A STUDY ON THE EAST/WEST STATION KEEPING PLANNING CONSIDERING WHEEL OFF-LOADING

Sang-Cherl Lee*, Bong-Kyu Park*, Bang-Yeop Kim*, Gwanghyeok Ju* and Koon-Ho Yang*

* COMS Project Office, Korea Aerospace Research Institute, Daejeon, Korea
(Tel : +82-42-860-2841; E-mail: sclee@kari.re.kr)

ABSTRACT: Now, on the developing COMS(Communication, Ocean and Meteorological Satellite) has solar panel on the South panel only. Therefore, the wheel off-loading has to be performed periodically to reduce a induced momentum energy by a asymmetric solar panel. One of two East/West station keeping maneuver to correct simultaneously longitude and eccentricity, orbit corrections may be performed during one of the two wheel off-loading manoeuvres per day to get enough observation time for meteorological and ocean sensor. In this paper, we applied a linearized orbit maneuver equation to acquire maneuver time and delta-V. Nonlinear simulation for the station keeping is performed and compared with general station keeping strategy for fuel reduction.

KEY WORDS: Geostationary Orbit, Orbit Maneuver, Station Keeping, Wheel Off-Loading, Solar Sail, Solar Panel, Meteorological Satellite

1. INTRUDUCTION

The general geostationary communication satellites have several symmetric solar panels on the North/South panel. But in case of meteorological satellite, its meteorological imager is installed on the earth deck and the radiation cooler are installed on the North or South panel considering of thermal radiation efficiency. The sun blazed upon the solar panel and the reflected heat is felt even cooler assembly. Because we have to install cooler assembly in order to avoid interference of solar panel. Therefor a deployed solar sail is installed in the North or South panel such as GOES, MTSAT meteorological satellite for the moment equilibrium.

The COMS contract to develop the COMS satellite and to provide support for system activities has been awarded by KARI to ASTRIUM France. The COMS joint project group is composed of KARI and ASTRIUM engineers. Now, on the developing COMS (Communication, Ocean and Meteorological Satellite) will be launched in 2008. A solar panel installed only on the South panel, on the other North panel, neither solar panel nor solar sail will be installed as shown in Figure 1. The accumulated momentum energy on several momentum wheels is dissipated by thrusters periodically so called wheel off-loading. The 7 prime and 7 redundant thrusters provide pulses for orbit and attitude control as required by the AOCS to manoeuvre the satellite during the station keeping phase in COMS. Especially, South panel of COMS will be installed 3 thrusters that will be used by firing combination to move satellite along by (–Y) axis in ECI. Then we can save fuel by performing North/South station keeping to move satellite upward in equatorial orbit plane by using same thrusters of wheel off-loading.

According to references 2, the baseline is to perform two wheel off-loading manoeuvres per day at 08:37 and 00:00 S/C local time, or 00:00 and 15:22 S/C local time, or 08:37 and 15:22 S/C local time. The timing of those manoeuvres will be selected as a function of the season in order to maximise the inclination correction along the direction of the secular drift.

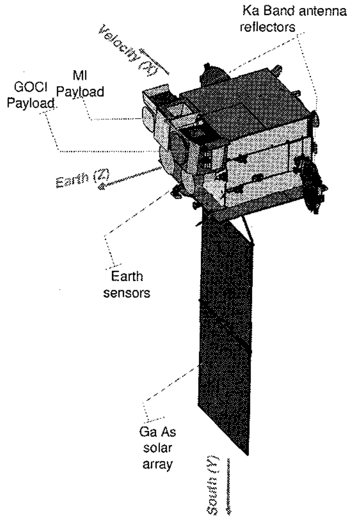

Figure 1. COMS Configuration

Also, It has a constraint to perform a wheel of-loading shall be done within 10min and North/South station keeping maneuver within 1 hour. Whenever the trusters are activated, normal observation mission may be impossible because of a satellite vibration, attitude stabilization, attitude orientation error.

