ICAO NAM/CAR/SAM RPG Workshop for ITU WRC-2019

Development of Wireless Link Applications for Small UAS in Japan

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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-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.

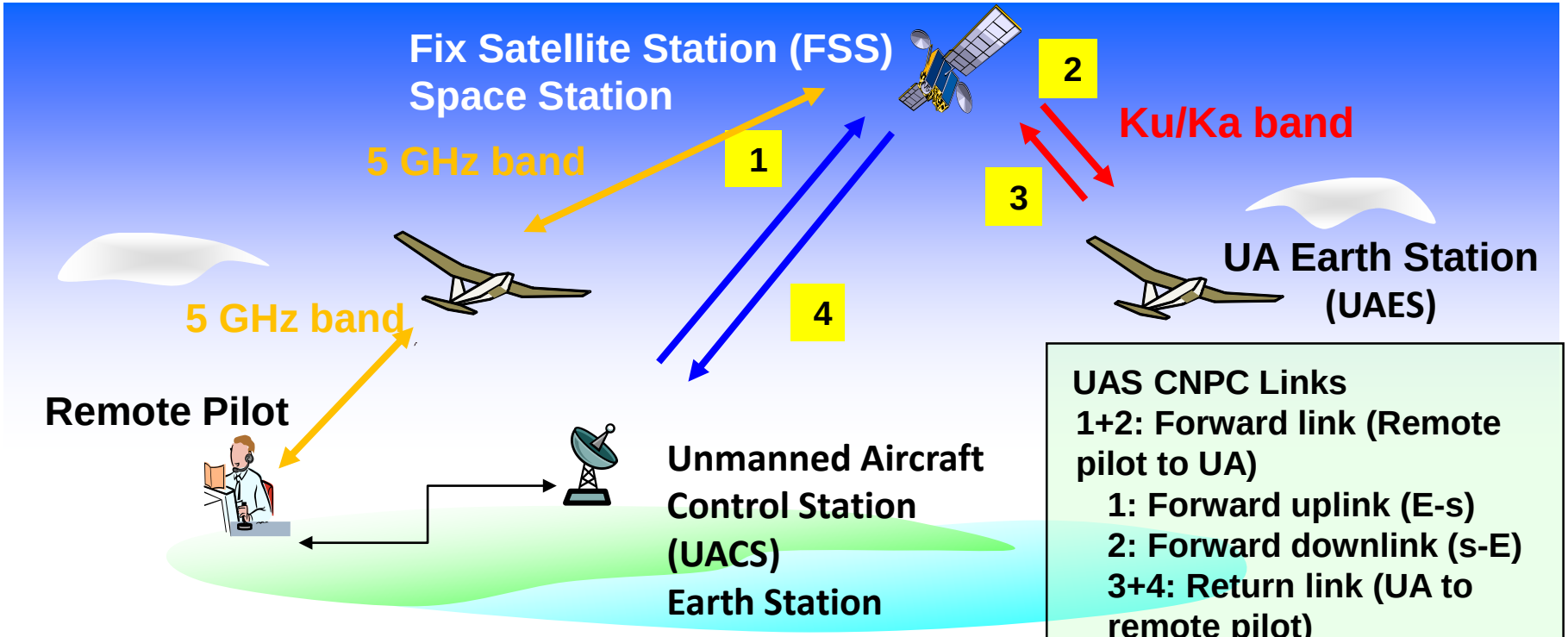
- Especially, the antenna beams of an on-board tracking antenna must be controlled properly not to affect the other satellite links.

Background-2

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

- 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

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



UAS CNPC Links
1+2: Forward link (Remote pilot to UA)
1: Forward uplink (E-s)
2: Forward downlink (s-E)
3+4: Return link (UA to remote pilot)
3: Return uplink (E-s)
4: Return downlink (s-E)

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)

