Development of TPF Generation S/W for KOMPSAT-2 X-Band Antenna Motion Control

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Abstract: The 2nd KOrea Multi-Purpose Satellite (KOMPSAT-2) has been developed by Korea Aerospace Research Institute (KARI) since 2000. Multi Spectral Camera (MSC) is the payload for KOMPSAT-2, which will provide the observation imagery around Korean peninsula with high resolution. KOMPSAT-2 has adopted X-band Tracking System (XTS) for transmitting earth observation data to ground station. For this, data which describes and controls the pre-defined motion of each on-board X-Band antenna in XTS, must be transmitted to the spacecraft as S-Band command and it is called as Tracking Parameter Files (TPF). In this paper, the result of the development of TPF Generation S/W for KOMPSAT-2 X-Band Antenna Motion Control.
Keywords: KOMPSAT-2, MSC, XTS, X-Band Antenna, TPF Generation S/W

1. Introduction

The KOMPSAT-2 has been developed to be launched at 2005. The KOMPSAT-2 will provide earth observation imagery around Korean peninsula. For this, the MSC, its payload, provide the capability of imaging with high resolution and transmitting with high data rate.

The XTS will be used in transmitting earth imagery data from the MSC. The purpose of the XTS is to ensure that the active X-band antenna is accurately pointed towards the ground station receiving antenna during the entire period of X-band contact between the KOMPSAT-2 and ground station when X-Band downlink is available.

The XTS is a system combined of many functional blocks. Since the XTS is essentially an open loop system with no real-time feedback from the ground, the achieved accuracy of pointing the RF beam from X-band antenna in the XTS towards the ground station will be totally dependent on executing an accurately defined tracking profile.

The tracking profile must be calculated on ground in advance, then transmitted to the KOMPSAT-2 in a compressed format as a Tracking Parameter File (TPF), then transferred to the MSC with decompression. Finally, the continuous profile for X-band antenna will be used for generating the motion of X-band antenna in the XTS.

In this paper, the design and development of TPF Generation S/W for KOMPSAT-2 X-Band Antenna Motion Control is addressed.

2. Overview for the XTS Operation

The KOMPSAT-2 Ground-Station should be accurately tracked during an X-band contact transmission pass by the on-board X-band antenna to meet the RF Link Budget.

For this, the tracking profile to be executed on-board should be calculated in advance, based on the KOMPSAT-2 orbit and attitude prediction information as the function of time. For accurate tracking performance, it will be necessary not only to predict accurately the KOMPSAT-2 orbit and attitude parameters as the function of time during the X-band contact interval, but also to establish an accurate synchronization between two time base; the one is used for the prediction on ground and the other is used for the actual execution of the tracking profile on the KOMPSAT-2.

As a result, the computational sequence necessary to drive an optimal tracking profile, which will be commanded to the X-band antenna, and the subsequent reduction of this tracking profile into a set of parameters called Tracking Parameter File (TPF), which will be uploaded to the KOMPSAT-2, are to be prepared on ground in advance. In addition, the definition of time bases, which are used in ground station, KOMPSAT-2 bus system and KOMPSAT-2 MSC system and their relationships are also to be prepared.

3. Onboard X-band antenna

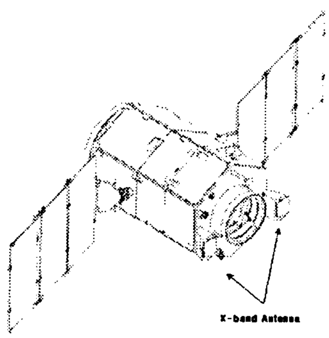

Fig. 1. Onboard X-Band Antenna

Fig. 1 shows the onboard X-band antenna. Two X-band antenna are to be operated. The main purpose of two module is to avoid interference with communication in

S-band and guarantee stable RF link when low elevation from ground station.

