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Future Prospect on Space Communication Infrastructure for Remote Sensing Satellites

Toward Next Generation Remote Sensing Satellite Infrastructure

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***Abstract*—Since earth observation satellites contribute in many fields of our life, such as disaster monitoring, environmental surveillance and weather forecast, the requirements on observation data are increasing to be higher in frequency as well as spatial and spectral resolution. Therefore, the amounts of data provided by on-board sensors become too large to downlink to ground stations. Nowadays, space communication is one of the bottle-neck for earth remote sensing satellite system. In this work, future prospect on space communication system using new technologies, such as inter-satellite link and optical communication, is addressed based on the analysis of future Japanese remote sensing satellites. The future communication system that provides a large amount of data is also effective to deliver the observation data to any ground station in the world.**

Keywords—remote sensing satellites; datalink; optical communication

I. INTRODUCTION

Earth remote sensing from satellites plays an important role as an infrastructure to maintain safe and reliable society by way of disaster/environmental monitoring and weather forecast. Although the limited remote sensing data in terms of frequency, spatial and spectral resolution have been used by interpolation so far, practical and operational users require higher performance data. Therefore, the specification for observation data becomes higher in ground sampling distance (GSD), number of spectral bands, swath and observation frequency. Moreover, movie data makes a new way of practical use, which is recently realized by Skybox. In change detection application, complementary use of optical and radar images, comparison with time-series data, and complex fusion of multi-source data are requested, which should be transferred to disaster area. Therefore, many space organizations operate several earth remote sensing satellites and prepare time-series data library of earth's surface obtained by several kinds of remote sensing technique.

As is mentioned above, increase in observation data by earth remote sensing satellites makes downlink performance to ground stations to be the bottleneck of data system. Inter-satellite communication system is under discussion now in Japan, which will change the mission plan of land remote sensing. Optical inter-satellite communication solves such problem of huge amount of data downlink in future. In this work, we discuss the role of optical communication system in remote sensing community.

II. DATA RATE IN EARTH REMOTE SENSING

A. Landsat-8 [1]

Landsat-8 has a wide swath of 180 km with GSD of 15 and 30 m for panchromatic and multispectral sensor, respectively, which was launched in 2013. Since all the land areas are observed every 16 days, no special observation plan exist other than operational observation. About 400 scenes are obtained every day and amounts to about 390 GB, which are stored in 500 GB data recorder. X-band downlink system with a performance of 384 Mbps is used at three ground stations, which are located at NOAA (Gilmore Creek Station, AK), USGS (Landsat Ground Station, SD) and KSAT (Svalbard). The total amount of downlink time is about 98 minutes/day. Moreover, many ground stations take part in receiving Landsat-8 data under the contract with USGS. In summary, Landsat-8 provides moderate spatial resolution data operationally, which is suitable to downlink all the land observation data using the ground stations located at polar region directly. Table 1 summarizes the specification of land remote sensing satellites.

B. Sentinel-1, 2 [2]

Sentinel satellites are provided by ESA in the Copernicus (GMES: Global Monitoring for Environment and Security) program. Sentinel-2 is the multispectral sensor with the GSD of 10-60 m (4 bands for 10 m, 6 bands for 20 m, 3 bands for 60 m). The wide swath of 290 km enables frequent high-resolution mapping. Coupling with lower spatial resolution bands and wavelet data compression down to one-third are the solution to accommodate high spatial resolution with low data rate of 490 Mbps. The amount of observation data is about 1000 scenes per day, i.e. about 900 GB/day, which is stored in 300 GB data

TABLE I. SPECIFICATION OF LAND REMOTE SENSING SATELLITES

Items	Landsat-8	Sentinel-2	ALOS-2	ALOS-3
Data Rate (Mbps)	c.a. 270	490	800	4000
Data Recorder (GB)	500	300	130	1000
Downlink Rate (Mbps)	384 (X)	520 (X) 1800 (Optical)	800 (X) 278 (Ka)	800 (X) 800 (Ka)
Data Amout (GB/day)	390	900	800	2000
Scene	400	1000	-	-

recorder. Acquired data is mainly transferred through X-band direct downlink system with the data rate of 520 Mbps (8 PSK) to four ground stations located at Kiruna, Svalbard, Maspalomas and Prince Albert. In addition, an optical communication system via geostationary satellite is on-board for demonstration, which achieves high downlink rate using three units of optical channel of 600 Mbps. Sentinel-1 is a C-band SAR and has the similar communication system although it has a smaller data recorder with 176 GB storage. Two sets of Sentinel-1 and -2 satellites will be on orbit in the operational stage of Copernicus program.

C. ALOS-2 [3]

ALOS-2 carries the next generation L-band SAR, PALSAR-2 with the heritage of ALOS/PRISM, which will be launched in 2014. Among various observation modes, the maximum data rate reaches up to 800 Mbps in spotlight mode, which exceeds the data rate of ALOS/PALSAR (240 Mbps). Therefore, the data recorder with 130 GB storage is equipped. The acquired data is downlinked both Ka-band via data relay satellite with the rate of 278 Mbps (QPSK, similar to ALOS) and X-band direct downlink with the rate of 400/200Mbps (QPSK) or 800Mbps (16QAM). ALOS-2 succeeds a promising property of L-band SAR of previous missions and improves the spatial resolution by increasing the data rate, which is feasible using the data relay communication satellite.

III. SPECIFICATION OF ALOS-3 AND EXPECTATION TO OPTICAL COMMUNICATION SYSTEM

A. Intial Design of ALOS-3 [4]

ALOS-3 satellite was designed by JAXA and METI as the platform of optical remote sensing sensors with the heritage of ALOS. Considering the requirements on disaster monitoring, 0.8 m-GSD panchromatic sensor with the swath of 50 km and 5 m-GSD multispectral sensor with the swath of 90 km were selected as the main mission payloads, which is enclosed with hyperspectral sensor as an optional sensor. Therefore, the data rate reaches up to 4 Gbps, which necessitates Ka-band data relay satellite with the downlink rate of 800 Mbps (2xQPSK). Even if X band direct downlink is simultaneously operated, the communication capability is not sufficient. Data fusion of three sensors is effective in producing high-spatial and high-spectral resolution data product [5]. Although such a configuration is promising, the downlink system becomes the bottle neck in the normal operation stage.

Moreover, since contact duration with the data relay satellite should be shared with ALOS-2 satellite, the downlink rate is limited, which means that the duty ratio of observation is further decreased by conflict.

B. Expectation to Optical Communication

The initial users of European Data Relay Satellite (EDRS) are Sentinel-1 and -2 that are the main satellites in Copernicus program [6]. EDRS is developed under ARTES 7 program to receive the earth remote sensing satellite data independent of non-EU ground station. Since Japan is located only in mid-latitude area, the necessity of the data relay communication satellite is much higher to keep autonomous space activities compared to EU and U.S.A.

After the successful mission of OICETS, NICT develops small optical terminals for micro satellites with weight of 50 kg [7]. Small optical terminal makes a way for any satellites to carry a downlink device as ultrahigh speed communication tools. Otherwise, the pointing movement of antenna for data relay communication of Ka-band induces undesired vibration, which causes the blurring of acquired image, which leads to more severe attitude requirements [8][9].

IV. CONCLUSION

This work surveys the data rate of earth remote sensing satellites and checked the feasibility of ALOS-3 satellites at the initial design phase. It is found that the next generation satellite infrastructure needs inter-satellite communication link with high speed, especially in land remote sensing data with high spatial resolution. To make reliable space infrastructure, combination of communication satellites with earth remote sensing program is important.

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