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Use cases and Spectrum Considerations for UAS (Unmanned Aircraft Systems)

<

**TECHNICAL REPORT**

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

# Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](https://portal.etsi.org/Services/editHelp%21/Howtostart/ETSIDraftingRules.aspx) (Verbal forms for the expression of provisions).

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# Executive summary

The document describes current situation regarding frequency use, radio equipment requirements and license requirements related to Unmanned Aircraft Systems (UAS) / Remotely Piloted Aircraft Systems (RPAS).

# Introduction

**European Commission**

In Europe the European Commission aims at establishing a common regulatory framework by 2019.

**ICAO**

**Aircraft Radio Station License**

Every aircraft of a contracting State, engaged in international navigation, shall carry an aircraft radio station license according to ICAO doc 7300 Article 29 (e).

Since unmanned aircraft are within the scope of ICAO this means the operator on the ground shall have such an aircraft radio station license when the unmanned aircraft is equipped with radio apparatus.

Often the aircraft radio station licenses are issued by the radiocommunication agency of the country where the operator resides. In some cases this is handled by the civil aviation authority of the country where the operator resides.

**Frequency License**

Aircraft that are not engaged in international navigation may not need an aircraft radio station license, but they may still need frequency licenses for the frequencies used.

**Radio Equipment Directive vs EMC Directive**

The DIRECTIVE 2014/53/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, Radio Equipment Directive (RED), applies to radio equipment using electromagnetic waves of frequencies lower than 3 000 GHz, propagated in space without artificial guide.

For frequencies above 3000 GHz the EMC Directive may be applicable.

**EASA Basic Regulation**

According to Article 4(4) of EASA Basic Regulation “unmanned aircraft with an operating mass of no more than 150 kg” are exempted from the scope of the EASA Basic Regulation.

**‘Prototype’ Commission Regulation on Unmanned Aircraft Operations**

A “‘Prototype’ Commission Regulation on Unmanned Aircraft Operations” has been created and published in which it is indicated that drones down to 0 kg may be covered by the EASA regulation on unmanned aircraft operations in the future. However, this is only a draft which is currently in discussion between EU parliament, Council and Commission and might change before actually becoming an approved and adopted regulation.

**EUROCONTROL RPAS CONOPS**

The Eurocontrol RPAS Concept of Operations (CONOPS) describes the operation of RPAS in European airpace from an Air Traffic Management (ATM) perspective and is complemental to the EASA CONOPS.

According to the EUROCONTROL CONOPS full implementation of it is targeted after 2023 and then the set of documents, rules and technologies will enable seamless and safe integration of RPAS into ATM.

The EUROCONTROL RPAS CONOPS assumes the required technology, standards, procedures and regulations will be available in the 2018 to 2023 time-frame.

The EUROCONTROL CONOPS addresses the variety of RPAS operations based on traffic classes. RPAS categories and airspace classes are used as secondary typologies.

* Type of operation: (VLOS, BVLOS. IFR/VFR)
	+ Class of traffic: Class 1, 2 etc
		- Class of airspace: Class A-Gc
			* Category of RPAS (from EASA CONOPS)

**U-space**

According to SJU U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones.[I,4]

1. U1 services provide the foundation
	1. Pan-European registration
	2. Pan-European identification
	3. geo-information to assist compliance with no-fly or restricted zones
2. U2 services support the management of drone operations
	1. • Semi dynamic geo-fencing
	2. • Flight approval
	3. • 4D flight trajectory planning and sharing
	4. • Weather information sharing
	5. • Tracking & surveillance
	6. • Drone aeronautical information management.
	7. • Avoidance of non-cooperative ground obstacles;
	8. • Procedural interface with ATC
	9. • Interface with manned aviation
	10. • Recovery and emergency
3. U3 services support more complex operations in dense areas
	1. • Detect & avoid of cooperative obstacles (drones and other air vehicles)
	2. • Avoidance of non-cooperative ground & air obstacles;
	3. • Dynamic geofencing
	4. • Interface with ATC
	5. • Live Traffic Feed
	6. • Dynamic interface between the U-space and drones (e.g. real-time interface which
	7. enables U-space service provider to require drone to re-route or land)
4. U4 is the full U-Space
	1. particularly services offering integrated interfaces with manned aviation, this block will rely on a very high level of automation, connectivity and digitalisation for both the drone and the U-Space system.