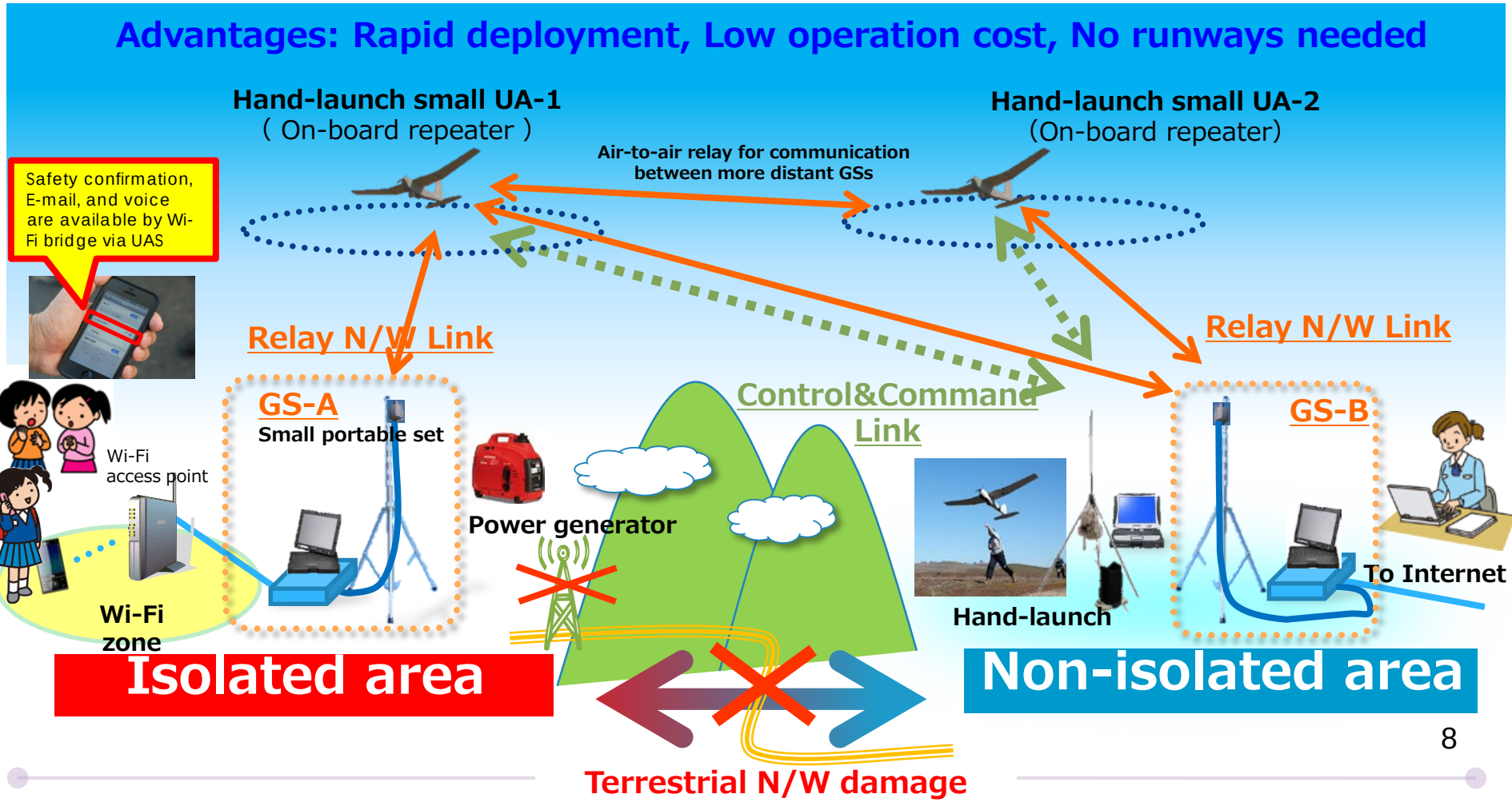
Frequency Regulations on UAS

- The frequency band 5030–5091 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 5030–5 091 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.



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

Mobile Phone Relay by UAS

Broadband Internet Satellite (WINDS)

Small UA: Puma-AE (ASL1000m)

Isolated rural area in disaster

NICT Earth Station in Kashima

Wireless Mesh Network by NerveNet

Mobile Earth Station

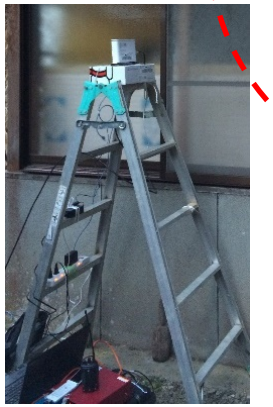
Internet

Femto Cell Zone

Femto cell Base staions

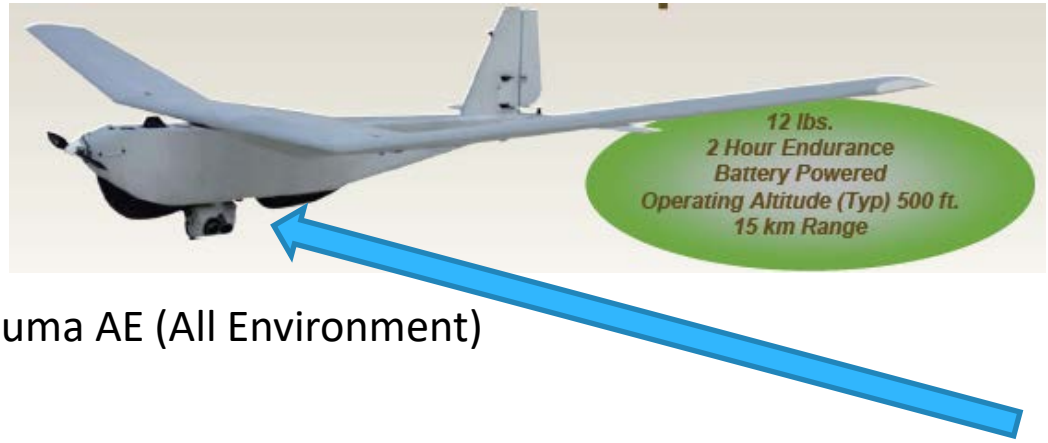
Optical Fiber Line

Mobile phone Networks

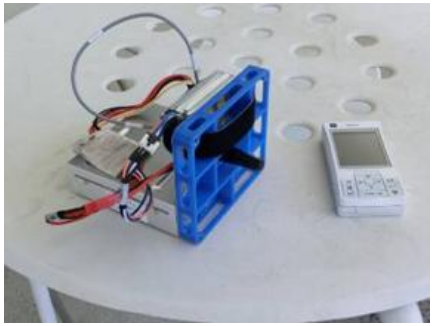


Small Unmanned Aircraft (UA) - PUMA-AE -

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 celling	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)

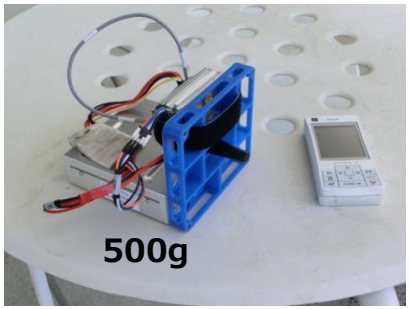
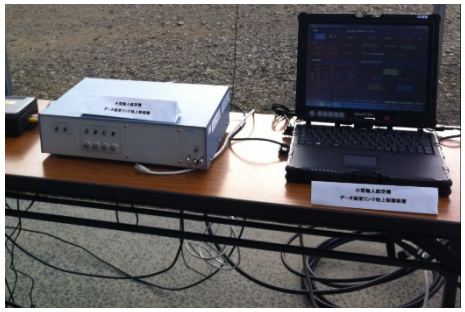


Onboard wireless relay station (OWRS)

Fixed-wing small UA

Name	Puma AE, Aeroviroment corp. USA
Wingspan, Weight	2.8 m, 5.9 kg
Structure	modular, Kevlar™ composite
Airspeed range	20-40 knots
Payload	Maximum : 0.5 kg
Nominal endurance	about 3 hours
Control range	9 km(2GHz)/ 7 km(5GH)
Wind speed	Maximum: 25 knots
Ceiling altitude	Maximum: 5 km
Control frequency, Signal power	2GHz/5GHz, 1W/0.1W (Experimental test station)

Payload for relaying the data

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

Please see also demonstration video

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.

