrea Multi-Purpose SATellite (KOMPSAT-2) System consists of Space Segment and Ground Segment. The KOMPSAT-2 Space Segment consists of a single KOMPSAT-2 satellite flying on a sun-synchronous low earth orbit and the MSC as a primary payload. The KGS consists of the KARI site where is located in Daejeon, Korea (and several user sites); Launch Service Segment, and various external interfaces. The KARI site is comprised of the primary Mission and Control Element and the Image data Reception and Processing Element. In order to satisfy the overall missions of the KOMPSAT-2 system the KARI site provides the capability to monitor and control the KOMPSAT-2 satellite, to conduct KOMPSAT-2 mission planning, and to receive, process, and distribute image data. The KARI site has RF communications links with the satellite at S-band (uplink and downlink) and X-band (downlink only). KOMPSAT-2 external interfaces include interfaces to external users of KOMPSAT-2 data, to additional ground stations to support LEOP and to augment X-band data acquisition, to weather data to support mission operation, and to International GPS Service providing high accuracy GPS data products to scientific users.

2.1.2. Mission Orbit Maintenance and Lifetime

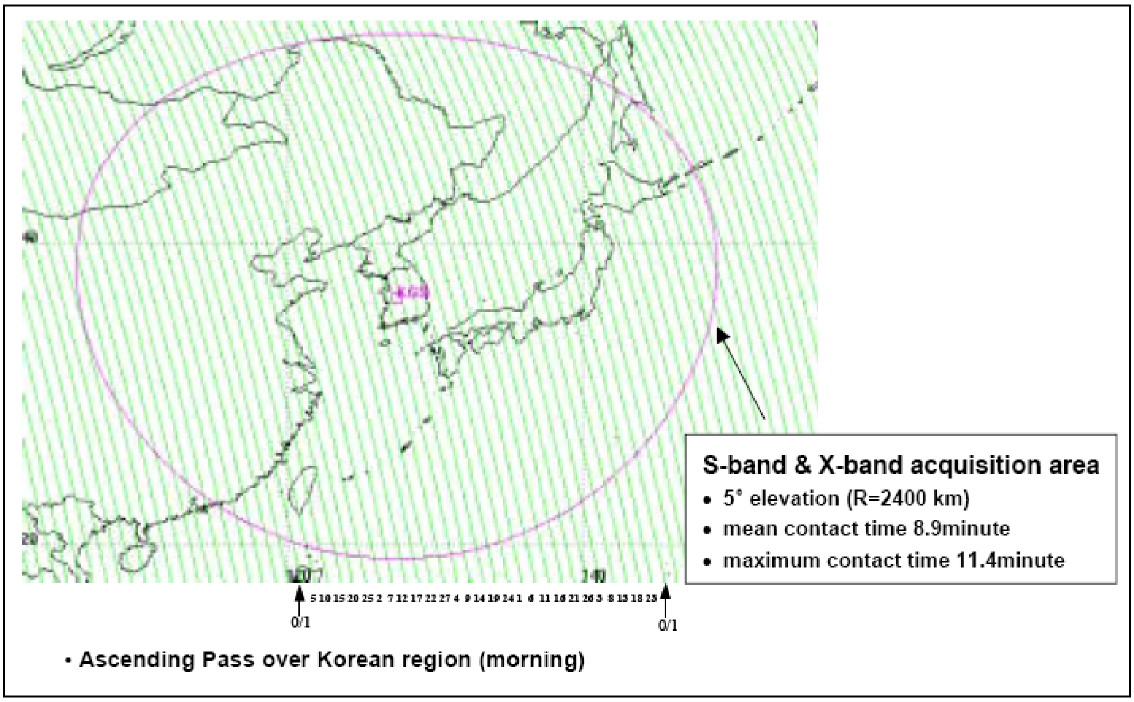

Figure 1 Example of the sequence of ascending passes

The Mission orbit of the KOMPSAT-2 is a sun-synchronous circular orbit with an altitude of 685.13 ±1 km. The Orbit inclination is 98.13 ± 0.05 degrees and the eccentricity from 0 to 0.001. The satellite operates with a nominal local time of ascending nodes of 10:50 AM +10/-15 min. Figure 1 shows ascending passes (solid lines) of the KOMPSAT-2 for 28 day and a boundary of contact (circle) between the KOMSPAT-2 and the KARI site based on the minimum elevation for contact of 5 degrees. The satellite passes Korean region during the day along ascending orbits and during the night along descending orbits. The KOMPSAT-2 satellite is designed for an operational service life of 3 years on the mission orbit.

2.1.3. Imaging Performance

The KOMPSAT-2 will allow the generation of high resolution images with a GSD of better than 1 m for PAN data and 4 m for MS data with nadir viewing condition at the nominal altitude of 685 km. The MSC has a single PAN spectral band between 500 - 900 nm and 4 MS spectral bands between 450-900 nm. PAN imaging and MS imaging can be operated simultaneously during mission operations. The swath width is greater than or equal to 15 km at the mission altitude for PAN data and MS data. The system is equipped with a solid state recorder to record images not less than 1,000km long at the end of life. The satellite fulfills drift and jitter accuracy requirements. The maximum LOS (LOS) drift will be 0.005 deg/sec and the maximum

LOS jitter will be 0.4 micro-radians over 4.7 milliseconds. The satellite can be rolled up to ±30 degrees off-nadir to pre-position the MSC swath. The KOMPSAT-2 can provide across-track stereo images by multiple passes of the satellite using off-nadir pointing capability. The satellite is compatible with daily revisit operation by off-nadir pointing with degraded GSD. Also, the image products according to the requested products quality standard can be made within one (1) day after satellite passes over the KGS. The spacecraft shall provide the yaw steering maneuver to limit cross-track smearing of MSC image data with TDI operation.

2.1.4. Mission Constraints

< Duty Cycle and Maximum Imaging Time >

The MSC operates at up to a 20% duty cycle per orbit. The PDTS of the MSC can provide a 128 Gbits on-board storage capability to support image collection outside of the boundary of contact of a ground station.

< Sun Incidence Angle >

Sun incidence angle in the KOMPSAT-2 satellite is the incidence angle of the sunlight with respect to telescope entrance plane of the payload module. This incidence angle should not exceed 34 degrees for protecting the Optical Module of the MSC. Therefore, it constrains satellite operations during the separation from launch vehicle, roll/pitch maneuver, maneuver mode, and etc.

< Opposite Roll Tilt >

Opposite roll tilt means that satellite’s roll direction for imaging and the direction of the X-band antenna for transmission are opposite. The maximum opposite roll tilt for imaging and real-time transmission to ground station is limited to 15 degrees. This angle is limited to avoid the interference between the X-band antenna and the structure of the satellite. Therefore, when a mission operation is real-time imaging and transmission, an operator has to confirm whether it is applicable to an opposite roll tilt operation or not by considering a ground pass of the satellite.

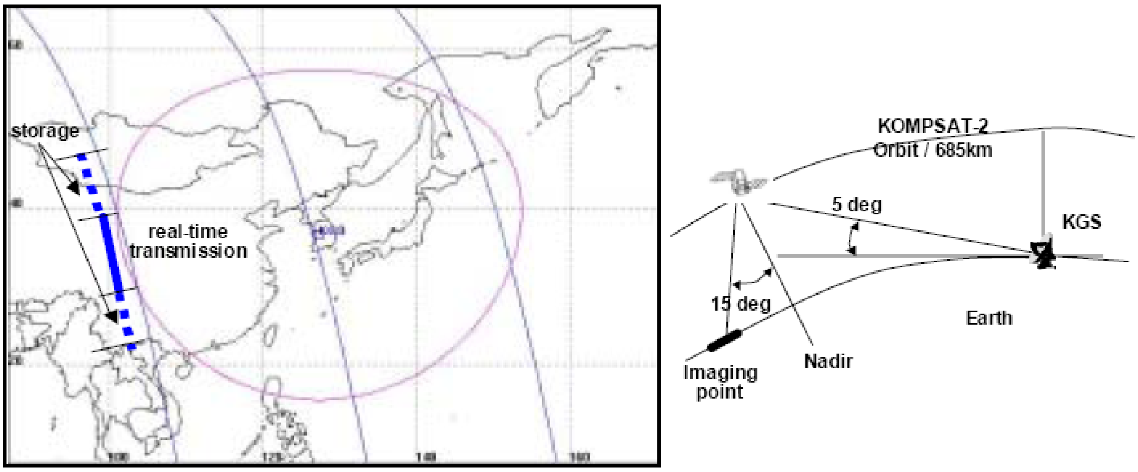

Figure 2 Opposite Roll Tilt Example

2.2. MSC

The KOMPSAT-2 payload consists of the MSC with the PDTS. The MSC is a high spatial resolution imaging sensor which collects visible image data of the earth's sunlit surface.

The MSC, the primary payload for the KOMPSAT-2, is a pushbroom-scanned sensor which incorporates a single nadir looking telescope. The sensor is submerged and rigidly attached to the spacecraft and the optical boresight of the telescope is aligned with the spacecraft +Z direction (nadir). The MSC collects PAN and MS monoscopic images of the earth. Stereoscopic images are made by ground processing of the images from multiple orbits. The MSC pointing is accomplished by rolling the spacecraft, as needed, so that the line of sight of the MSC may pass over the desired location or swath. The spacecraft has a roll capability of ±56 degrees to support special imaging revisit cases.

At the nominal mission altitude with the spacecraft nadir pointing, the MSC collects data with a GSD of 1 meter for PAN and 4 meters for MS data and with a swath width of approximately 15 km. The MSC is designed to operate with a duty cycle of up to 20 % per orbit. All MSC electronics will provide full redundancies without a single point failure. Image telemetry data can be compressed on-board.

The MSC will include programmable gains and offsets to allow for in-flight adaptation of the instrument sensitivity to landscape luminosity. Gains and offsets will be selectable by commands. The MSC will provide on-board calibration functions to calibrate a degradation of camera performance due to the instrument aging. The calibration functions are controlled by ground commands.

