THE PERFORMANCE TEST OF AN INITIAL iNET-LIKE RF NETWORK USING A TETHERED AEROSTAT IN JAPAN

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ABSTRACT

Through the use of early iNET-prototype IP Transceiver technology, Kawasaki Heavy Industries, Ltd. (KHI) has been able to communicate with flight test vehicles during a recent research program. This technology provides a two-way high-capacity communication that has not been achieved with conventional telemetry and can be used not only for flight testing, but also for rescue work. KHI has been authorized to use S-band IP Transceivers since last year in Japan, and various communication tests have been performed. This paper describes Japan's first simulation of an iNET RF network which incorporated testing that performed data backfill, voice communication and video transmission. A data backfilling test was performed using retransmit of lock-off data (which is lost as the aircraft maneuvers) on command from the ground station. Moreover, a tethered aerostat is considered a very useful communication relay platform in the event of a large-scale disaster which results in the destruction of infrastructure. Also, the silence of an aerostat can be very important for search and rescue work.

KEYWORDS

iNET, RF Network, Tethered Aerostat, IP Transceiver

INTRODUCTION

KHI has been responsible for the development of the Japan Self-Defense Force's aircraft, Japan Aerospace Exploration Agency (JAXA) experimental aircraft and KHI aircraft, such as the BK117 helicopter. We have utilized conventional telemetry systems in various flight tests for many years. Approximately 10 years ago, KHI obtained information about iNET at ITC, and had a great deal of interest in the 52 user-case scenarios discussed at the CTTRA workshop. Since then, KHI has been working on research and development similar to iNET, especially two-way high-capacity communication, and has been promoting the introduction of such technology in Japan. We have been authorized to use S-band IP Transceivers since last year in Japan, and have carried out initial iNET-like RF tests. We have conducted high-quality video transmission tests, lock-off data retransmission tests and voice communication tests, and none of these tests were possible with conventional streaming telemetry systems. As a result, we were able to achieve some of the 52 scenarios that have been targeted by iNET. Furthermore, KHI used a tethered aerostat as the test platform for the instrumentation package developed for these tests. In the absence of strong winds, the aerostat is quiet and there is no vibration, therefore tethering is also easy. For these reasons, a tethered aerostat is considered a very useful communication relay platform to aid in search and rescue work in the event of a large-scale disaster when normal communication infrastructure is destroyed. This paper describes the results of these tests.

TEST OBJECTIVES

KHI carried out a two-way communication test between the aerostat containing our network-telemetry equipment package and the ground system.
Specifically, we wanted to demonstrate and confirm the applicability of the following capabilities.

- Demonstrate the use of two-way high-capacity wireless IP communication over long distances, and investigate available transmission data rates.
- Confirm the usable data retransmission function: The missing data by lock-off is downloaded from an on-board computer by a command from the ground station.
- Build a long-distance voice communication system by combining an IP Transceiver and the Radio Interface Unit which provides a seamless interface between radios and telephones using Voice over IP Technology.
- Verify the usefulness of a tethered aerostat as a communications relay platform.

TEST SETUP

IP Transceiver

The IP Transceiver (Teletronics Technology Corporation's nXCVR-2130A) was a key component of this test; it automatically switches the subcarrier modulation according to the received signal level and the packet error rate. The correlation of modulation, received signal strength and data rate is shown in Table 1. When the packet error rate is greater than 3%, the IP Transceiver switches to the next-step of lower modulation.

Table 1 : Modulation, Received Signal Strength and Data rate

Modulation	Code rate	Received Signal Strength (RSS) [dBm]	Data rate	
			Specification*1	Actual*1
16QAM	3/4	RSS ≥ -69	24.9 Mbps	20.3 Mbps
	1/2	-69 > RSS ≥ -71	16.6 Mbps	13.9 Mbps
QPSK	3/4	-71 > RSS ≥ -77	12.4 Mbps	10.5 Mbps
	1/2	-77 > RSS ≥ -79	8.3 Mbps	6.8 Mbps
BPSK	3/4	-79 > RSS ≥ -81	6.2 Mbps	4.7 Mbps
	1/2	-81 > RSS	4.2 Mbps	3.2 Mbps

*1 TDMA setting is as follow.
Air to Ground : Ground to Air = 4 : 1

Tethered Aerostat

The aerostat can be easily tethered and has no vibration such as the fixed-wing aircraft and rotorcraft. Therefore, the aerostat, when equipped with various communication units, is suitable as a platform for communications relay and disaster area monitoring in the area of a large-scale disaster. The details of the tethered aerostat are shown in Figure 1 and Table 2.