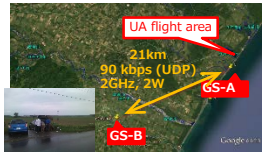
Memuro	Hokkaido
Date	June 2014
UA type	2GHz CNPC UA
Project	Small UA utilization in Agriculture **Video image of potato field**   EO camera on UA IR camera on UA

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) 

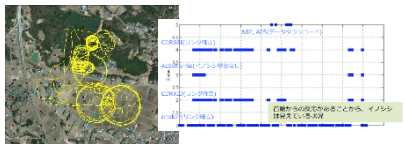
DMAT

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

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

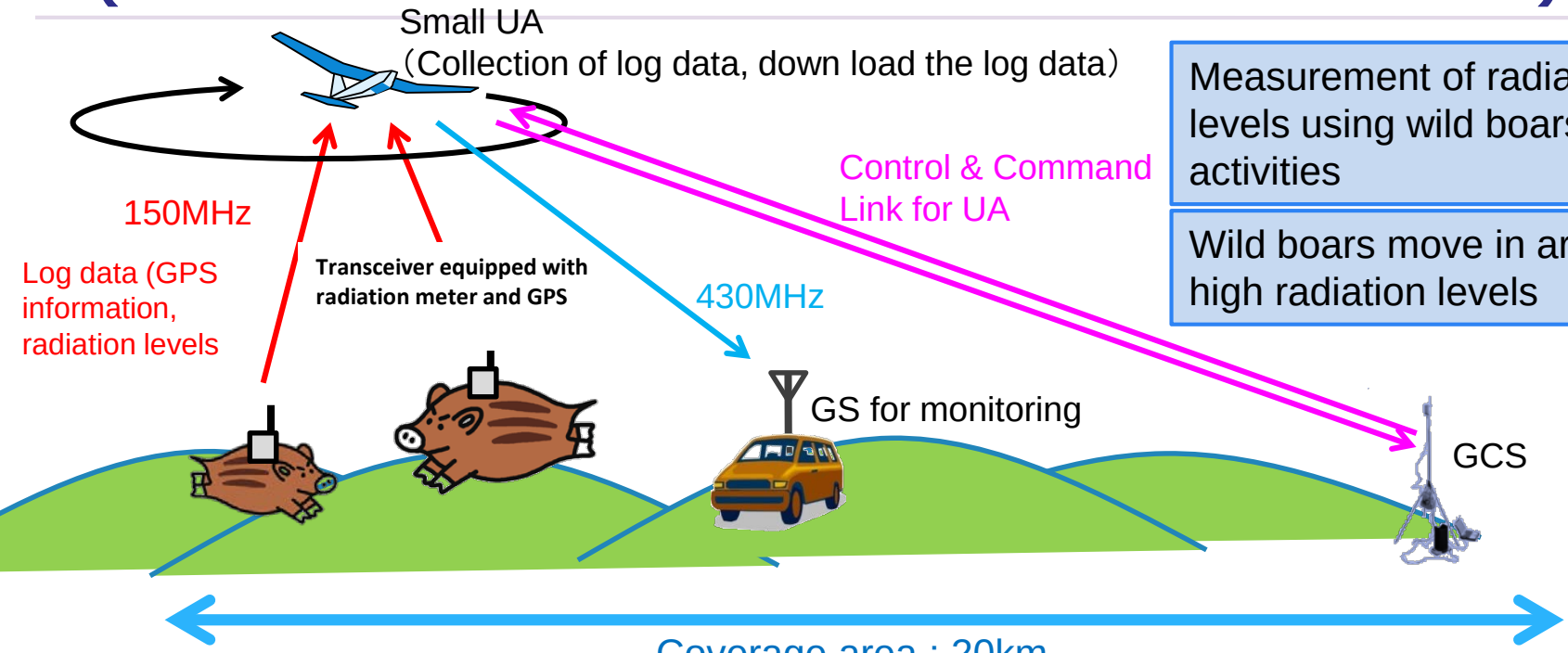
Sendai	Miyagi (Tohoku Univ.)
Date	March 2013, July 2013, July 2014
UA type	2GHz CNPC UA
Project	Demonstration, UA based wireless relay test in disaster, Long-distance relay test (city area)

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

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

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



Measurement of radiation levels using wild boars activities

Wild boars move in area of the high radiation levels

Collar-type transceiver (GPS, 150MHz)

On board receiver

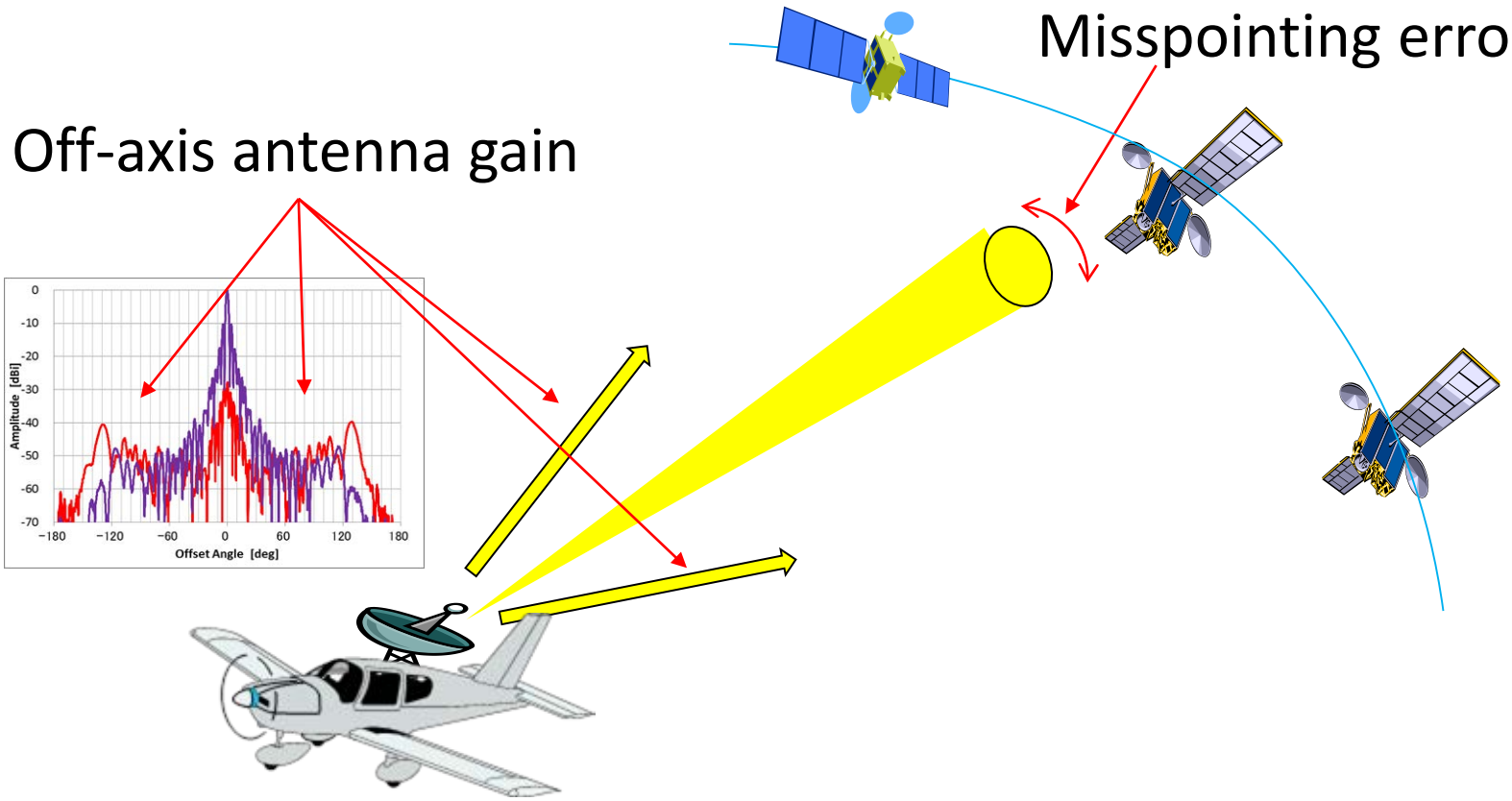
Restricted area
due to the nuclear accident

