ORBIT ANALYSIS OF A REMOTE SENSING SATELLITE FOR LOCAL OBSERVATION OF THE EARTH SURFACE

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ABSTRACT
Earth observing systems are evaluated by performance parameters including area coverage and observation repetitivity; the type of mission is in fact determined by the area to be covered (global or regional) and by whether the repetitivity requirement calls for continuous or intermittent observation. This paper, presents works on single satellite mission analysis for intermittent coverage, concentrates on manipulation of the ground track patterns of satellite. The task, then, is to describe an orbit design analysis oriented to obtain efficient revisit coverage and repeat cycles by instruments embarked on satellite deployed on orbit. Results are depicted, by considering an orbit analysis for observation of the middle east area.

1. INTRODUCTION
One of the most important bases of using space is detecting information about our planet earth and its atmosphere by remote sensing Satellite Systems. For this purpose, the specific operational orbit as one of the basic component of space mission plays a special role in Satellite System design. It can be emphasized that the quality of a space mission is proportionally depends on its orbital selection [1]-[3]. Orbital selection (determination of its hexagonal parameters), in its turn is a faction of requirements specified for the mission. The mission requirements related to orbital determination of Satellite movement in remote sensing Satellite Systems is categorized as five divisions as follows: 1. Sight width and locations resolution accuracy of the Satellite payload equipment’s for different geographical region of earth surface should be similar. 2. The Satellite should have a continuance from of receiving in formation possibilities from all the earth surfaces. (In the other hand all the earth surfaces should be covered). 3. Brightness changing intensity of earth surfaces facing the Satellite should be minimum during the Satellite payload equipment operational time. 4. The time for one complete satellite’s earth surfaces Coverage should be minimum. 5. Repeated coverage of a specific region of the earth surface should have a deterministic period.

The survey areas accessible to a sensor mounted in a satellite, as it travels around the earth, depend on the instrument field of view and on orbital parameters as altitude and inclination which determine the satellite trace over the surface of the earth [4]-[8]. The orbit to be used in any particular remote sensing mission has always been determined through a trade–of between coverage objectives and the capabilities of the sequential trace pattern development, taking also into account the desired ground resolution [9]-[14]. Coverage missions usually fall into two general categories:
i) Complete intermittent survey of a given area during a relatively short period;
ii) Continuous surveillance of a target area.

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A single satellite is able to yield coverage of the area for a few numbers of consecutive revolutions, creating a significant gap in coverage between them. This gap, less than the orbital period, can be covered either in a low repetition cycle by a large swath of the instrument or with a scarce temporal resolution if a better detail of observation is required. The best solution is obtained when the gap (either temporal or spatial) is reduced by using a satellite constellation which can consist of satellite deployed on one or more orbital planes [13]. This solution, in fact, has the potential of significantly improving the frequency of observation or the possibility of reducing the minimum spacing between ground tracks at the same repetition cycle of the single satellite. In this paper all of above subjects are discussed and results are depicted, by considering an orbit analysis for observation of the Middle East area.

2. SELECTION OF THE SPACECRAFT’S ORBIT AND INITIAL VALUES OF ITS UNITS

For remote sensing satellites there is circular, Sun-synchronous (SSO), stabilized to an altitude and local time (under-vehicle point) orbit with an altitude of about 400 to 1000 km [15]. Such orbit is optimum for hydrometeorogical, natural resource and oceanographic vehicles. The selection of orbit is determined by the following main factors.
1) Spacecraft passes by the same Earth latitudes approximately in the same local time (under identical conditions of the earth surface illumination). It is very important for the decoding and comparison of the information of the observable earth surface state at series of imaging in the visible and near IR spectrum ranges.
2) Simplification of the spacecraft design.
3) Maintenance of a thermal mode of instrumentation by simple enough means (almost constant angle between the orbital plane and the direction to the Sun).
4) Convenience of the communication sessions (they are carried out in the same day time approximately).

It is known, that the most intensive development of a cloud cover above the Earth surface happens in the second half of day. In the morning the shielding effect of could cover is less. Therefore for remote sensing satellites there is such a Sun-synchronous orbit, which will ensure the information instrumentation activity above the given locale in the first half of day (about 9-11 p.m. of local time). The imaging should be conducted on a descending part of an orbit in order to compensate the latitude change of a solar angle. These orbit parameters are determined by the launch time [1].

The level of the solar activity in the guessed initial stage of spacecraft activity (2004-2005) is expected to be near the minimum [1]. Solar activity is expected to be increasing during spacecraft functioning (up to the maximum at the end of the five year lifetime of spacecraft). The solar activity index f10, 7 will change from 80 units in the first three years up to 120, 170 and 200 units in 2008, 2009 and 2010 years accordingly. In the beginning of the next five year period the level of the solar activity is expected close to the maximum with transition to the minimum at the end of this period.

According to this spacecraft should be able to reach and stay on the orbit without correction and the following requirements should be satisfied:
- Approximately constant periodicity (about two times a week) of the same earth surface segment view;
- Altitude stability in the range of ±15 km to the current average level.
- Monitoring of the Northern hemisphere on a descending orbit in the first half of day (9-11 a.m. of equator local time);
- Spacecraft active lifetime is 5-7 years.

