3 Ultra-High-Speed Satellite Communication Technology
3-1 WINDS Fundamental Experiments of NICT in Post-Operation Phase

Takashi TAKAHASHI, Kazuyoshi KAWASAKI, Byeong-pyo JEONG,
Norihiko KATAYAMA, Tomoshige KAN, and Mitsugu OHKAWA

Wideband InterNetworking engineering test and Demonstration Satellite (WINDS) was developed for establish the technologies of high data rate satellite communications and launched on February 23, 2008. After the initial check out on the geostationary orbit, NICT and JAXA, which are the organization developed WINDS, started their fundamental experiments. The application experiments, which were advatised by the Ministry of Internal Affairs and Communications, started from October, 2008.

WINDS was moved to the second stage operation from March 2013 and NICT planed the later phase fundamental experiments and carried out.

In this paper, the later phase fundamental experiments of NICT are described.

1 Introduction

The Wideband InterNetworking engineering test and Demonstration Satellite "KIZUNA" (WINDS) is an engineering test and demonstration satellite to establish high-speed satellite communication technology that was developed by the National Institute of Information and Communications Technology (NICT) and Japan Aerospace Exploration Agency (JAXA). It was launched on February 23, 2008, by an H-IIA rocket from Tanegashima Space Center of JAXA [1].

After the initial checkout phase, the Regular operation phase (nominal phase) started and we have performed verification of the performance of the onboard instruments and fundamental transmission experiments according to the NICT "fundamental experiments" plan.

Since April 2013, WINDS shifted to the Post-operation phase and we have planned Fundamental experiments in the post-operation phases to be implemented.

2 WINDS experiments

WINDS was launched on February 23, 2008, and shifted to the Regular operation phase since July 2008, after being placed in geostationary orbit and having its health verified through the initial checkout. The timeline

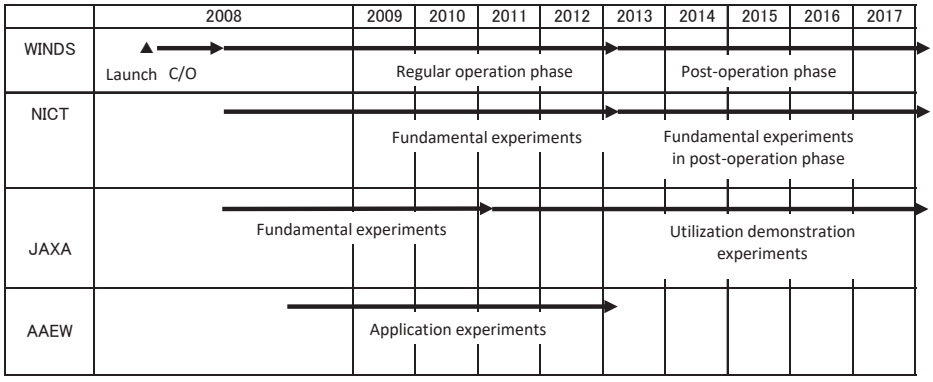

Fig. 1 Progress of operation and experiments of WINDS

of the operation and experiments of WINDS is shown in Fig. 1.

Then, the Fundamental Experiments were performed by the two satellite developers, NICT and JAXA. First of all, the basic communication properties were obtained. Then, application experiments adopted by the Ministry of Internal Affairs and Communications through solicitation started from October 2008. There were 53 proposals for application experiments and they were scheduled and promoted by forming the Association for Application Experiments of WINDS.

NICT implemented fundamental experiments [1] during the Regular operation phase. Fundamental experiments consist of verification of the performance of onboard devices, basic transmission, high-speed satellite network, and network application, ranging from basic properties of the satellite communication network to applications.

Since April 2013, when WINDS surpassed its design life of 5 years, it shifted to the Post-operation phase and the application experiments were completed. During the Post-operation phase, JAXA has been implementing Utilization demonstration experiments and NICT has been performing post-operation experiments.

Since April 2013, the Post-operation phase started and NICT has been performing experiments according to the Post-operation fundamental experiment plan with fundamental experiments that have been performed since the Regular operation phase and new experiments such as Satellite communication experiments for disaster countermeasures.

The framework of the Post-operation experiments is shown in Fig. 2. The schedule of the experiments is arranged by an Experiments coordination meeting between NICT and JAXA. The experiment plan and the results are reported to the Satellite Application Experiment Promotion Conference organized by the Ministry of Internal Affairs and Communications and the experiment is promoted based on the evaluation and advice by the Conference.

