

FSMP-WG/4 and regional spectrum seminar

Development of Wireless Link Applications for Small UAS in Japan

March 27-28, 2017

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This study is carried out under a government-commissioned research project of the Ministry of Internal Affairs and Communications.

Contents

- Background of UAV Wireless Communication Systems
- Development of UAV-based wireless relay network system in natural disasters
- Development of on-board satellite tracking antenna for UAS
- Recent UAS radio regulation status in Japan
- Conclusions


Background-1

- **Unmanned aircraft systems (UAS) or drones** have received a lot of attention in recent years in the world for several applications
 - ▶ wind and flood damage and fire, monitoring and observation, deliveries of goods
 - Reliability of communication and the safe operation of UAS is becoming urgent need with the expansion of the needs of the UAS.
 - The World Radiocommunication Conference (WRC)
 - ▶ WRC 2012 (WRC-12) decided the allocation of the frequency band 5 GHz band (5030 MHz ~ 5091 MHz) for the UAS **Control and Non-Payload Communications (CNPC)** Link.
 - ▶ WRC (WRC-15) decided to allocate the Ku/Ka frequency bands to establish a communication link between UA and remote pilot through satellite, and the details of its operations have being discussed in ITU-R
- ➔ **Research and development of interference mitigation techniques has become a pressing issue.**


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Background-2


- In past disasters such as Great Hansin Earthquake and Great East Japan Earthquake, some isolated areas appeared in disasters area.



Isolated school



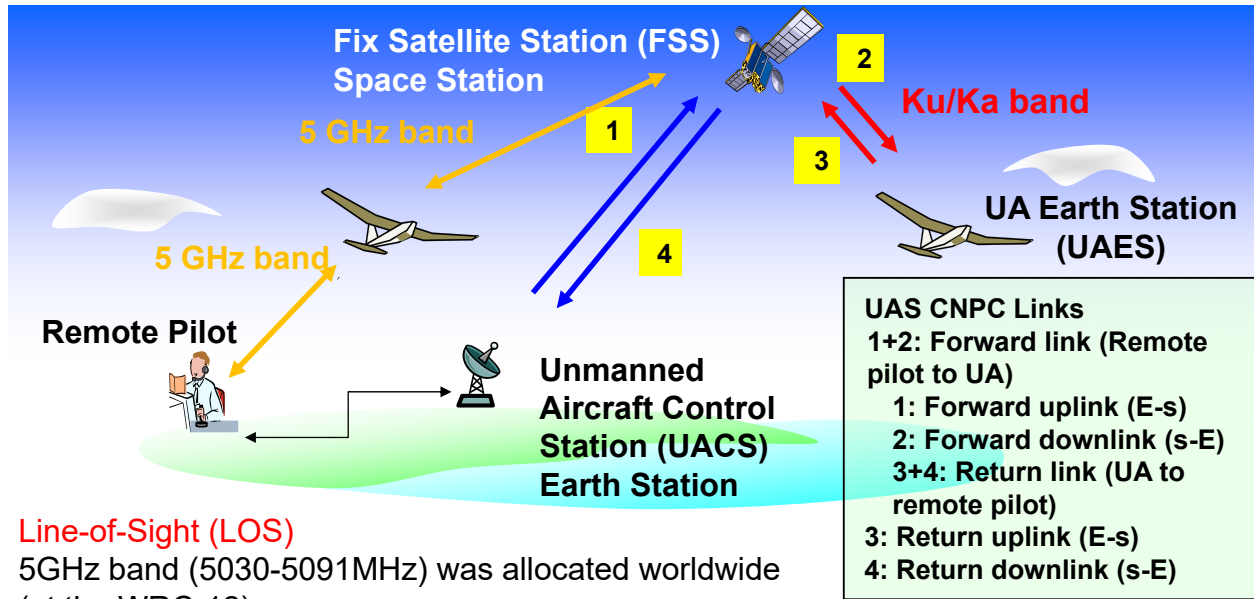
Isolated airport



Isolated place
- The transportation system and communication system were interrupted by earthquake and tsunami
- The demand of wireless relay network using unmanned aircraft system has grown
- Various applications using UAS are being studied in Japan
- **We report the development of a UAV-based wireless relay network system and the current status of frequency regulations for UAS wireless link in Japan**

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Control and Non-Payload Communications (CNPC) Link for UAS



Line-of-Sight (LOS)

5GHz band (5030-5091MHz) was allocated worldwide (at the WRC-12)

Beyond-Line-of-Sight (BLOS)

5GHz band (5030-5091MHz) was allocated worldwide (at the WRC-12)

Allocations of Ku/Ka bands in the FSS band are being discussed now (toward the WRC-19)

