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Korea Deep-Space Antenna Establishment and Operation

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Abstract

KDSA (Korea Deep-Space Antenna) has been established for the S-Band TT&C (Telemetry, Tracking and Command) and X-Band mission data receiving of KPLO (Korean Pathfinder Lunar Orbiter) which is the first Korea lunar exploration mission launched on August 5, 2022. KDSA is comprised of four parts, 35m antenna, RF/BB channel unit, base foundation, and operating software. KDSA started its operation for KPLO mission from August 15, 2022 and maintained its communication with KPLO at Lagrange L1 point, around 1.55M km distance from the Earth which is the most far away from the Earth in the KPLO trajectory before LOI (Lunar Orbit Insertion). In this paper, overall KDSA establishment and operation in KPLO mission were presented.

Keywords: KDSA, KPLO, Deep Space, Lunar, Ground, Antenna

1. Introduction

KPLO is the first Korean lunar mission launched at the Cape Canaveral Space Station in US on August 5, 2022. KPLO with 6 payloads was flying to the Largrane L1 point and returned to enter the lunar transfer orbit in BLT trajectory [1]. The first LOI (Lunar Orbit Insertion) manuvers was conducted on December 16, 2022. After KPLO commissioning phase in luanr orbit in January 2023, KPLO will continue routine operation for the mission lifetime until th end of 2023.

KDSA has been developing as a ground station for KPLO mission from September 2018 to November 2021 (39 months). The BWG (Beam-wave Guide) type with mirrors of KDSA has a merit to deploy heavy and complex units such as HPA (High Power Amplifier) and cryogenic LNA (Low Noise Amplifier) with Helium compressor into the first floor of base foundation. Ka-band extension is feasible by adding relevant mirror and feed into the BWG in future mission. KDSA has total 7 mirrors, one is FSS (Frequency Selective Surface) and the others are metal curve plate. The travel range of KDSA is 3 to 90 degrees EL and ±270 degrees AZ and the maximum travel speed is 0.8 degrees/seconds. SRCU (Sub-Reflector Control Unit) is remotely control the position of sub-reflector to compensate the off-pointing due to the mechanical changes such as main reflector's deformation depending on the elevation angle. 10kW S-Band SSPA (Solid-State Power Amplifier) has been installed and 2:1 redundant cryogenic LNA installed for S-Band and X-Band receiving functionality. Foundation with considering wind load of 35m antenna has been installed with HVAC, UPS, and generator. Operation software is responsible for the overall monitoring and control of KDSA, KDSA schedule management based on Web-based interface. KDSA provides SLE (Space Link Extension) forward CLTU, SLE return all frames/channel frames services and TDM generation which are all aligned with CCSDS blue book standards. Fig. 1 shows the KDSA at SK Broadband site in Yeo-ju, away from Seoul 65 km east-south.

Fig. 1. Korea Deep-Space Antenna, KDSA

2. KDSA Establishment

Regarding the establishment of KDSA, the original plan was to retrofit an existing 32m antenna in Boeun Site own by another local company, KTsat, and reuse its existing operational facilities such as building, electric supplier and network. In this plan, it was expected to reduce time and cost for preparing a desirable site and operational environment. However, from the feasibility studies on the existing 32m antenna which had been operating as C-Band teleport service by communicating with geostationary satellite, some issues were raised. One of issues was related to the diameter of hole for beam wave guide in the main reflector of 32m antenna, which should be enlarged for S-Band communication with KPLO. In that case, 32m antenna stucture needed to be entirely dissembled and redesigned which lead to cost and time increasing. On the other hand, there was a risk to use main reflector and driving motors mechanical parts which had been pointing with fixed direction to geo-stationary satellites in three decades. Although the surface roughness of main reflector was not obtained through photogrammetric measurement, when it comes to the changes of antenna structure for the improvement of the poiting accuracy, the radiation modeling needs to be validated from a very long-term measurement with radio star which taken around 6 to 12 months more than new antenna after antenna integration is completed. Consequently, it was determined that retrofit of existing antenna has not much benefits in terms of cost and time by comparing the installation of new antenna. KARI has been contracted with SK Broadband as a prime contractor for the KDSA establishment. In the contract, SK Broadband proposed to provide a part of its site in Yeo-ju for the KDSA establishment. Fig. 2 shows the functional architecture of KDSA for the explanation KDSA components and interface with both KPLO and KMOC (KPLO Mission Operation Center) at KARI headquarter in Daejeon.