4. TPF Generation S/W Functions

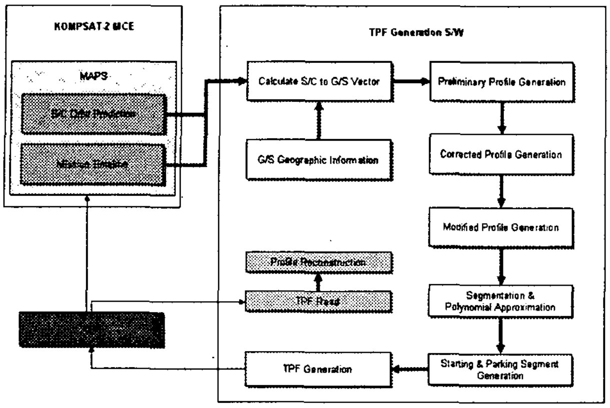

Fig. 2. TPF Generation S/W Functional Block Diagram

Fig. 2 shows the functional block diagram of TPF Generation S/W.

1) Interface with the Mission Control Element (MCE)

The TPF generation S/W has an interface with the Mission Control Element (MCE). The mission timeline, which provides prediction on X-band contact and related MSC mission, and the KOMPSAT-2 orbit prediction data providing the KOMPSAT-2 position are used in TPF generation S/W as calculation inputs.

2) Calculation of Pointing Vector from the KOMPSAT-2 to Ground Station

The geographic information of target ground station and the KOMPSAT-2 attitude information needed to calculate from the KOMPSAT-2 to ground station pointing vector. Especially for the latter, the mission timeline from the MCE contains the KOMPSAT-2 attitude information for accurate imaging to the imaging target. This attitude information is applied in driving the final pointing vector from the KOMPSAT-2 to ground station. In this case, the attitude determination and control logic of the KOMPSAT-2 bus system is applied in calculating pointing vector from the KOMPSAT-2 to ground station.

3) Preliminary Tracking Profile Generation

The preliminary tracking profile is generated using the pointing vector from KOMPSAT-2 to ground station. The preliminary tracking profile is only the other form of the pointing vector from KOMPSAT-2 to ground station. It consists of two parameters, azimuth and elevation, instead of 3-D coordinate values. In this case, it is assumed that the origin of on-board X-band antenna coordinates coincide with that of the KOMPSAT-2 body coordinates and there is no mis-alignment between two coordinates. Also, the direction of RF beam bore-sight vector is perfectly on the line of Z-axis of each X-band antenna plate.

4) Corrected Tracking Profile Generation

The preliminary tracking profile provides the ideal pointing direction from the KOMPSAT-2 to ground station. But actually, there are two on-board X-band antenna in the MSC. Each of them has its own translation and mis-alignment compared to the KOMPSAT-2 body coordinates. And the direction of th RF beam bore-sight vector of each X-band antenna does not coincide with the X-band antenna coordinates. So, there is a need for calculating new tracking profile on the consideration of RF link error budget.

The resultant corrected tracking profile is the revised tracking profile considering the selection of one of both antenna, mis-alignment information and RF beam bore-sight vector direction.

5) Modified Tracking Profile Generation

The corrected tracking profile, which represents the optimal angular motion of on-board X-band antenna for tracking target ground station accurately with the RF beam on the KOMPSAT-2, may contain singularities inherently or as result of the applied corrections. Also there may be the possibility that the corrected tracking profile shows angular dynamics and elevation angular range exceeding the on-board X-band antenna performance limits. Therefore, the corrected profiles should be checked for singularities, angular dynamics and elevation angular range for its applicability to the on-board X-band antenna motion control before the transmission to the KOMPSAT-2. In such cases, there is a need for modifying the corrected tracking profile to new one, which is called as the modified tracking profile.

If there are sections which show high dynamics or elevation angular range overshoot in the corrected profiles, they are replaced with new sections containing lower dynamics or allowed elevation angular range for sections containing singularities or high dynamics or which exceeds the on-board X-band antenna elevation angular range limits in the corrected tracking profile, applying intentional trade off between high dynamics or elevation angular range overshoot and RF link budget margin. In this case, new sections to be substituted are generated through polynomial approximation. The resultant new section should be designed to fit to the previous segment and the following segment with minimal loss of continuity in position and velocity and guarantee the allowable angular motion for the on-board X-band antenna.