Figure 1 : The appearance of the tethered aerostat

Table 2 : The specification of the tethered aerostat

Fuselage length	10 m
Volume	50 m^3
Altitude	200 m max.
Note	The power can be supplied from the ground by a cable.

Two-Way High-Capacity Communication Test and Data Backfill Test

The system configuration of these tests is shown in Figure 2. The ground station is a very simple configuration.

The details of data transmitted from the aerostat to the ground station are shown in Table 3. The total data rate of the video encoder and the DAU is 6 Mbps. The data rate downloaded from the data recorder is automatically adjusted according to the available communication capacity. If the recorder can be downloaded at 4 Mbps, then the total data rate is 10 Mbps (the sum of 4 Mbps and 6 Mbps that stream from other sources on the aerostat).

Table 3 : The details of data transmitted from the aerostat to the ground station

Data Source	Data rate	Notes
Video Encoder	4.5 Mbps	
DAU	1.5 Mbps	
Data Recorder	Variable	Download of the recorded data

The test location and test setup are shown in Figure 3. The location was selected based on the visibility between the aerostat and the ground station. Straight-line distance from the aerostat to the ground station was approximately 34 km, and the ground station was at an elevation of approximately 60 meters.

The procedures for the data backfill tests are shown below:
(1) By changing the direction of the ground station antenna, we simulate a radio wave interruption for a period of time
(2) Turning the antenna back in the direction of the aerostat, we reestablish the radio link
(3) Sending the lock-off data retransmission request from the ground station
(4) Retransmitting the lock-off data from the aerostat

