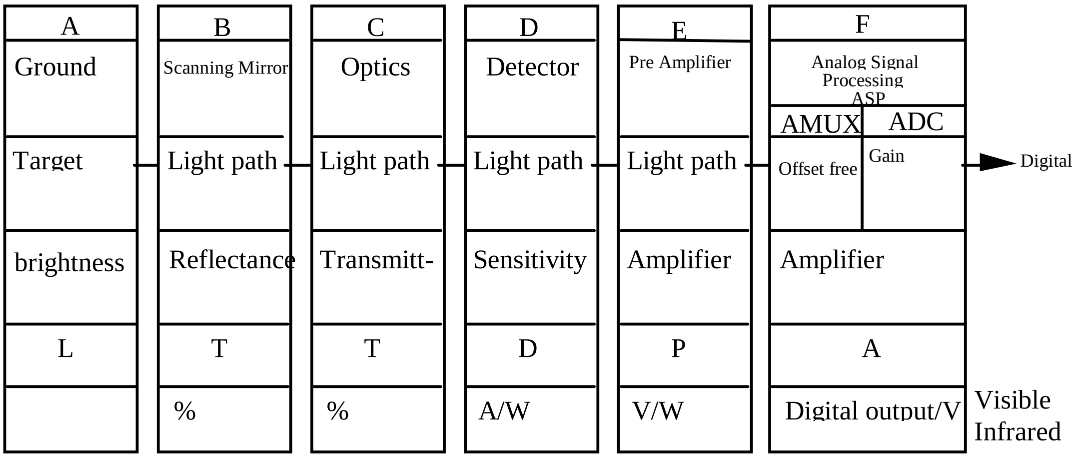
5. Generation Of Radiometric Correction Information

5.1 Radiometric Model

5.1.1 Block Diagram

The following figure shows distortion elements on OCTS sensitivity.



A	B	C	D	E	F
Ground	Scanning Mirror	Optics	Detector	Pre Amplifier	Analog Signal Processing ASP AMUX / ADC
Target	Light path	Light path	Light path	Light path	Offset free / Gain
brightness	Reflectance	Transmitt-	Sensitivity	Amplifier	Amplifier
L	T	T	D	P	A
	%	%	A/W	V/W	Digital output/V

Fig. 5.1.1 Block Diagram Of Radiometric Model

5.1.2 Radiometric Model Equation

Calibration Function for output level V of OCTS is given as follows;

$$V_C = F_d\left(V_V\right) = F_d\left(F_a\left(L_0\right)\right) \tag{5.1-1}$$

where,

V_C: OCTS output (digital value)
V_V: OCTS output (voltage value)
F_d: A/D Conversion Function
L_0: Incidence brightness
F_a: Amplifier characteristics of analog signal processor

are further expressed as follows:

$$V_C = (\alpha \cdot L_0 \cdot T_S \cdot T_O \cdot D \cdot P \cdot A_{am} + O_{am}) \cdot A_{ad} + O_{ad} \tag{5.1-2}$$

where,

V_C: OCTS output (digital value)
V_V: OCTS output (voltage value)
L_0: Incidence brightness
α: Coefficient $(S\cdot(d/f)^2)$, S: caliber f: focal distance d: detector size
T_S: Reflectance of scanning mirror
T_O: Transmittance of optics unit
D: Detector sensitivity
P: Pre-amplifier gain
A_{am}: Analog signal processing unit analog multiplexor gain
A_{ad}: Analog signal processing unit A/D converter gain
O_{am}: Analog signal processing unit analog multiplexor offset
O_{ad}: Analog signal processing unit A/D converter offset

Parameters that indicate the above characteristics have the following characteristics.

$$\begin{aligned}
T_S &= T_{S0}(i) \cdot \eta(i,\theta) \\
T_O &= T_O(i) \\
D &= D_0(i,j) \cdot \left(1 + \beta_d(i,j) \cdot \left(t_d - t_{d0}\right)\right) \\
P &= P_0(i,j) \cdot \left(1 + \beta_p(i,j) \cdot \left(t_p - t_{p0}\right)\right) \\
A_{am} &= A_{am0}(i,j) \cdot \left(1 + \beta_{am}(i,j) \cdot \left(t_{am} - t_{am0}\right)\right) \\
A_{ad} &= A_{ad0}(i,g) \cdot \left(1 + \beta_{ad}(i,g) \cdot \left(t_{ad} - t_{ad0}\right)\right) \\
O_{am} &= O_{am0}(i,j) \cdot \left(1 + \beta_{Oam}(i,j) \cdot \left(t_{am} - t_{am0}\right)\right) \\
O_{ad} &= O_{ad0}(i,g) \cdot \left(1 + \beta_{Oad}(i,g) \cdot \left(t_{ad} - t_{ad0}\right)\right)
\end{aligned} \tag{5.1-3}$$

where

i: Band
j: element
g: gain
θ: Tilting Angle
t_d: Detector temperature
t_p: Pre amplifier temperature
t_{am}: Analog multiplexor temperature
t_{ad}: A/D converter temperature