The MSC characteristics are summarized as follows:

- PAN GSD: 1m
- MS GSD: 4m
- PAN band wavelength: 500～900 nm
- MS bands: 4 bands
- Swath width: 15 km ±2%
  - Effective swath width: 13.6 km
- Life time: 3 years
- Duty cycle: 20% per orbit
- SNR: 100 for PAN and MS
- MTF: 8% for PAN, 12% for MS (excluding linear motion, jitter, and drift of satellite)
- TDI number for CCD: 32
- Quantization: 10 bits
- Non-uniformity correction before Compressing
- Data compression: JPEG-like (almost 1:5)
- Image data encryption: encrypted
- Image storage capacity: 128 Gbit
- Data transmission rate: 320 Mbps
- Clear Aperture: 600mm
- FOV: ±0.62°
- PAN Channel
  - EFL: 9000mm ± 90mm
  - Spectral region: 500nm - 900nm
- MS Channel
  - EFL: 2250mm ± 25mm
  - Spectral region
    MS1 (Green): 520nm - 600nm
    MS2 (Blue): 450nm - 520nm
    MS3 (NIR): 760nm - 900nm
    MS4 (Red): 630nm - 690nm
- KOMPSAT-2 Mission Requirements:
  - Sun synchronous orbit
  - Altitude: 685.13km
  - Inclination: 98.127°
  - Local time of ascending node: 10:50 AM
  - 180° phase difference with KOMPSAT-1

- KOMPSAT-2 tilt for imaging:
  - Roll tilt: ±30°
  - Pitch tilt: ±30°

2.3. Ground System

The KGS is composed of the MCE and the IRPE at the KARI site. The KGS provides the capability to monitor and control the KOMPSAT-2 satellite, to conduct KOMPSAT-2 mission planning, and to receive, process, and distribute KOMPSAT-2 image data to satisfy the overall missions of the KOMPSAT-2 system. The KGS has RF communications links with the satellite at S-band (uplink and downlink) and X-band (downlink only). External interfaces of the KGS consist of uplink and downlink directly with the KOMPSAT-2 satellite and indirectly through a potential of 10 additional ground stations that support either X-band image acquisition or S-band for the LEOP. Other interfaces include interfaces to off-site users for data distribution, to the launch site during launch operations, and to the KOMPSAT-2 AIT facility to support satellite to ground segment compatibility testing. The KGS also interfaces to a source of weather data such as Korean ground based weather forecasting. The IRPE provides the capability to receive and store KOMPSAT-2 data, to support collection planning, to generate standard imagery products, and to distribute image products to users. The IRPE provides the X-band reception interface from the satellite. Each IRPE consists of RAS, CAP, and PSS.

3. KOMPSAT-2 imagery data

3.1. Standard Products

The standard processing level of the MSC image data that is provided to the users is Level 1R or Level 1G.

Figure 3 shows the sequence of MSC image data processing. The KOMPSAT-2 IRPE processes raw data received from the antenna to Level 1A automatically. Level 1R and Level 1G image data are only processed if there is a request to do. Processing levels are defined below.

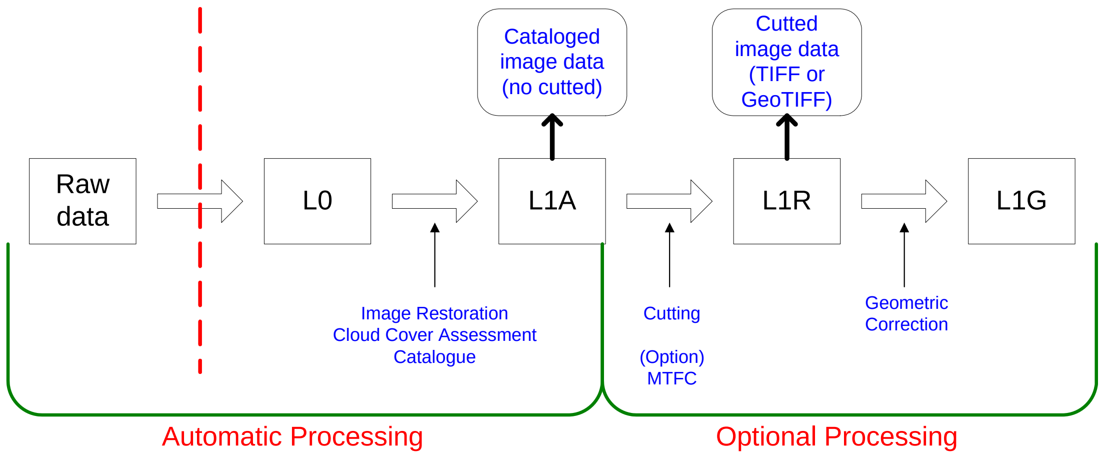

Figure 3 MSC image data Level processing

3.1.1. Processing Level Definition of MSC image data product

< Level 0 >

Level 0 data is the received and stored image data within which any and all communications artifacts (e.g. synchronization frames, communications headers) are removed.

< Level 1A >

Level 1A data is a processed image data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (i.e., platform ephemeris) computed and appended to the Level 0 data, and catalogued by KGRS-2, corrected by the MSC image restoration, cloud cover assessed (CCA) and stored by raw format with imagery data and ASCII format with ancillary data.

< Level 1R >

Level 1R data is the image data cut by catalogue (15000 column X15500 line), optionally MTF corrected and stored by Tiff format. (Generally, the remote sensing satellite image data is radiometrically corrected in the processing step of Level 1R. However for the MSC image data it is not, because MSC image data is already radiometrically corrected by the NUC (Non-Uniformity Correction) within the MSC.). If user wants, MTFC (MTF correction or MTF compensation) will be applied to the Level 1R image data optionally.

< Level 1G >

Level 1G data is geometrically corrected from Level 1R image data using KOMPSAT-2 ancillary data only and stored by GeoTiff format. Level 1G data projected onto ellipsoid (h=0), map oriented and terrain displacement. If user wants, MTFC (MTF correction or MTF compensation) will be applied to the Level 1R image data optionally.

3.2. The Structure of MSC image data

3.2.1. PAN imagery

The MSC PAN Imagery may be reconstructed from 6 separate PAN image data channels as will be detailed below. Each PAN Data channel will provide a strip of the total PAN Image of 2528 pixels wide. The total width of a MSC PAN Image swath will thus produce 6 x 2528 = 15,168 pixels. Of these pixels the overlapping pixels (in butting zone) per image data channel must be discarded, leaving a PAN Image swath containing more than 15.000 pixels. MSC has two CCD line; PAN Primary (PAN-P) and PAN Redundancy (PAN-R). PAN-R will be just used in case of malfunction of PAN-P. The total number of pixels in PAN-P band is 15,065 and in PAN-R band is 15,023. The total length of a MSC PAN Image will depend on the duration of the image scan, i.e. the number of PAN image lines.

3.2.2. MS imagery

The Multi Spectral Imagery in MSC may be reconstructed from 2 separate MS image data channels, as will be detailed below. Each MS data channel will provide image data of two entire MS Images, each one for a different spectral band, each one 3792 pixels wide. The total width of an MSC MS image swath will thus produce 3792 pixels. Of these pixels 42 pixels per spectral band Image must be discarded with an average of 21 pixels on each, leaving an exact 3,750 pixels wide MS Image swath. MS spectral bands will be also referred to as “colors”;

MS1: Green

MS2: Blue

MS3: Near Infrared

MS4: Red

The total length of a MSC MS image will depend on the duration of the image scan, i.e. the number of MS image lines.

3.3. Data File Size

The size of a MSC Level 1R data or a MSC Level 1G data, which includes PAN and MS image data, is about 600Mbytes.

3.4. KOMPSAT-2 Grid Reference System

The KGRS-2 consists of a set of grid points aligned with the KOMPSAT-2 orbital ground track, numbered with reference to the earth's geographic coordinate system. The derivations in the following sections are based upon an earlier derivation for the KOMPSAT-1 Grid Reference System. The KGRS-2 is designed to be a right-handed (K, J) system, with the K-coordinate denoting relative longitudinal position on the earth's surface (increases to the right on a map), and the J-coordinate denoting relative latitudinal position (increases upwards on a map). The numbering of K begins with the prime meridian (0 longitude) for K = 1, with K increasing as longitude increases. The numbering of J uses a fixed value of J = 1000 at all points on the equator, with J increasing as latitude increases.

The definition of the KGRS-2 constants depends upon certain orbital parameters for the KOMPSAT-2 satellite. These orbital parameters are:

i = 98.127 (orbital inclination)

e = 0.0 (eccentricity of circular orbit)

h = 685.13 km (altitude of orbit)

a = 7063.275 km (orbital semi-major axis)

rep = 409 orbits (repetition rate of orbital cycle)

p = 5907.72 s (period of orbit (seconds))

s = 13.6 km (effective swath)

The KGRS-2 coordinate system is applicable for all latitudes reached by the KOMPSAT-2 spacecraft. Due to the inclination of the KOMPSAT-2 (i = 98.127), the applicable latitude range is from –81.873 (at an orbital elongation of -90) to +81.873 (at an orbital elongation of +90). Within that latitude range, the J coordinates are numbered from J = 332 to J = 1668, with J = 1000 at the equator. The K coordinates range from K = 1 to K = 2863.