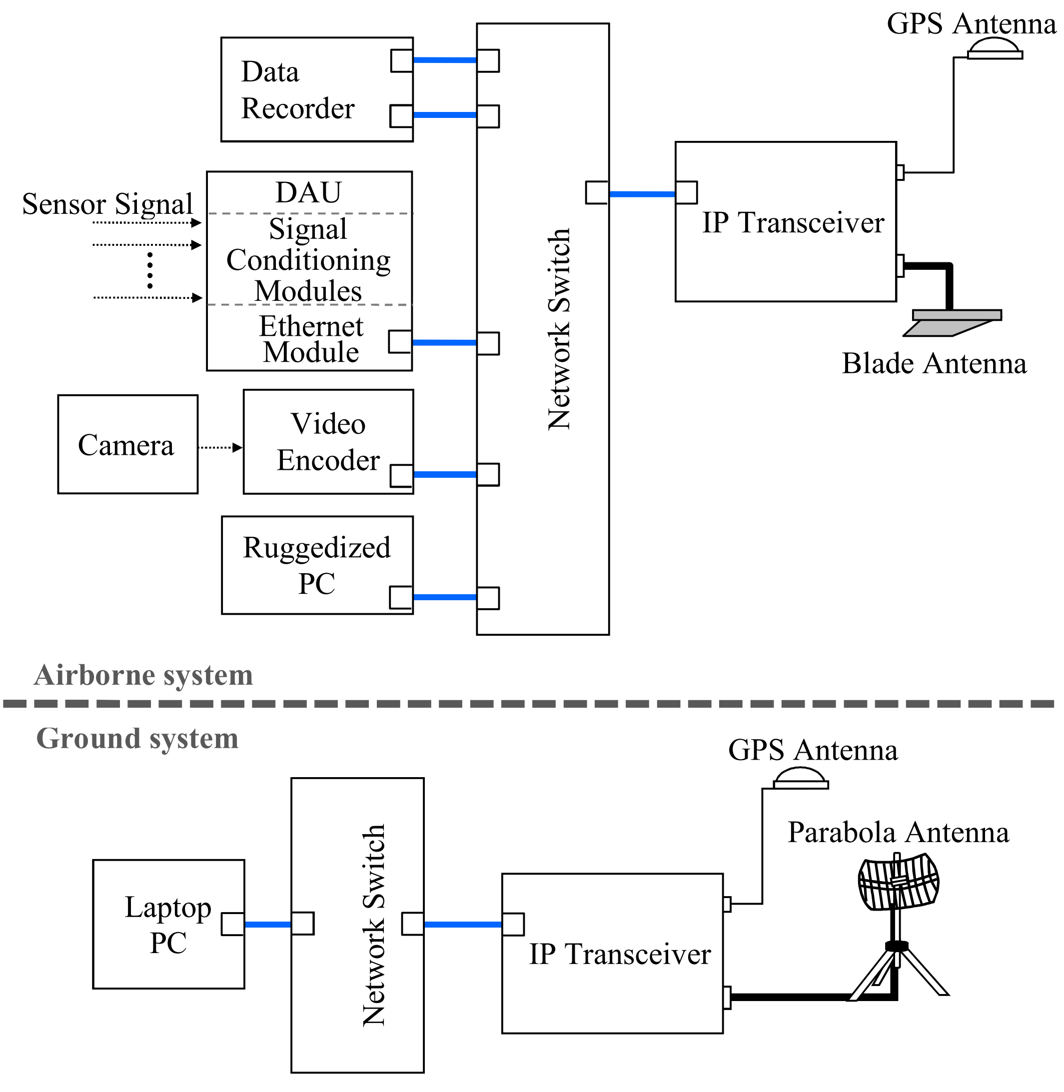
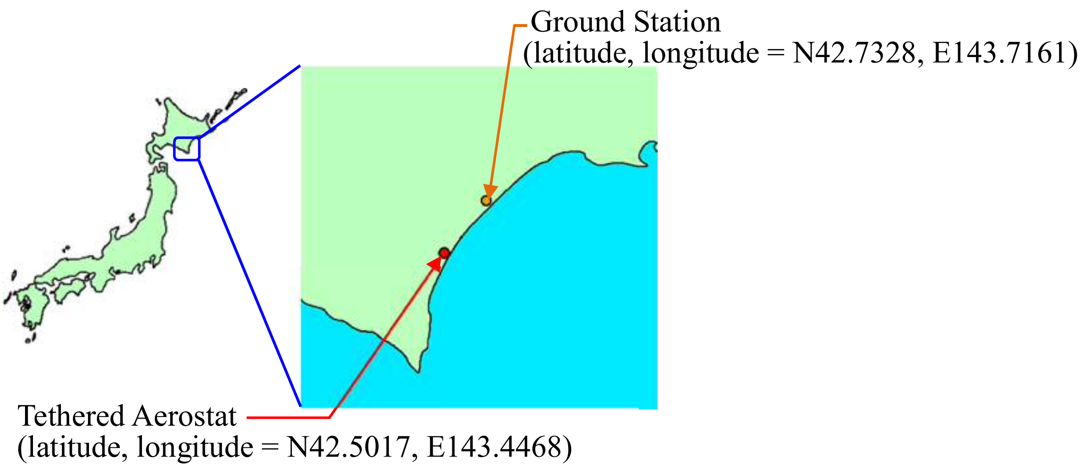
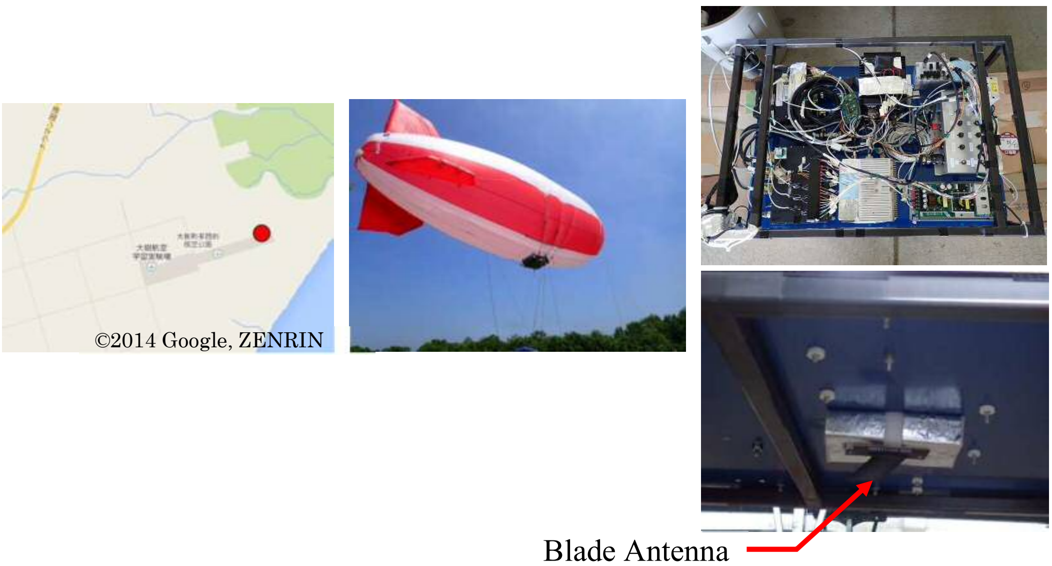