3. DEVELOPMENT OF ON-BOARD ANTENNA FOR UAS

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

Key Points of Tracking Antenna Design



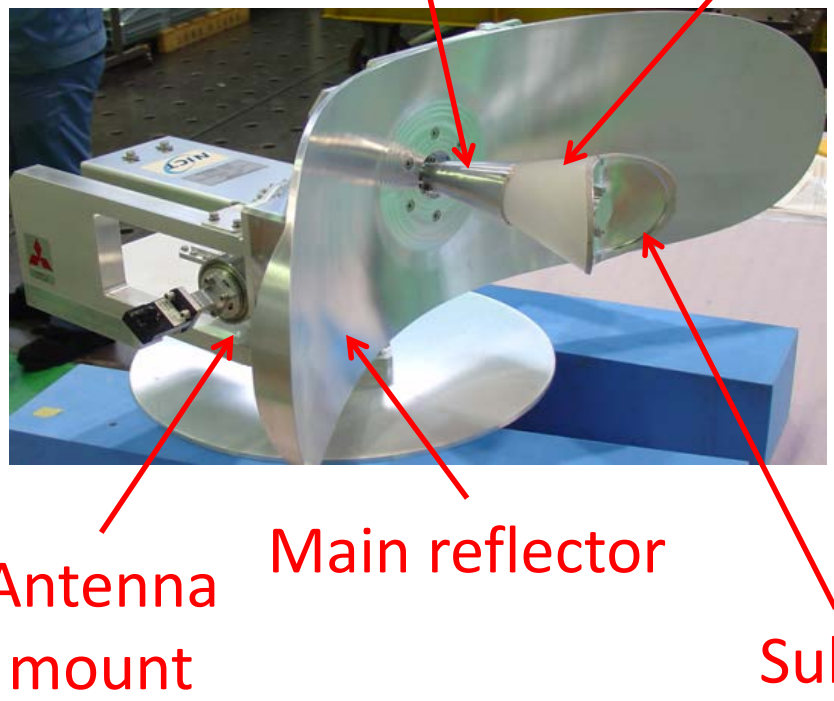
Results of Antenna Design

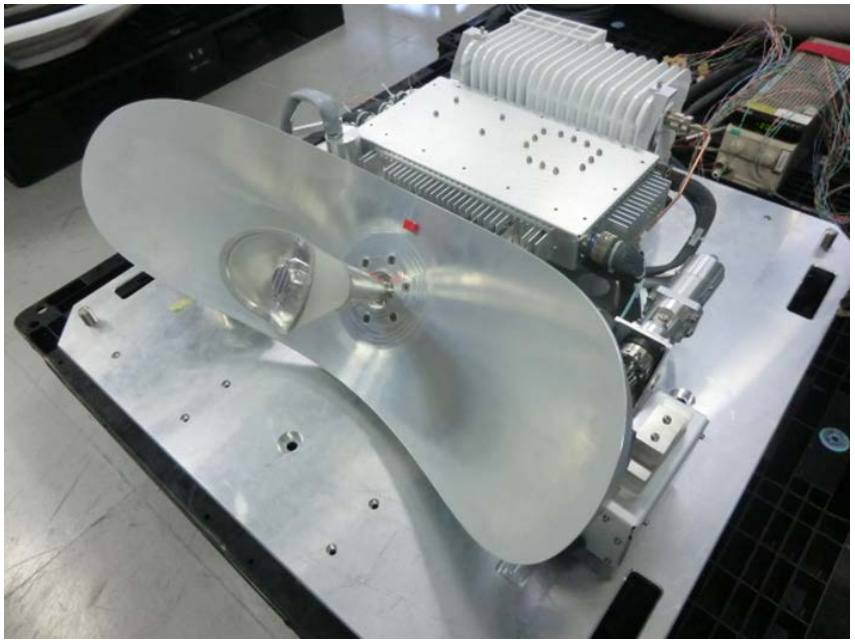
No	Items	Values	Comments
1	G/T	Over 10.0 dB/K@18.9GHz	Information speed: 5Mbps Margin: 1.5dB
2	e.i.r.p.	Over 46.7 dBW@28.6GHz	Information speed: 5Mbps Margin: 0.8dB
3	e.i.r.p. density	26.5 dBW/40kHz@ 28.6GHz	Information speed: 5Mbps Symbol rate: 6.02Msps
4	BUC output	10W	

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 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	