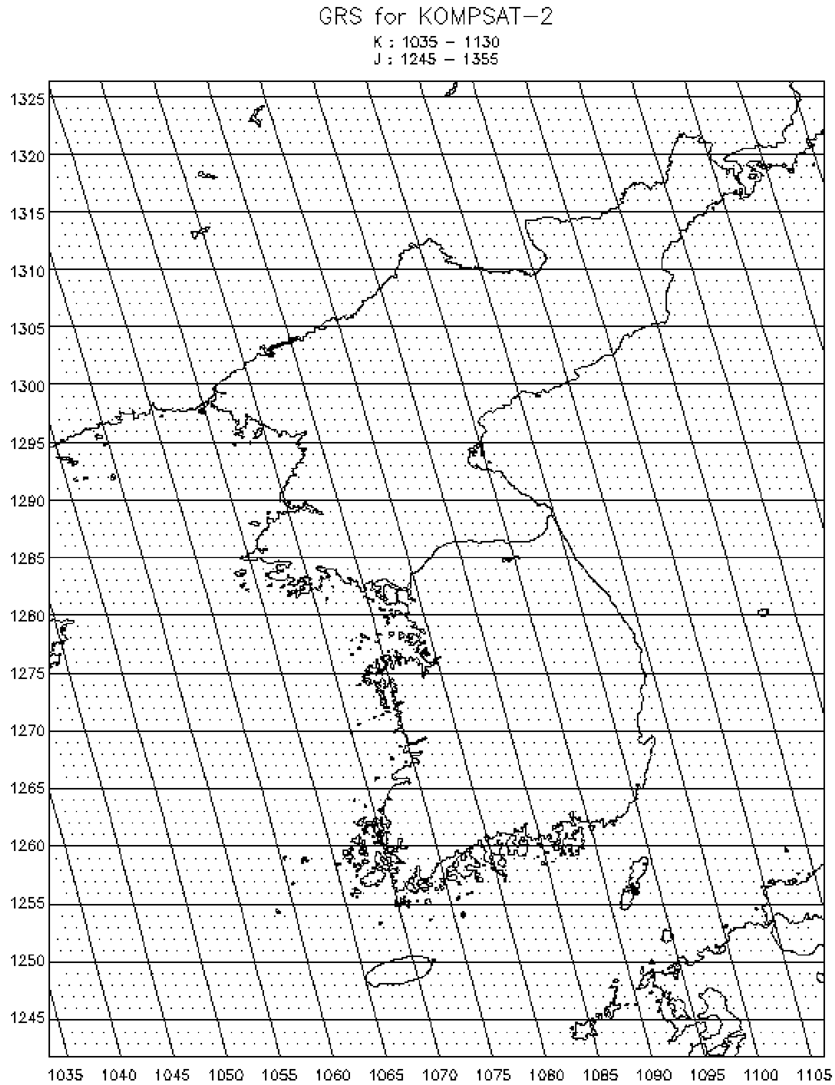

Figure 4 Example of KGRS-2 nearby Korea

4. MSC image data format

4.1. File Naming Convention

4.1.1. TIFF Level 1R

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrPAxx_tt.tif - PAN

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrMXAxxB_tt.tif - MS

YYMMDDHhmmss – Scene center time in UTC

nnnnn – Orbit number

PPPP – Path number

rrrr – Row number

P – P(Pan only)

MX - M(MS only) X(1,2,3,4)

A – P(positive), N(negative) tilt angle

xx – Tilting angle(first two digit)

B – G(Green), B(Blue), N(NIR), R(Red)

tt – 1R

4.1.2. GeoTIFF Level 1G

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrPAxx_tt.tif - PAN

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrMXAxxB_tt.tif - MS

YYMMDDHhmmss – Scene center time in UTC

nnnnn – Orbit number

PPPP – Path number

rrrr –Row number

P – P(Pan only)

MX - M(MS only) X(1,2,3,4)

A – P(positive), N(negative) tilt angle

xx – Tilting angle(first two digit)

B – G(Green), B(Blue), N(NIR), R(Red)

tt – 1G

4.1.3. Tiff and GeoTIFF – Ancillary text file

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrPAxx_tt.txt - PAN
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrMXAxxB_tt.txt - MS
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrPAxx_tt.eph - PAN
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrMXAxxB_tt.eph - MS
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrPAxx_tt.rpc - PAN
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrMXAxxB_tt.rpc - MS

YYMMDDHhmmss – Scene center time in UTC
nnnnn – Orbit number
PPPP – Path number
rrrr –Row number
P – P(Pan only)
MX - M(MS only) X(1,2,3,4)
A – P(positive), N(negative) tilt angle
xx – Tilting angle(first two digit)
B – G(Green), B(Blue), N(NIR), R(Red)
tt – 1R or 1G

4.1.4. Browse & Thumbnail

MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrTtt_br.jpg
MSC_YYMMDDHhmmss_nnnnn_PPPPrrrrTtt_tn.jpg

YYMMDDHhmmss – The first imaging time (UTC)
nnnnn – Orbit number
PPPP – Path number
rrrr – The first row number
T – P(Pan only) M(MS only) B(Pan+MS)
tt – 1R or 1G

4.2. Archived Media

The MSC image data will be basically archived in DVD or CD for Users.

4.3. Composition in an Archived media

4.3.1. TIFF and GeoTIFF

The composition in an archived media for storing plural scenes in one media is the same as the GeoTiff (Level 1G or Level 1R) or Tiff (Level 1R) format. However, in case of TIFF & GeoTIFF, each 'SCENE_NNN' directory has image files, the number of which is the same as the number of image bands, and the three files of a Browse image data, a Thumbnail image data and ancillary text file. The "readme.txt" file in Root directory has the information of all files in the archived media.

5. GeoTIFF and Ancillary data

5.1. GeoTIFF Overview

The GeoTIFF tags conform to a hierarchical data structure of tags and keys. This is similar to the tags which have been implemented in the "basic" and "extended" TIFF tags already supported in TIFF Version 6 specification. A GeoTIFF library and software tool is required to access GeoTIFF data. The GeoTIFF homepage (http://www.remotesensing.org/geotiff) is offered information about the GeoTIFF library and software tool since it has been open software. The following references are highly recommended to comprehend this data format. These are also designate in GeoTIFF website.

GeoTIFF Format Specification Version: 1.8.2

5.2. The version of GeoTIFF

The GeoTIFF file is produced based on GeoTIFF Revision 1.0.

5.3. The Content of an ancillary data text file

The ancillary data text file consists of ephemeris information data file and general information data file. The ephemeris information data file uses the “EPH” file extension and general information data file uses the “TXT” file extension

5.3.1 The ephemeris information data file

Field name	Format	Remark
IMG_ACQISITION_START_TIME	%4d %2d %2d %2d %2d %8.6f	Imaging start time (YYYY MM DD hh mm ss.ssssss). UTC
IMG_ACQISITION_END_TIME	%4d %2d %2d %2d %2d %8.6f	Image end time (YYYY MM DD hh mm ss.ssssss).

BEGIN_EPEMERIS_BLOCK		
NMR_EPH	%d	Ephemeris Number
EPH_TIME	%4d %2d %2d %2d %2d %8.6f	Ephemeris Time (YYYY MM DD hh mm ss.ssssss). UTC
EPH_POD_POS_XYZ_ECEF_KM	3[%10.5f]	Position X, Y, Z (WGS84, ECEF) (Km)
EPH_POD_VEL_XYZ_ECEF_KMS	3[%11.7f]	Velocity X, Y, Z (WGS84, Km/sec)
EPH_PAD_RPY_DEG	3[%14.9f]	Attitude Angle Roll, Pitch, Yaw (degree)
EPH_SUN_ANGLE_DEG	2[%12.7f]	Solar Azimuth Angle, Solar Elevation Angle (degree)
END_EPHEMERIS_BLOCK		
AUX_SATELLITE_NAME	%s	KOMPSAT2
AUX_SATELLITE_SENSOR	%s	KOMPSAT2 Sensor name(MSC)
AUX_TILT_ANGLE_ROLL_DEG	%7.3f	Roll Tilt angle (degree)
AUX_TILT_ANGLE_PITCH_DEG	%7.3f	Pitch Tilt angle (degree)
AUX_BITS_PER_PIXEL	%d	Bit per Pixel
AUX_SAMPLES_PER_LINE_PAN+MS	%d	Sample per Line in PAN+MS
AUX_LINES_PER_IMAGE_PAN+MS	%d	Line number in PAN+MS
AUX_SCENE_CENTER_XY_PIXEL	%d %d	Pixel value of Image center for Pan and MS (pixel) (across-track, along-track)
AUX_IMAGE_GSD_METER	2[%5.3f]	P+MS GSD(meter) (along-track, across-track)
AUX_LINE_SCAN_TIME_USEC	[%12.9f]	Line Scan Time for PAN and MS(sec)
AUX_IMAGE_SATELLITE_AZIMUTH_DEG	%f	Satellite azimuth angle(degree) Angle between the projection of the image center and local counted from local north(clock-wise)
AUX_IMAGE_SATELLITE_INCIDENCE_DEG	%f	Ground incidence angle at the image center(degree)
AUX_IMAGE_PAD_POD_FLAG	%s	POD/PAD (Yes or No) (TRUE, FALSE)
AUX_PROJECTION_NAME	%s	Projection name (UTM, TM)
AUX_PROJECTOIN_PARAMETER	%s	Parameter value (UTM: Hemisphere, Zone #, TM: West, Middle, East) (ex: HEMISPHERE_ZONE23, TM_MIDDLE)
AUX_PROJECTOIN_ELLIPSOID	%s	Ellipsoid name (Bassel, WGS84, etc)
AUX_RESAMPLING_NAME	%s	Resampling method (NN (Nearest Neighbor, BL (Bilinear), CC (Cubic Convolution))

AUX_LOCATION_KGRS_KJ	%d %d	KOMPSAT-2 Grid Reference System (K, J)
AUX_IMAGE_SHIFT_TO_ALONG	%d	Image shift along track
AUX_IMAGE_ORBIT_NUMBER	%d	Image orbit number
AUX_IMAGE_CENTER_LATLONG_DEG	2[%13.8f]	Center Latitude and Longitude (degree)
AUX_IMAGE_CENTER_ALTITUDE	%f	Satellite altitude from WGS 84 ellipsoid at the image center(meters)
AUX_IMAGE_TL_LATLONG_DEG	2[%13.8f]	Top Left(0,0) Latitude and Longitude (degree)
AUX_IMAGE_TC_LATTONG_DEG	2[%13.8f]	Top Center(samples/2,0) Latitude and Longitude (degree)
AUX_IMAGE_TR_LATTONG_DEG	2[%13.8f]	Top Right(samples,0) Latitude and Longitude (degree)
AUX_IMAGE_BL_LATLONG_DEG	2[%13.8f]	Bottom Left(0,lines) Latitude and Longitude (degree)
AUX_IMAGE_BC_LATTONG_DEG	2[%13.8f]	Bottom Center(samples/2,lines) Latitude and Longitude (degree)
AUX_IMAGE_BR_LATTONG_DEG	2[%13.8]	Bottom Right(samples, lines) Latitude and Longitude (degree)
AUX_STRIP_ACQ_DATE_UT	4d% 2d% 2d%	Strip imaging Date (YYYYMMDD)
AUX_ STRIP_ACQ_START_UT	%2d %2d %8.6f	Strip imaging start time (hhmmss.ssssss)
AUX_ STRIP_ACQ_CENTER_UT	%2d %2d %8.6f	Strip imaging center time (hhmmss.ssssss)
AUX_ STRIP_ACQ_END_UT	%2d %2d %8.6f	Strip imaging end time (hhmmss.ssssss)
AUX_ STRIP_ACQ_DURATION_SEC	[%12.9f]	Strip Imaging duration (sec)

