

# On-board Ka-band Satellite Tracking Antenna for Unmanned Aircraft System

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**Abstract** – The National Institute of Information and Communications Technology (NICT) has been developing an on-board Ka-band tracking antenna system which realizes the communication link between unmanned aircraft (UA) and remote pilot via satellite with the increased use of UA research and standardization of the control communication system for UA. The tracking on-board antenna designed for UA has various functions such as low-profile and broadband. In this paper, we explain the results of the development and the background of the tracking antenna so far.

**Index Terms** — Unmanned aircraft, satellite, CNPC, on-board antenna, Ka-band

## I. INTRODUCTION

Recently, unmanned aircraft system (UAS) has received a lot of attention in recent years in the world for various applications such as wind and flood damage and fire, supervision and monitoring in various fields. Some applications using UAS have been proposed. For example, a wireless relay system using small portable unmanned aircraft (UA), which can be computer-controlled autonomous flight and does not require runway, has been studied to ensure communication to disaster areas [1].

Towards the next World Radiocommunication Conference 2015 (WRC-15), a new agenda was agreed to determine the Ku/Ka frequency bands in order to establish a communication link between UA and remote pilot via satellite. The realization UAS control and non-payload communications (CNPC) link between the remote pilot and UA in the beyond-line-of-sight (BLOS) areas means that the flight made possible in a wide range by the use of the functions of the global scale of fixed satellite service (FSS) network. Since Ku/Ka-bands are already congested, we have to consider sharing the band with existing systems such as FSS and the interference from/to the satellites is also important issue. Therefore, research and development of interference mitigation techniques has become an urgent issue. In particular, the antenna beams of on-board tracking antennas must be designed and controlled properly to prevent harmful effects on other satellites.

In this paper, we present the development of an on-board Ka-band tracking antenna to meet the needs of the implementation of the UAS CNPC link between UA and satellite.

## II. DESIGN PRINCIPLES OF THE KA BAND RADIATION UNIT

When we develop on-board antennas for UA, we must take into account the characteristics of the propagation of links between satellite and UA and the motion characteristics of the UA. It is also necessary to refer to relevant standards such as protection criteria of existing systems and UAS. Although there is no ITU-R recommendations or reports on the use of the FSS for CNPC links to operate the UAS at this point, we referred to the working document towards a new report ITU-R M.[UAS-FSS] in ITU-R [2] in the study. In addition, there is another discussion on the use of Earth Stations on Mobile Platforms (ESOMPs), which allow aircraft, ships and trains have high-speed connections between satellite platforms in the Ka band.

Considering the above factors, we will develop an on-board Ka band antenna for UAS that meet the several conditions such as off-axis e.i.r.p. which satisfies ITU-R Recommendation S.524-9 [3] and lowering the height of the mounting system of the antenna, weight, and power savings.

Phased array system is advantageous to control the angle of the formation of flexible beam. Furthermore, the diameter of rotation and the height of the phased array antenna can be reduced. On the other hand, there are several disadvantages such as the decrease in gain due to the decrease in the effective aperture plane in accordance with the changes of the angle of the beam, the high power consumption, and high cost. Referring to several Ku/Ka band airborne antennas under development or existing, they introduce the mechanical drive system of elevation and azimuth control.

Considering the current possible technologies, the mechanical drive system of elevation and azimuth control seems to be suitable for UA on-board antenna at this point. We also introduce a Cassegrain system with elliptical aperture reflector because it can be expected low weight and manufacturing costs while reducing the antenna height. It also provides the wide frequency band which supports the ESOMPs frequency band.

As for the link budget and required antenna specifications, we suppose the maximum communication speed per one UA is 5 Mbps. As the reference satellite, we assume a broadband communication satellite system ‘WINDS’ developed as an experimental communication satellite to demonstrate

technology for broadband satellite communications with Internet Protocol (IP) [4].

We used the hybrid analysis of physical optics (PO) approximation and the finite element method (FEM) to design and analyze the Cassegrain antenna. Furthermore, the reflector shaping technique [5] that reflects the deletion of the scattered waves such as diffracted waves was used to achieve the low profile and to meet the low side lobe defined by ITU-R S.524-9.