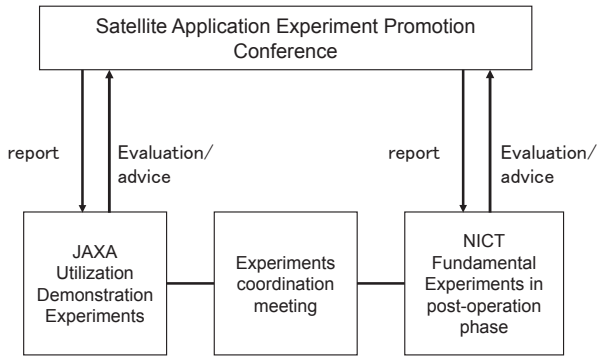

Fig. 2 Implementation system of experiments during the Post-operation phase

3 NICT Post-operation fundamental experiments

the items of the Post-operation fundamental experiments that NICT planned and performed are summarized in Table 1.

Here, we introduce them although some of them have already been completed after more than 4 years since the Post-operation fundamental experiments started.

3.1 Function verification experiment of Fully-automatic transportable station

After the Great East Japan earthquake occurred in March 2011, we have developed a Fully-automatic transportable station that persons other than specialists can easily set up and acquire a satellite link with it.

We verified the function and performance of the earth terminal.

3.2 Function verification experiment of Small-sized vehicle station

We have developed an earth station that enables communication with a base station of a rescue party by tracking a satellite while moving by car to the disaster area, which is a lesson learned by the experience of the Great East Japan earthquake.

We verified the function and performance of this earth station such as the tracking property and basic propagation characteristics.

Table 1 Items of fundamental experiments in Post-operation phase

No. of experiment	Item of experiment
N-L-01	Function verification experiment of Fully-automatic transportable earth station
N-L-02	Function verification experiment of Small-sized vehicle station
N-L-03	Function verification experiment of small station on vessel
N-L-04	Satellite network experiment
N-L-05	Satellite communication experiments for disaster countermeasures
N-L-06	Connection experiment with ground networks
N-L-07	Medical ICT satellite communications experiment
N-L-08	Basic experiments for future satellite technology

Also, we measured propagation characteristics with this earth terminal while moving. The results are introduced in **3-11** of this report.

3.3 Function verification experiment of small station on vessel

We mounted the antenna used for the Small-sized vehicle station and verified its function and performance such as the tracking property and basic transmission characteristics by linking a vessel and land station via satellite.

The earth station was installed on a research vessel in collaboration with the Japan Agency for Marine-Earth Science and Technology. We succeeded for the first time in the world in the tele-operation of a remotely-operated vehicle connected with the research vessel from land via satellite [2].

3.4 Satellite network experiment

This experiment has been performed since the fundamental experiments during the Regular operation phase. We evaluate throughput of upper protocol (TCP/IP, etc.) of a satellite network of a star type or mesh type.

3.5 Satellite communication experiments for disaster countermeasures

We could show the presence of satellite communication in the Great East Japan earthquake that occurred in March 2011, by offering temporary communication lines using WINDS.

We will perform a verification experiment to offer various data such as video to grasp the situation of damage, data and voice necessary for rescue in a case where communication infrastructure is damaged widely due to a large-scale disaster by a comprehensive network linking a satellite communication network and ground network such as a wireless LAN network.

The results are introduced in **3-3** of this report.

3.6 Connection experiment with ground networks

Since the fundamental experiments during the Regular operation phase, we will verify comprehensive transmission properties such as video, voice, and data, etc. when a ground network such as JGN and a wireless network are linked to the WINDS network.

We introduce an example of an experiment in **3-4** of this report in which we distributed high-quality video taken by a 3D 4K-HDTV camera by combining 622/1244 Mbps dual rate high-speed burst modem, a Time Division Multiple Access satellite communication network system and JGN.

3.7 Medical ICT satellite communication experiment

This experiment has been performed since fundamental experiments during the nominal phase in collaboration with Yokohama National University.

It is becoming more and more important to establish safe and secure medical security systems. The purpose of the experiment on a medical ICT network using satellite communication is to be of some help in establishing a more efficient healthcare system and remote medical education system by introducing satellite communication to a body area network (BAN) that collects various biomedical signals in real time and transmission of diagnostic images.

3.8 Basic experiments for future satellite technology

The following eight kinds of experiment were planned as basic experiments for technology expected for future communication satellites such as next engineering test satellites.