Therefore to obtain a maximum observation time, as shown in figure 2, one of two East/West station keeping maneuver to correct simultaneously longitude and eccentricity, orbit corrections may be performed with one of the two wheel off-loading manoeuvres everyday.

In this paper, we introduce a new East/West station keeping strategy having one fixed time of two wheel off-loading maneuver. Usually the manevuer time and velocity increments are changed by every condition and we applied a linearized orbit maneuver equation to acquire the maneuver time and delta-V. Nonlinear simulation for the station keeping was performed and compared with general station keeping strategy.

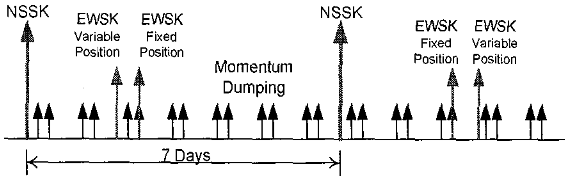

Figure 2. Figure placement and numbering.

2. MANEUVER STRATEGY

ITU-R shall effect allocation of bands of the radiofrequency spectrum, the allotment of radio frequencies and the registration of radio frequency assignments and of any associated orbital position in the geostationary satellite orbit in order to avoid harmful interference between radio stations of different countries because the geostationary orbit is limited natural space resources.

More than that, the geostationary satellite is always perturbed by the combined the gravitational attractions of the Sun and Moon, the bulge of the earth, the solar radiation pressure which causes the position and velocity changed continuously. The satellite must be controlled by combination with East/West and North/South station-keeping maneuver about a period of one or two week so as to keep the satellite within ±0.05° of the station keeping box. Whereas satellite's orientation is maintained by momentum wheels supplemented by thrusters.

A maneuver planning is a processing to get velocity increments and maneuver time for East/West station keeping maneuver. According to references 3 and 4, It is easy to see that by selecting two velocity increments and maneuver time, one can obtain any desired combination of longitude change and eccentricity vector change. Second maneuver time is started at 12 hours later after first manver time. But we need new methods to acquire that one of two maneuver time is synchronized with one of wheel off-loading maneuver time. The equation can be expressed as

$$F_1 = \Delta\lambda - \frac{3(\alpha_N - \alpha_1)}{V_{SYN}}\Delta V_{T1} - \frac{3(\alpha_N - \alpha_2)}{V_{SYN}}\Delta V_{T2} = 0 \qquad (1)$$

$$F_2 = \Delta e_x - \frac{2\cos\alpha_1}{V_{SYN}}\Delta V_{T1} - \frac{2\cos\alpha_2}{V_{SYN}}\Delta V_{T2} = 0 \qquad (2)$$

$$F_3 = \Delta e_y - \frac{2\sin\alpha_1}{V_{SYN}}\Delta V_{T1} - \frac{2\sin\alpha_2}{V_{SYN}}\Delta V_{T2} = 0 \qquad (3)$$

where, α_1, α_2 is a sidereal angle from the vernal equinox and represents maneuver time at each East/West station keeping maneuver. It is not convenient to get a solution of equation more than angle expression. Therefore we can convert the angle expression to time expression by using the following equation.

$$\alpha_1 = \omega_e(T_{T1} - T_V) \qquad (4)$$

$$\alpha_2 = \omega_e(T_{T2} - T_V) \qquad (5)$$

where, ΔV_{T1}, T_{T1} and ΔV_{T2}, T_{T2} represent first and second maneuver velocity increments and maneuver time respectively. And T_V is represents the time when satellite pass by the vernal equinox. The α_N represents maneuver time of next station keeping cycle. $\Delta\dot{\lambda}$, Δe_x, Δe_y represent a difference of desired drift, a difference of desired x component of eccentricity vector and a difference of desired y component of eccentricity vector. To solve the simultaneous non-linear equation, we can use the following equation (6)–(7). This is solved by the following scheme of Newton's method in three variables, x_1, x_2, x_3 and three function, $F_1(x_1, x_2, x_3)$, $F_3(x_1, x_2, x_3)$ and $F_2(x_1, x_2, x_3)$ is