Candidate Unmanned Aircrafts for the Research

Target UAs of this research

Small type UAs



Medium and Large type UAs
 Require Beyond-Line-of-Sight (BLOS) operations

Frequency Regulations on UAS

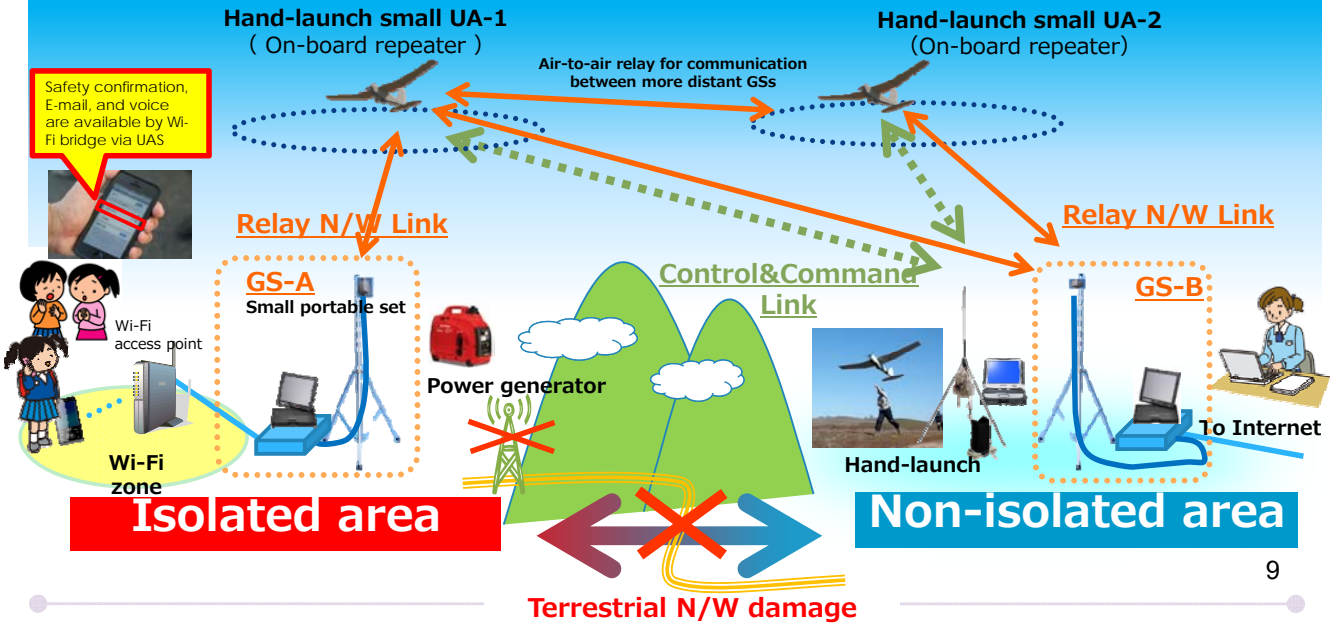
- The frequency band 5 030–5 091 MHz was allocated for the CNPC link at WRC-12
 - ▶ The definition of internationally standardized system is required under the footnote 5.443C of ITU-R Radio Regulations
 - ▶ NICT is interested in usage of the frequency band 5 030–5 091 MHz for CNPC link which realizes safe operations of small UAs in a short range with small transmission power.
- Several discussions on UAS frequency usages including channel plan are carried out in ICAO
 - ▶ ICAO has a policy that calls for enacting a general framework of flight rules by around 2018
 - ▶ The technological and industrial development of the field of unmanned aircraft in Japan has been started
- UAS Traffic Management (UTM) system by NASA

2. DEVELOPMENT OF UAS WIRELESS RELAY NETWORK

Solution: Unmanned Aircraft-based Wireless Relay Network

NICT started R&D on disaster-resilient wireless communication system using small unmanned aircraft system (UAS) in order to ensure the communication infrastructure between the isolated and the non-isolated areas at the time of disasters.

Advantages: Rapid deployment, Low operation cost, No runways needed



Case-1 Experiment on Mobile Phone Relay NICT System for Isolated Rural Area in Disaster



Small Unmanned Aircraft (UA) - PUMA-AE -

Name	PUMA-AE (AeroVironment, UAS)
Wingspan, Weight	2.8m, 5.9kg
Payload	0.5kg
Flight time, range	2-4 hours, 15-20 km
Wind speed	25 knots (13m/s)
Max. flight ceiling	5000 m (200~400m in the demo)
Power, operation	Electric, hand launch, deep-stole landing, autonomous flight by GPS and other sensors, water proof

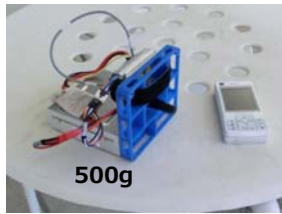




Puma AE (All Environment)



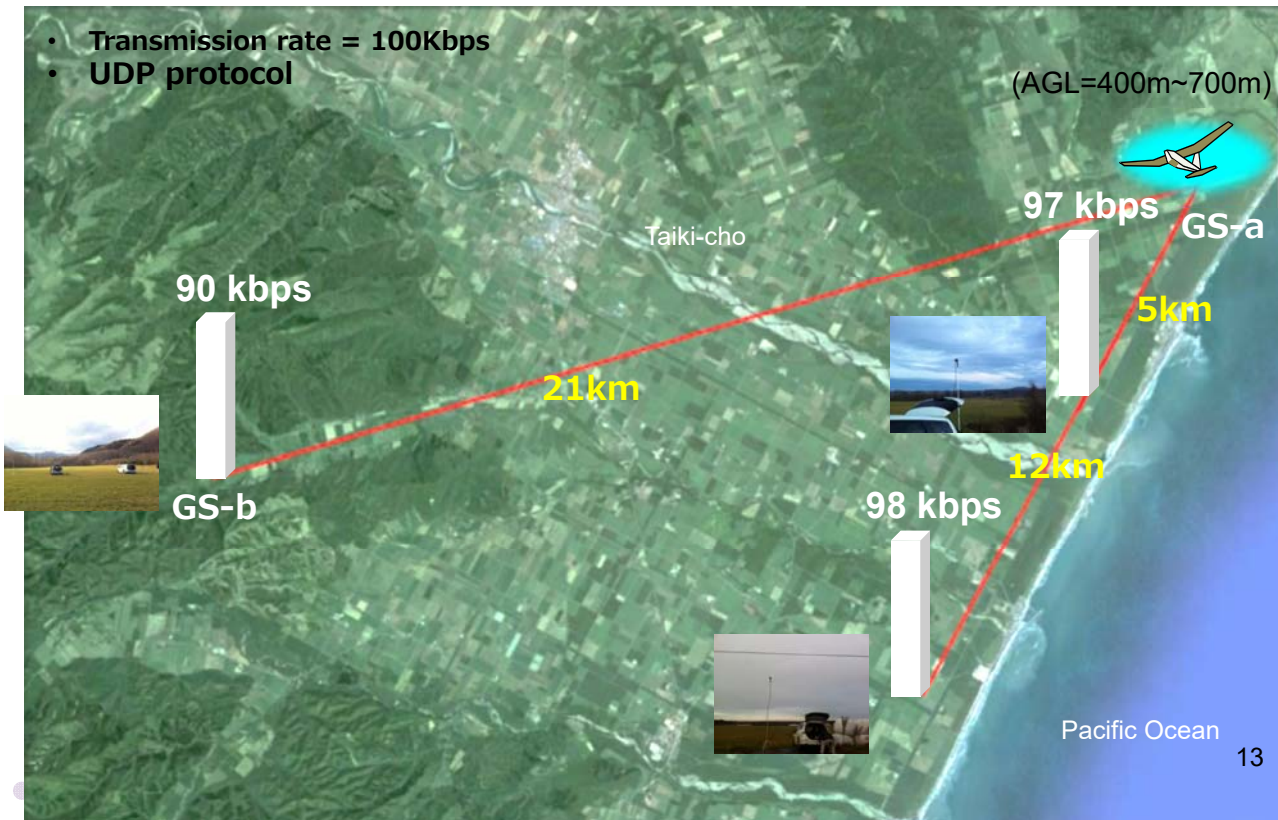
Onboard wireless relay station (OWRS)