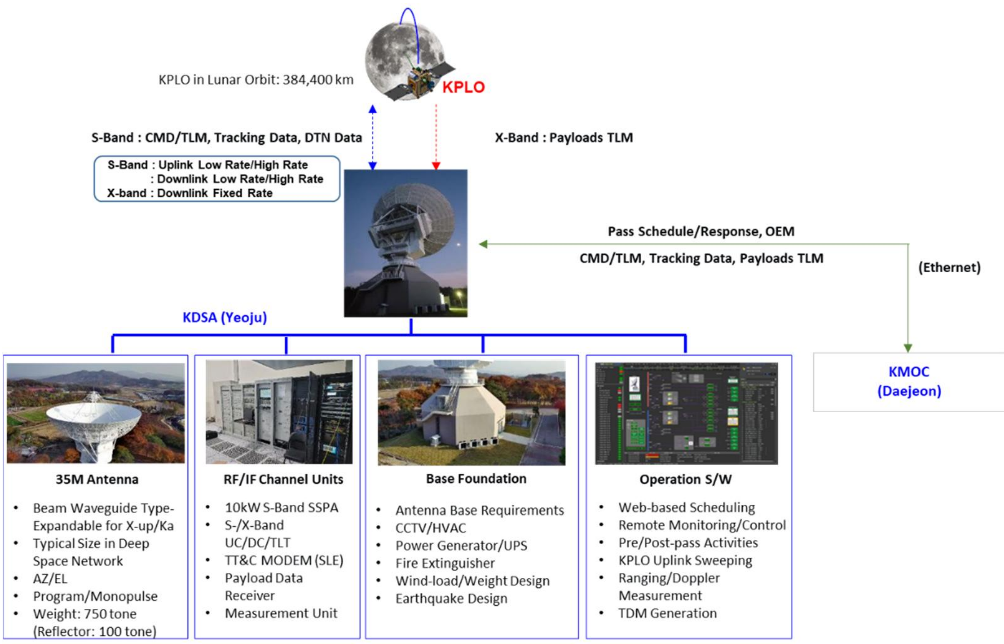

Fig. 2. KDSA Functional Architecture

KDSA communicates with KPLO in S-Band and X-Band. In S-Band, SOH (State of Health) telemetry and command are exchanged and ranging/Doppler measurement is accomplished. S-Band uplink and downlink data rate is changeable depending on the KPLO operational situation. In X-Band, 8.5 Mbps payload data id downlinked to KDSA. Between KDSA and KMOC, pass schedule request and confirmation is supposed to be done before KPLO pass. If pass schedule is confirmed, then CCSDS OEM (Orbit Ephemeris Message) is delivered to KDSA for the program tracking of KDSA to KPLO in pass duration. During pass time, the real-time command and telemetry in CCSDS SLE format can be exchanged between KDSA and KMOC. The result of ranging/Doppler measurement is formatted as CCSDS TDM and delivered to KMOC for the input of flight dynamics analysis. In parallel with KPLO TT&C operation, payload data is also delivered to KMOC in real-time.

35-meter Main reflector of which weight is up to 100 tones was lifted in December 2020 with 650 tons of crawler crane. The surface roughness of main reflector was measured with photogrammetry method and the result is less than

0.24 mm rms. Fig. 3 shows the lift of main reflector and photogrammetry works at night for the measurement of surface roughness.

Fig. 3. KDSA 35-meter Main Reflector Lifting and Surface Roughness Measurement

Characteristics of CETC16 cryogenic LNA with 14.04K of noise temperature, 10kW Teledyne SSPA (Solid-State Power Amplifier) and T4 Science hydrogen maser with 8.45E-14/1 sec. of Allan deviation was measured during FAT (Factory Acceptance Test). Regarding CCSDS SLE provider, Safran CORTEX CRT equipped with CSGW (CORTEX SLE Gateway) was applied [2]. All frequency converter including TLT (Test Loop Translator) are procured from

Operation S/W is responsible for the overall operation of KDSA by providing user-interface for the remote monitoring and control of KDSA, schedule management, TDM generation, pre-pass/pass/post-pass activities, and so on. Schedule management of operation S/W is to receive schedule request of KDSA user and analysis any conflict with pre-determined pass time and make a decision on the approval, reject, or manual modification. Schedule request can be uploaded into KDSA operation S/W in two ways, one is using securing FTP and the other is using web browser. Fig. 4. shows main GUI of operation S/W for the monitoring and control and schedule management, respectively.