5.3.2 General information data file

Field Name	Format	Remark
INST_LAST_NUC_DATE	%4d %2d %2d	Last update date of NUC (YYYYMMDD)

INST_LAST_GEO_DATE	%4d %2d %2d	Last update date of Geometric Cal/Val parameters(YYYYMMDD)
INST_COMPRESSION_FLAG	%s	Compression Yes or No (ex: TRUE, FALSE)
INST_COMPRESSION_RATIO_OF_PAN	%d	PAN Compression Ratio
INST_COMPRESSION_RATIO_OF_MS	4[%d]	MS1, MS2, MS3, MS4 Compression Ratio (ex: 1 2 3 4)
INST_TDI_GAIN_OF_PAN	%d	PAN TDI level (gain)
INST_TDI_GAIN_OF_MS	4[%d]	MS1, MS2, MS3, MS4 TDI level (gain) (ex: 1 2 3 4)
INST_ELEC_GAIN_OF_PAN	13[%d]	PAN Electrical Gain (12) (ex: 1 2 3 4 5 6 1 2 3 4 5 6)
INST_ELEC_GAIN_OF_MS	5[%d]	MS Electrical Gain (4) (ex: 1 2 3 4)
INST_ELEC_OFFSET_OF_PAN	13[%d]	PAN Electrical Offset (12) (ex: 1 2 3 4 5 6 1 2 3 4 5 6)
INST_ELEC_OFFSET_OF_MS	5[%d]	MS Electrical Offset (4) (ex: 1 2 3 4)
INST_BAND_DISPLAY	%s	Band identification (PAN, R, B, NIR, R)
INST_BAND_WIDTH	%d	Spectral Band width in micro(400, 80, 70, 140, 60)
INST_PAN_CCD_ALIGNMENT	4[%12.7f]	PAN CCD alignment (meter)
INST_MS_CCD_ALIGNMENT	4[%12.7f]	MS CCD alignment (meter)
INST_PAN_FOCAL_LENGTH	%[%12.8f]	PAN Focal length(meter)
INST_MS_FOCAL_LENGTH	%[%12.8f]	MS Focal length(meter)
INST_CCD_MODE	%s	PAN and MS of Primary or Redundant
CAL_MTF_OF_PAN	%d	PAN MTF value at Nyquist Frequency
CAL_MTF_OF_MS	4[%d]	MS MTF value at Nyquist Frequency
CAL_RADIANCE_GAINOFFSET_PAN	2[%6.2f %6.2f]	Gain/Offset to convert DN to Radiance in PAN
CAL_RADIANCE_GAINOFFSET_MS	4[%6.2f %6.2f]	Gain/Offset to convert DN to Radiance in MS
BEGIN_CALGCP_BLOCK		
NMR_GCP	%d	GCP Number
CAL_GCP_XY_LLH_UTM	5[%14.9f]	GCP (X, Y, Lat, Long, Height) (WGS84, UTM)
END_CALGCP_BLOCK		
CAL_DEM_FILE	%s	File name for DEM data CALDEM_071122100001_12345_00010001PP10_1G.txt

		CALDEM_071122100001_12345_00010001MP10_1G.txt NULL (no DEM)
AUX_FILE_NAME	%s	Each PAN, MS1, MS2, MS3 and MS4 Image File Name
AUX_STRIP_ID	%s	Associated data strip ID
AUX_STRIP_BEGIN_END	%d %d	First and last line of the image into the data strip
AUX_IMAGE_LEVEL	%s	Image Level (ex: L1A, L1R, L1G)
AUX_PRODUCT_LEVEL	%s	Product Level (ex: L1A, L1R, L1G)
AUX_CLOUD_STATUS	%d	Cloud Status
AUX_IMAGE_QUALITY	%s	Image Quality
AUX_IMAGE_BAD_LINES	%d	Bad/reduced quality lines
AUX_IMAGE_BAD_COLS	%d	Bad/reduced quality columns
AUX_SATELLITE_NAME	%s	Satellite Name (KOMPSAT2)
AUX_SATELLITE_SENSOR	%s	Sensor Name (MSC)
AUX_TILT_ANGLE_ROLL_DEG	%7.3f	Roll Tilt angle (degree)
AUX_TILT_ANGLE_PITCH_DEG	%7.3f	Pitch Tilt angle (degree)
AUX_BITS_PER_PIXEL	%d	Bit per Pixel
AUX_SAMPLES_PER_LINE_PAN+MS	%d	Sample per Line in PAN+MS
AUX_LINES_PER_IMAGE_PAN+MS	%d	Line number in PAN+MS
AUX_SCENE_CENTER_XY_PIXEL	%d %d	Pixel value of Image center for PAN and MS (along-track, across-track)
AUX_IMAGE_GSD_METER	2[%5.3f]	PAN+MS GSD(meter) (along-track, across-track)
AUX_LINE_SCAN_TIME_USEC	%f	Line Scan Time for PAN and MS(sec)
AUX_IMAGE_SATELLITE_AZIMUTH_DEG	%f	Satellite azimuth angle(degree) Angle between the projection of the image center and local counted from local north(clock-wise)
AUX_IMAGE_SATELLITE_INCIDENCE_DEG	%f	Ground incidence angle at the image center(degree)
AUX_IMAGE_PAD_POD_FLAG	%s	POD/PAD (Yes or No) (TRUE, FALSE)
AUX_IMAGE_MTF_FLAG	%s	MTF (Yes or No) (TRUE, FALSE)
AUX_PROJECTION_NAME	%s	Projection name (UTM, TM)
AUX_PROJECTOIN_PARAMETER	%s	Parameter value (UTM: Hemisphere, Zone #, TM: West,

		Middle, East) (ex: HEMISPHERE_ZONE23, TM_MIDDLE)
AUX_PROJECTOIN_ELLIPSOID	%s	Ellipsoid name (Bassel, WGS84, etc)
AUX_RESAMPLING_NAME	%s	Resampling method (NN (Nearest Neighbor, BL (Bilinear), CC (Cubic Convolution))
AUX_LOCATION_KGRS_KJ	%d %d	KOMPSAT2 Grid Reference System (K, J)
AUX_IMAGE_SHIFT_TO_ALONG	%d	Image shift along track
AUX_IMAGE_ORBIT_NUMBER	%d	Image orbit number
AUX_IMAGE_CENTER_LATLONG_DEG	2[%13.8f]	Center Latitude and Longitude (degree)
AUX_IMAGE_CENTER_ALTITUDE	%f	Satellite altitude from WGS 84 ellipsoid at the image center(meters)
AUX_IMAGE_TL_LATLONG_DEG	2[%13.8f]	Top Left(0,0) Latitude and Longitude (degree)
AUX_IMAGE_TC_LATTONG_DEG	2[%13.8f]	Top Center(samples/2,0) Latitude and Longitude (degree)
AUX_IMAGE_TR_LATTONG_DEG	2[%13.8f]	Top Right(samples,0) Latitude and Longitude (degree)
AUX_IMAGE_BL_LATLONG_DEG	2[%13.8f]	Bottom Left(0,lines) Latitude and Longitude (degree)
AUX_IMAGE_BC_LATTONG_DEG	2[%13.8f]	Bottom Center(samples/2,lines) Latitude and Longitude (degree)
AUX_IMAGE_BR_LATTONG_DEG	2[%13.8]	Bottom Right(samples, lines) Latitude and Longitude (degree)
AUX_STRIP_ACQ_DATE_UT	4d% 2d% 2d%	Strip imaging Date (YYYYMMDD)
AUX_ STRIP_ACQ_START_UT	%2d %2d %8.6f	Strip imaging start time (hhmmss.ssssss)
AUX_ STRIP_ACQ_CENTER_UT	%2d %2d %8.6f	Strip imaging center time (hhmmss.ssssss)
AUX_ STRIP_ACQ_END_UT	%2d %2d %8.6f	Strip imaging end time (hhmmss.ssssss)
AUX_ STRIP_ACQ_DURATION_SEC	[%12.9f]	Strip Imaging duration (sec)
AUX_IMAGE_L0_PROCESSED_UT	%4d %2d %2d %2d	Time that process the Level 0 (YYYYMMDDHHMMSS.SS)

	%2d %5.2f	
AUX_IMAGE_L1A_PROCESSED_UT	%4d %2d %2d %2d %2d %5.2f	Time that process the Level 1A (YYYYMMDDHHMMSS.SS)
AUX_IMAGE_L1R_PROCESSED_UT	%4d %2d %2d %2d %2d %5.2f	Time that process the Level 1R (YYYYMMDDHHMMSS.SS)
AUX_IMAGE_MINMAX_OF_PAN+MS	%d %d	Maximum and Minimum DN value in PAN+MS
AUX_RECEIVED_STATION_NAME	%s	Ground station Name that received
AUX_RECEIVED_STATION_ LOCATION_LATLONG_DEG	2[%13.8f]	Location of Latitude, Longitude(degree)
AUX_PROCESSED_STATION_NAME	%s	Ground station Name that processed
AUX_PROCESSED_STATION_ LOCATION_LATLONG_DEG	2[%13.8f]	Location of Latitude, Longitude(degree)
AUX_PROCESSED_PRODUCER	%s	Operator name (ex: OperatorA)
AUX_PROCESSED_SW_VER	%s	Name of Image data processing S/W
AUX_REQUESTER_NAME	%s	Requester Name
AUX_REQUESTER_COMPANY	%s	Request Company
AUX_REQUESTER_DATETIME	%s	(YYYYMMDDHHMM)
COPYRIGHT	%s	Copyright and restricated use
LICENCE	%s	Licencing information