$$x^{(n+1)} = x^{(n)} - J^{-1}(x^{(n)})F(x^{(n)}), \quad n = 0,1,\ldots, \qquad (6)$$

where, x_1, x_2, x_3 represent ΔV_1, ΔV_2 and T_1 respectively. The state vector can be improved by iteration of calculation with Newton-Raphson method. Where the Jacobian matrix J is given by

$$J = \begin{bmatrix} \frac{\partial F_1}{\partial \Delta V_{T1}} & \frac{\partial F_1}{\partial \Delta V_{T2}} & \frac{\partial F_1}{\partial \Delta T_{T1}} \\ \frac{\partial F_2}{\partial \Delta V_{T1}} & \frac{\partial F_2}{\partial \Delta V_{T2}} & \frac{\partial F_2}{\partial \Delta T_{T1}} \\ \frac{\partial F_3}{\partial \Delta V_{T1}} & \frac{\partial F_3}{\partial \Delta V_{T2}} & \frac{\partial F_3}{\partial \Delta T_{T1}} \end{bmatrix} \qquad (7)$$

where, elements of jacobian matrix represent the following equation (8)- (16).

$$\frac{\partial F_1}{\partial \Delta V_{T1}} = -\frac{3\omega_e}{V_{syn}}(T_N - T_{T1}) \qquad (8)$$

$$\frac{\partial F_1}{\partial \Delta V_{T2}} = -\frac{3\omega_e}{V_{syn}}(T_N - T_{T2}) \qquad (9)$$

$$\frac{\partial F_1}{\partial \Delta T_{T1}} = +\frac{3\omega_e}{V_{syn}}\Delta V_{T1} \qquad (10)$$

$$\frac{\partial F_2}{\partial \Delta V_{T1}} = -\frac{2}{V_{syn}}\cos(\omega_e(T_{T1} - T_V)) \qquad (11)$$

$$\frac{\partial F_2}{\partial \Delta V_{T2}} = -\frac{2}{V_{syn}}\cos(\omega_e(T_{T2} - T_V)) \qquad (12)$$

$$\frac{\partial F_2}{\partial \Delta T_{T1}} = +\frac{2}{V_{syn}}\sin(\omega_e(T_{T1} - T_V))\,\Delta V_{T1}\,\omega_e \qquad (13)$$

$$\frac{\partial F_3}{\partial \Delta V_{T1}} = -\frac{2}{V_{syn}}\sin(\omega_e(T_{T1} - T_V)) \qquad (14)$$

$$\frac{\partial F_3}{\partial \Delta V_{T2}} = -\frac{2}{V_{syn}} \sin(\omega_e (T_{T2} - T_V)) \tag{15}$$

$$\frac{\partial F_3}{\partial \Delta T_{T1}} = -\frac{2}{V_{syn}} \cos(\omega_e (T_{T1} - T_V))\, \Delta V_{T1}\, \omega_e \tag{16}$$

3. SIMULATION RESULT

We have done a simulation with nonlinear numerical integration for a year with following two cases. In case of 'Case 1', we use a general East/West station keeping strategy to get the maneuver time and velocity increments which were changed by every circumstances. In case of 'Case 2', we use one fixed East/West station keeping maneuver with one of the maneuver time 15:22. Both of them are used by all minimum fuel inclination initialization targeting for North/South station keeping.

