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Ku-BAND HELICOPTER-SATELLITE COMMUNICATION EXPERIMENT USING AN ACTIVE PHASED ARRAY ANTENNA

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1. Introduction

A disaster monitoring and management system using helicopter satellite communications technologies is presented. We have developed an on scene disaster information transmission system [1,2,3] using Ku-band helicopter satellite communications with an active phased array antenna.

The main technical difficulty for a helicopter-satellite communication link is the interruption caused by the helicopter's rotating blades. To overcome this interruption, we used a time diversity transmission technique at the forward link and a blade-synchronized transmission technique at the return link. Furthermore, onboard position estimation is performed using on-scene video pictures. Some field experiments were performed with satisfactory results.

2. Background

The delay in organizing relief after the initial stages of a disaster due to lack of information is well documented. Helicopters are widely used to collect information during large-scale disasters and other emergencies, as they are highly mobile and are an effective means to quickly gather information. However, the current method to transmit this information from a helicopter is poor.

Currently, the gathered information, including video pictures collected by a helicopter, is usually transmitted through relay stations on the ground. However, such a communication mechanism is limited to the coverage area of the ground relay station, which usually has a coverage radius of 30km. Moreover, in some cases such as in a mountainous area or over the sea, it is difficult to locate a relay station.

Thus, a large number of relay stations are needed to operate a system over a wide coverage area. These two limitations will be greatly reduced if we can transmit information between a helicopter and a ground base station via a geostationary satellite. We have developed a helicopter satellite communication system (HSCS) for this purpose and its concept is shown in Figure 1.

3. Outline of the System

When the helicopter satellite communication system was designed, the following points were especially taken into consideration.

(1) The overall system must be small and lightweight.
(2) Communication is possible, even if the helicopter shakes to some extent.
(3) The transmitting power must not endanger the on-board crewmembers.
(4) The transmitting power must not interfere with the other existing radio communication systems.
(5) The off-axis radiation characteristics and the polarization performance of the transmitting

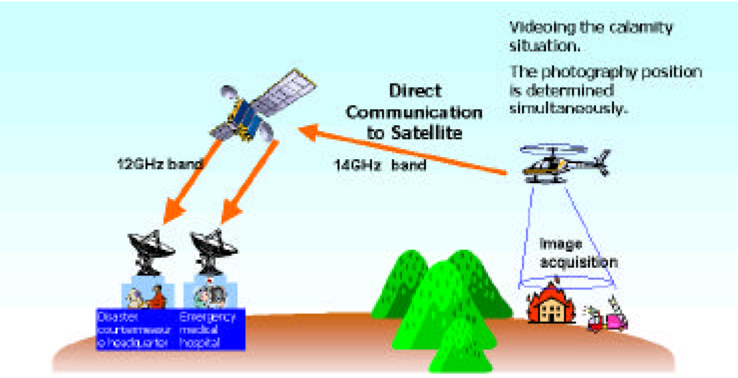

Figure 1 HSCS concept

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antenna must meet the regulated standards.

(6) The photographing position equipment must be able to detect images.

The external view of the telecommunications equipment, camera, and so forth that are mounted on the helicopter is shown in Figure 2 and a block diagram of the HSCS is illustrated in Figure 3.

This system is divided into three components, the NICT Kashima base station that imitated the anti-disaster headquarters, the helicopter radio station, and the relay satellite. When the antenna is mounted under the blade, the periodic interception of the radio waves by the helicopter's blade affects communication link with the satellite. In the case of transmission from a helicopter, a system which transmits in synchronization with the timing of the blade has been developed to countermeasure the blade's interception of the radio wave when transmitting. A magnetic pickup mounted on the helicopter is used to detect the interception timing. A time diversity system, which transmits the data repeated at multiples of the timing, is used when receiving on the helicopter.