6. Sensor Modeling

6.1 Preprocessing for Geometric Correction of KOMPSAT-2

The produced KOMPSAT-2 Level 1R and Level 1G data for users who calculate the ground coordinate, mapping, photogrammetric application etc. are preprocessed on KOMPSAT-2 IRPE(Image Request Processing Element) system. The main preprocessing steps are following this;

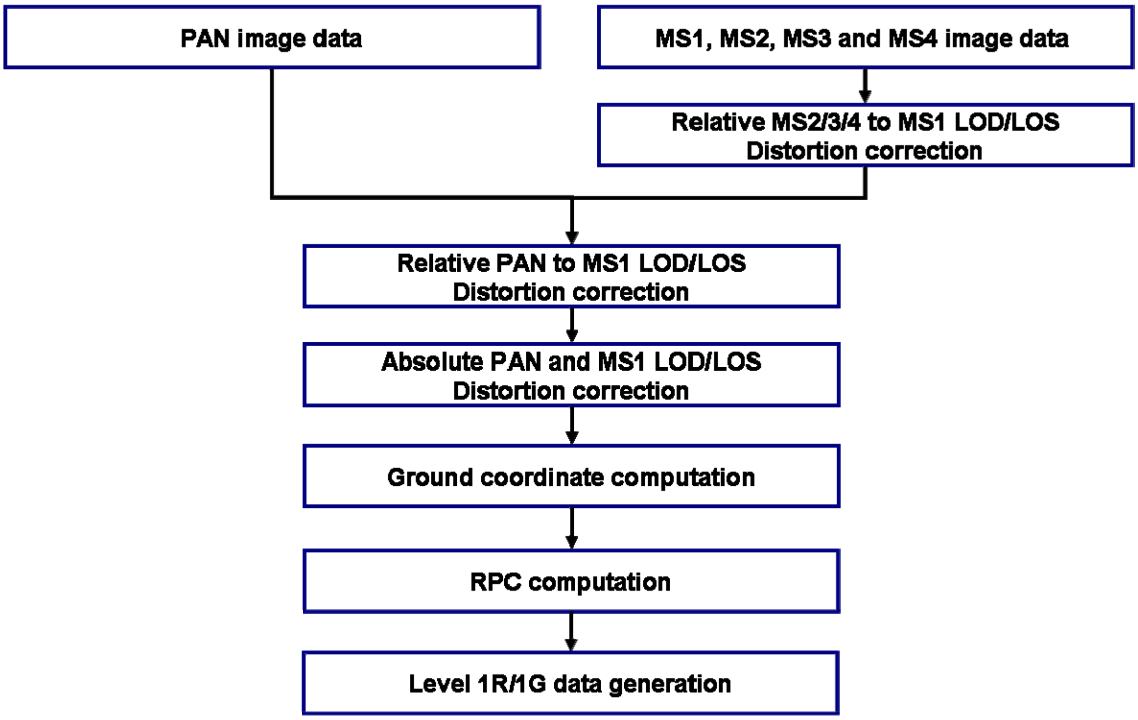

Figure 5 Workflow of KOMPSAT-2 geometric correction preprocessing

In Figure 5, Absolute LOD/LOS distortion correction consists of the across-track correction (LOD) and along-track correction (LOS). This correction calibrates the image data with lense distortion and CCD distortion etc. to absolute ground true data such as ground control point, high accurate ortho-rectified image. The purpose of this correction is to calibrate the KOMPSAT-2 optic system distortion. For example, the absolute PAN LOD and LOS distortion correction curve are as following;

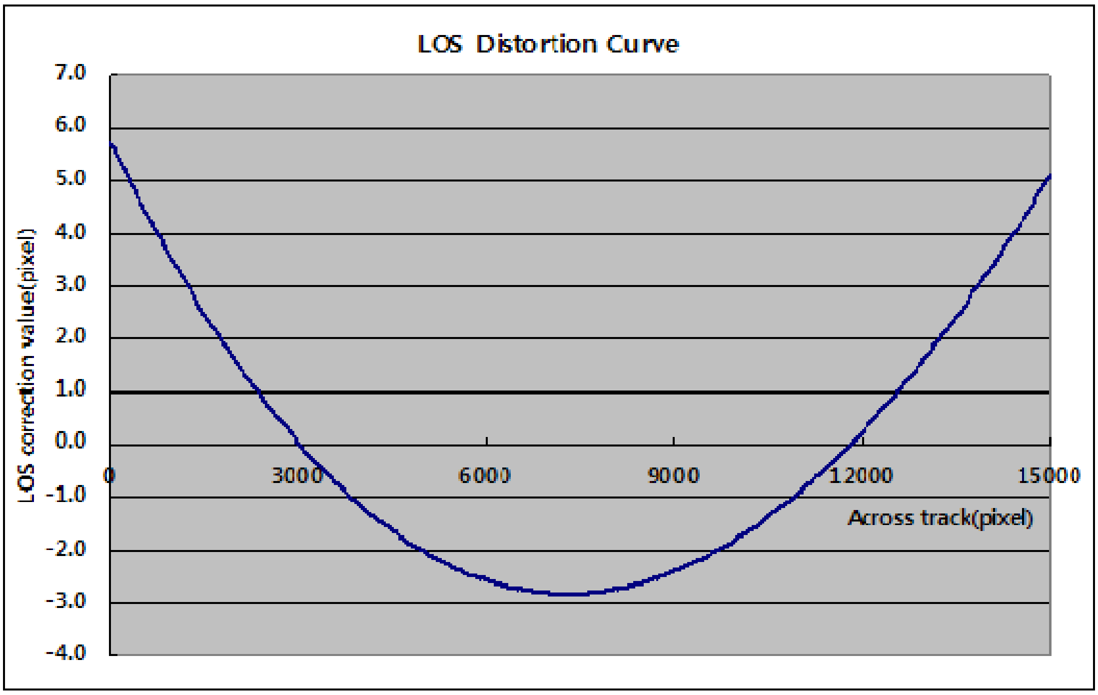

Figure 6 Absolute PAN LOS distortion curve

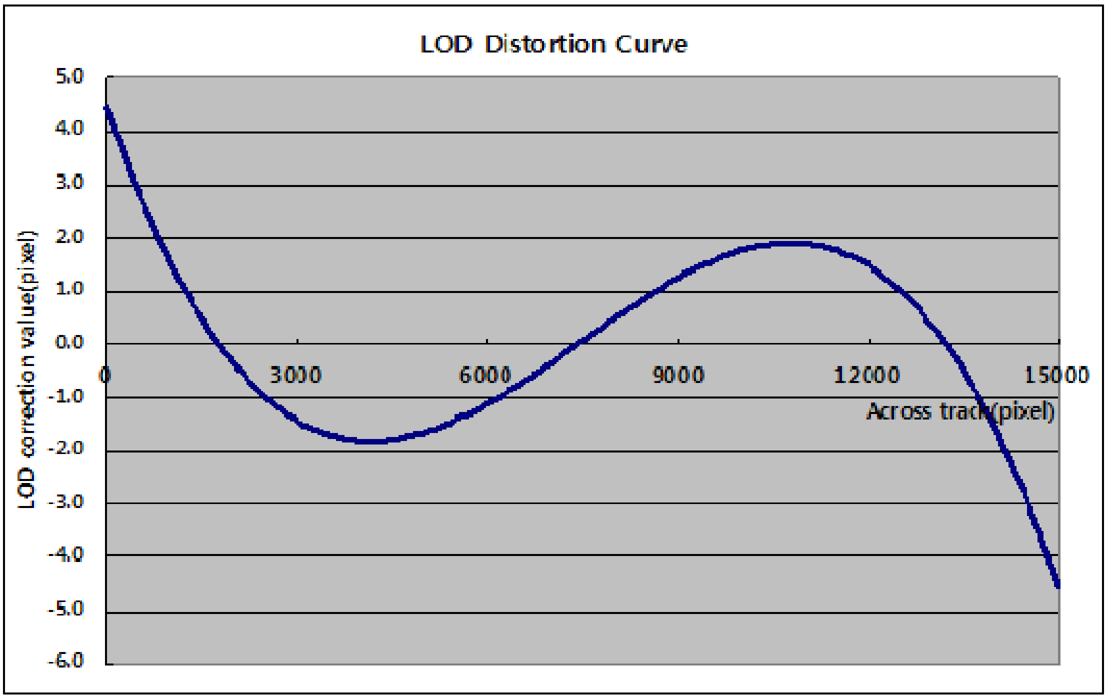

Figure 7 Absolute PAN LOD distortion curve

The relative MS to MS LOD/LOS distortion correction and PAN to MS distortion correction are calibrated each MS bands and PAN band to MS band with across-track distortion and along-track distortion. The purpose of this correction is to registration of among MS bands and between PAN band to MS bands.

6.2 KOMPSAT-2 Direct Sensor Modeling

The basic sensor model of KOMPSAT-2 MSC is realized on the co-linearity condition. The spacecraft perspective center, image point and the corresponding ground point are assumed to be on one straight line using six basic coordinate systems. The origin of sensor coordinate system is considering coincided with the origin of the spacecraft which is located at the spacecraft center of mass.

The Figure 8 gives a description of basic sensor model of KOMPSAT-2 MSC.