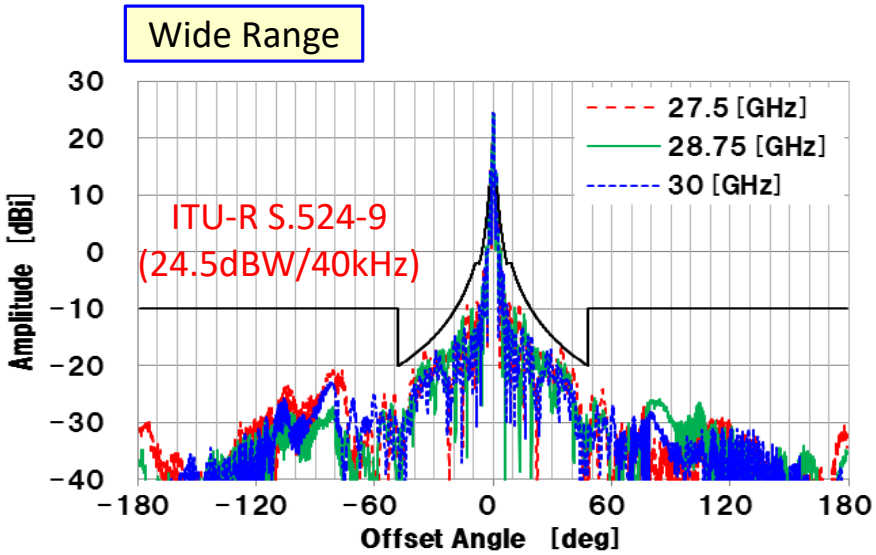
As the reference satellite, we assume a broadband communication satellite system 'WINDS' developed as an experimental communication broadband satellite

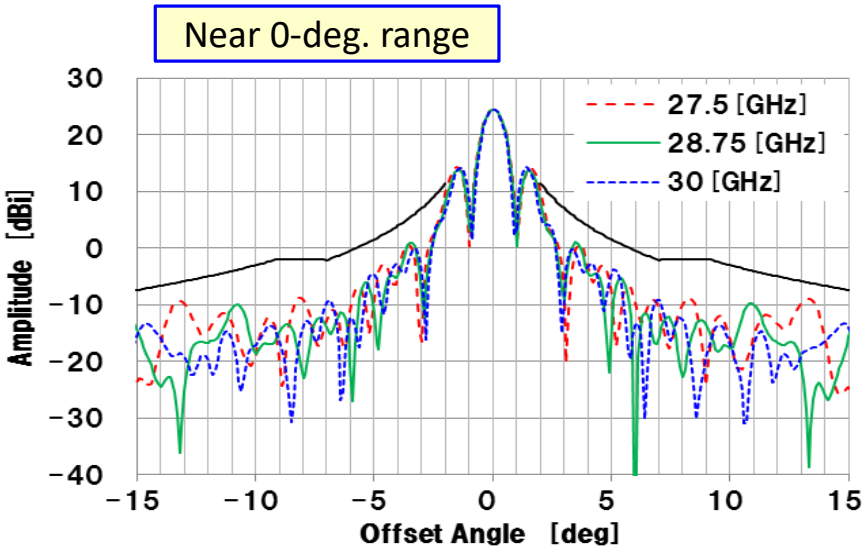
Appearance of Radiation and Drive Units of On-board Antenna