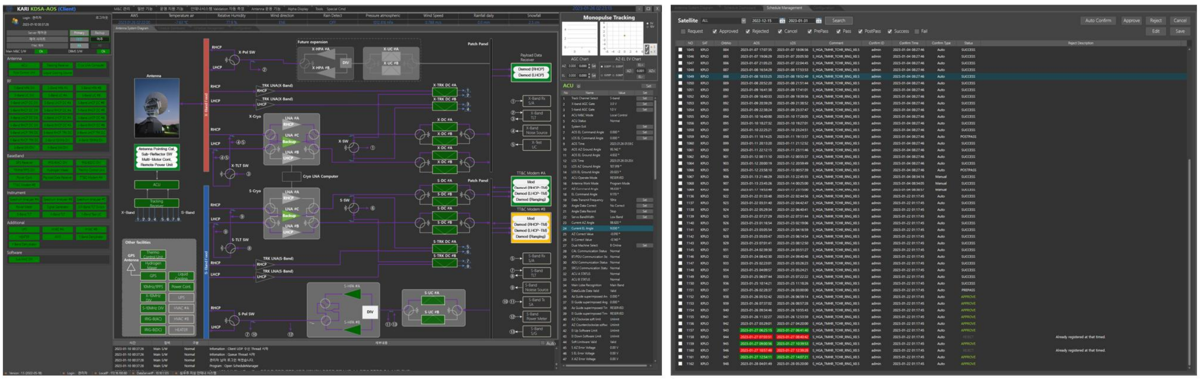

Fig. 4. Main M&C and Schedule Management Screen of Operation S/W

OSAT (On-Site Acceptance Test) was conducted in the second half of 2021. G/T and pointing accuracy were measure with Radio stars. In 2022, prior to KPLO launch, ranging measurement with geostationary satellite, GK2A, was conducted to prove KDSA S-Band up/downlink functionality. Regarding the RF compatibility with KPLO in ground test campaign, frequency converters, CORTEX CRT and HDR were moved to a portable rack placed at AIT (Assembly, Integration and Test) test hall for the coaxial cable interface with KPLO and Ethernet interface with KMOC, respectively. From KPLO/KDSA RF compatibility test and ETE (End-to-End) test, KDSA setup validation for KPLO mission operation was finally completed. While KPLO was in launch campaign at the Cape Canaveral Air Force Station, KDSA was tracking to NASA lunar orbiter, LRO and Jupiter orbiter, JUNO for the KDSA tracking and receiving validation before KPLO launch.

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3. KDSA Operations in KPLO mission

The first contact of KPLO after KPLO was launched at the Cape Canaveral Air Force Station with SpaceX launcher was NASA DSN (Deep Space Network) in Canberra. KDSA did a successful the shadow tracking of KPLO in parallel with DSN34. KDSA operation for KPLO mission was starting on August 15, 2022. As defined in the operation flow (see Fig. 5), when KMOC uploads a schedule request file into security FTP, then KDSA operation S/W displays KMOC request on the screen. KDSA operator run an auto-approval because KPLO is the single mission at KDSA. If the time interval between LOS time of previous pass and AOS time of current pass is less than 30 minutes, operation S/W displayed a conflict message. Then, KDSA operator request KMOC to modify AOS and LOS time accordingly. Once, KPLO schedule request is confirmed, then KDSA starting pre-pass activities such as ranging/Doppler calibration and data bit stream continuity checking in internal loop configuration, antenna pointing changes on CCSDS OEM file and TDM configuration upload. OEM file contains KPLO ephemeris data with 1 second step from AOS-30 minutes to LOS+20 minutes. The coordination and time system are ITRF (International Terrestrial Reference Frame) and UTC (Coordinated Universal Time), respectively. In TDM configuration, basically, all relevant parameters of ranging and Doppler measurement were set according to CCSDS TDM blue book [3]. The start of ranging and Doppler is nominally at AOS+10 minutes and stop at LOS -10 minutes. During pass time, KMOC makes a phone call for RAF SLE link connection when KPLO telemetry is receiving. Once, if two conditions, one is that KPLO telemetry is proved as error-free in its contents and the other is elevation angle of KDSA is over 10 degrees, are satisfied, then KDSA starting uplink sweeping prior to sending command. After uplink sweeping is completed in normally and on-board transponder is locked, FCLTU SLE link connection is activated and KMOC sends a test command and check the increment of command counter from telemetry. X-Band payload telemetry is received and delivered to KMOC in real-time. Both S-Band SOH telemetry and X-Band payload telemetry data is also recording at operation S/W and delivered to KMOC after KPLO pass is completed as a part of post-pass activity. After KPLO pass is completed, operation S/W uploads ranging/Doppler TDM files, recorded telemetry files, and specific pass log file into the security FTP for the download at KMOC.