In addition, the correction considering the on-board X-band antenna backlash is also applied in generating the modified tracking profile.

6) Segmentation of the Modified Tracking Profile & Polynomial Approximation

After generating the modified tracking profile, it needs to be divided into some segments. Each segment is the basic unit for the following processing, polynomial approximation. The segmentation of the modified tracking profile results in lower polynomial order for the same accuracy of approximation. The length of each segment is determined by iteratively checking the approximation error. The number of segments needed for each modified tracking profile depends on the length of the profile and on the characteristics of the profile such as dynamics.

Then, the polynomial approximation are applied to each segment of the modified tracking profile. So, a large amount of modified tracking profile data in each segment will be reduced to each polynomial coefficient set. Resultant polynomial coefficient sets describe the whole angular motion of the on-board X-band antenna in azimuth and elevation for actual data transmission interval. The order of the polynomial approximation on each segment delivers the required accuracy and smoothness of transition between segments.

7) Starting & Parking segments Consideration

In the case of the normal operation of the XTS, the on-board X-band antenna starts and ends its motion at parking position. Meanwhile, polynomial coefficient sets during X-band transmission interval determines the angular position range where actual X-band data transmission is available. So, there should be the consideration of adding two interval describing the angular motion before and after the actual X-band data transmission interval for the whole description of the on-board X-band antenna during one X-band contact pass. These two intervals are called as starting segment and parking segment.

Both starting and parking segments are designed with constant time duration. There are also polynomial approximations for these two segments. As a result, the last profile of the starting segment matches the first profile of the first segment of the modified tracking profile and the first profile of the parking segment matches the last profile of the last segment of the modified tracking profile with minimal discontinuity in position and velocity.

8) TPF Generation

The TPF is finally generated as the result of previous calculations. The TPF consist of previous calculation results in both the actual X-band transmission interval and starting and parking interval. Each fixed TPF segment structure contains parameter fields such as polynomial coefficient set, start time when relevant polynomial coefficient set is available and average time of the interval when relevant polynomial coefficient set is valid.

After formatted, the TPF is to be transmitted to the KOMPSAT-2 in advance before the relevant X-band contact pass. Then, the uploaded TPF are to be used in reconstructing the angular motion of the on-board X-band antenna in the on-board MSC. Table 1 shows the sample of contents of the TPF.

Table 1. TPF Contents

Azimuth parameter	Seg. #1	Seg. #2	…	Seg. #n
C_{00}	1.804877519607544	4.144270163351977		5.739323616027832
C_1	0.090967029333115	0.013313871322650		0.029205098748207
C_2	0.000048210455134	0.000100335606135		- 0.000134133879328
C_3	-0.000032620151615	-0.000000044547758		-0.00000783595078
C_4	0.000000000000000	-0.000000012703605		0.000000000000000
C_5	0.000000000000000	-0.000000000122762		0.000000000000000
C_6	0.000000000000000	0.000000000000777		0.000000000000000
C_7	0.000000000000000	0.000000000000016		0.000000000000000
t_s	369288298	369288418		369288618
t_a	369288418	369288616		369288738

Elevation parameter	Seg. #1	Seg. #2	…	Seg. #n
C_{00}	-0.403991907835007	-0.565525052106446		-0.27791124582290
C_1	-0.019741857424378	0.003243967007820		0.013643139041960
C_2	0.000030515888284	-0.000029954484474		0.000016828225853
C_3	0.000007989930054	-0.000000481483949		-0.00000542697489
C_4	0.000000000000000	-0.000000000700770		0.000000000000000
C_5	0.000000000000000	0.000000000043430		0.000000000000000
C_6	0.000000000000000	0.000000000000261		0.000000000000000
C_7	0.000000000000000	-0.000000000000002		0.000000000000000
t_s	369288298	369288418		369288618
t_a	369288418	369288616		369288738

Where C_{00}, …, C_7 are polynomial coefficients and t_1, t_2, … and t_a means the start and average time of the inteval during which the relevant polynomial coefficients is valid.