① Orthogonal frequency-division multiplexing (OFDM) transmission experiment

A broadband transponder of 1.1 GHz is installed on WINDS. We have developed a high-speed satellite communication modem by multi-level modulation frequency multiplication that makes use of the property of this transponder. We verified high-speed transmission technology at 3.2 Gbps by orthogonal frequency-division multiplexing that multiplies 16APSK (50 Mbps) code to 16 frequency multiplication.

The result of this experiment is introduced in **3-5** of this report.

② Experiment of reallocation of satellite communication line that can be reconstructed

We developed a channelizer that increases the efficiency of frequency use in traffic conditions in a disaster that change moment by moment. We verified that a satellite communication line is reallocated by changing the bandwidth and center frequency using a channelizer linked with the earth station by transmitting multiple data signals of 1 ~ 64 Mbps via WINDS [3].

③ SHV transmission experiment

We verify technology necessary for next-generation satellite broadcasting in collaboration with NHK.

We verify transmission characteristics at the date rate

of 150-1,000 Mbps, using transmission materials and Super High Vision (SHV) that NHK has developed.

The result of this experiment is introduced in **3-6** of this report.

④ Dynamic demand assign experiment

We verify the technology of dynamic slot assignment according to user association, not based on a planned slot assignment.

It is necessary to rewrite software of the onboard baseband switch of WINDS. We confirmed operability in a ground test using software upload evaluation apparatus.

⑤ Experiment of verifying health of APAA

This experiment has been continuously performed since the initial checkout phase after the launch by JAXA and NICT. We check the health of APAA elements by a rotating-element electric-field vector method.

The results of this experiment are introduced in **3-7** of this report.

⑥ Airborne communication experiment

We will develop the airborne earth station and verity the establishment of broadband links that enable transmission of large-volume data such as Pi-SAR observation data.

The result of this experiment is introduced in **3-8** of this report.

⑦ Experiment of transmission of Ka band multi-level modulation code

This experiment is performed under an agreement between JAXA and NICT. We will perform the fundamental experiment to understand the effect of variation of characteristics of the transmission line such as non-linearity and rainfall attenuation in transmission of multi-level digital modulation code such as QPSK, 16 QAM, 16 APSK and 64 QAM, etc., and discuss countermeasures.

The result of this experiment is introduced in **3-9** of this report.

⑧ Seaborne communication experiment

These days, technology of investigating marine resources has been developed and a system that enables real-time transmission of observation data taken by Remotely Operated Vehicle (ROV) and tele-operation of ROV from an on-shore base and a system to transmit the observation data obtained by Autonomous Underwater Vehicles (AUV) from Autonomous Surface Vehicles (ASV) to Research Vessel (RV) or an on-shore base have been designed.

We are developing high-speed satellite communication devices that can be mounted on RV and ASV and that enable an antenna to track a satellite automatically to establish stable satellite communication links. A remote access system is installed in the earth terminal in which ASV is equipped to enable unmanned operation to implement power management and emergent off-the-air, etc.

We will perform verification of tracking performance, satellite line establishment and transmission characteristics by seaborne communication experiments at a data rate range from several Mbps to several tens of Mbps between vessels on the sea or between a vessel and a land station using these earth stations.

The result of this experiment is introduced in **3-10** of this report.

4 Conclusion

WINDS was launched on February 23, 2008, and has been used for experiments of various satellite communication.

The satellite shifted to the Post-operation phase since April in 2013 and NICT planned Post-operation phase fundamental experiments. Here, we introduced the Fundamental experiments in the post-operation phase plan such as verification of the Fully-automatic transportable station function.

Although nine years have passed since the launch, we will continue to implement the Fundamental experiments in the post-operation phases.

References

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Takashi TAKAHASHI

Associate Director, Space Communications Laboratory, Wireless Networks Research Center
Satellite communication

Kazuyoshi KAWASAKI

Senior Researcher, Space Communications Laboratory, Wireless Networks Research Center
Satellite communication

Byong-pyo JEONG, Dr. Eng.

Senior Researcher, Applications Laboratory, Resilient ICT Research Center
Disaster response, GIS Satellite communication

Norihiko KATAYAMA, Dr. Eng.

Researcher, Space Communications Laboratory, Wireless Networks Research Center
Satellite communications, Propagation, Network

Tomoshige KAN, Dr. Eng.

Researcher, Space Communications Laboratory, Wireless Networks Research Center
Satellite communication propagation

Mitsugu OHKAWA, Ph.D.

Senior Researcher, Space Communications Laboratory, Wireless Networks Research Center
Satellite communications system