# 1 Scope

*This clause* ***numbered 1 shall start on a new page****. More details can be found in clause 2.9 of the* [*EDRs*](https://portal.etsi.org/Services/editHelp%21/Howtostart/ETSIDraftingRules.aspx)*.*

*The Scope* ***shall not*** *contain requirements. Forms of expression such as the following should be used:*

The present document contains information related to use of radio in Remotely Piloted Aircraft Systems (RPAS).

The present document …

EXAMPLE: The present document provides the necessary adoptions to the endorsed document.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non‑specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

 [i.1][tab] <Standard Organization acronym> <document number>: "<Title>".

[i.1] ICAO doc 7300 ed. 9 “Convention on International Civil Aviation”

[i.2] ICAO business plan

[i.3] EUROCONTROL RPAS ATM CONOPS Edition 4.0

[I,4] SESAR JU, U-space <presentation>, Mara Dame, EASA, Cologne, 05/07/2017

[i.5] ITU-R Rep. ITU-R M.2171 (12/2009) “Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace”

[i.6] ITU-R Report ITU-R M.2233 (11/2011) “Examples of technical characteristics for unmanned aircraft control and non-payload communications links”

[i.7] ICAO doc 10019 “MANUAL ON REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS)”, First Edition — 2015

[i.8] ECC Report 268 “Technical and Regulatory Aspects and the Needs for Spectrum Regulation for Unmanned Aircraft Systems (UAS)” Approved <Month> 2017 (?)

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**<defined term>:** <definition>

**Radio equipment:** electrical or electronic product, which intentionally emits and/or receives radio waves for the purpose of radio communication and/or radio determination, or an electrical or electronic product which must be completed with an accessory, such as antenna, so as to intentionally emit and/or receive radio waves for the purpose of radio communication and/or radio determination; [RED, Article 2(1)(1)]

**example 1:** text used to clarify abstract rules by applying them literally

NOTE: This may contain additional information.

 

**ADD e-Identification Requires exact definition. Which is the final destination of this information? See: “European Aviation Safety Agency Opinion No 01/2018”)**

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

t

* Use the **EW** style and separate this from the definition with a tab. Use the **EX** style for the last term.

<1st symbol> [tab]<1st Explanation> *(style EW)*

<2nd symbol> [tab]<2nd Explanation> *(style EW)*

<3rd symbol> [tab]<3rd Explanation> *(style EX)*

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ASBU Aviation System Block Upgrades ([ICAO ASBU 2016](https://www.icao.int/airnavigation/Documents/ASBU_2016-FINAL.pdf))

ATC Air traffic control

ATM/ANS Air Traffic Management/Air Navigation Services

BLOS Beyond Line-of-Sight

C2 link Command and control link. The data link between the remotely-piloted aircraft and the remote pilot station for the purposes of managing the flight ([ICAO ASBU 2016](https://www.icao.int/airnavigation/Documents/ASBU_2016-FINAL.pdf))

DAA Detect-And-Avoid.

EASA European Aviation Safety Agency

EC European Commission

ECC Electronic Communications Committee

EVLOS Extended Visual Line-of-Sight

EMCD EMC Directive

ICAO International Civil Aviation Organization

LOS Line of Sight

RED Radio Equipment Directive

RF Radio Frequency

RPA Remotely Piloted Aircraft

RPAS Remotely Piloted Aircraft Systems

UA Unmanned Aircraft

UACS Unmanned Aircraft Control Station

UAS Unmanned Aircraft Systems

UAV Unmanned aerial vehicle

UTM UAS Traffic Management

VLOS Visual Line-of-Sight

# 4 System Overview

# 5 Use case definition

##

**GENERIC USE CASES**

**Use Case**:

ATC Voice Use Case.