9) Reconstruction on Ground Station

Prior to uploading to the KOMPSAT-2, each TPF is used in reconstructing on ground, generating the a-priori reconstructed profiles. The purpose of the profile reconstruction on ground is to check the characteristics of the profile which is to be generated in onboard MSC and verify the validity of the TPF.

In addition, some statistics are to be driven for checking the validity of the TPF. For this, the angular motion profiles are reconstructed on ground according to the same way that onboard MSC does. Statistics such as below items are to be checked and verified.

- The angular motion of the onboard X-band antenna, not to exceed its dynamics limits.
- Smoothness and Monotony of the angular motion

- Axis pointing error and total pointing error compared to the corrected tracking profiles
- RF link budget compliance based on slant range and total pointing error computed from the comparison of reconstructed tracking profile and corrected tracking profiles.

4. Development of TPF Generation S/W

Fig. 3 shows the main window of the TPF Generation S/W. TPF Generation S/W was developed using Visual C++ 6.0 and provide Graphic User Interface (GUI). All of functions which are addressed previous paragraph were implemented in TPF Generation S/W.

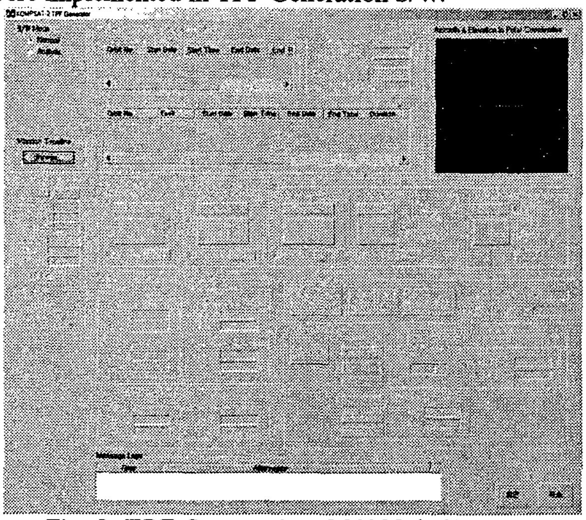

Fig. 3. TPF Generation S/W Main Window

Fig. 5 shows the status after generating a TPF using TPF Generation S/W.

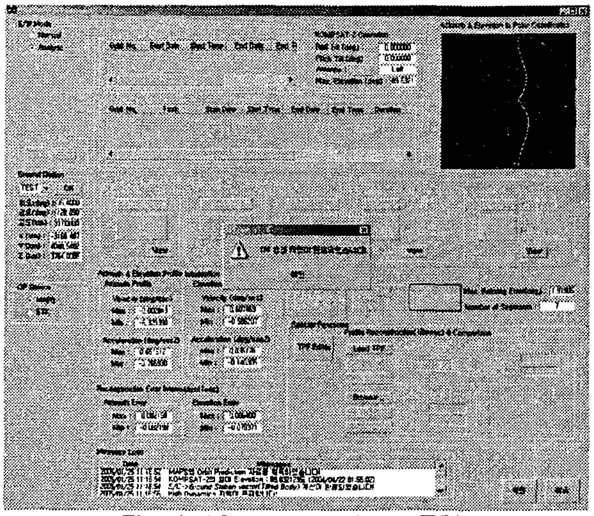

Fig. 4. After generating a TPF

The TPF Generation S/W was finally verified according to the test procedure at 2005.

5. Conclusion

In this paper, the design and development of TPF Generation S/W for KOMPSAT-2 X-Band Antenna Motion Control is addressed.

But, there are some configurable parameters which will be driven from several test before and after the launch. It seems that the better performance of X-band antenna tracking using TPF Generation S/W will be achieved after tuning these parameters optimally

References

[1] MSC X-Band Tracking System Interface Control Document Rev. D, 2005, ELOP