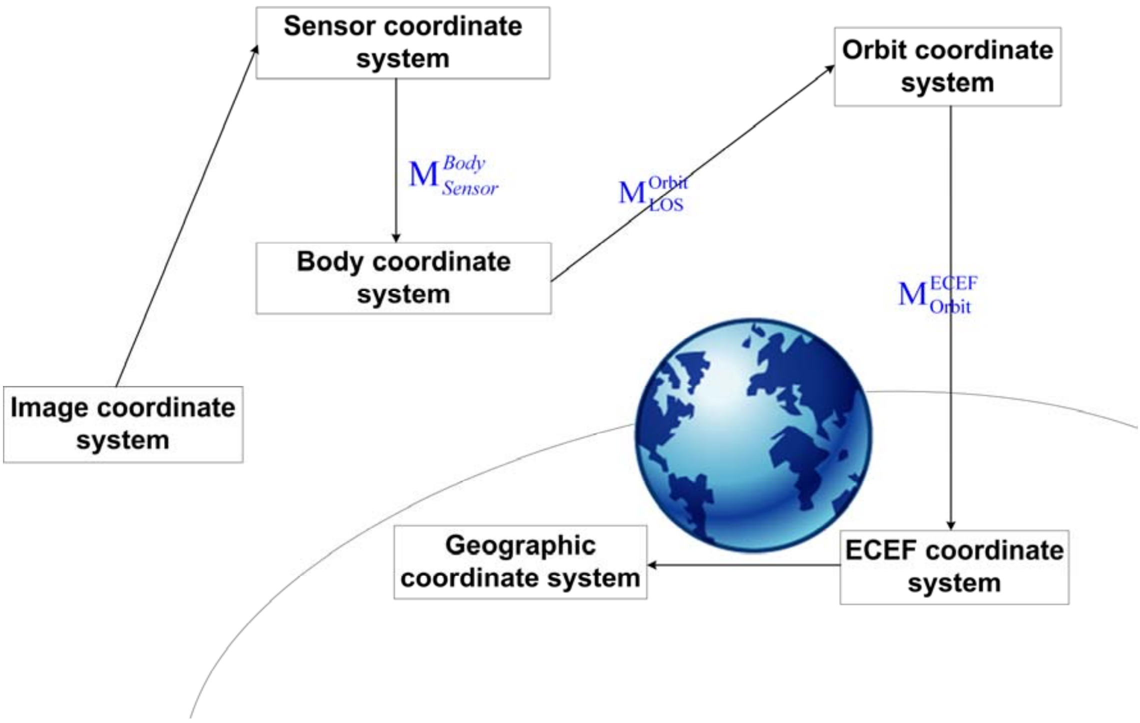

Figure 8 Coordinate Systems Overview and Coordinate Transformations

6.2.1. Time Calculation

KOMPSAT-2 spacecraft is a line sensing imaging system, and every scan line is imaged at different time. The time calculation is required to determine the nominal spacecraft position and attitude of the spacecraft at every scan line as well as deviation from the nominal value. The ancillary data is provided an image acquisition start, center and end time in UTC.

Time (t) for any line is given by reference to the scene center data;

t = center time - line rate × (line - center line)

6.2.2. Ephemeris Interpolation

KOMPSAT-2 level 1R data includes ephemeris data to give the spacecraft position and velocity every 1 second. The three components (X, Y, Z) of spacecraft given by ephemeris data set, which are position, velocity and data of each instant time (t), i.e., spacecraft position vector [P] and spacecraft velocity vector [V] for each instant times are given;

$$\vec{P}(t) = \sum_{j=1}^{8} \frac{\vec{P}(t_j) \times \prod_{\substack{i=1 \\ i \neq j}}^{8} (t - t_i)}{\prod_{\substack{i=1 \\ i \neq j}}^{8} (t_j - t_i)} \qquad \vec{V}(t) = \sum_{j=1}^{8} \frac{\vec{V}(t_j) \times \prod_{\substack{i=1 \\ i \neq j}}^{8} (t - t_i)}{\prod_{\substack{i=1 \\ i \neq j}}^{8} (t_j - t_i)}$$

$P(t_i)$: the satellite position coordinates
$V(t_i)$: the satellite velocity coordinates
t_i : times corresponding to the positions and velocities.

We recommended 8 datasets for each interpolation process. Spacecraft position and velocity are expressed in the ECEF reference frame using WGS-84 ellipsoid.

6.2.3. Image Coordinate System

The image coordinates are divided to column and row pixel numbers. When the image is displayed, column and row numbers are increasing when it goes right and downward direction. The origin of image coordinate system is located upper left corner at the first pixel on the first scan line as shown in Figure 9.

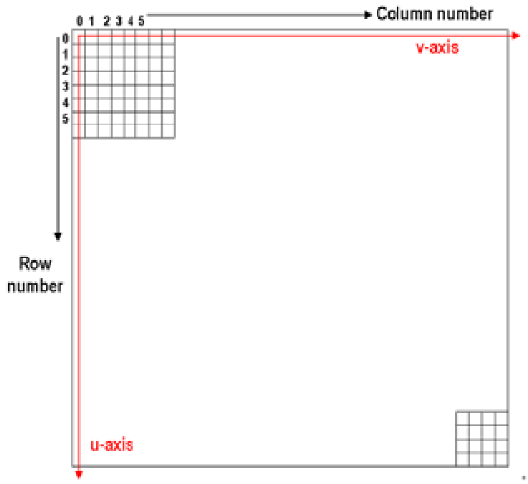

Figure 9 Image coordinates system

6.2.4. Sensor Coordinate System

The image coordinate (v,u) of the point in the image coordinate system to be transformed to (x, y, z) coordinate in the sensor coordinate system, as seem in Figure 8. The spacecraft of mass is located in origin of the sensor coordinate system. The z-axis points in direction to the surface of the earth. The y-axis is direction to the direction of spacecraft and the x-axis completes the right handed coordinate system.

The (x, y, z) coordinates are calculated using the pixel size, d, focal length, f, KOMPSAT-2 alignment value fx, fy, lx, ly from ancillary file. The sensor coordinate (x, y, z) is given by;

$$x = (v \times \text{CCD size}) + f_x$$

$$y = ax + b$$

$$\vec{x} = \frac{\vec{x}}{\|\vec{d}\|},\quad \vec{y} = \frac{\vec{y}}{\|\vec{d}\|},\quad \vec{z} = -\frac{\vec{f}}{\|\vec{d}\|}$$

$$a = (ly - fy)/(lx - fx)$$

$$b = fy - (a \times fx)$$

$$\|d\| = \sqrt{x^2 + y^2 + z^2}$$

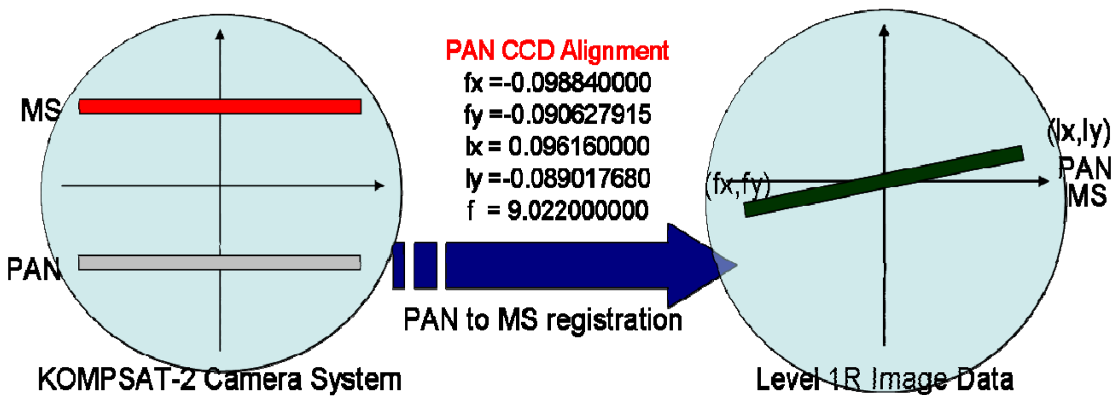

Figure 10 CCD alignment

Where, fx, fy, lx, ly are CCD alignment values into the focal plan of KOMPSAT-2 after LOD and LOS distortion correction, as given in figure 10. The value of CCD alignment is on the general information data file (extension: TXT). For example,

INST_PAN_CCD_ALIGNMENT -0.098840000, -0.090627915, 0.096160000, -0.089017680

INST_PAN_CCD_ALIGNMENT fx, fy, lx, ly

6.2.5. Body Coordinate System

The body coordinate system is fixed with the origin of the KOMPSAT-2 spacecraft on the center of mass. The coordinate axes are defined by the spacecraft attitude control system. The X-axis is the spacecraft axis in direction of velocity vector; Z-axis is the spacecraft toward nadir. The Y axis completes the right handed coordinate system.

The transformation from the spacecraft body to the orbit coordinate system is defined by the spacecraft attitude and bias angle which is determined the resulted KOMPSAT-2 geometric Cal/Val. This transformation is formation of three-dimensional rotation matrixes; performed functions with components of the spacecraft roll, pitch and yaw these attitude angles.

The proper order is required to perform the rotation about roll, pitch and yaw. The transformation matrix is following:

$$T_{BODY \to Orbit} = R_{Yaw} \cdot R_{Pitch} \cdot R_{Roll}$$

$$R_{roll} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\xi_r & \sin\xi_r \\ 0 & -\sin\xi_r & \cos\xi_r \end{bmatrix} \quad R_{Pitch} = \begin{bmatrix} \cos\xi_p & 0 & -\sin\xi_p \\ 0 & 1 & 0 \\ \sin\xi_p & 0 & \cos\xi_p \end{bmatrix} \quad R_{Yaw} = \begin{bmatrix} \cos\xi_y & \sin\xi_y & 0 \\ -\sin\xi_y & \cos\xi_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

6.2.6. Orbit Coordinate System

The spacecraft center of mass is located in origin of the orbit coordinate system, and fixed in the respected the KOMPSAT-2 Orbit Plane. The Z-axis points in direction to the surface of the earth, i.e. the spacecraft direct to the negative position vector in ECI system. The X-axis is direct to the velocity vector of spacecraft on orbit plane, and the Y-axis is perpendicular to the orbit plane. The orbit coordinate system is the reference system for the attitude controller.

The position and velocity ephemeris of KOMPSAT-2 are given in the WGS 84 system. In particular, the velocities given from auxiliary data are inertial velocities in ECEF.