Table 1. Simulation Case

	EWSK (7days Periods)
Case1	General Station Keeping Strategy
Case2	One Fixed Maneuver (15h22m)

We use the general East/West station keeping strategy, simulation results is shown in figure 3 and figure 4. When we use one fixed maneuver for station keeping at 15h 22m with one of wheel off-loading simultaneously, simulation results is shown in figure 5, figure 6. Figure 3 shows that the satellite is maintained very well between 128.15°E and 128.25°E for one year. Figure 4 shows that semi-major changes with station keeping maneuver periodically for one year. Figure 5 shows that the satellite is maintained between 128.15°E and 128.25°E. Figure 6 shows that semi-major changes with station keeping maneuver periodically for one year presented in case 2. But this semi-major are increase sometimes sorely because of control of eccentricity vector. Table 2 and 3 contain maneuver time and manever velocity increments for East/West station keeping for two month according to case 1, 2. In table 3, we can find that one of two East/West station keeping maneuver time is 15h22m. The following Table 4 describes a total delta-V comparison of two cases for one year.

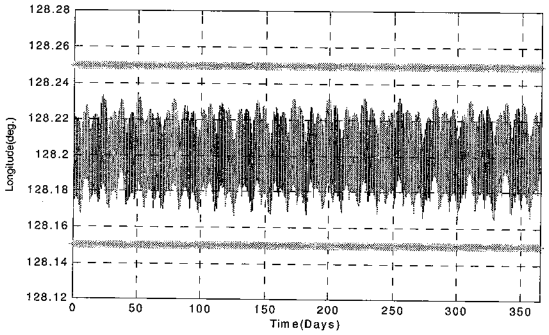

Figure 3. Longitude Change in General EWSK Strategy

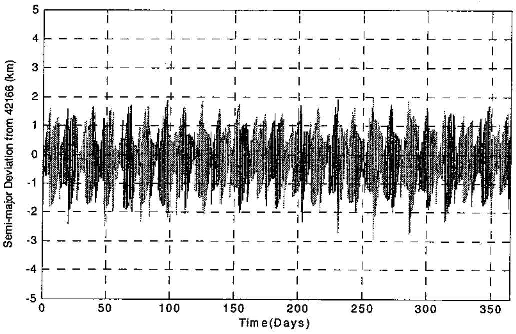

Figure 4. Semi-major Change in General EWSK Strategy

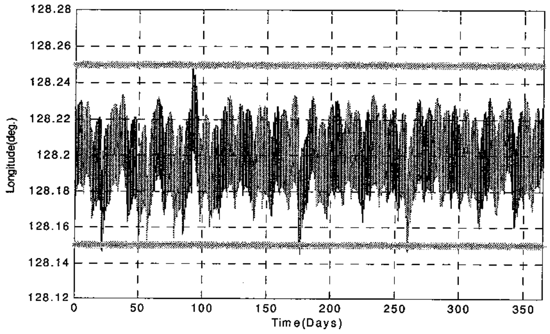

Figure 5. Longitude Change in One Fixed EW SK Maneuver Strategy

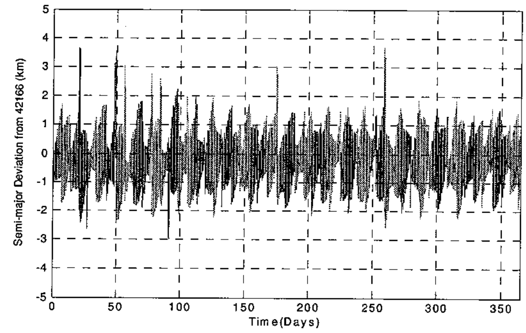

Figure 6. Semi-major Change in One Fixed EWSK Maneuver Strategy

Table 2. EW Delta-V in General EWSK Strategy

No	Year	MM	DD	hh	mm	ss	ΔV (km/sec)
EW 1st ΔV #1	2008	1	7	5	49	3.59	-4.3426E-05
EW 1st ΔV #2	2008	1	7	17	47	5.64	-8.3295E-08
EW 2nd ΔV #	2008	1	14	4	35	8.50	-3.8591E-05
EW 2nd ΔV #	2008	1	14	16	33	10.55	9.3057E-07
EW 3rd ΔV #1	2008	1	21	11	21	51.69	-5.2486E-05
EW 3rd ΔV #2	2008	1	21	23	19	53.73	1.6109E-05
EW 4th ΔV #1	2008	1	28	12	0	1.21	-5.0582E-05
EW 4th ΔV #2	2008	1	28	23	58	3.26	1.3702E-05
EW 5th ΔV #1	2008	2	4	1	34	55.50	-3.0964E-05
EW 5th ΔV #2	2008	2	4	13	32	57.55	-5.2652E-06
EW 6th ΔV #1	2008	2	11	4	29	6.87	-3.1942E-05