Figure 2 Photograph of the HSCS

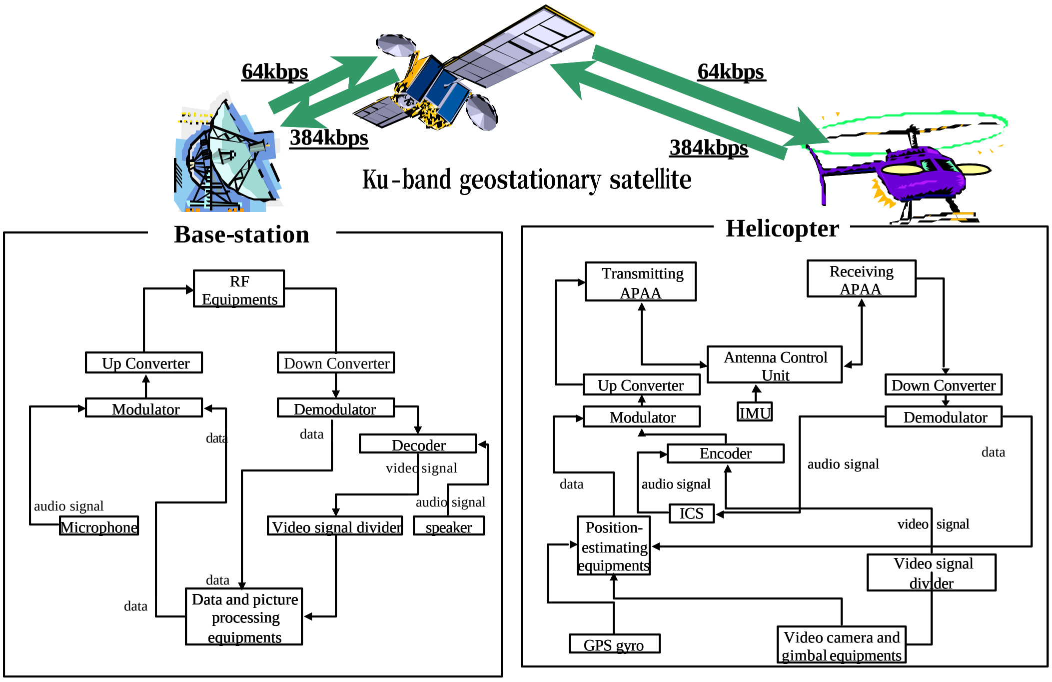

Figure 3 Blockdiagram of the HSCS

Active phased array antennas (APAA) are preferred because they can be easily mounted on a helicopter as a transmitting and receiving antenna. Although the frequency is in the Ku (14/12-GHz) band, it is important to avoid interference with/from other satellite communication systems. The off-axis radiation power must, therefore, be reduced. To achieve this reduction, the spread spectrum technique is being used. The regulation for the very small aperture terminal (VSAT) is assumed to be applying for off axis radiation. The transmitting and receiving APAA included 536 and 624 elements (Figure 4). To reduce the cross-polarization radiation, a two-point pin feed circular patch antenna with parasitic elements was adapted [4] for the antenna element. Each element consisted of a RF module implemented on a microwave monolithic integrated circuit. The RF modules were then connected to the beam forming network and control circuit (Figure 5). The APAA can automatically track the satellite in the ranges of 0 – 360 degrees in azimuths and 30 – 90 degrees in elevation. The polarization angle is also automatically tracked.

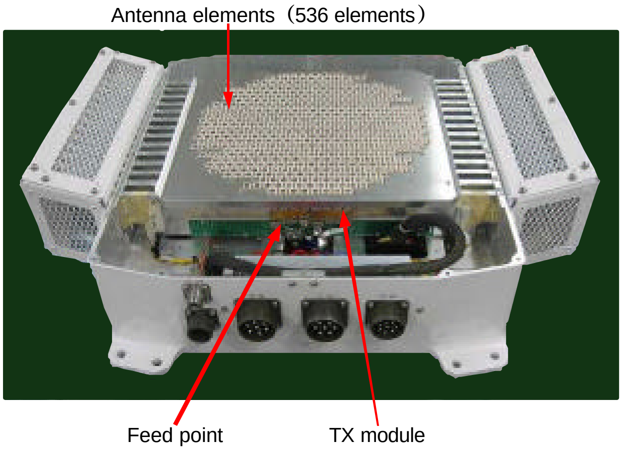

Figure 4 TX APAA without radome

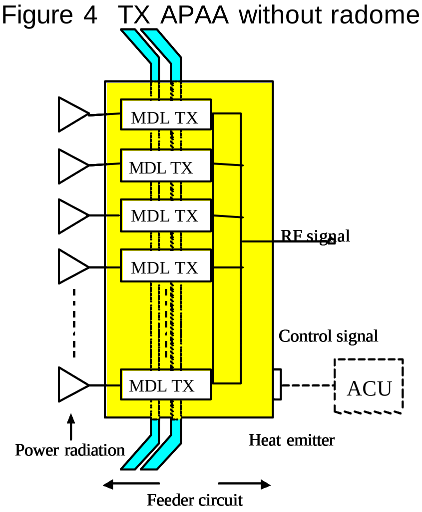

Figure 5 Blockdiagram of an APAA

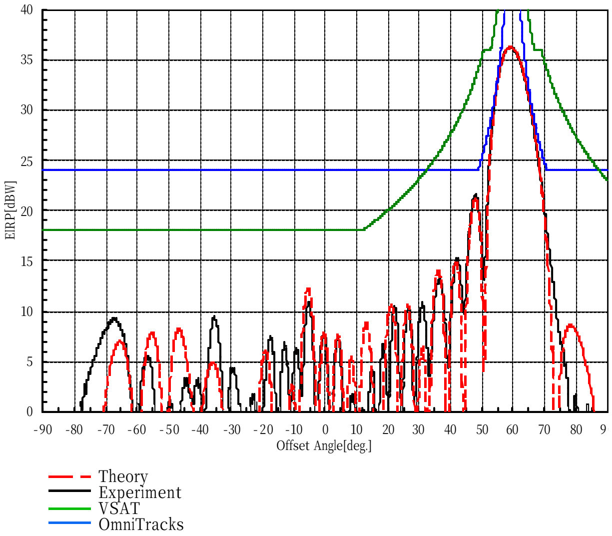

Figure 6 TX antenna pattern

The EIRP of the transmitting antenna was 35 dBW, and the bit rate was assumed to be 384 kbps from the helicopter to the satellite and 64 kbps from the satellite to the helicopter. The measured and calculated transmitting antenna patterns are shown in Figure 6 together with the VSAT and the OmniTracks standard off-axis patterns. Experimental cross polarization ratio was –20.2 dB at the El = 30 degrees, and the G/T of the RX-APAA was 2.4 dB/K.