Also, η is coefficient for reflection when tilting, and β_d, β_p, β_{am}, β_{ad}, β_{Oam}, β_{Oad} are coefficients to indicate temperature characteristics of each segment.

$$
\begin{aligned}
&G_r\left(i,j,g\right) = \alpha \cdot T_{S0} \cdot T_O \cdot D_0 \cdot P_0 \cdot A_{am0} A_{ad0} \\
&f_G\left(i,j,g,\theta,t_d,t_p,t_{ad},t_{am}\right) = \eta \cdot \left(1+\beta_d \cdot \left(t_d - t_{d0}\right)\right) \cdot \left(1+\beta_p \cdot \left(t_p - t_{p0}\right)\right) \\
&\qquad\qquad \cdot \left(1+\beta_{am} \cdot \left(t_{am} - t_{am0}\right)\right) \cdot \left(1+\beta_{ad} \cdot \left(t_{ad} - t_{ad0}\right)\right) \\
&O(i,j,g,t_{ad},t_{am}) = O_{am} \cdot A_{ad} + O_{ad}
\end{aligned}
\qquad (5.1\text{-}4)
$$

By the above equation, (5.1-2) can be written as

$$V_C = f_G \cdot G_\gamma \cdot L_0 + O \qquad (5.1\text{-}5)$$

Here, f_G G_γ is gain for entire OCTS and f_G is a changeable element according to environment (tilt angle, gain setting and temperature of each segment) whereas G_γ is not subject to environment. O is an offset element to entire OCTS and is changeable according to environment, since including O_{ad} and O_{am} . But, changing factor is very small and offset value itself is also small, so environment dependence is to be ignored.

5.1.3 Correction Coefficients

(1) Radiometric correction of visible and near infrared

Radiometric correction is performed for visible and near infrared band based on OCTS radiometric characteristics indicated in (5.1-5). From (5.1-5), the following equation is determined.

$$L_0 = \frac{V_C - O}{f_G \cdot G_\gamma} \qquad (5.1\text{-}6)$$

Calculation method for radiometric correction coefficients is to get incidence brightness L_0 from OCTS output V_C of each pixel by calculating the right section of the above formula following (5.1-4). Radiometric correction equation is as follows.

$$L_0 = aV_C + b \qquad (5.1\text{-}7)$$

Here,

$$a = \frac{1}{f_G \cdot G_\gamma}$$

$$b = -\frac{O}{f_G \cdot G_\gamma}$$

(2) Radiometric correction of thermal infrared

Since reference black body is observed for each scanning, calibration is performed with this data.

As is in (5.1-6), when radiation brightness of black body is L_I and OCTS output from black body observation is V_I , the following equation is established.

$$L_I = \frac{V_I - O}{f_G \cdot G_\gamma} \qquad (5.\ 1\text{-}\ 8)$$

Therefore gain is described as follows.

$$f_G \cdot G_\gamma = \frac{V_I - O}{L_I}$$

Using this calibrated gain, incidence radiation brightness is calculated as follows:

$$L_0 = L_I \frac{V_C - O}{V_I - O} \qquad (5.1\text{-}\ 9)$$

Radiometric correction equation is as follows.

$$L_0 = cV_C + d \qquad (5.1\text{-}\ 10)$$

Here, c and d should be used as correction coefficients for the following equations.

$$c = \frac{L_I}{V_I - O}$$

$$d = \frac{O}{V_I - O}$$

5.2 Generation Of Visible And Near Infrared Correction Coefficient

5.2.1 Telemetry Processing

In order to calculate correction coefficients, it is necessary to select gain data G_γ stored in database from gain setting first and then determine f_G , coefficients which are variable under the environment shown in (5.1-4). Parameters to calculate f_G are as follows:

g: Gain setting
θ: Tilt angle
t_p: Pre-amp temperature
t_{am}: Analog multiplexor temperature
t_{ad}: A/D converter temperature