EW 6th ΔV #2	2008	2	11	16	27	8.92	-8.4044E-06
EW 7th ΔV #1	2008	2	18	10	23	38.50	-5.7666E-05
EW 7th ΔV #2	2008	2	18	22	21	40.55	2.3443E-05
EW 8th ΔV #1	2008	2	25	10	52	26.69	-5.1674E-05
EW 8th ΔV #2	2008	2	25	22	50	28.73	1.4131E-05
EW 9th ΔV #1	2008	3	3	21	59	58.22	-3.0746E-05
EW 9th ΔV #2	2008	3	4	9	58	0.27	-1.1486E-05
EW 10th ΔV #	2008	3	10	6	9	57.80	-2.2898E-05
EW 10th ΔV #	2008	3	10	18	7	59.84	-1.1868E-05

Table 3. EW Delta-V in One Fixed EWSK Maneuver Strategy

No	Year	MM	DD	hh	mm	ss	ΔV (km/sec)
1st ΔV #1	2008	1	7	15	22	0.00	3.9893E-06
1st ΔV #2	2008	1	8	6	0	50.25	-4.0035E-05
2nd ΔV #1	2008	1	14	15	22	0.00	-2.4921E-06
2nd ΔV #2	2008	1	15	4	18	11.60	-4.0738E-05
3rd ΔV #1	2008	1	21	15	22	0.00	7.6849E-05
3rd ΔV #2	2008	1	22	13	24	20.45	-1.2648E-04
4th ΔV #1	2008	1	28	15	22	0.00	-8.7701E-05
4th ΔV #2	2008	1	28	18	1	8.23	7.1061E-05
5th ΔV #1	2008	2	4	2	18	51.81	-2.7093E-05
5th ΔV #2	2008	2	4	15	22	0.00	-8.3760E-06
6th ΔV #1	2008	2	11	15	22	0.00	-1.1058E-05
6th ΔV #2	2008	2	12	4	2	32.99	-3.5299E-05
7th ΔV #1	2008	2	18	15	22	0.00	7.9273E-05
7th ΔV #2	2008	2	19	12	49	31.04	-1.2911E-04
8th ΔV #1	2008	2	25	15	22	0.00	7.7905E-05
8th ΔV #2	2008	2	26	13	18	12.04	-1.1184E-04
9th ΔV #1	2008	3	3	15	22	0.00	-2.6065E-06
9th ΔV #2	2008	3	3	22	37	5.86	-1.8400E-05
10th ΔV #	2008	3	10	15	22	0.00	-1.6602E-05
10th ΔV #	2008	3	11	5	8	42.16	-2.4142E-05

Table 4. Total Delta-V for Two Cases (1 year)

	General SK Maneuver	One Fixed Time Maneuver Strategy
EW	2.773 m/sec	5.842 m/sec

CONCLUSION

On this study, we introduce a method to get maneuver time and maneuver magnitude for station keeping with considering of wheel off-loading. And we also have nonlinear simulation for the station keeping performed and compared with general station keeping strategy for fuel reduction. If one of two delta-v in East/West station-keeping are fixed, magnitude of delta-v increased and maneuver time delayed. But longitude of satellite is maintained its satation keeping box very well. We also confirm that delta-v needed in East/West station keeping more than 45% of magnitude of delta-v using the general satation keeping strategy.

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