KOMPSAT EOC Grid Reference System

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Abstract

The grid reference system (GRS) has been useful for identifying the geographical location of satellite images. In this study we derive a GRS for the KOMPSAT Electro-Optical Camera (EOC) images. The derivation substantially follows the way that SPOT defines for its GRS, but incorporates the KOMPSAT orbital characteristics. The KOMPSAT EOC GRS (KEGRS) is designed to be a (K,J) coordinate system. The K coordinate parallel to the KOMPSAT ground track denotes the relative longitudinal position and the J coordinate represents the relative latitudinal position. The numbering of K begins with the prime meridian of K=1 with K increasing eastward, and the numbering of J uses a fixed value of J=500 at all center points on the equator with J increasing northward. The lateral and vertical intervals of grids are determined to be 12.5 km about at the 38° latitude to allow some margins for the value-added processing. The above design factors are being implemented in a satellite programming module of the KOMPSAT Receiving and Processing System (KRPS) to facilitate the EOC data collection planning over the Korean peninsula.

1. Introduction

The KOMPSAT EOC Grid Reference System (KEGRS) defines a grid system that meets requirements of the KOMPSAT system operators and is suitable for use by data users and image data collection planners. The KEGRS is mainly used for:

- telemetry stream segmentation into scenes
- organization and indexing of scenes stored in catalogs
- accessing catalogs and ordering of the KOMPSAT EOC images and products
- image data collection planning

The KEGRS consists of a set of grid points aligned with the KOMPSAT orbital ground track, numbered with reference to the earth's geographic coordinate system. Each grid is 12.5km by 12.5km on the Korean peninsula about at the 38° N. The derivations in the following sections are based upon an earlier similar derivation for the SPOT (see Ref.). We will consider in this paper only the Intermediate Zone (-55° to +55° latitude range). The GRS 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). In the

Intermediate Zone (-55° to +55° latitude range), 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=500 at all center points on the equator, with J increasing as latitude increases. The definition of the KEGRS constants depend almost entirely upon certain orbital parameters for the KOMPSAT satellite. These orbital parameters for KOMPSAT and the constants are listed in Table 1.

Table 1. KOMPSAT Orbital Parameters and the Constants

Symbol	Value	Meaning
i	98.127°	Orbital inclination
e	0.000	Eccentricity of circular orbit
h	685.13	Altitude of orbit(km)
a	7063.275	Orbital semi-major axis
rep	409	Repetition rate of orbital cycle (orbits)
p	5907.72	Period of orbit (seconds)
Λ_1	0.000000	Longitude of the ascending node of the reference track K=1.
C_1	0.11266716	Spacing of the J rows in degrees of latitude along-track
C_4	0.989957150	Sine of the nominal KOMPSAT orbital inclination [=SIN(98.127)]
C_5	-0.141367754	Cosine of the nominal KOMPSAT orbital inclination [=COS(98.127)]
C_8	1.0067395	Square of the ratio of the Earths equatorial radius to polar radius [=(6478.137/6356.752)^2].
C_9	0.14669927	Number of degrees per adjacent track (in K), assuming 409 orbits between repetitions, and 5 intermediate tracks imaged by rolling KOMPSAT satellite [=360/6*409]
C_{10}	14.62492410	Mean Motion (number of orbits) traversed by KOMPSAT per day (409 orbits between repetitions in 27.96596 days).
S_k	16.33048765	Equatorial distance between adjacent K-Tracks (C_9 expressed as kilometers).
R_e	6378.137	Earth equatorial radius (km).

2. Expressing Geographic Coordinates (Λ, Φ) in terms of GRS Designators (K, J)

2.1. Latitude of Node (K, J)

The KEGRS J coordinate is used to first calculate the geocentric latitude, from which the true latitude is derived. The geocentric latitude of row J is given by the relation:

$$\Psi = \varepsilon \cdot \arcsin[\ C_4 \cdot \sin(\ C_1 \cdot r)] \quad [1]$$

where:

$$r = |J - 500| \quad [2]$$

$$\varepsilon = \frac{J-500}{r} \quad (\varepsilon=1, \text{ if } J=500) \quad [3]$$

The required latitude is derived from the geocentric latitude by the relation:

$$\Phi = \arctan(C_8 \cdot \tan \Psi) \qquad [4]$$

2.2 Longitude of Node (K,J)

The longitude of a node (K,J) is computed by determining the longitude of the K-th orbital track relative to the longitude of track 1, and determining the longitudinal offset due to the orbital inclination at the previously determined geocentric latitude.

The equatorial longitude Λ_T for track K is determined by the following:

$$\Lambda_T = \Lambda_1 + C_9 (K - 1) \qquad [5]$$

The longitudinal offset for non-equatorial nodes ($J \neq 500$) consists of determining the following equations:

$$\omega = \arctan\left(\frac{\sin \Psi}{C_4}\right) \qquad [6]$$

$$\Delta\Lambda = \arctan\left(\frac{C_5 \cdot \sin \Psi}{C_4 \cdot \cos \omega}\right) + \frac{\omega}{C_{10}} \qquad [7]$$

Note that $\Delta\Lambda$ is zero if the specified node is on the equator (J = 500). The term ω is related to the theoretical nodal elongation of the satellite (assuming the imaging sensor is always pointing at nadir), and is the longitudinal offset for the node (K,J).

