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ANGLES ONLY ORBIT DETERMINATION FROM SINGLE TRACKING STATION

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ABSTRACT

Satellite orbit determination using angles only data from single ground station is carried out. The KOMPSAT-1 satellite mono-pulse angle tracking data from 9-meter S-band antenna at KARI site in Daejeon are used for the orbit determination. Various angle tracking arcs from one-day to five-day are processed and the orbit determination results are analyzed. Antenna pointing data are predicted based on the orbit determination results to check the possibility of re-acquisition and tracking of the satellite signal. Normal satellite mission operations including orbit determination, antenna prediction, satellite re-acquisition and automatic tracking from predicted antenna angle pointing data are concluded to be possible when three-day angle tracking data from single tracking station are used for the orbit determination.

Keywords: orbit determination, angles only data, single station, satellite tracking, antenna pointing, NORAD TLE, STSAT, KOMPSAT

1. INTRODUCTION

NORAD Two-Line-Element (TLE) is widely used for the small and micro satellite operations and control as a primary input to the antenna pointing control and mission scheduling (Lee 2002). However, this kind of TLE users have trouble to track and operate their satellites when they fail to access the updated TLE.

Mission operations of the micro satellites in Korea such as the KITSAT-1, 2, 3, and STSAT-1 are totally dependent upon the NORAD TLEs. Whereas the KOMPSAT-1 operation is free from TLEs because the satellite has the capability of the GPS navigation and ranging (Lee et al. 1998). Normally, the KOMPSAT-1 GPS navigation solutions from on-board are used as the primary input to orbit determination (OD) and also TLE can be generated independently (Cho et al. 2002, Lee & Park 2003). In Launch and Early Orbit Phase (LEOP) operations of the KOMPSAT-1, ground antenna ranging and angle tracking data were used for ODs and mission operations (Lee et al. 2003).

When the satellite ground station antenna has a capability to auto-track the satellite signal, the antenna azimuth and elevation angles data can be collected and used for the OD. In case the antenna pointing angle predictions from the OD using angles data guarantees the re-acquisition of the satellite signal, normal satellite mission operations and control can be possible without using the NORAD

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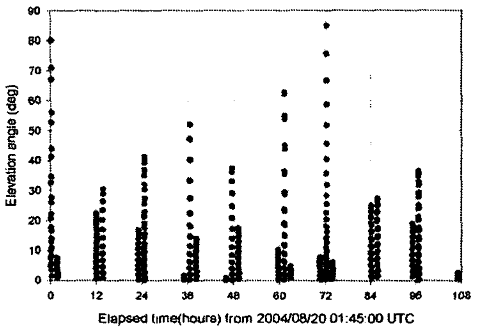

Figure 1. Elevation angles.

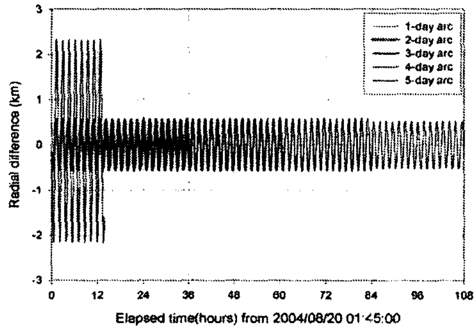

Figure 2. Radial difference.

TLE. The satellite tracking antenna at SatRec KAIST has has a capability to auto-track the STSAT-1 satellite.

In this paper, satellite OD using angles only data from single tracking station was performed to check the re-acquisition of the satellite signal from predicted antenna pointing data. The KOMPSAT-1 satellite angle tracking data from one-day to five-day arcs were used for analyzing the OD accuracy. The OD results using GPS navigation solutions were used as the reference satellite orbit. Predicted satellite antenna pointing data based on the OD were compared with the real satellite tracking data to evaluate the offset angles.