Payload for relaying the data

Pictures	Transceiver of on-board	Transceiver of GS	Antenna of GS
	 500g		
Frequency	2 GHz, 5 GHz bands (Experimental)		
Bandwidth	8 MHz		
Signal power	2 W for 2 GHz, 1 W for 5 GHz band		
Modulation	MSK/TDMA/TDD		
MAC	TDMA/TDD, 33 msec/frame		
Antenna for GS	planar patch antenna		
Antenna for On-board	$\lambda/4$ whip antenna		
Data rate/Throughput	6 Mbps/400 kbps		
Frame synchronization	1PPS by GPS		

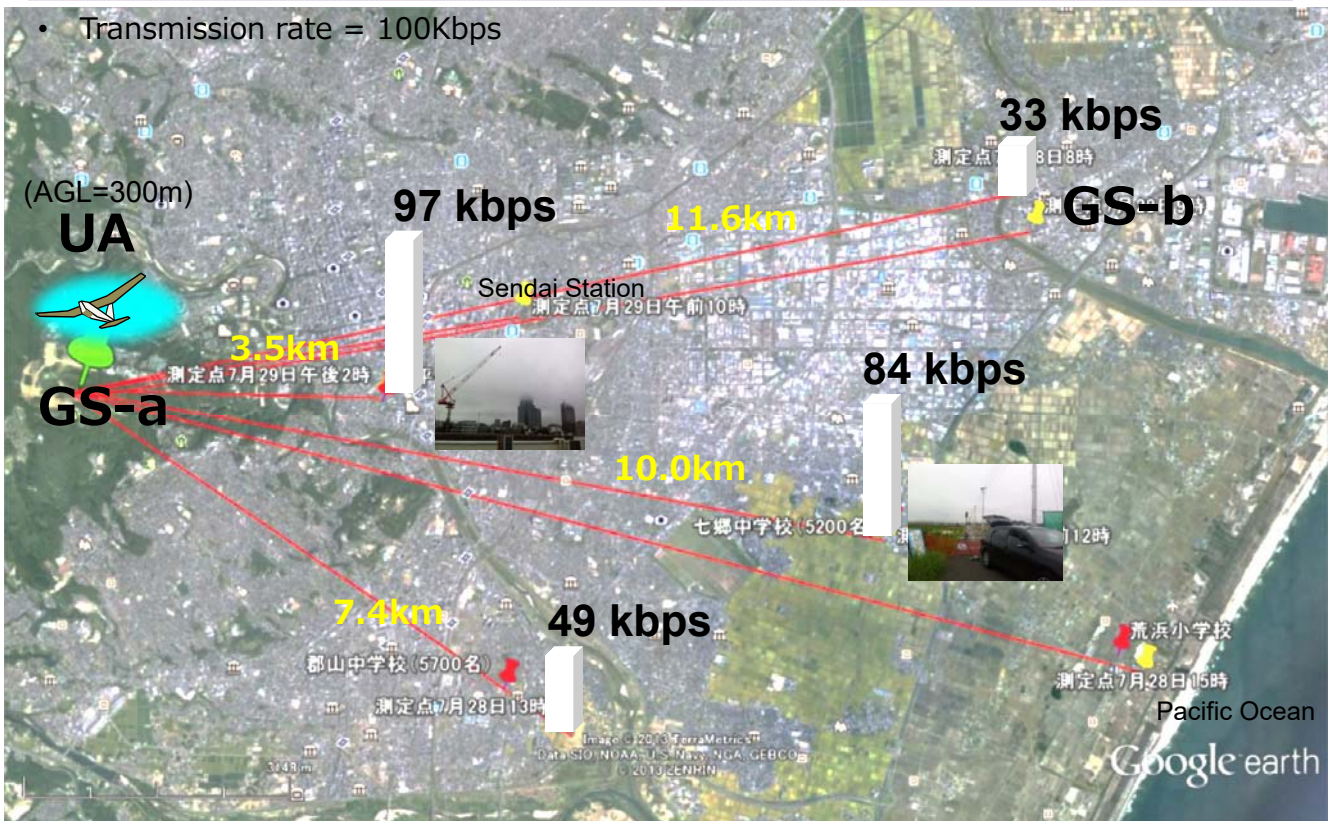
Urban area vs. Rural area

- Transmission rate = 100Kbps
- UDP protocol



Urban area vs. Rural area

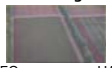

- Transmission rate = 100Kbps





Demonstration Examples of Wireless Relay System using UAS

- Utilization in agriculture, tracking of wild animal, monitoring of environmental level, and disaster medical by using on-board video camera or on-board transponder
- We have conducted on the demonstration and experimental measurement all over JAPAN
- Total number of flights is **over 200 times**, total flight time is **over 100 hours**.

NICT has submitted an application form for permission of flight or a report form for flight with domestic aviation act accordingly to the place and flight altitude.