**Actor(s)**:

Remote Pilot, ATCo.

**Scope**:

Evaluate impact on ATCo-Remote Pilot of High Latency introduced by Satcom (voice as primary for ATC control)

This use case is aimed at evaluating the ATCo and RPIL operational capability and situation awareness BRLOS En-Route flight Phase during which the ATC Voice is relayed through L-band/Ka-band Satcom system.

ATCo HMI will implement a dedicated symbology for visualizing the RPA.

In this situation it will be also possible to reproduce and evaluate some example of voice “step-on” (see the note below) between an ATCo controlling an En-Route high-density sector with only one RPAS, and the RPIL.

**Operational range**

 ATC control (equivalent to national/international)

CNPC (Control and Non-Payload Communications)

 Command and Control

 e-identification

 ATC Relay

 Detect and Avoid

Payload communication

**Brief**:

This use case is aimed at evaluating the ATCo and RPIL operational capability and situation awareness BRLOS En-Route flight Phase during which the ATC Voice is relayed through L-band/Ka-band Satcom system.

ATCo HMI will implement a dedicated symbology for visualizing the RPA.

In this situation it will be also possible to reproduce and evaluate some example of voice “step-on” (see the note below) between an ATCo controlling an En-Route high-density sector with only one RPAS, and the RPIL.

**Stakeholders**

Regulators, Air Navigation Service Providers

**Postconditions**

Minimal Guarantees: a number of voice “step-on” are reproduced and evaluated by experts.

Success Guarantees: a number of voice “step-on” with respect to “standard latency” case are reproduced and evaluated by experts.

**Preconditions:**

* ATCo and RPIL has been briefed and trained to use Simulation Platform
* “Step-on” measurements have been conducted with same set-up but using a “low voice latency” system (e.g. GND-GND network)

**Triggers:**

RPA is in Climb/En-Route flight Phase and RPAS control has switched from RLOS to BRLOS

**Basic flow:**

1. ATCo provides instructions to RPIL for FL change for maintaining separation with other traffic
2. RPIL request FL or Route change to ATCo due to adverse weather conditions
3. ATCo provides instructions to RPIL for passing control to another sector ATCo (e.g. approach ATCo)

**Use Case diagram:**



Figure : ATC Voice Use Case diagram

Note 1:

If someone transmits before a communication is complete, it will disrupt the communication and/or jam the frequency with two transmissions at once, thus requiring the communication to be repeated. This situation is referred to as “stepping on” or “blocking.”

Note 2:

The total end-to-end latency is due to parts which are time variable (i.e. those involving Satcom from the fading introduced by the meteorological conditions and RPAS attitude), others which are mostly fixed (i.e. the latency introduced by the radio equipment, the response time of a router, the latency introduced by the terrestrial channel between Fucino Teleport and RPS).

Note 3:The following main contributions to latency are considered:

* -Satcom Space Link - ranges approx. from 0.5 s to 1 s
* -Satcom Gnd Link - 20 ms
* (RPS) GCS HMI - approx. 100 ms

(RPA) VCMS approx. 200 ms

**Use Case**:

CPDLC Use Case

**Use Case:**

BRLOS Comms System performance in clear sky conditions

**Use Case:**

BRLOS Comms System performance in degraded weather conditions

**BLUE FORCES USE CASES**

**Actor(s)**:

**Use case description**:

Speed

Range (if not in the table)

Use Case diagram (this one but adapted to the document needs)