The rotation matrix convert orbital to ECEF is constructed by following equation;

$$\vec{Z} = -\frac{\vec{P}}{\left\|\vec{P}\right\|} \quad \vec{Y} = \frac{\vec{Z} \times \vec{V}}{\left\|\vec{Z} \times \vec{V}\right\|} \quad \vec{X} = \vec{Y} \times \vec{Z}$$

$$T_{Orbit \to ECEF} = \begin{bmatrix} (X)_X & (Y)_X & (Z)_X \\ (X)_Y & (Y)_Y & (Z)_Y \\ (X)_Z & (Y)_Z & (Z)_Z \end{bmatrix}$$

6.2.7. Earth Centered Rotating Coordinate System (Earth-Centered, Earth-Fixed (ECEF) coordinate system)

The Earth Centered Rotating (ECR) coordinate system is Earth fixed with its origin at the center of mass of the Earth (see Figure 9). It corresponds to the Conventional Terrestrial System (CTS) defined by the International Earth Rotation Service (IERS), which is the same as the U. S. Department of Defense World Geodetic System 1984 (WGS84) geocentric reference system.
The relationship between ECR and geodetic coordinates can be simply expressed in its direction form

$$x = (N+h)\cos(lat)\cos(lon)$$

$$y = (N+h)\cos(lat)\sin(lon)$$

$$z = \left(N\left(1-e^2\right)+h\right)\sin(lat)$$

$$N = a/\left(1-e^2\sin^2(lat)\right)^{\frac{1}{2}}$$

$$e^2 = 1-\frac{b^2}{a^2}$$

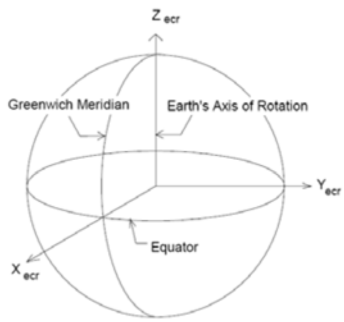

Figure 11 ECR Coordinate System

Where:
(x, y, z) ; ECR coordinates
(lat, lon, h) ; Geodetic coordinates
N ; Ellipsoid radius of curvature in the prime vertical
e ; Ellipsoid eccentricity
a, b ; Ellipsoid semi-major and semi-minor axes

There are no closer solutions for the inverse problems (which is the interesting problem here). Latitude and height must be solved iteratively for points that do not lie on the ellipsoid surface.

6.2.8. Geodetic Coordinate System

The geodetic coordinate system is based on the WGS84 reference frame with coordinates expressed latitude, longitude, and height above the reference Earth ellipsoid. According to the definition of the ECR Coordinate System none ellipsoid is required, however the Geodetic Coordinate System is depending on the choice of an Earth ellipsoid. Latitude and longitude are defined as the angle between the ellipsoid normal and its projection onto the equator and the angle between the local meridian and the Greenwich meridian, respectively.

6.3. RPC

The RPC for the KOMPSAT-2 MSC sensor is generated from the resulted KOMPSAT-2 DSM using the RFM.
The RPC generation in KOMPSAT-2 IRPE system consists of 4 main parts as shown in Figure 12.

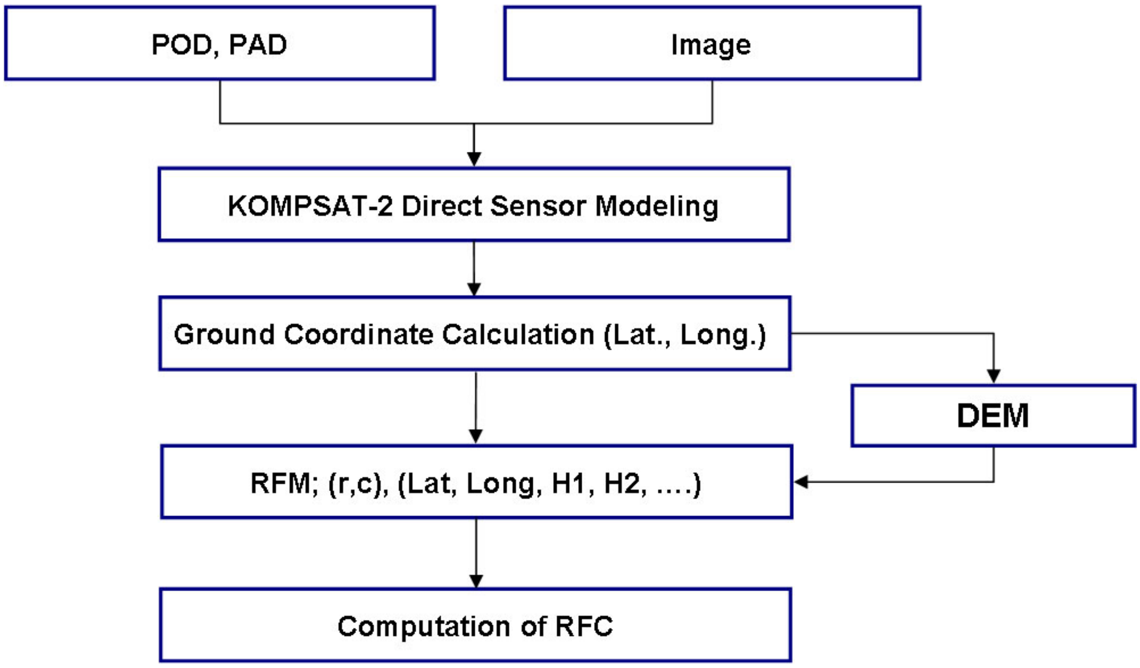

Figure 12 The KOMPSAT-2 RPC generation workflow.

KOMPSAT-2 RFM is forward method which can be calculated from ground coordinate (Latitude, Longitude, Height) to image coordinate (Column, Row). Auxiliary file(***.rpc) gives RPC parameters for "ground to image" location model.

A least-squares approach is utilized to determine the RPC a_n, b_n and d_n from a three-dimensional ground coordinates generated using the KOMPSAT-2 MSC camera model. The basic relationship of the KOMPSAT-2 MSC camera model that describes the ground coordinates in term of sensor coordinates is realized by the co-linearity condition in which the KOMPSAT-2 MSC perspective center, an image point and the corresponding ground point are assumed to be on one straight line. The 3D ground coordinates of object points in RFM are generated by intersecting the rays emanating from a 2-D grid of image with a number of constant elevation planes. (See Figure 12)

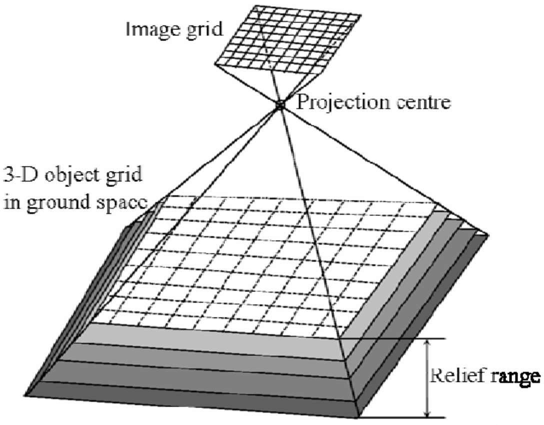

Figure 13 Use a 3-D object grid to solve for the RFM

In the RFM, image pixel coordinates (c, r) are expressed as the ratios of polynomials of ground coordinates (X, Y, Z). In order to improve the numerical stability of equations, the two image coordinates and three ground coordinates are normalized to fit the range from –1.0 to 1.0 using offset values and scale factors. Coefficients of the RFM are called RPC. In general, distortions caused by optical projection can be represented by ratios of first order polynomials, while corrections such as earth curvature, atmospheric refraction, and lens distortion etc., can be well approximated by second order polynomials. Some other unknown distortions with high order components can be modeled using a RFM with third order polynomials.

The RFM is given as;

$$c_n = \frac{p1(X_n, Y_n, Z_n)}{p2(X_n, Y_n, Z_n)}$$

$$r_n = \frac{p3(X_n, Y_n, Z_n)}{p4(X_n, Y_n, Z_n)}$$

$$p2 \equiv p4$$

r_n, c_n, : the normalized row and column index of pixels in image.

X_n, Y_n, Z_n : the normalized coordinate values of object points in ground space(Longitude, Latitude, Height)

$p1(X_n, Y_n, Z_n)$, $p2(X_n, Y_n, Z_n)$ and $p3(X_n, Y_n, Z_n)$ are expressed as

$$\begin{aligned} p1(X_n, Y_n, Z_n) = {} & a_0 + a_1 X + a_2 Y + a_3 Z + a_4 X^2 + a_5 XY + a_6 X\,Z + a_7 Y^2 + \\ & a_8 YZ + a_9 Z^2 + a_{10} X^3 + a_{11} X^2 Y + a_{12} X^2 Z + a_{13} X\,Y^2 + \\ & a_{14} XYZ + a_{15} XZ^2 + a_{16} Y^3 + a_{17} Y^2 Z + a_{18} YZ^2 + a_{19} Z^3 \end{aligned}$$

$$p2(X_n, Y_n, Z_n) = 1 + b_1 X + b_2 Y + b_3 Z + b_4 X^2 + b_5 XY + b_6 X Z + b_7 Y^2 + b_8 YZ + b_9 Z^2 + b_{10} X^3 + b_{11} X^2 Y + b_{12} X^2 Z + b_{13} XY^2 + b_{14} XYZ + b_{15} XZ^2 + b_{16} Y^3 + b_{17} Y^2 Z + b_{18} YZ^2 + b_{19} Z^3$$

$$p3(X_n, Y_n, Z_n) \equiv p4(X_n, Y_n, Z_n) = 1 + d_1 X + d_2 Y + d_3 Z + d_4 X^2 + d_5 XY + d_6 X Z + d_7 Y^2 + d_8 YZ + d_9 Z^2 + d_{10} X^3 + d_{11} X^2 Y + d_{12} X^2 Z + d_{13} XY^2 + d_{14} XYZ + d_{15} XZ^2 + d_{16} Y^3 + d_{17} Y^2 Z + d_{18} YZ^2 + d_{19} Z^3$$

The total number of RPC for each polynomial is {(N+1)(N+2)(N+3)}/6. For example, when N is 3, each $p1(X_n, Y_n, Z_n)$, $p2(X_n, Y_n, Z_n)$ and $p3(X_n, Y_n, Z_n)$ equation becomes a 3rd order three-dimensional polynomial with 20 coefficients.