Memuro	Hokkaido
Date	June 2014
UA type	2GHz CNPC UA
Project	Small UA utilization in Agriculture Video image of potato field
 	

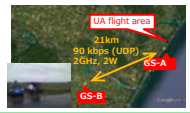
Sakaide	Kagawa
Date	May 2014, May 2015
UA type	2GHz CNPC UA, 5GHz CNPC UA
Project	Small UA utilization of Disaster Medical Assistance Team (DMAT)
 	

Shimanto	Kochi
Date	Feb. 2015
UA type	5GHz CNPC UA
Project	Demonstration experiment of collaboration of UA based wireless relay with the mobile operators network via femto cell


Shirahama	Wakayama
Date	March 2014
UA type	2GHz CNPC UA
Project	Demonstration experiment of UA based wireless relay in disaster

Ootone airport	Ibaraki
Date	Dec. 2013, Dec. 2014
UA type	2GHz CNPC UA
Project	Interview of TV program "WBS" on TVTOKYO, etc.

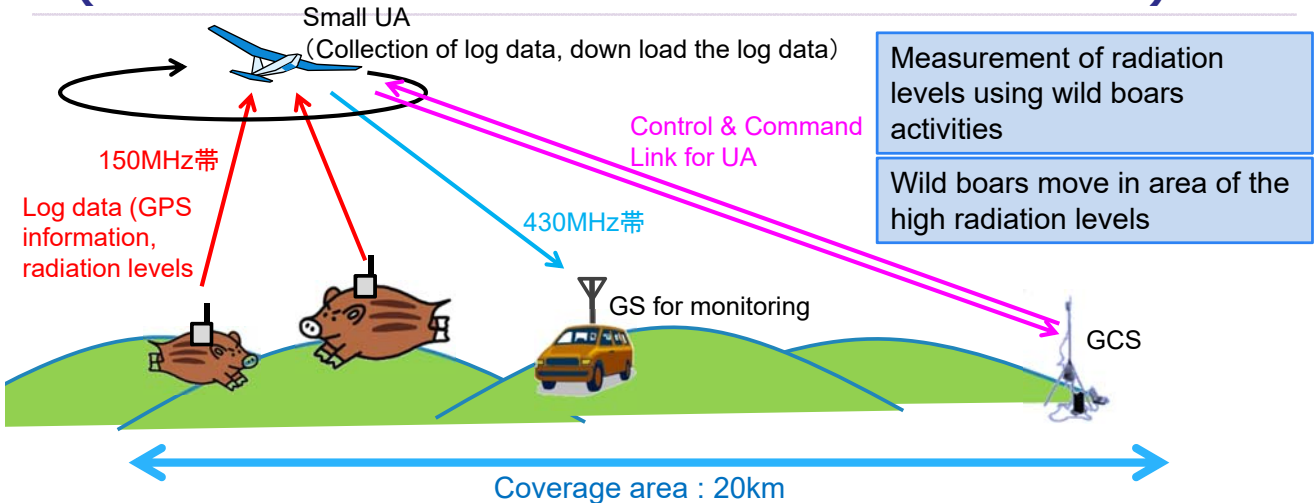
Syonan village	Kanagawa
Date	March 2013
UA type	2GHz CNPC UA
Project	Flight training

Taiki	Hokkaido
Date	June 2013, Nov. 2013
UA type	2GHz CNPC UA
Project	Long-distance relay test (rural area)
	

Sendai	Miyagi (Tohoku Univ.)
Date	March 2013, July 2013, July 2014
UA type	2GHz CNPC UA
Project	Demonstration, UA based wireless relay test in disaster, Long-distance relay test (city area)

Tomioka	Fukushima
Date	Oct. 2014
UA type	2GHz CNPC UA
Project	Tracking of wild boars in the restricted residence area by radioactive materials
	

Demonstration: Tracking wild boars (2014.10 Fukushima : difficult-to-return zone)



Collar-type transceiver (GPS, 150MHz)



On board receiver



Restricted area due to the nuclear accident

3. DEVELOPMENT OF ON-BOARD ANTENNA FOR UAS

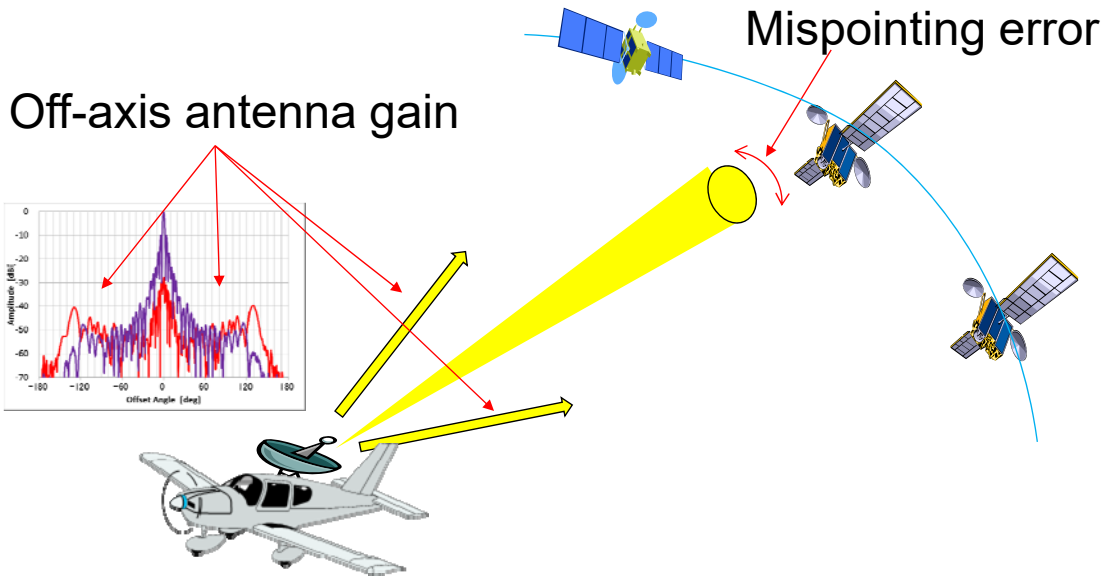
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ESOMPs to ESIM at ITU-R WRC-15