Table I summarizes the results of the antenna design.

TABLE I  
RESULTS OF ANTENNA DESIGN

No.	Items	Values	Comments
1	Tx Frequency	27.5-30.0 GHz	
2	Rx Frequency	17.3-20.2 GHz	
3	Off-axis e.i.r.p.	ITU-R S.524-9 24.5dBW/40kHz	
4	Size	Height < 22.2 cm	Without adome
5	Polarization	Tx: right-handed circularly Rx: left-handed circularly	
6	G/T	Over 10.0dB/K@18.9GHz	
7	e.i.r.p.	Over 46.8dBW	

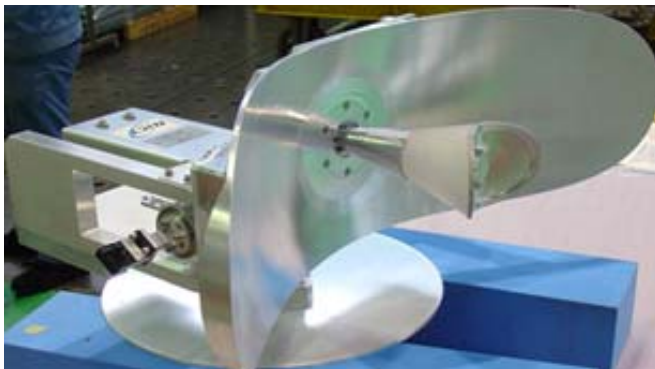
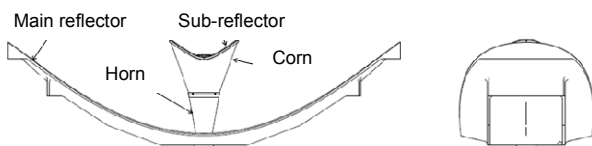


Fig. 1. Appearance of the radiation unit.

### III. EVALUATION OF RADIATION UNIT OF ON-BOARD ANTENNA

We have developed a radiation unit of the on-board antenna as shown in Fig. 1 as the first step towards the development of the Ka-band on-board antenna for UAS and evaluated several characteristics of the radiation unit. As shown in Fig. 1, the radiation unit consists of main, sub-reflector, the primary radiator and reflector cone. The shape of the main reflector is close to elliptical due to the low profile.

The observed antenna gain shows more than 35.2 dBi at 18.9 GHz. The measured receive G/T values vary between 11.5 dB/K and 13.4 dB/K. The off-axis radiation patterns obtained in a compact range anechoic chamber are shown in Fig. 2. As the results, we confirmed that the obtained values

and results satisfy the requirements which realize 5 Mbps communication speed and that the radiation unit of the antenna satisfies the antenna requirements defined in Recommendation ITU-R S.524-9.

### IV. CONCLUSION

In this paper, we first explained the background of a new communication system that uses the frequency band of the fixed-satellite service for feeder command and useful non-communication load for the operation of the system unmanned aircraft and the current state of development of the tracking antenna on board Ka-band for the unmanned aircraft system. As a first step of development, we have developed a unit of radiation of the antenna board and evaluated its characteristics.

We will develop the other units to tracking antenna on board and present the results of a further study.

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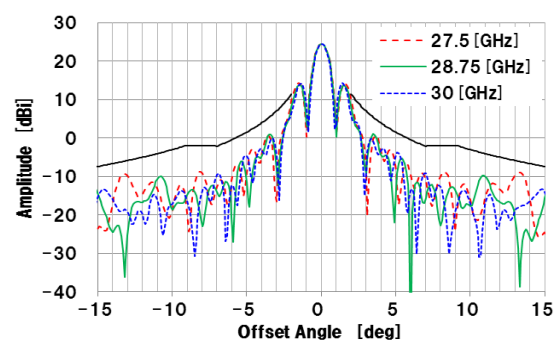


Fig. 2. Measured off-axis radiation pattern around 0 degrees.