Figure 2 : System Configuration



(a) Test Location



(b) Aerostat

(c) Ground Station

Figure 3 : Test Location and Test Setup

Voice Communication Test

KHI built a long-distance voice communication system by combining IP Transceivers and the Radio Interface Unit, which provides a seamless interface between radios and telephones, using Voice over IP Technology. The system configuration of this test is shown in Figure 4. We can speak on different frequencies between radios using the Radio Interface Unit equipped on the aerostat. In addition, the voice communication between the IP phone and radios is possible through the IP Transceivers. Thus, our system allows for the voice communication of up to three people. Test setup is shown in Figure 5.

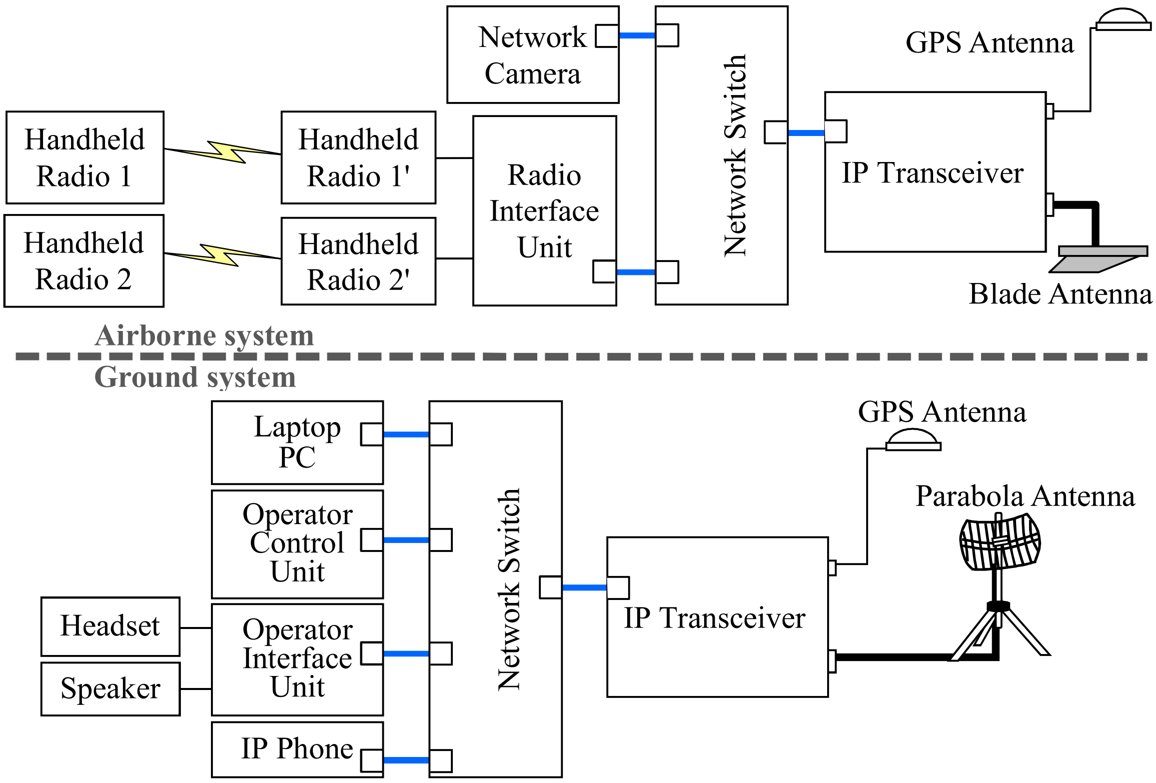


Figure 4 : Voice Communication Test Configuration

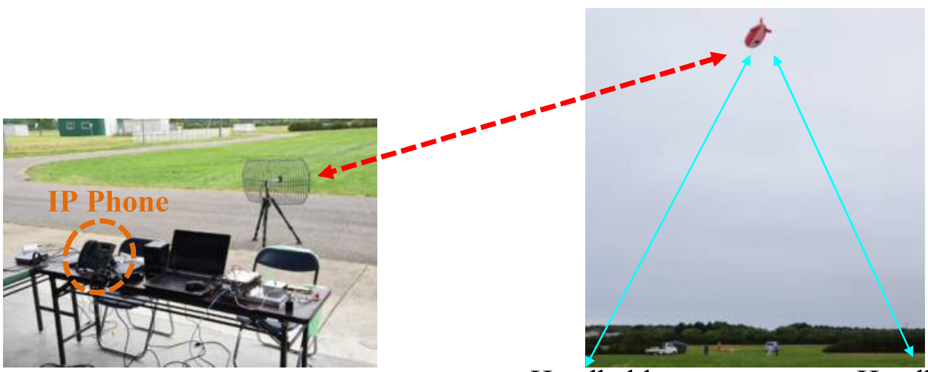
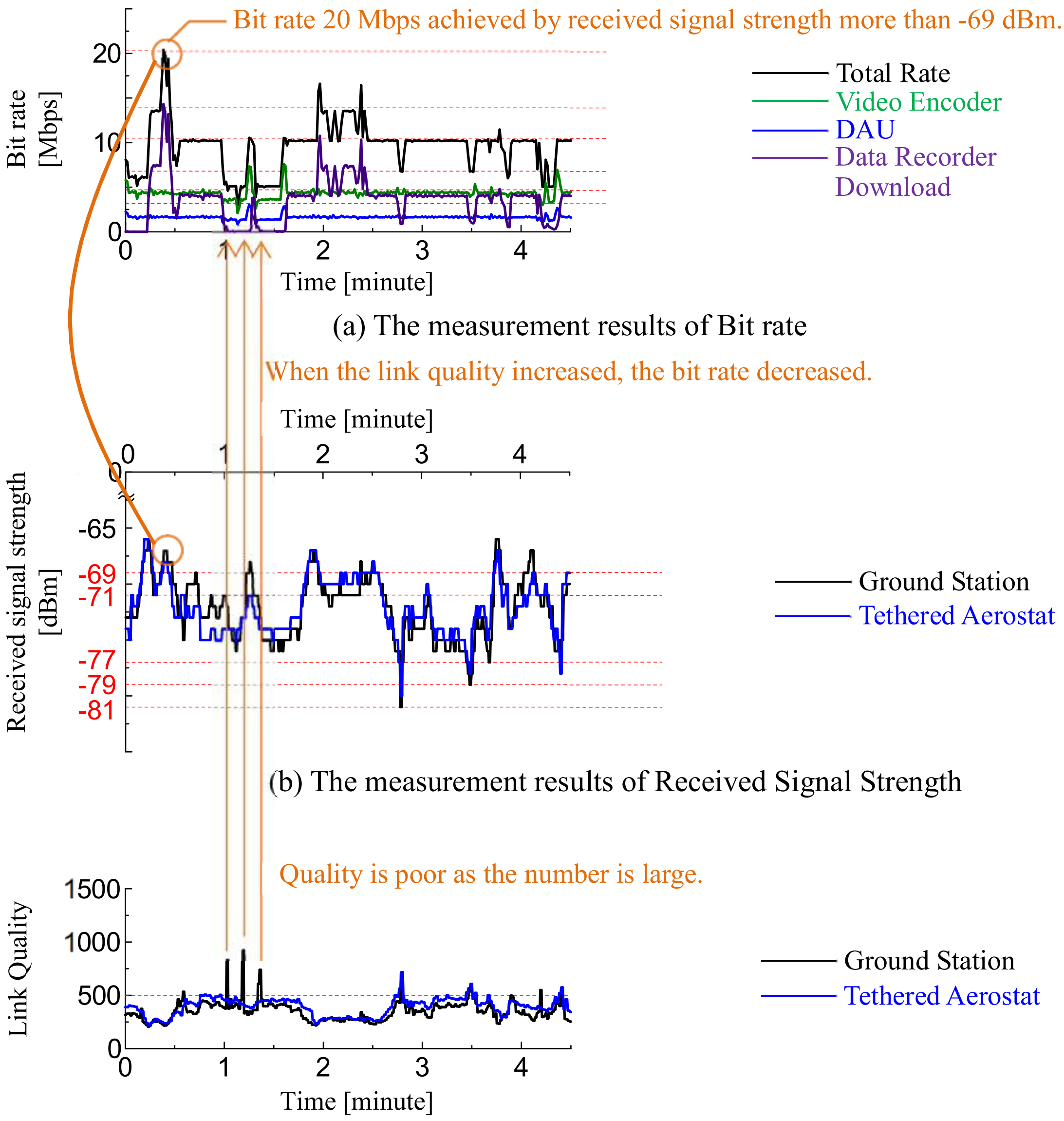