- At WRC-15
 - ▶ Resolution 156[COM5/2] was approved.
 - ▶ ESOMPs(Earth station on mobile platforms) was renamed to **ESIM**(Earth stations in motion)
 - ▶ 29.5-30.0 GHz and 19.7-20.2 GHz bands are allocated for ESIM as primary, which are already allocated
- Control and Non-Payload Communications (CNPC) Link for UAS
 - ▶ Ku and Ka-bands: still being discussed in ITU-R
 - ▶ Off-axis e.i.r.p. satisfies ITU-R Recommendation **S.524-9**
 - ▶ Misspointing of antenna beam toward satellite must be within **0.2 degrees**.
 - ▶ Whenever possible, to reduce the size, weight, power saving

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Key Points of Tracking Antenna Design



Comparison of Specifications of Ku and Ka Band Antennas

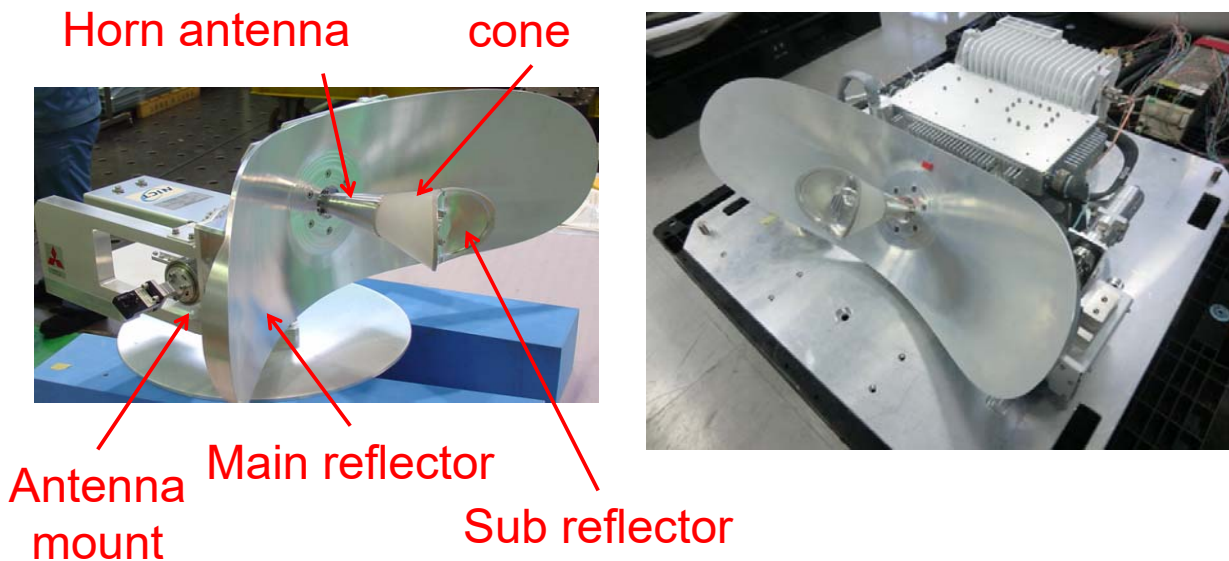
Type	HR6400 RF	—	—	MODEL 2340	Our antenna	Evaluation
Make	AeroSat	EMS	QEST	Viasat	NICT	—
Picture						—
Equivalent aperture size	—	—	39cm (estimated)	39cm (estimated)	Ø37.5cm	—
Height	22cm	20cm	21cm (estimated)	21cm	26cm	△
Diameter rotation	82cm	94cm	82cm (estimated)	81cm	90cm	△
Weight	34kg	39kg	41kg (estimated)	34kg	24kg	◎
G/T	12.7dB/K	unknown	11.1-12.4 dB/K ?	11.3 dB/K	13.4dB/K@19.2GHz	◎
EIRP	42.5dBW	unknown	44-46dBW ?	43.5dBW	48.1dBW@29.0GHz	◎
Polarization	—	—	fix	switchable	fix	○
Freq. TX RX	14.0-14.5GHz 10.7-12.7GHz	unknown	29.0-30.0GHz 19.2-20.2GHz	28.1-30.0GHz 18.3-20.2GHz	27.5-30.0GHz 17.3-20.2GHz (ESOMPs)	◎ 20

Results of Antenna Design

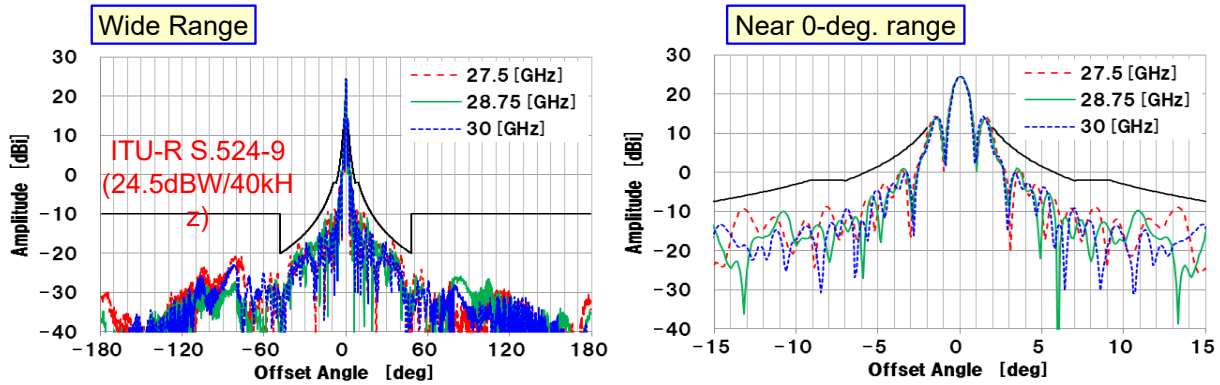
No	Items	Values	Comments	No	Items	Values	Comments
1	G/T	Over 10.0 dB/K@18.9GHz	Information speed: 5Mbps Margin: 1.5dB	1	Tx Frequency	27.5-30.0 GHz	
2	e.i.r.p.	Over 46.7 dBW@28.6GHz	Information speed: 5Mbps Margin: 0.8dB	2	Rx Frequency	17.3-20.2 GHz	
3	e.i.r.p. density	26.5 dBW/40kHz @28.6GHz	Information speed: 5Mbps Symbol rate: 6.02Mpsps	3	Off-axis e.i.r.p.	ITU-R S.524-9 24.5dBW/40kHz	
4	BUC output	10W		4	Size	Height < 22.2 cm	Without radome
				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	