Evaluation Results – Off-Axis Radiation Patterns

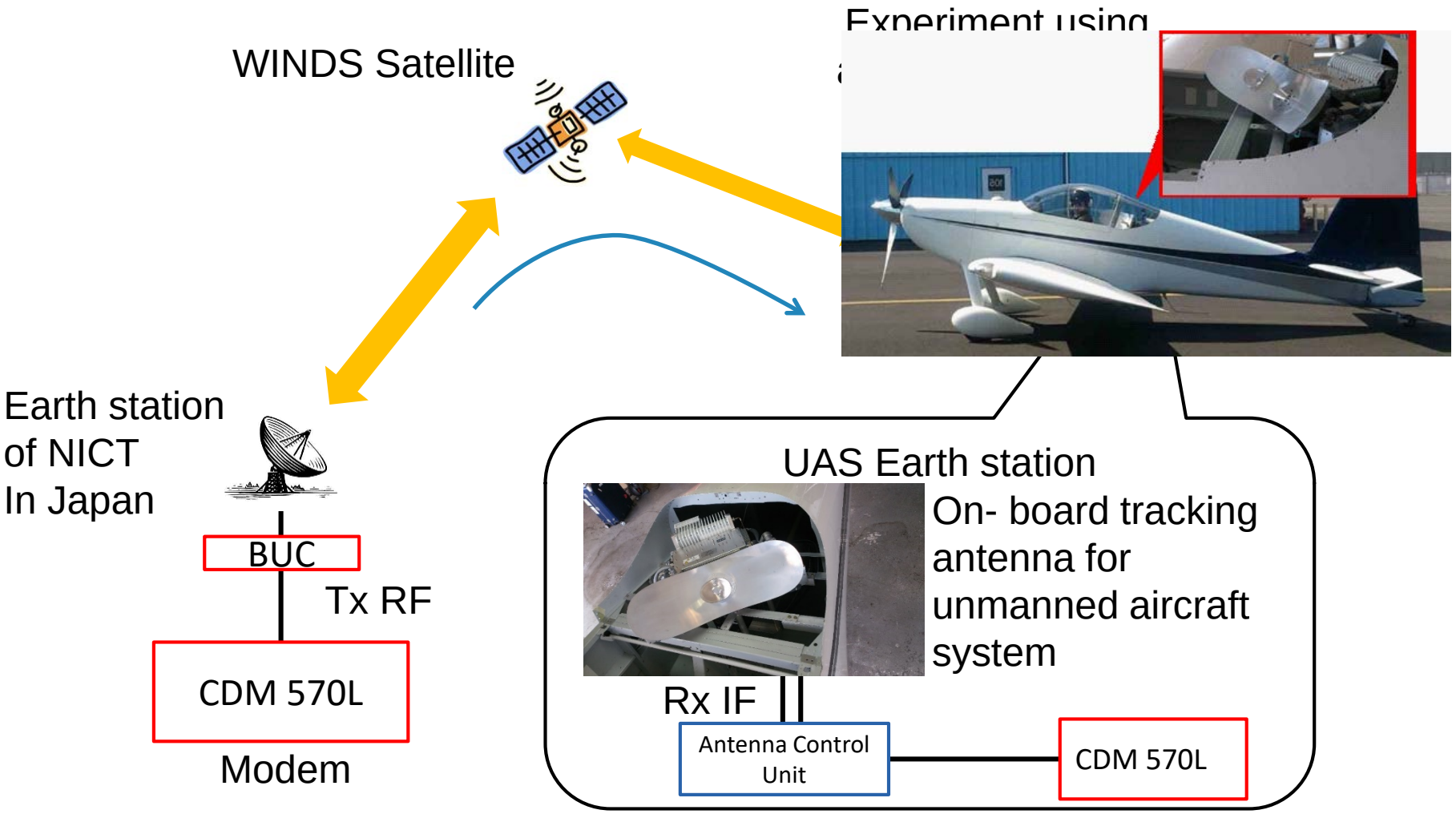




Measured off-axis radiation patterns

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

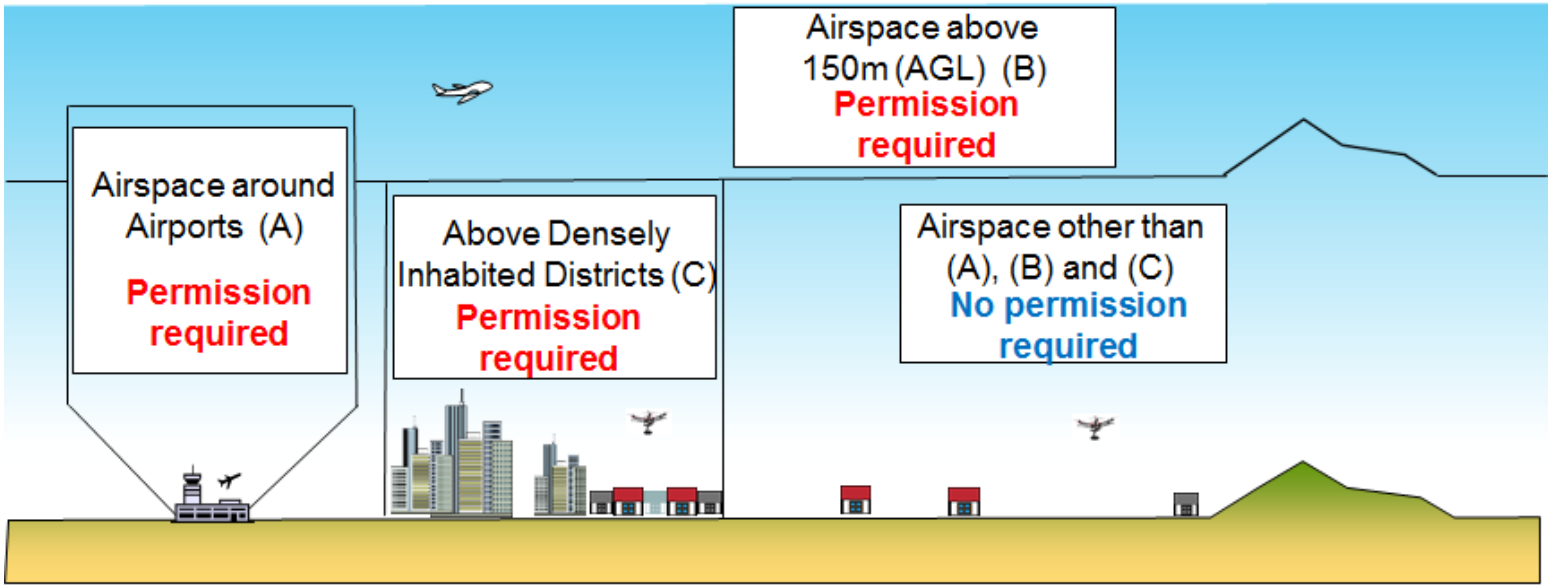


4 RECENT STATUS OF UAS RADIO REGULATION IN JAPAN

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

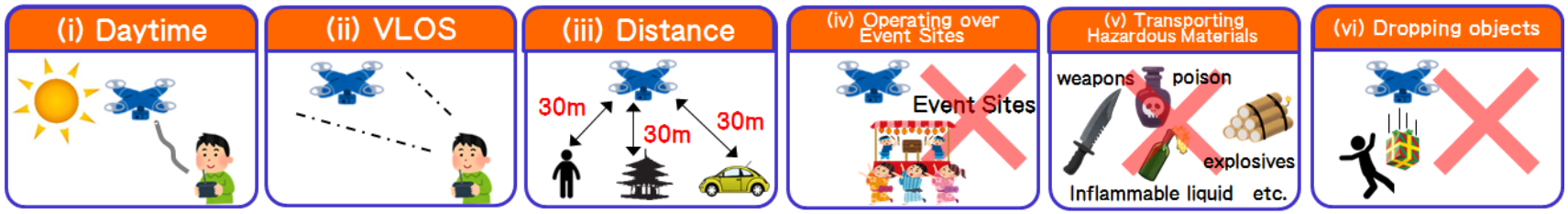
Definition and Prohibited Airspace for Flight