Initial values of the orbit elements, satisfying to the given above requirements, for coverage of the Middle East area are shown below:
Average initial orbital altitude \( (h_{av}) \): 500 km
Period \( (T_{av}) \): 97.391 min
Altitude of an ascending node \( (h_{a}) \): 634 km
Large semi-axis \( (a) \): 7015 km
Eccentricity \( (e) \): 0.00116

3. VIEW PERIODICITY

From the given in the first section requirements to the remote sensing information updating by remote sensing satellite it follows:
- Monitoring of the Middle East area. by means of the multispectral mid resolution \((\geq 100 \text{ m})\) observation instrumentation should be implemented with no more than four day period;
- Monitoring of the multispactral high resolution \((\leq \text{some hundred meters})\) observation instrumentation should be implemented with no more than four day period also. Fundamentally the problem could be solved by three main ways:
  - By the quantity increasing of the working vehicles and the proper ballistic system construction;
  - By the reorientation of the observation instrumentation or spacecraft;
  - By the installation of the wide-angle observation instrumentation.

The creation of the system, consisting of several identical spacecraft’s, gives rather simple solution of these technical problems. But such solution should be ignored because it is a rather expensive way of reaching the demanded observation periodicity.

In order to define if it is possible to fulfill the demanded conditions of the remote sensing information updating, there were done the calculation of the observation periodicity with the help of the different vision zone instrumentation as without usage of the spacecraft rotation (full monitoring), and as with the usage of the sight line device rotation (local monitoring). The results of these calculations are given in the table 1.

Table 1: periodicity estimation of the continuous observation of the Earth surface for different geographic latitudes and the vision fields of device with their sight line rotation and without it (days)

<table>
<thead>
<tr>
<th>Latitude belt boundaries, deg</th>
<th>Swath width, km (deg)</th>
<th>800 km (±31.0°)</th>
<th>200 km (±8.7°)</th>
<th>60 km (±2.6°)</th>
<th>30 km (±1.3°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without rotation</td>
<td>With rotation ± 30°</td>
<td>Without rotation</td>
<td>With rotation ± 30°</td>
<td>Without rotation</td>
</tr>
<tr>
<td>0.50</td>
<td>4.0</td>
<td>4.0</td>
<td>23.2</td>
<td>4.0</td>
<td>57.2</td>
</tr>
<tr>
<td>50-60</td>
<td>3.0</td>
<td>3.0</td>
<td>11.0</td>
<td>3.0</td>
<td>47.2</td>
</tr>
<tr>
<td>60-65</td>
<td>3.0</td>
<td>3.0</td>
<td>10.5</td>
<td>3.0</td>
<td>39.0</td>
</tr>
<tr>
<td>65-70</td>
<td>2.0</td>
<td>2.0</td>
<td>6.9</td>
<td>2.0</td>
<td>35.2</td>
</tr>
<tr>
<td>70-80</td>
<td>1.0</td>
<td>1.0</td>
<td>5.0</td>
<td>1.0</td>
<td>21.3</td>
</tr>
</tbody>
</table>
The analysis of the obtained results shows, that the proper view periodicity could be achieved by the combination of the second and the third ways of monitoring. It means, that the mid resolution instrumentation should have a view field not less than 62°, and the instrumentation of more high resolution – not less than 5.2°. The demanded swath is provided with spacecraft rotation to ±30°.

It is necessary to mark, that spacecraft rotation up 30 deg. can increase the observation frequency only of the definite, rather small segments of the Earth (monitoring of regions, objects, i.e. local monitoring). Therefore, such mode can be applied for a short period of time, otherwise the monitoring of the other regions would become impossible, and the advantages of the space imaging in comparison with the air photography will come to naught. The rotations of the sight line make the spacecraft control more difficult and increase the information cost, naturally.

4. VIEW PARAMETERS

The conditions of the receiving information from the spacecraft depend essentially upon the latitude of the receiving station. At the latitude of about the information reception can be implemented on the two adjoining orbits (see Fig.1). Therefore two communication sessions are possible in the morning (9-11 a.m.) in the mode of the direct information reception from the IR devices or in the mode of reproduction of the recorded information from all kinds of devices could be conducted, if necessary, in the morning as well. Thus, the minimum time between the sessions—from 1.5. hour (two adjoining orbits) till 10 hours (morning-evening). The efficiency of the information delivery—from real time till 10 hours (record-reproduction). Besides the information sessions and the reproduction of the recorded information the combined sessions could be conducted, i.e. as the reception of the information from spacecraft in a real-time mode and of the recorded earlier as well. However, in this case all the information devices can’t work simultaneously (there will be not enough transfer rate).

![Fig.1: Orbital Ground Trace (Orbital Map)](image)

The orbital maps are the maps, on which the, under – vehicle traces are displayed by straight lines parallel to grid verticals. They allow to estimate visually and quietly the possible places of the imaging, time and the duration of communication sessions and many other things. All the one needs to use these maps are the longitude and time of the ascending orbit node.
5. CONCLUSIONS

In present article with categorizing the earth remote sensing satellite system requirements, an orbit design analysis oriented to obtain efficient revisit coverage and repeat cycles by instruments embarked on satellite which will be deployed on a Sun-synchronous orbit. Orbital parameters evolution is selected for five years. Estimation of orbital correction and the effect of optical instruments in selected orbit in this paper are discussed.

6. REFERENCES