As the reference satellite, we assume a broadband communication satellite system 'WINDS' developed as an experimental communication broadband satellite

Appearance of Radiation and Drive Units of On-board Antenna



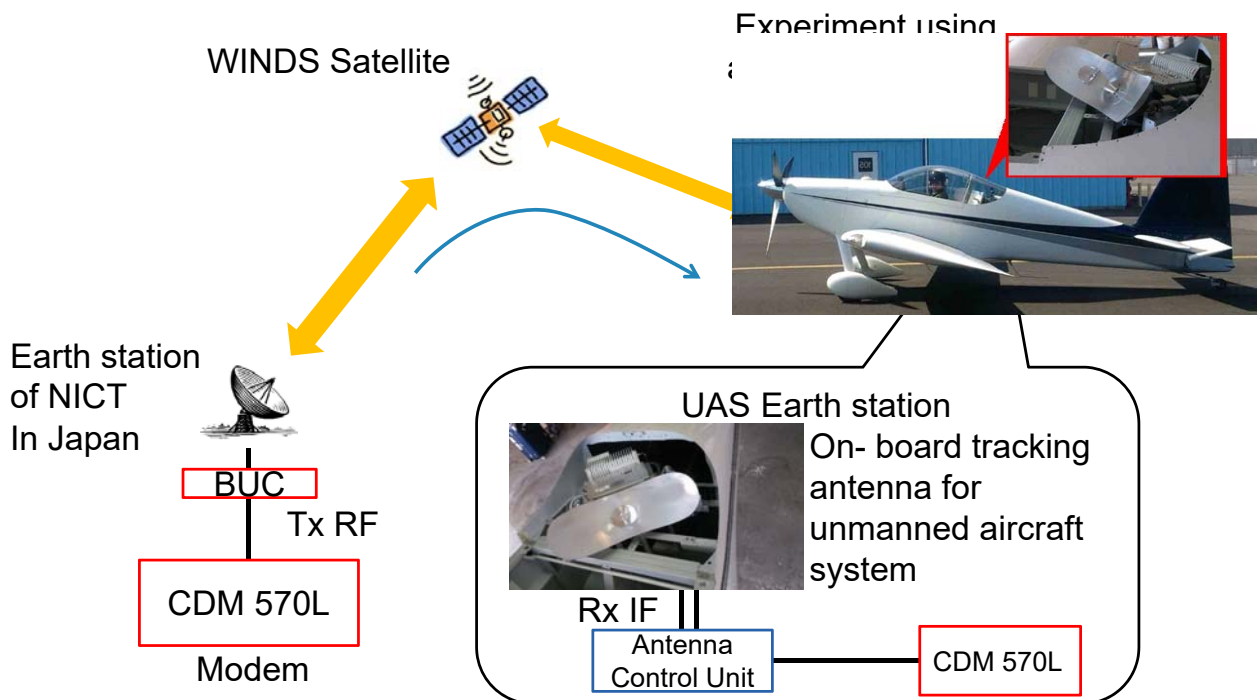
Evaluation Results – Off-Axis Radiation Patterns



Measured off-axis radiation patterns

We confirmed the developed radiation unit of the on-board antenna satisfied the antenna requirements defined in ITU-R S.524-9

Evaluations of the Antenna using Actual Airplane in 2015



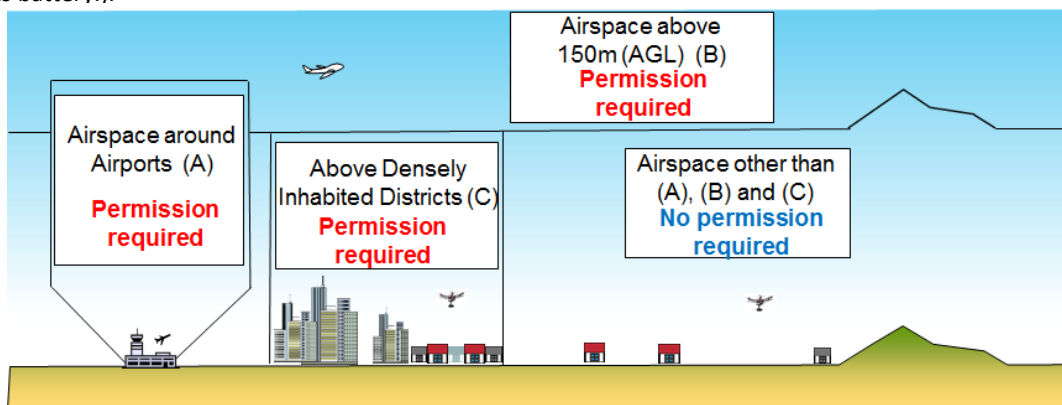
4 RECENT STATUS OF UAS RADIO REGULATION IN JAPAN

Japan's new safety rules on Unmanned Aircraft (UA)/Drone from Dec. 10 2015.









Definition and Prohibited Airspace for Flight

The term "UA/Drone" means any airplane, rotorcraft, glider or airship which cannot accommodate any person on board and can be remotely or automatically piloted (Excluding those lighter than 200g. The weight of a UA/Drone includes that of its battery.).