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

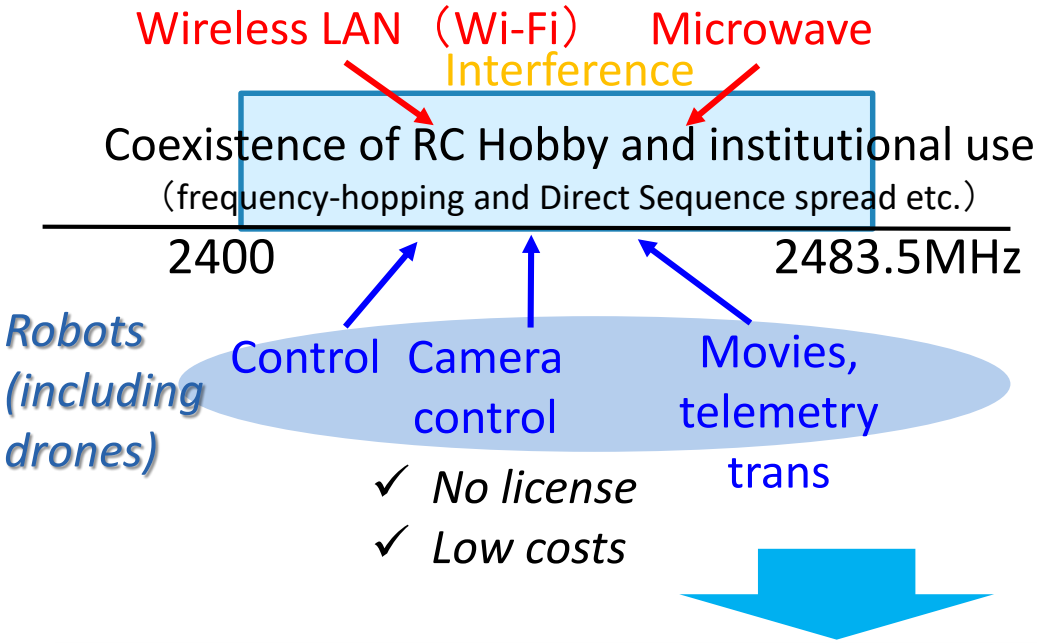
Operational Limitations

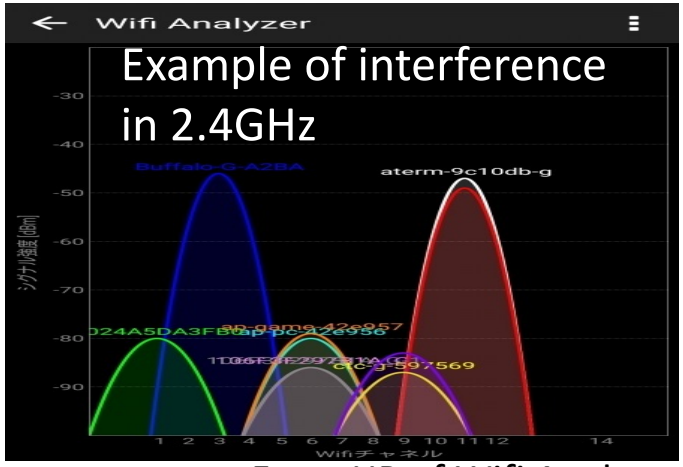


*https://www.mlit.go.jp/en/koku/uas.html

Current Status of Wireless Control Link for Robotics Applications

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





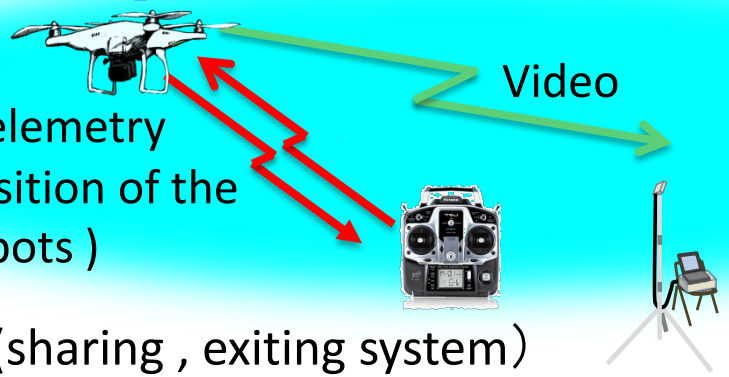
From HP of Wifi Analyzer

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



Unlicensed bands (sharing , exiting system）

2.4GHz band （～10mW/MHz, about 84MHz 920MHz band （～20mW, about7MHz）	➢ Short range （～1㎞） ➢ **No coordination between users**	**As before, hobby and commercial use**

Licensed band (Sharing band, unmanned mobile video tx ; starts in 2016 Sep

2.4GHz band （～1W, 10MHz） 5.7GHz band （～1W, 120MHz）	➢ Long range （～5㎞） ➢ Broadband transmission ➢ **Require coordination between users**	**Mainly video transmission (or command and teremetry)**
169MHz band （～1W, 340+190kHz） （air :10mW ）	➢ Long range （～5㎞） ➢ Suitable for back-up line ➢ **Require coordination between users**	**Backup line** **5fps video transmission**

