Discussions on Optical Communications started in CCSDS

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1.Preamble

In CCSDS, space networking by radio communications has been discussed and recently a study group for optical communications was formed in CCSDS because this technology has several advantages and has matured in the last decades through important developments and demonstrations.[1]

In IOAG, space network scenarios have also been discussed within the Space Internetworking Strategy Group (SISG). A specialized study group other than SISG is the Optical Link Study Group (OLSG) that started reviewing operation scenarios where optical communications are to be used.[2]

Following previous review titled "International Meetings for Space Agencies", the optical communication recently discussed in CCSDS will be introduced in this review with histories of its development and demonstrations.

2.Optical Intersatellite Link

2.1.ESA/CNES Joint Program

Around the year of 1991, a joint program of optical intersatellite communications in the 0.8-micron band between ESA and CNES was started. It is called "SILEX (Semi-conductor Inter-Satellite Link Experiment)".This program consists of ESA's data relay satellite called "ARTEMIS (Advanced data Relay Technology Mission Satellite)" and a LEO satellite called "Satellite Probatoire d'Observation de

la Terre 4 (SPOT-4)" from CNES and an optical terminal was mounted on both satellites. ARTEMIS terminal is called "Optical PAyload for inter Satellite Link Experiment" (OPALE) and SPOT-4 terminal is called "PASsenger Telecom(PASTEL).[3][4]

The intersatellite link between ARTEMIS and SPOT-4 was validated and succeeded in a way where the SPOT-4 satellite transmitted optical return link (50Mbps) after receiving optical forward beacon from ARTEMIS satellite in the intersatellite link and then ARTEMIS demodulated the optical return signal and transmitted the return data to feederlink stations in Ka band.[5]

2.2. JAXA/ESA Joint Program

Around the year of 1995, the development of Japanese communication terminal for the optical intersatellite link was started following SILEX program and it became a joint program with ESA's ARTEMIS satellite. This LEO experimental test satellite that JAXA developed with NEC is called "Optical Inter-Orbit Communications Engineering Test Satellite: OICETS (Kirari)".[6]

Unlike optical communication between ARTEMIS and SPOT-4, OICETS transmitted the optical return link (50Mbps) after receiving the forward beacon from ARTEMIS and also had a function to receive the optical forward link (2Mbps).This success of data transmission for both links broadened possibility of application of optical communication in space.[7][8] In addition, OICETS had an another function to establish an optical direct link to a ground station with its body fixed in an inertial space. This will be introduced in the next section.[7]

3.Optical LEO-ground Links with international cooperation

Following the success of optical intersatellite link experiment, around years after 2006, several organizations (ESA, DLR, JPL and NICT) all over the world signed agreements with JAXA to conduct the experiment of optical direct-to-Earth link. Optical ground stations were spread in 4 separate locations in the world: Tokyo (Japan), Tenerife (Spain), Munich (Germany), California (US) and provided opportunities to acquire regional characteristics of atmospheric influence between space and ground and in this regard, it was an experiment and demonstration to pave a possible way of optical communication. Each organization conducted its experiment based on its plan and succeeded in the establishment of optical communication link including the retrieval of atmospheric characteristics.[9]

4.Emerging Of New Optical Terminal

Following the communication experiment in the 0.8-micron band, a laser communication terminal (LCT) emitting and operating at 1.064 µm was built by Tesat-Spacecom.GmbH and accommodated on the German LEO satellite TerraSAR-X.
The optical communication link between this satellite and ground stations was conducted and succeeded. In addition, the optical intersatellite link of 5.6Gbps between this satellite and NFIRE satellite also succeeded. In Europe, the ESA plans the EDRS and ALPHASAT programs. EDRS shall provide future data relay satellites coming after ARTEMIS; it will use optical terminals developed by Tesat-Spacecom.GmbH.[10]

5.International Meeting For Space Agencies

After this historical background of the development and demonstration of optical communications in Europe and Japan, several new working groups including a group for optical communications were formed in CCSDS based on the result of study conducted by SISG in IOAG. [1][2] The group for the optical communications in CCSDS was named “Optical Coding and Modulation Group” (OCM) with N. Perlot. a DLR representative as a chairman for this group. There have been 3 meetings. First meeting was at ESA/ESTEC in Netherlands, second one in Portsmouth/USA and third one in London/UK. Space agencies having joined these meetings are mainly CNES, DLR, ESA, JAXA and NASA .[1]

In this meeting, the name of this group is entitled “Coding and Modulation” but may change in the future. It was proposed by JAXA and DLR to define operation concept first and discuss on the technologies to be used and services to be provided there in order to limit the scope of the study.[1]

In the discussion of this group, proposed wavelengths are mainly 1064 nm and 1550 nm..[1]
Scenarios are categorized: Intersatellite and direct-to-Earth links are supported by Japan, Europe and US agencies and deep space links are supported by NASA and DLR.[1]

Based upon this activity in CCSDS, IOAG formed a study group called “Optical Link Study Group (OLSG)”.[2] In this group, other space agencies which are CNES (France) and ASI (Italy) stated to join this group in addition to DLR (Germany) and ESA in Europe.

6. Conclusions

As introduced above, activities such as definitions of operational requirements and review of technical standards are in process among space agencies, assuming the utilization of optical communications as a consequence of successful demonstrations.

In addition to relying on successful demonstrations, it is important to pursue investigations on system improvement. In particular, developing mitigation techniques for atmospheric propagation can improve future standards. For this purpose, channel measurements from OICETS campaigns conducted in many places in the world would make contributions to future operation scenarios discussed in CCSDS by space agencies.

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[10]TESAT LASER COMMUNICATION TERMINAL PERFORMANCE RESULTS ON 5.6GBIT COHERENT INTER SATELLITE AND SATELLITE TO GROUND LINKS
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8.Authors

1.Tatsuya Mukai

In 1998 he started working in former NASDA and has been engaged in developments of experimental ground systems of OICETS satellite and of Wideband Inter-Networking Demonstration Satellite(WINDS). After these programs, he has been engaged in spectrum management ,development of OICETS ground system and spectrum coordination for Data Relay Test Satellite(DRTS). In addition, Since around the year of 2003, he has worked for ITU and SFCG and also for IOAG and CCSDS since 2007.

2.Yoshihisa Takayama

In 1999 he started working for NICT and moved to JAXA in 2004 and conducted the experiment of OICETS optical communication. In 2007, he moved back to NICT and his current research encompasses conjugate optics, computational electromagnetics and free space laser communications.

3.Nobuhiro Kura

In 1990 he started working for the Space Engineering Development Co,Ltd. and was engaged in the development of experimental ground systems of ETS-6 and ADEOS satellites. From 2001 to 2002, he moved to the former NASDA and also was engaged in the development of OICETS experimental ground system. In 2004, he also moved to JAXA and joined the experiment of OICETS optical communications and back to SED in 2007.

4. Nicolas Perlot

In 2002 he started working for DLR where he made his PhD thesis on the optical atmospheric communication channel. His current research encompasses free-space laser communications and random-media propagation. He is involved in international coordination for optical space communications at CCSDS.