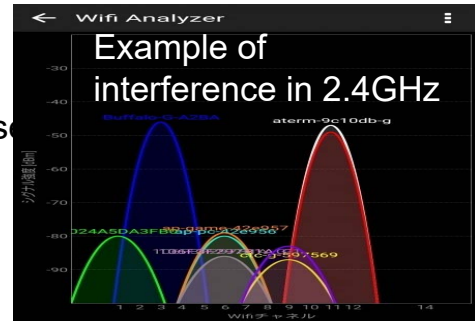
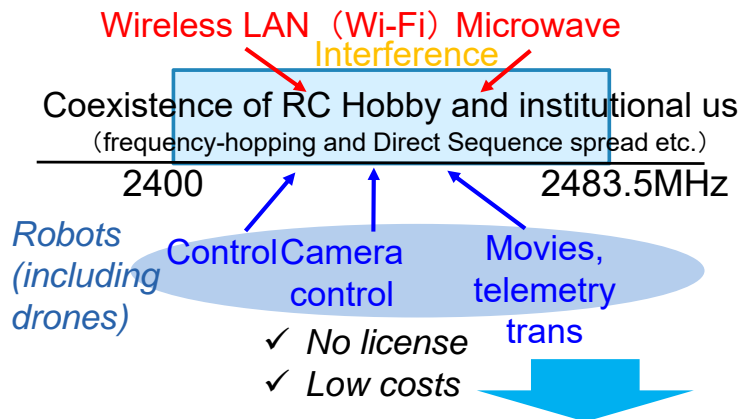
Conceptual Airspace

Operational Limitations

<p>(i) Daytime</p> 	<p>(ii) VLOS</p> 	<p>(iii) Distance</p> 	<p>(iv) Operating over Event Sites</p> 	<p>(v) Transporting Hazardous Materials</p> 	<p>(vi) Dropping objects</p> 
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Current Status of Wireless Control Link for Robotics Applications

2.4 GHz-band is mainly used (partly 920MHz-band, 73MHz-band)



- There is no guarantee of the guarantee of connections when congested, therefore the band is not discouraged for command and control transmission except video
- The band is not suitable for long distance transmission due to the power limit (within 1km for control, 200-300m for video, telemetry transmission)

For example

無線機器使用禁止
Followings Prohibited

ロボット誤作動防止のため、下記無線機器の会場内でのご使用は禁止しております。

携帯ゲーム機／携帯音楽プレーヤー

iPod Phone Nintendo DS SONY PSP
その他「無線LAN」を使用する機器など

Bluetooth機器

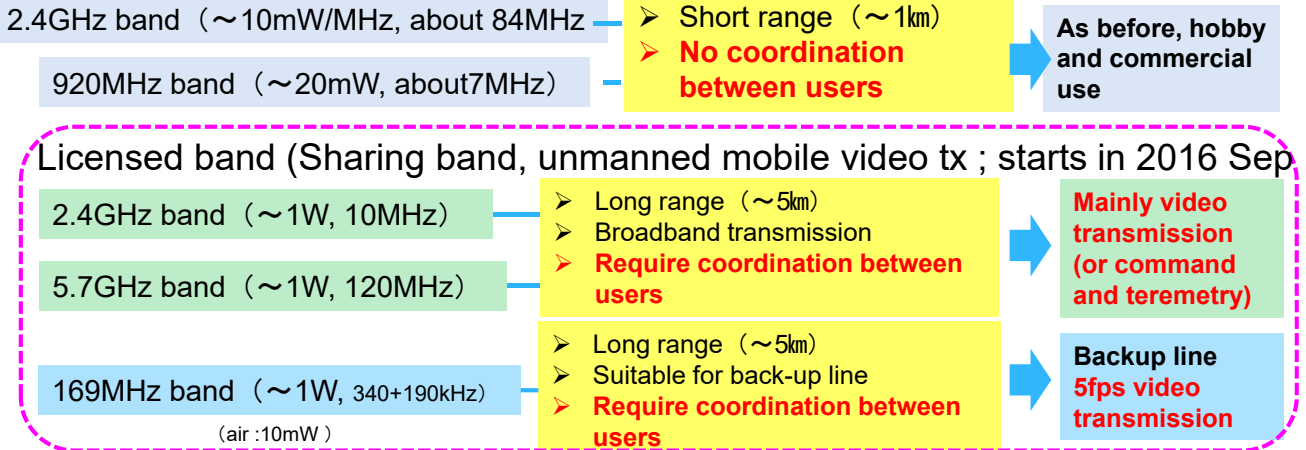
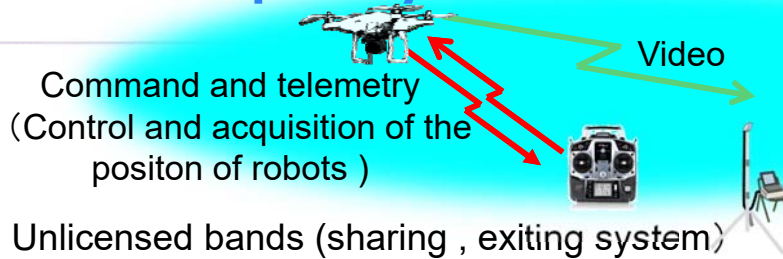
Bluetooth™ 携帯電話 Cell Phone
ヘッドセット Headset
PDA

PC無線機材

ワイヤレスキーボード Wireless Keyboard
ワイヤレスマウス Wireless Mouse

カメラ

New Frequency Allocation for Robot Control



Mutual coordination among robot users across different industries in the same area and its surrounding area. And adjustment with business entities other than robots that use the same frequency band for safety radio operations ²⁹

From the draft report by Ministry of Internal Affairs and Communication Information Council Robot Working Group