Figure 5 : Voice Communication Test Setup

TEST RESULTS

Two-Way High-Capacity Communication Test

The measurement results of Bit Rate, Received Signal Strength (RSS) and Link Quality are shown in Figure 6. Although the original plan was to raise the aerostat up to 200m, our altitude was limited to 120m due to strong winds and dense fog. However, we were able to achieve a maximum bit rate of 20 Mbps and the average bit rate was approximately 10 Mbps. Ensuring visibility by stabilizing the aerostat, or raising the height of the aerostat, it is considered that stable 20Mbps communication is possible.



(a) The measurement results of Bit rate

(b) The measurement results of Received Signal Strength

(c) The measurement results of Link Quality

Figure 6 : The measurement results of Bit Rate, Received Signal Strength and Link Quality

The expected values in this test setup of the received signal strength and the bit rate are shown in Table 4.

Table 4 : Computed value of Received signal strength (RSS) and Bit rate

Tx Power	Distance	**Measured value**		Computed value		
		RSS	**Bit rate**	RSS	Bit rate	Modulation
20 W (Average)	34 km	Average* -72 dBm Max. -66 dBm	Average* 9.6 Mbps Max. 20.5 Mbps	-66.2 dBm	24.9 Mbps	16QAM3/4

* Average value from 0 to 4.5 minutes.

When the distance is 34 km, the RSS is calculated to be -66.2 dBm. This is a sufficient RSS for receiving data using 16QAM 3/4, which is limited to being active a power level greater than 69 dBm. The average measured RSS value was -72 dBm, but the measured maximum value is equivalent to the computed value. These results are sufficient to convince us that we can reliably communicate at 20 Mbps with a distance of 34 km.

Data Backfill Test

KHI could accurately retransmit the data of the radio communication link interruption interval. The configuration setup of the data retransmit testing is shown in Figure **7**. The left side is showing data lost and the right side is showing data retransmit. The measurement data rate is shown in Figure 8. When the radio link was interrupted, a temporary data drop occurred. After recovery of the radio link, the data retransmission request was sent to the aerostat from the ground station. As a result of the data retransmission, it was confirmed that the data rate was increased temporarily to downlink the lost packets and the lost data was displayed at the ground station.