Finally, the longitude of node (K,J) is determined by the following:

$$\Lambda = \Lambda_T + \Delta\Lambda \qquad [8]$$

3. Expressing GRS Designators (K,J) in terms of Geographic Coordinates (Λ, Φ)

3.1 Calculation of J

The KEGRS J coordinate is calculated by converting the specified latitude to geocentric latitude, determination of the theoretical nodal elongation, and converting the nodal elongation to grid units.

The geocentric latitude of a given latitude is given by the relation:

$$\Psi = \arctan\left[\frac{\tan \Phi}{C_8}\right] \qquad [9]$$

The theoretical nodal elongation of the satellite when observing line of latitude is expressed by:

$$\xi = \arcsin\left[\frac{\sin \Psi}{C_4}\right] \qquad [10]$$

where ξ is the nodal elongation of latitude line counted from the ascending node.

The J grid coordinate is determined by adding the equatorial J coordinate (J=500) to the nodal elongation expressed in grid units and rounding:

$$J = 500 + E\{ \frac{\xi}{C_1} \} \quad [11]$$

where E{x} is the nearest whole number to x.

3.2 Calculation of K

The KEGRS K coordinate is calculated by combining the geocentric latitude (equation [9]) with the theoretical nodal elongation (along track), and converting to longitudinal grid units.

The theoretical nodal elongation (along track) is given by the relation:

$$\omega = \arctan\left(\frac{\sin \Psi}{C_4}\right) \quad [12]$$

The GRS K coordinate is calculated to be:

$$T = 1 + \frac{1}{C_9} \cdot \left[(\Lambda - \Lambda_1) - \frac{\omega}{C_{10}} - \arctan\left(\frac{C_5 \cdot \sin \Psi}{C_4 \cdot \cos \omega}\right) \right] \quad [13]$$

$$K = E\{ T \} \quad [14]$$

where T is the relative track number (floating point), and E{x} is the nearest whole number to x.

Finally, the value for K should be adjusted to numerically wrap-around within the range of [1:2454] by either adding 2454 (if less than 1) or subtracting 2454 (if larger than 2454).

4. GRS Roll Angle Calculations

Each orbital pass of the KOMPSAT provides the ability to image swaths of the earths surface approximately parallel to the ground-track of the satellite. Although the parallelism suffers at high latitudes, the approximation is faithful at anticipated operational latitudes within the GRS Intermediate Zone. Parallel swaths are imaged by commanding the satellite to roll by a specific angle to the left (negative roll angle) or right (positive roll angle). The cross-sectional geometry of the roll operation is depicted in Fig. 1.

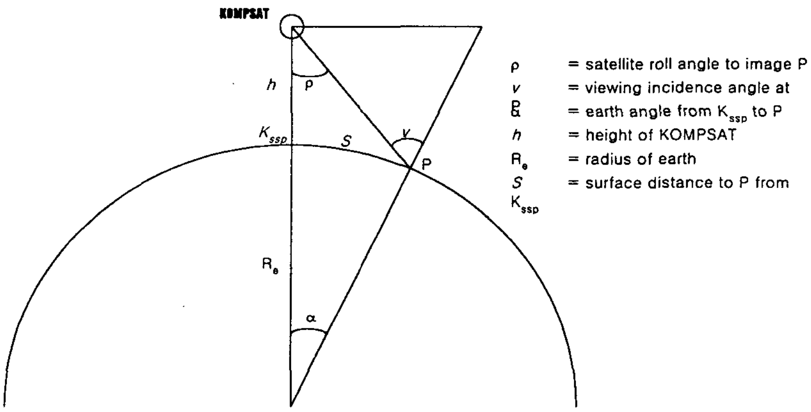

Fig. 1. KOMPSAT Roll Angle Geometry

The determination of the roll angle from the sub-spacecraft path to a given P(K,J) scene coordinate is determined through the following set of equations. It is first necessary to express the K-coordinate of the sub-spacecraft path (without rounding-off) using the following equation (based upon equation [13]):

$$\text{Kssp} = 1 + \frac{1}{C_9} \cdot \left[(\Lambda - \Lambda_1) - \frac{\omega}{C_{10}} - \arctan\left(\frac{C_5 \cdot \sin\Psi}{C_4 \cdot \cos\omega}\right) \right] \qquad [15]$$

where Kssp is the relative track number (floating point) of any point (Φ, Λ) along the sub-spacecraft path. The values of geocentric latitude and theoretical nodal elongation are given by the relations in equations [9] and [12] respectively.

The arc distance S along the surface from the satellite ground track (K=Kssp) to a GRS grid point P(K,J) is depicted in Fig. 2.