総務省情報通信審議会 ロボット作業班

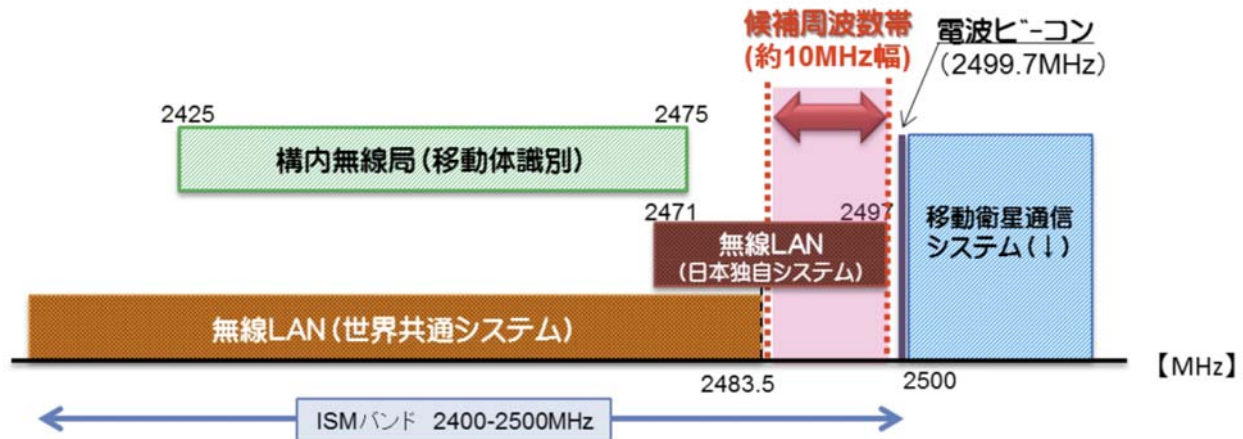


図 3.1 2.4GHz 帯における候補周波数帯

New Frequency Allocation in 5-GHz Band

http://soumu.go.jp/main_content/000395485.pdf

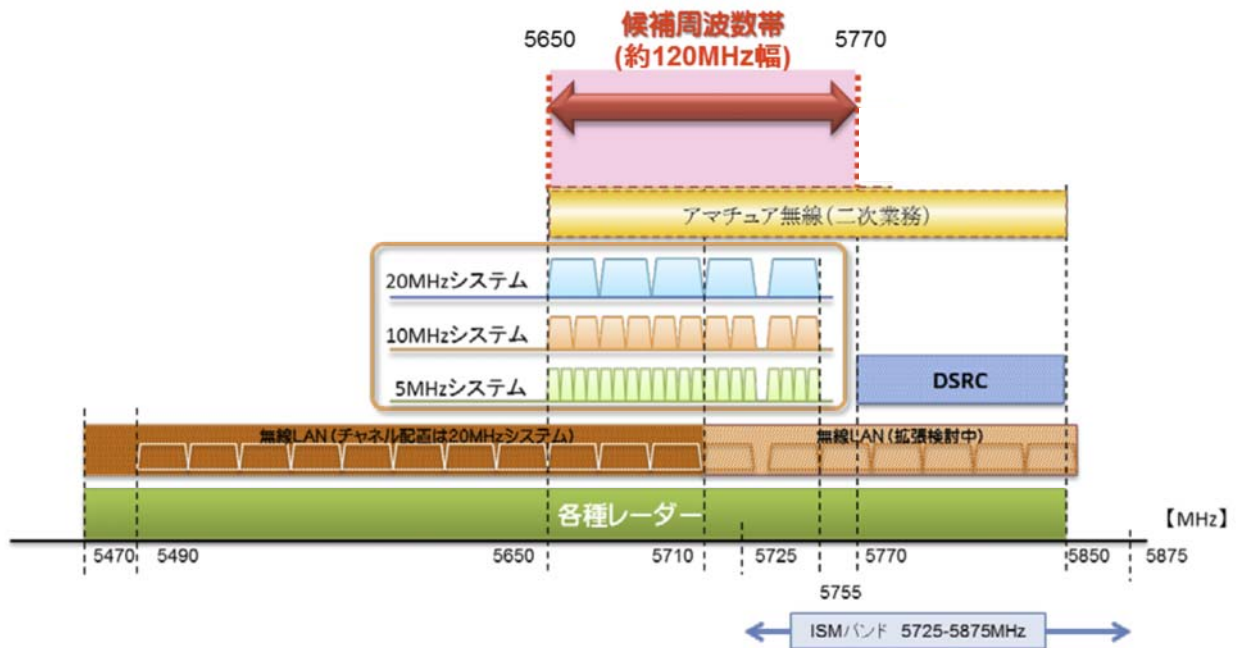


図 3.2 5.7GHz 帯における候補周波数帯

New Frequency Allocation in 169-MHz Band

http://www.soumu.go.jp/main_content/000395485.pdf

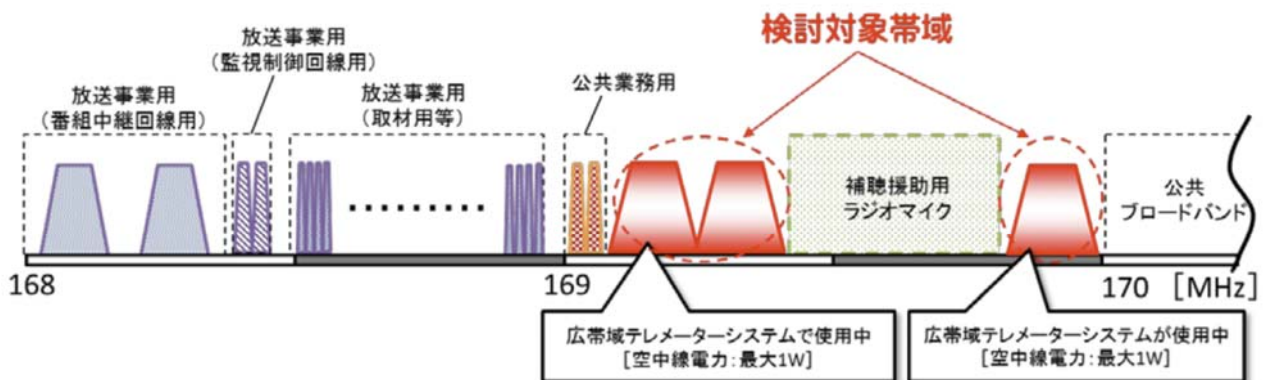


図 3.3 169MHz 帯における候補周波数帯

Conclusions

- We developed and tested UAV-based wireless relay network systems in natural disasters
- On-board Ka band tracking antenna for unmanned aircraft system
 - ▶ Status of current standardization
 - ▶ We evaluated the antenna system using actual airplane and a satellite
- Recent Status of UAS radio regulations in Japan
 - ▶ New frequency bands are allocated for robots and UAS