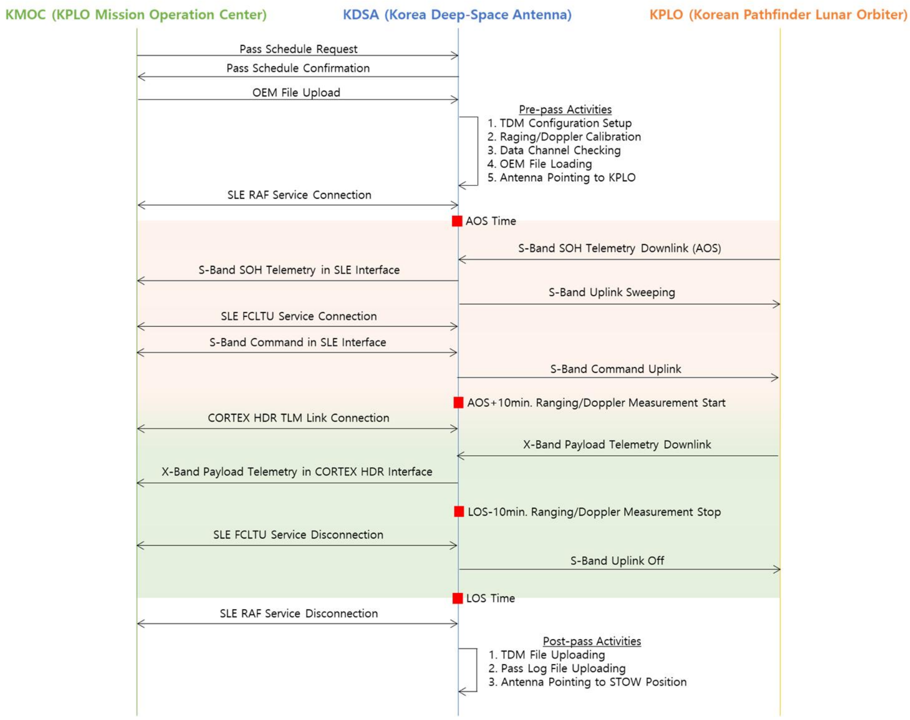

Fig. 5. KDSA Operation Flow in KPLO Mission

KDSA has been operating in nominal condition for the KPLO mission support even though KPLO was 1.55M km away from the Earth. When the Sun introduction? occurred in the last week of August, 2022, due to the noise increasing caused by the Sun, both S-Band and X-Band link performance was significantly degraded. New operation guideline was added as KDSA operation is stalled when the pointing angle difference between the Sun and KPLO is less than 3 degrees.

4. Conclusions

KDSA established in November 2021 has been operating for the KPLO mission operation. Web-based operation has not been applied in KPLO mission but is in consideration for other agency missions. X-Band uplink capability and Delta-DOR capability are those of parts to be newly deployed at KDSA in future. KDSA with 35m main reflector, cryogenic LNA, 10 kW SSPA and CCSDS SLE interface has a capability of supporting lunar as well as deep space missions. As a validation purpose, KDSA has an experience to track NASA LRO, JUNO and Artemis-1. It is looking forward to KDSA experience at lunar and deep-space missions with an international coordination, which is crucial to improve KDSA service catalog in future.

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