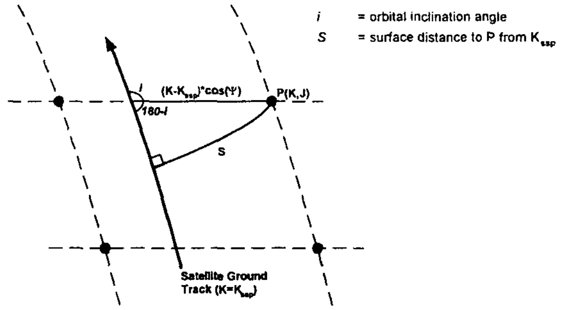

Fig. 2. Sub-Spacecraft path to Scene Distance Geometry

The derived equation for distance S is:

$$S = C_4 \cdot (K - K_{SSP}) \cdot S_k \cdot \cos\Psi \qquad [16]$$

where:

$$S_k = C_9 \cdot \left(\frac{2\pi \cdot \text{Re}}{360}\right) = 16.33048765 \text{ Km}$$

S_k is the nominal distance (in Km) between adjacent K-tracks at the equator.

The corresponding earth-centered angle a subtended by S (on the surface) is:

$$\alpha = \frac{S}{R_e} \qquad [17]$$

The roll angle ρ is determined by:

$$\rho = \arctan\left(\frac{\sin\alpha}{\frac{h}{\text{Re}} + (1 - \cos\alpha)}\right) \qquad [18]$$

Additionally, the angle of viewing incidence, υ, for the scene at GRS point (K,J) from its local normal vector may also be determined from the above equations [17] and [18] as:

$$\upsilon = \alpha + \rho \qquad [19]$$

The viewing incidence angle of a scene is useful when considering the suitability of a scene for orthorectification. Incidence angles near zero are most suitable for the orthorectification process.

5. Summary

The KEGRS will be used in two ways: first, it will be used to manage the KOMPSAT image database system, and second, to plan the image collection for the KOMPSAT EOC cartographic missions. Like the SPOT system the user can request the data with the GRS node (K,J), or with the geographic coordinate of area of interest. We can also calculate the satellite roll angle for the specific KEGRS (K,J) node and command the satellite to point the specific area. With this ability we can collect the KOMPSAT EOC images for the main mission of the EOC, the generation of the Korean map in three years.

An example of the KOMPSAT EOC GRS system is depicted in Fig. 3.

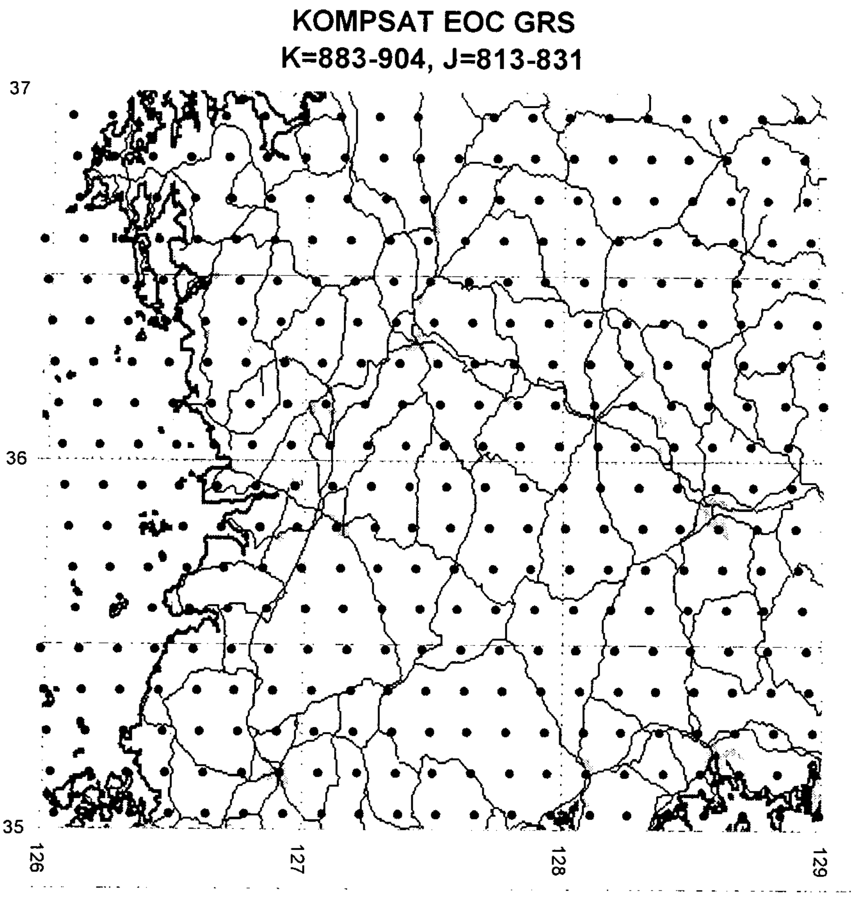

Fig. 3. KOMPSAT EOC Grid Reference System overlay on Korean background map.

References

"SPOT User's Handbook", CNES and SPOT Image, Volume 1 Appendix 4