The normalization of the coordinates is computed using the following equations:

$$r_n = \frac{r - r_o}{r_s}, \quad c_n = \frac{c - c_o}{c_s},$$

$$X_n = \frac{X - X_o}{X_s}, \quad Y_n = \frac{Y - Y_o}{Y_s}, \quad Z_n = \frac{Z - Z_o}{Z_s}$$

r_o, c_o, X_o, Y_o and Z_o are the offset values

$$r_o = \frac{r_{\max} + r_{\min}}{2}$$

$$c_o = \frac{c_{\max} + c_{\min}}{2}$$

$$X_o = \frac{X_{\max} + X_{\min}}{2}$$

$$Y_o = \frac{Y_{\max} + Y_{\min}}{2}$$

$$Z_o = \frac{Z_{\max} + Z_{\min}}{2}$$

r_s, c_s, X_s, Y_s and Z_s are the scale factors

$$r_s = \frac{r_{\max} - r_{\min}}{2}$$

$$c_s = \frac{c_{\max} - c_{\min}}{2}$$

$$X_s = \frac{X_{\max} - X_{\min}}{2}$$

$$Y_s = \frac{Y_{\max} - Y_{\min}}{2}$$

$$Z_s = \frac{Z_{\max} - Z_{\min}}{2}$$

7. Contact

7.1. How to access the KOMPSAT-2 imagery data you want to get?

This section describes the KOMPSAT-2 data policy. KARI is a non-profit organization supported and funded by the government of the Republic of Korea.

KARI has been granted the property rights, distribution rights and sales rights of the KOMPSAT-2 products on behalf of the Korean government. According to the decision from the Korean government regarding worldwide commercialization of KOMPSAT-2 imagery, KARI assigns Korea Aerospace Industry (hereinafter referred to as the “KAI”) and SPOT Image inc. in promoting the KOMPSAT-2 sales. KAI is responsible for the customers incorporated or with a billing office in the United States of America, UAE, Saudi Arabia, Kuwait, Qatar, Oman, Yemen, Egypt, Iran, Iraq, Jordan, Lebanon, and Syria. SPOT Image is responsible for the customers incorporated or with a billing office in the rest of the world except Korean peninsula.

KARI shall be entitled to distribute the KOMPSAT-2 products to Category-1 customers directly and without any limitations. A Category-1 customer means any third parties requesting products within a Category-1 projects as identified by KARI. Category-1 projects mean any scientific and educational research projects, demands from the Korean government and specific Public Relations activities managed on a non-commercial and non-profit basis.

KARI and/or its representative will operate, maintain and manage its own archive and catalog search system for the customers.

KARI has developed the KOMPSAT-2 satellite as per the national space development plan, so the needs of the Korean government shall be considered with the highest priority, pursuant to the Korean national policy and benefits. Furthermore, the distribution and sales of the KOMPSAT-2 products and/or services shall be in accordance with the Korean government’s policy and national interests. When necessary and for the Korean government, KARI shall be entitled to limit the distribution and sales of the KOMPSAT-2 products subject to the Korean government distribution guidelines.

7.2. Homepage

The customers for KOMPSAT-2 data can access the search and catalog system for KOMPSAT-2 data through the KARI homepage (www.kari.re.kr) or homepage of the Space Caputure2 (www.spacecapture.kr).

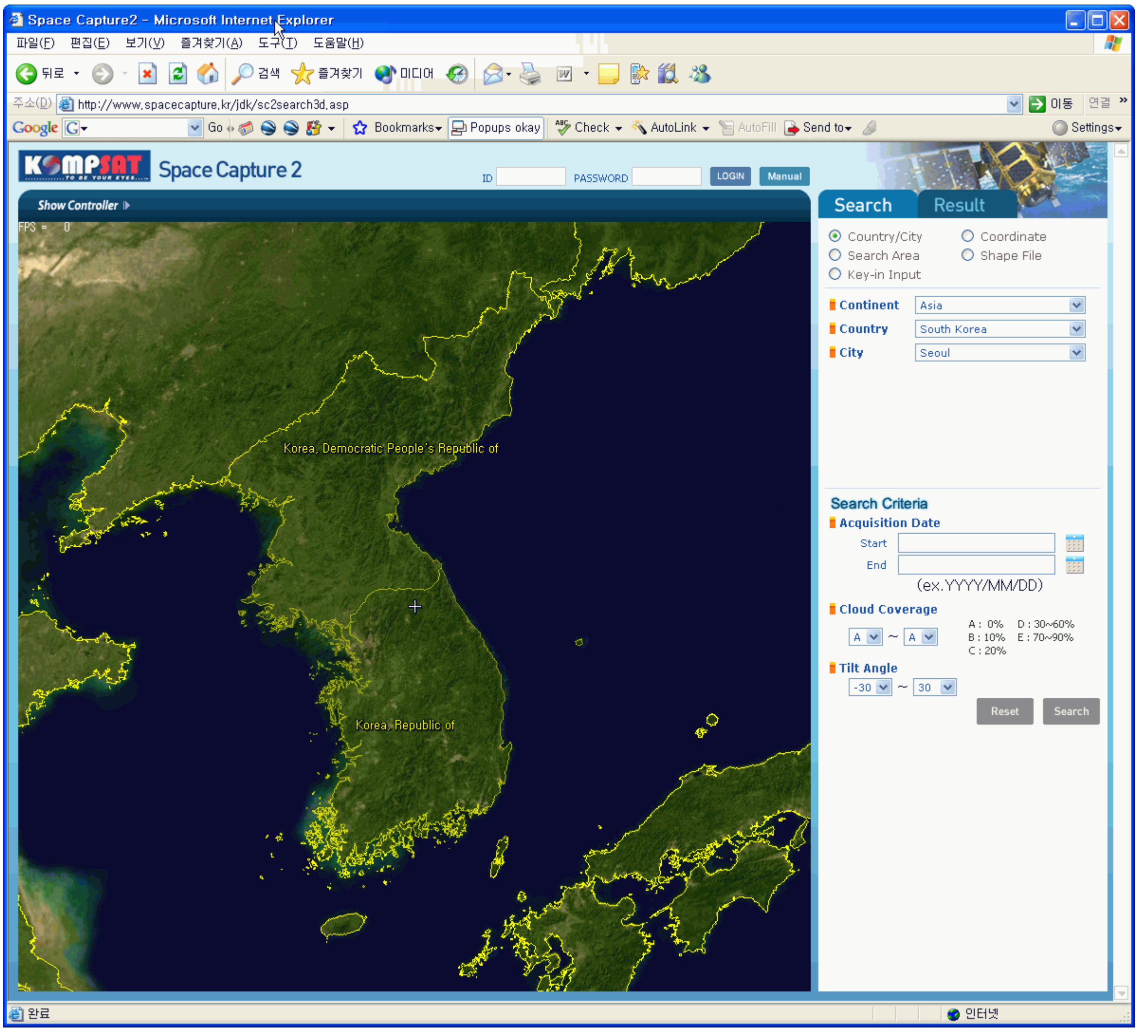

Figure 14 Space Capure2 Homepage

8. Regulations governing Image Distribution

The policy of commercial distribution of KOMPSAT-2 satellite imagery will be described in this section

8.1. Copyright

In brief, copyright covers a certain number of rights granted to the author of an original work, whether scientific or artistic in nature, which are added to the usual right of ownership. These rights are granted exclusively and automatically, at least under the copyright laws of the Republic of Korea.

The users of KOMPSAT-2 data acknowledge the right of KARI to copyright protection and/or protection against unauthorized use of the KOMPSAT-2 products, in accordance with the copyright laws of the Republic of Korea and applicable international agreements. The intellectual property rights related to the KOMPSAT-2 products are protected through the end-user license agreement. The users of KOMPSAT-2 data undertake to have printed the following copyright notice on all products, in such a way that KARI's copyright be plain to all "© KARI ____. (year appearing on the product delivered by KARI)."

The author of a Derived Works and Products is entitled to his own copyright in return for his creative contribution. This copyright is complementary to that owned by KARI.

8.2. General Terms of Sale

KARI has launched an optical remote sensing satellite with a very high-resolution sensor known as KOMPSAT-2 by July 28, 2006. KOMPSAT-2 data is now available for commercial uses in 2007. KARI is operating KOMPSAT-2 during its life time to satisfy both the government needs and commercial needs. In addition and on behalf of the Korean government, KARI intends to market any customers for the KOMPSAT-2 products and related services.

When the user buys a KOMPSAT-2 image and pays the current stated price, he obtains in return one or more copies of the products requested. However, the sale is subject to the following conditions:

- the user can only use the KOMPSAT-2 products for his own private needs and is forbidden to make these products or reproductions of these products available to a third party, either on a non-paying or a paying basis, whether temporarily or permanently.

- KARI may, however, grant approval to the user to sell these data and reproductions derived from them.
- All KOMPSAT-2 products, Data and Derived Works, must bear the indication: all “© KARI ____. (year appearing on the product delivered by KARI) and be accompanied by a note setting forth the above regulations.

Purchase of a KOMPSAT-2 image gives the owner what is generally referred to as a right of private use, which includes the right to transform the image. On the other hand, any and all collective and public use is prohibited and particularly any right to distribute the image.

The specific terms and conditions of KOMPSAT-2 data sales will be specified through the SPOT Image and KAI, respectively.

8.3. Special Agreement

The users of KOMPSAT-2 data agree to make the KOMPSAT-2 products available on an open and non-discriminatory basis consistent with United Nations Resolution A/41/65 of December 3, 1986 on “The Principles Relating to the Remote Sensing of Earth from Space”.

The specific terms and conditions of KOMPSAT-2 data sales will be specified through the SPOT Image and KAI, respectively. If the purchaser wishes to make a different use of the purchased images than provided for in the General Terms of Sale, they should try to contact the commercial provider of the image, either SPOT Image or KAI.