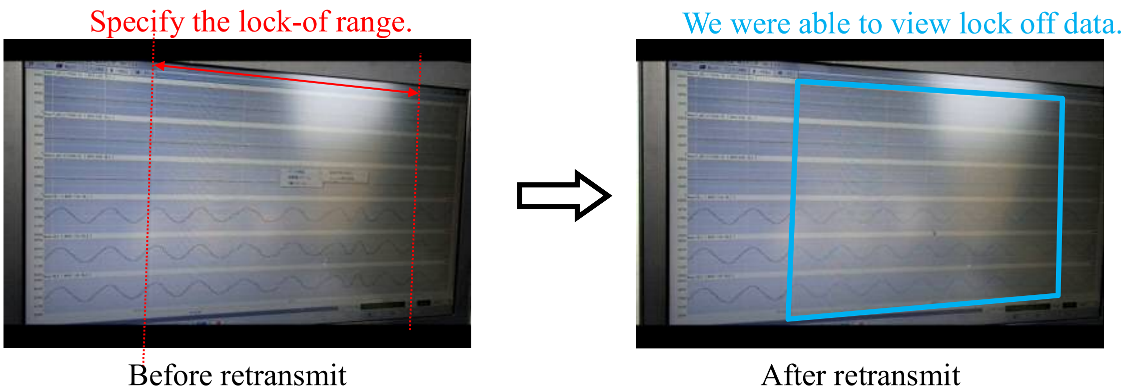


Figure 7 : The situation of lock-off data retransmit test

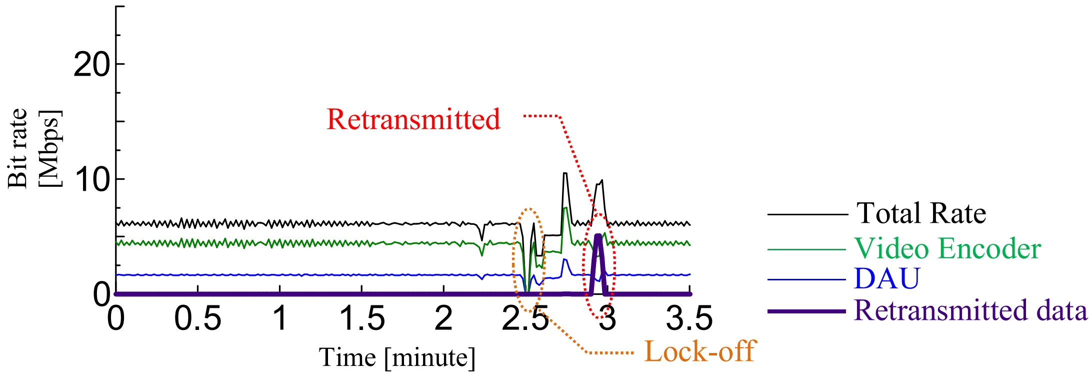


Figure 8 : The measurement data rate

Voice Communication Test

Three users could speak using different frequency radios and an IP phone. The voice to IP multicast conversion is done by the VoIP module of the Radio Interface Unit. It is necessary to pre-configure the voice multicast addresses into the switches and the IP Transceivers for routing.

CONSIDERATION

We considered the operational guidelines of the IP Transceivers based on the communication performance. Depending on the flight test environment and the flight test range, the amount of data which can transmit in real-time is limited. Therefore, the priority of the transmission data must be determined.

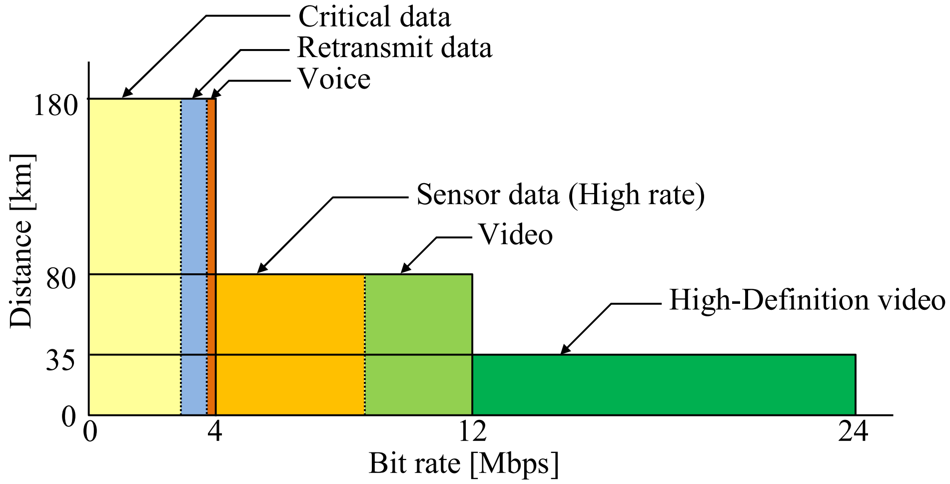


Figure 9 : Example of the transmission data priority

If the bandwidth that can be achieved at the required communication distance is insufficient, we suggest a high-gain antenna on the aircraft. In that case, it may be necessary to mount multiple antennas since the communication direction of each antenna may be limited.