2. ANGLES ONLY ORBIT DETERMINATION

KOMPSAT-1 angles tracking data from 20th of August, 2004 were used for OD. In order to find the optimal spans of the angle tracking data arcs, angles only data from one-day to five-day were processed for OD. Figure 1 shows the elevation angles during the 5-day tracking period. The satellite passes of the elevation angles over 10 degrees were tracked and used for angles only OD. The operational OD using 5-day GPS navigation solutions was used as a reference orbit for comparisons. Figures 2 $\sim$ 4 present the radial, along-track, and cross-track differences between the angles only OD and the reference orbit. As shown in the figures, the radial and cross-track difference is much smaller than along-track difference. The along-track difference indicates the time offset in satellite tracking. The OD using 3-day angle data shows a stable results in Figure 3.

A series of ODs using 3-day angles only data were performed for 10 days like a normal satellite mission operation. Figure 5 shows the position differences between 3-day angles only ODs and a GPS based reference orbit. The maximum position difference reaches about 5 km. A major difference appears in along-track direction as shown in Figure 6.

3. OFFSET ANGLES IN ANTENNA TRACKING

Antenna pointing data are predicted based on the OD results. Consequently, the errors in the OD are expressed as the offset angles in antenna tracking. In order to evaluate the antenna offset angles, antenna pointing data are generated based on the 3-day angles only OD results and 3-day GPS based OD results. Figure 7 shows the offset angle between the two antenna pointing data. The offset angles are well below 0.3 degrees and it shows no problem in re-acquisition of the satellite

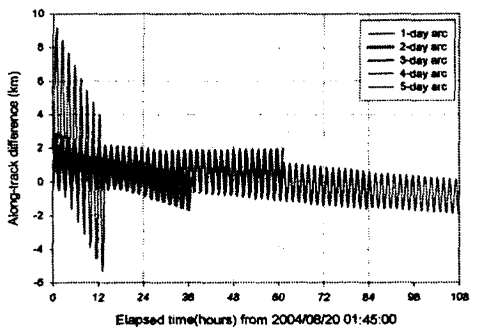

Figure 3. Along-track difference.

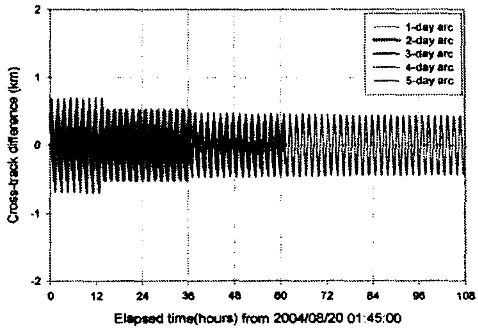

Figure 4. Cross-track difference.

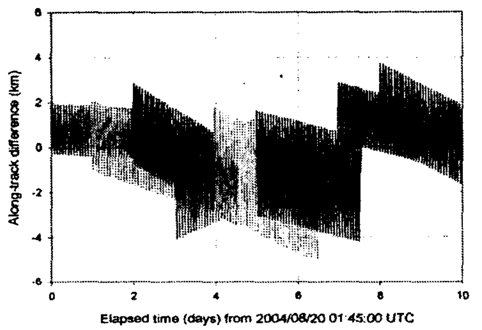

Figure 5. Position difference in 3-day angles only OD.

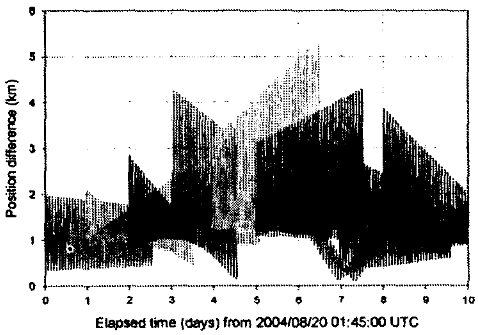

Figure 6. Along-track difference in 3-day angles only OD.

signal using 9-meter S-band antenna. Real angle tracking data were processed by the cubic-spline interpolation method for the comparison with the antenna pointing data from 3-day angles only OD. Figure 8 presents the offset angles between the real tracking data and the predicted antenna pointing data. A maximum offset of 0.8 deg. is shown in Aug. 24 and the normal offset angles are below 0.5 deg. The half-power-beam-width (HPBW) of a 9-meter S-band antenna is about 1.17 deg. Then, the re-acquisition of the satellite signal is possible when the offset angles are about 0.5 degrees.