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

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

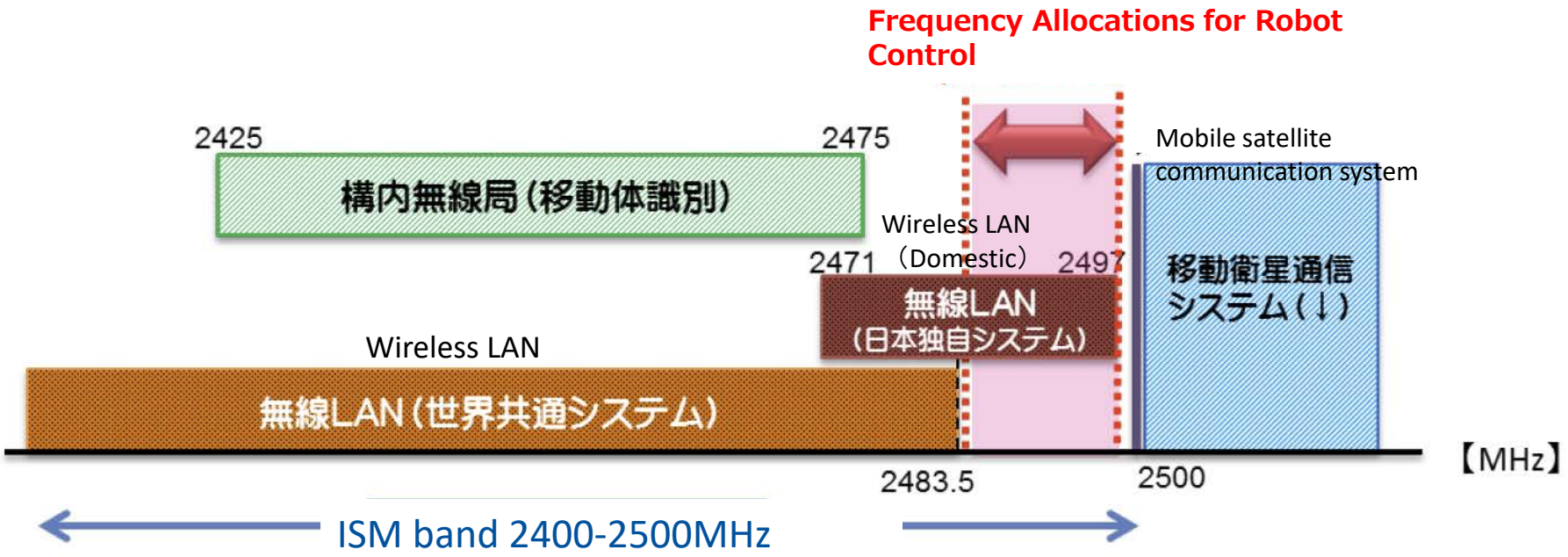


Figure Frequency allocation of 2.4GHz band

New Frequency Allocation in 5-GHz Band

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

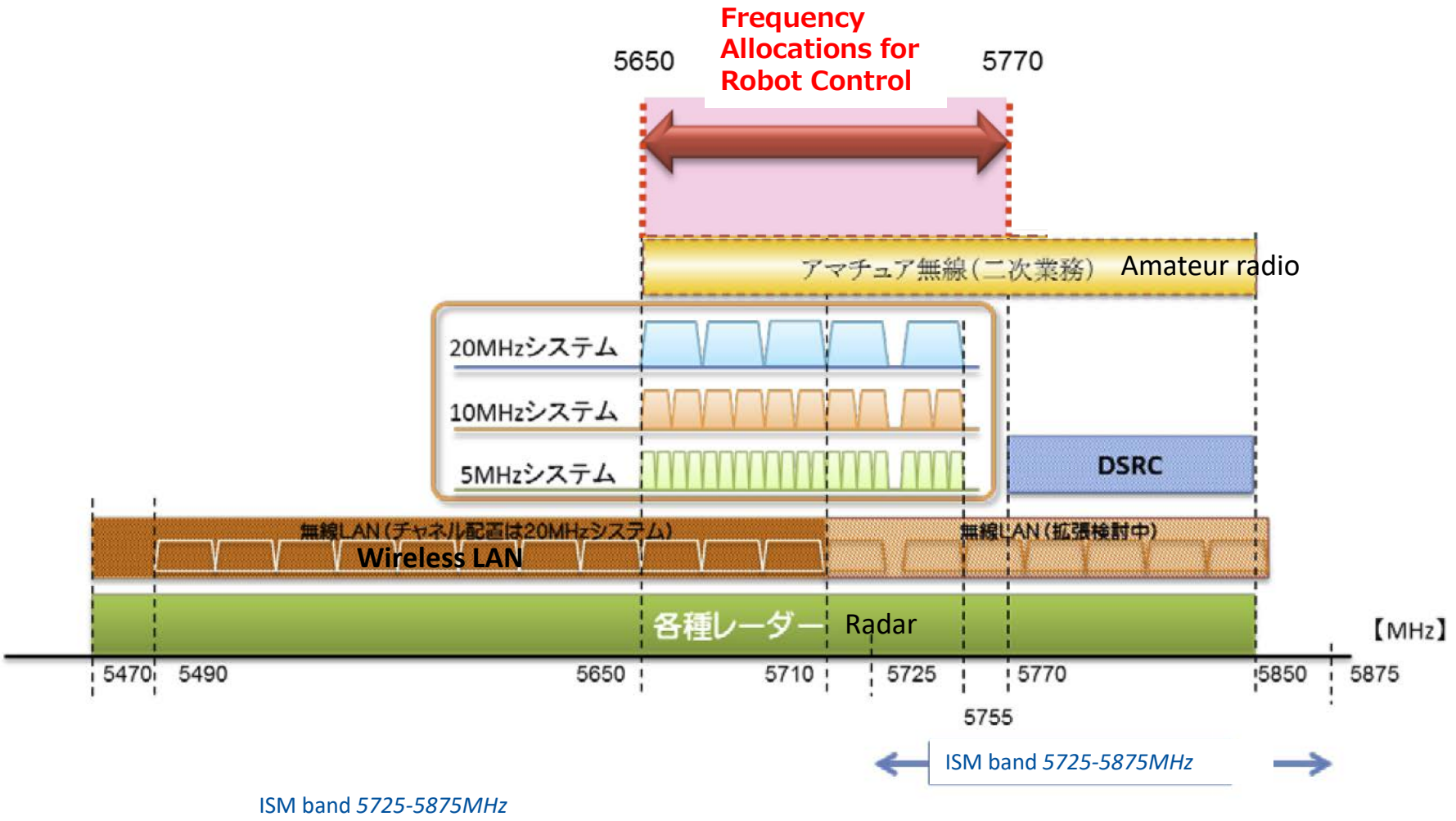


Figure Frequency allocation of 5.7GHz band

New Frequency Allocation in 169-MHz Band

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

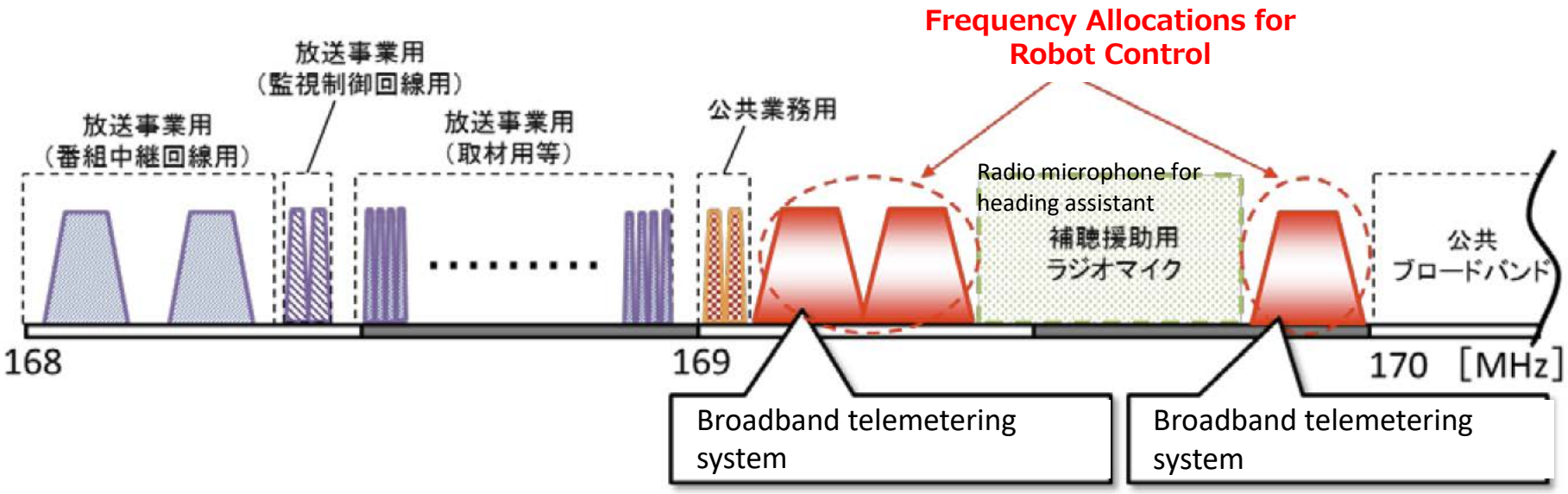


Figure Frequency allocation of 169MHz band

5. 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
  - However, the frequency allocation is required for safety operation of small UAS

Thank you for your kind attention