Among these, gain and tilt angle are used for status data for telemetry. The following parameters are used for temperature of each segment:

- Optical assembly cover temperature (which represents visible and near infrared detector temperature and visible and near infrared pre amplifier temperature)
- SRU Frame Temperature (which represents analog multiplexor temperature)
- SRU Frame Temperature (which represents temperature at A/D converter segment)

Data of frame which considered to be missing or the first inspection error will be interpolated from normal data before and after the data.
Using the above telemetry data, f_G is determined by the following equation:

$$f_G\left(i, j, g, \theta, t_d, t_p, t_{ad}, t_{am}\right) = \eta \cdot (i, \theta)\left(1 + \beta_d \cdot \left(t_d - t_{d0}\right)\right) \cdot \left(1 + \beta_p(i, j) \cdot \left(t_p - t_{p0}\right)\right)$$
$$\cdot\left(1 + \beta_{am}(i, j) \cdot \left(t_{am} - t_{am0}\right)\right) \cdot \left(1 + \beta_{ad}(i, g) \cdot \left(t_{ad} - t_{ad0}\right)\right) \tag{5.2-1}$$

5.2.2 Reading Calibration Coefficients

Gain G_γ and offset O which have been calibrated from calibrated coefficients database will be read at separate inspection facilities. These data is by each element of each band (and gain is set according to gain setting) . These data are searched from database by date of scene center and using observation date as a key (date calibration data is acquired) and the newest data before scene center date is used.

5.2.3 Calculation Of Calibration Coefficients

Coefficients of the following equation a, b, c, d and table F are used as Radiometric calibration coefficients in order to generalize interface:

$$L_0 = aF^{-1}\left(cV_C + d\right) + b \tag{5.2-2}$$

Therefore, in case of visible and near infrared, calibration equation is (5.1-7), the above coefficients should be put as follows and table F is prepared for identical conversion table.

$$\begin{aligned} a &= \frac{1}{f_G \cdot G_\gamma} \\ b &= 0 \\ c &= 1 \\ d &= -O \end{aligned} \qquad (5.2\text{-}3)$$

5.3 Generation Of Thermal Infrared Correction Coefficients

5.3.1 Processing Of Telemetry

In case of thermal infrared, in order to calculate correction coefficients, it is necessary to determine radiation brightness from reference black body from reference black body temperature for each scanning. For black body temperatures, the following telemetry is used;

- Calibration segment Reference black body temperature 1
- Calibration segment Reference black body temperature 2
- Calibration segment Reference black body temperature 3
- Calibration segment Reference black body temperature 4
- Calibration segment Reference black body temperature 5

Among these, average of black body temperature from 2 to 5 is used. However, in case any of black temperature 2-5 found an error in the preliminary inspection and the difference of minimum and maximum of black temperature 2 through 5 is more than 5K, use black body temperature 1 instead. Also, in case telemetry frame is damaged, data linear interpolated from the data before and after will be used.
When black body temperature of each scan has determined, then moving average is to be performed in scanning direction to get smoothed data.

When black body temperature is determined, it can be converted to radiation brightness of each band that corresponds by using a temperature and brightness conversion table.

5.3.2 Reading Of Calibration Coefficients

From calibrated coefficients database offset O and data of non-liner function F_{m0} which have been calibrated at separate inspection facilities will be read. These data are by each element of each band. These data are searched from database by using date of scene center with using observation date as a key (date calibration data was acquired) and the newest data before scene center date is used.

5.3.3 Processing Of Black Body Observation Data

For black body observation data of each band, the average of data of all five samples by each scanning is taken and then, moving average is performed in scanning direction.

5.3.4 Calculation Of Calibration Coefficients

Correction equation for thermal infrared will be (5.1-14). Since calibration coefficients are the same as visible and near infrared as indicated as below,

$$L_0 = aF^{-1}\left(cV_C + d\right) + b \qquad (5.3\text{-}1)$$

each coefficient will be

$$
\begin{aligned}
a &= 1 \\
b &= 0 \\
c &= \frac{F_{m0}\left(L_I\right)}{V_I - O} \\
d &= -\frac{O \cdot F_{m0}\left(L_I\right)}{V_I - O}
\end{aligned}
\qquad (5.3\text{-}2)
$$

where, L_I is radiation brightness and V_I is black body observation value corresponding to black body temperature. For table F, non-liner table F_{m0} will be used.