Figure 9 shows the antenna offset angles in 2004/08/24 00:46:40 UTC KOMPSAT-1 morning pass. The interval of the offset angle is 5 seconds. The offset angles starts from about 0.35 degrees in the satellite rising time and the maximum offset angle appears in the satellite set time. This is because the satellite signal is interfered by the trees in the backyard mountain. Figure 10 presents the antenna offset angle in 2004/08/27 14:25:05 UTC KOMPSAT-1 night pass. The antenna tracking starts from the elevation angle of about 15 degrees and the offset angle is about 0.3 degrees. Theses results show the possibility of the re-acquisition and automatic tracking of the satellite signal. When the satellite signal is acquired by the mono-pulse feed in antenna, the antenna keeps on track the signal to the satellite set time.

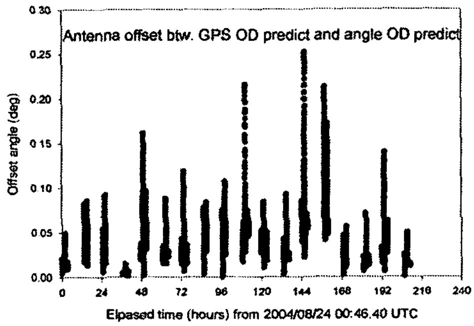

Figure 7. Offset angles from GPS based OD.

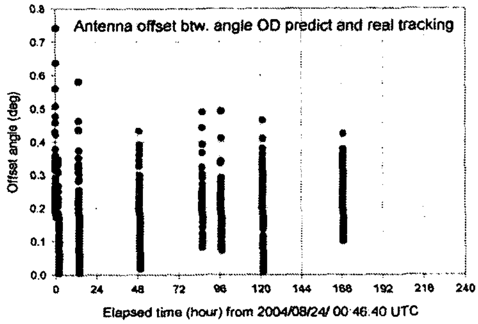

Figure 8. Offset angles from real tracking data.

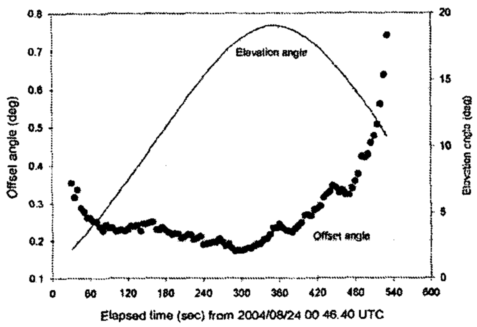

Figure 9. Offset angles in Aug. 24.

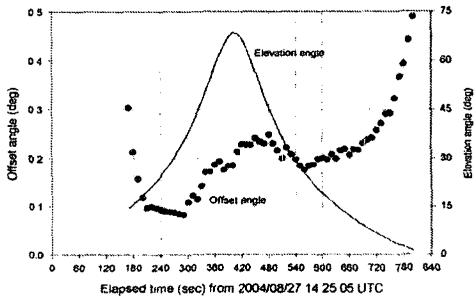

Figure 10. Offset angles in Aug. 27.

4. CONCLUSIONS

The angles only orbit determination from single ground station was performed to verify the possibility of the satellite mission operations and control without using the NORAD TLE. The analysis was accomplished for the KOMPSAT-1 satellite case and it can be applicable to the another Low Earth Orbit (LEO) satellites such as the STSAT-1 case. The antenna pointing data prediction using 3-day angles only orbit determination produced good results for re-acquisition of the KOMPSAT-1 satellite signal. Therefore, STSAT-1 satellite mission operations and control without the NORAD TLE are possible with mono-pulse tracking antenna system and orbit determination software.

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