The helicopter can transmit semi-moving images or still pictures, voice and data, and can receive voice and data. The images are encoded using an MPEG-4 codec that can also simultaneously detect and transmit additional information, such as the photographing position on the ground. In contrast, the base station sends audio signals and data to the helicopter via a Ku-band geostationary satellite. The main equipment in the base station included a Cassegrain antenna with a diameter of 13 m, a high power amplifier , a low noise amplifier , a modulator and demodulator, as well as an encoder and a decoder. The specifications of the HSCS are summarized in Table 1.

4. Experimental Results

Figure 7 shows the receiving waveform received by the helicopter station when interfered with the rotor blade. Degradation of the receiving level is 13dB in maximum and had a period of 39 msec, and this corresponded to the rotor revolution period of the helicopter.

Figure 8 shows the bit error rate received by the base station with the blade synchronization method. Degradation of experimental signal with the theoretical value is about 0.5 dB when the forward error correction was turned ON and OFF, and this is within design guidelines.

Flight experiment of the HSCS was successfully performed in late November 2004. Figure 9 shows a picture sent from the helicopter in the Gifu area and received at the Kashima station via satellite.

5. Summary

We have outlined a helicopter satellite communication system that provides a method of collecting and transmitting real time information via satellites. The system has been constructed and field experiments demonstrated that method was able to successfully transmit and receive data.

Reference

[1] H. Wakana, “Satellite communications technologies for disaster monitoring and disaster management.”, 102nd. CRL Meeting for reading research papers, Jun., 2002.

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[3] M. Sato, et. al, “Flight test plan of helicopter satellite communication system for transmission of disaster and emergency information”, Society Conference of IEICE, Vol.B-3-23, pp.269, Sep., 2004.

[4] O Itoh, et. al, “A dual polarized patch antenna with low-cross-polarization by perturbing parasitic element”, Society Conference of IEICE, Vol.B-1-103, pp.135, Sep., 2002.

Acknowledgements

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Table 1 HSCS specifications

Antenna type		**Active Phased Array Antenna**
Frequency	**TX**	**14.0-14.5 GHz**
	RX	**12.25-12.75 GHz**
Polarization		**Linear polarization**
Azimuth scan angle		**0-360 degree**
Elevation scan angle		**30-90 degree**
EIRP		**more than 35 dBW (designed value)**
G/T		**more than 0.5 dB/K (designed value)**
Modulation		**• Return link; BPSK/SS spread factor 6** **• Forward link; BPSK**
FEC		**½-convolution code + RS code (204,188)**
Overall rate	**Tx**	**384 kbps**
	Rx	**64 kbps**

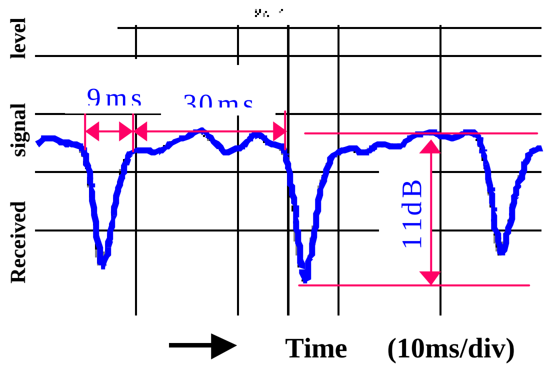

Figure 7 Receiving waveform (forward link)

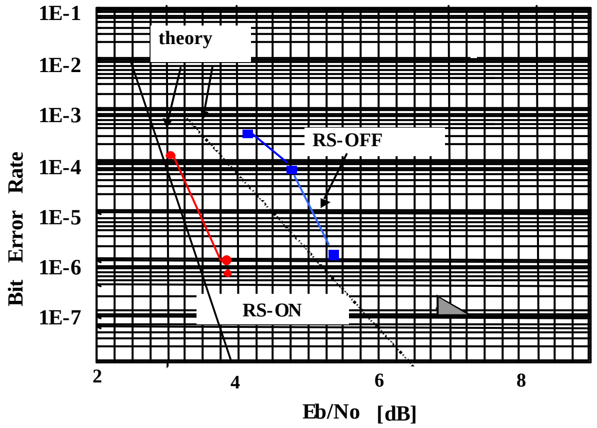

Figure 8 Bit error rate characteristics (return link)

Figure 9 Received picture (640X480pixel, Gifu University)