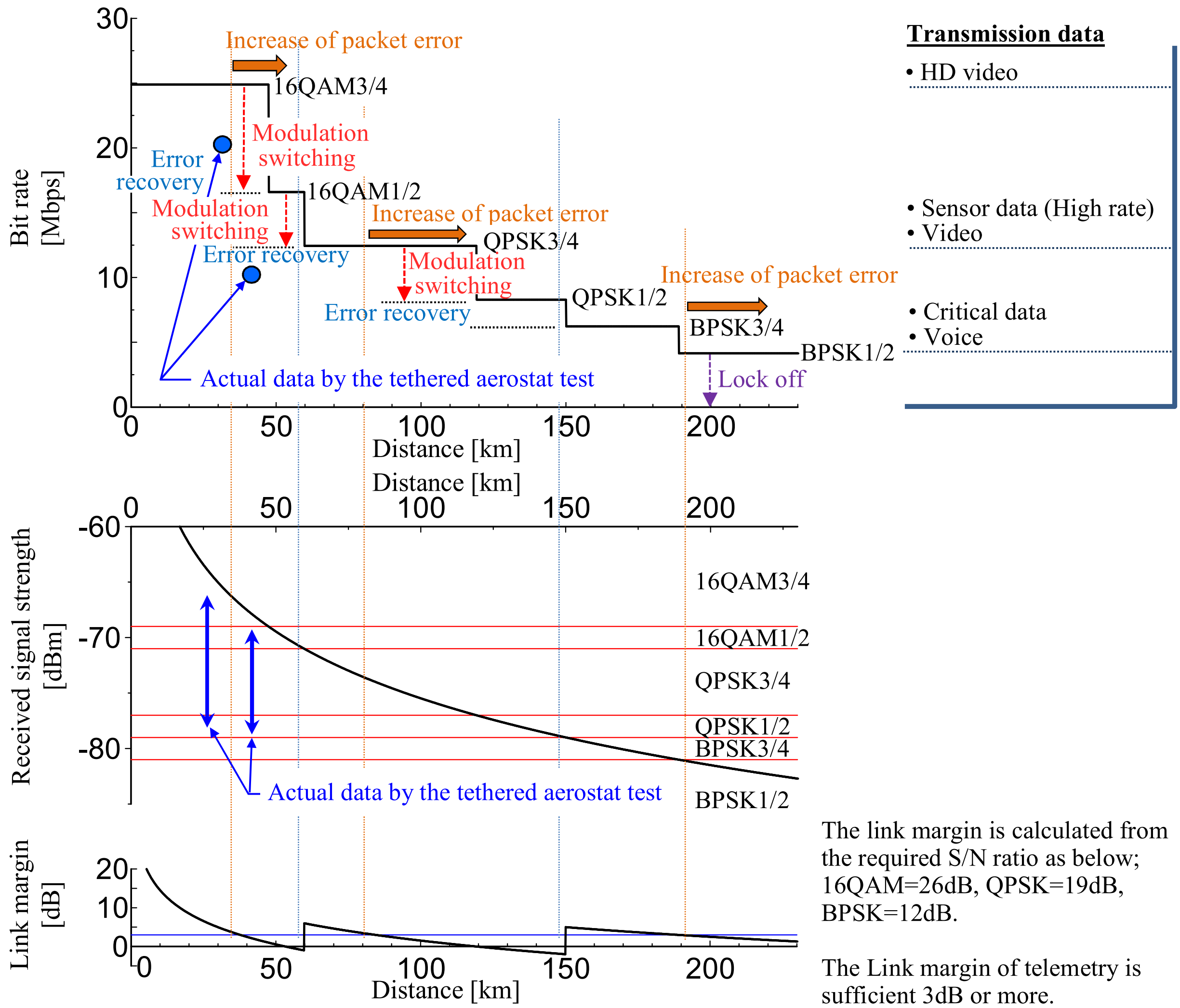


Figure 10 : Operational Guidelines of IP Transceiver

CONCLUSIONS

- For the first time in Japan, using a network telemetry communication architecture modeled after the proposed iNET system, we have demonstrated the transmission of measurement data, including video data, from an aerostat.
- At a distance of 34 km, our tests recorded a maximum bit rate of 20 Mbps.
- The measured value of the received signal strength was comparable to the computed value.
- The data retransmission function applied to our two-way communication technology worked well. We were able to confirm its effectiveness.
- By combining the IP Transceivers and the Radio Interface Unit, we were able to show that it is possible to establish long-distance wireless simultaneous voice links among different users using radios operating on different frequencies and an IP phone.
- We have demonstrated the usefulness of a tethered aerostat as a communications relay platform.