Potential Communication Requirement Table

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Link | Pilot - RPAS | ATC - RPAS | Peak data rate | Average data rate | Latency | Security level | Availability/continuity | DensityN/km2 | Range |
| C&C uplink | Uplink |  |  |  |  |  |  |  |  |
| C&C Downlink | Downlink |  |  |  |  |  |  |  |  |
| Navaid Settings | Uplink |  |  |  |  |  |  |  |  |
| Navaid Display data | Downlink |  |  |  |  |  |  |  |  |
| e-identification (\*) | Downlink |  |  |  |  |  |  |  |  |
| ATC voice relay | Uplink | Downlink |  |  |  |  |  |  |  |
| ATS data relay | Uplink | Downlink |  |  |  |  |  |  |  |
| Sense and avoid target track data | Downlink |  |  |  |  |  |  |  |  |
| Airborne weather radar data | Downlink |  |  |  |  |  |  |  |  |
| Video situational awareness | Downlink |  |  |  |  |  |  |  |  |
| PAYLOAD UP | Uplink |  |  |  |  |  |  |  |  |
| PAYLOAD DOWN | Downlink |  |  |  |  |  |  |  |  |

(\*) See “Definitions”

**Use Case:**

 Law Enforcement Mission

**Use Case:**

 Fisheries Control mission

**Use Case:**

 Fire Crisis Management mission

**AIRPORT USE CASES**

**DELIVERY USE CASES**

**RURAL USE CASES**

**INFRASTRUCTURES USE CASES**

## 5.1 Communication

*Communication between pilot and drone/controller*

## 5.2 Surveillance

*Communication between drone and controller*

## 5.3 Navigation

*Communication between pilot and drone*

## 5.4 Mission

*Communication between pilot and drone*

# 6 Potential System Requirements

# 7 System Technologies

# 8 Spectrum and Bandwidth considerations

## 8.1 Considerations according to ECC (draft) report 268

The ECC report 268 “focusses on UAS that fly in circumstances where they do not need communications with air traffic control (ATC). This is the case of aircraft flying under visual flight conditions (VFR) in airspace classes E (controlled airspace) and F and G (uncontrolled airspace as far as not designated as Radio Mandatory Zone (RMZ))”

The ECC report 268 focusses on UAS in the “Open” and “Specific” categories in the “Prototype Commission regulation” from EASA, a range of UAS in which ECC believes many new UAS applications for professional use will emerge.

The understanding of airspace classes in ECC report 268 is based information in the Annex 4 of the ITU-R Report M.2171, and they claim it roughly corresponds to the “Open” categories “A2” and “A3” and the “Specific” category where a requirement for electronic identification is foreseen.

According to ECC report 268 it is nearly impossible to determine the amount of spectrum that will be needed for UAS applications due to the many possibilities for new innovative UAS applications.

* Command and control subject to aeronautical safety constraints
* Payload not subject to aeronautical safety constraints

The most common channel bandwidth for telecommand and control between 300 kHz and 3 MHz, mostly spread spectrum and duty cycled. Spectrum may be shared. Systems must be robust, possibly under shared licensed access.

Payload bandwidth in the order of 10 MHz max.

Freq. tuning range for cordless cameras, portable video links and mobile video links according to ERC Recommendation 25-10 considered as a possibility for UAS video downlinks.

According to ECC report 268 Non-professional UAS is expected to use frequency opportunities under general authorisations on a non-protected basis, i.e. on a shared, un-coordinated frequency use, e.g.

1. 2400-2483.5 MHz according to ERC/REC 70-03 Annexes 1 and 3
2. 5725-5875 MHz according to ERC/REC 70-03 Annex 1

5 GHz WAS/RLAN as defined by ECC/DEC/(04)08 is not allowed for UAS. The background is that RLAN operation while in motion may not allow a proper application of the DFS mechanism.

LTE technology may be used for UAS.

## 8.2 ECC Frequency Considerations according to CG (No formal conclusions yet)

ECC WGFM#88 established a CG looking into some candidate frequency bands for UAS

1. 1900-1920 MHz – mobile links –competing spectrum demand and existing licenses? DECT/SRD(?) UAS command and control may need the whole 20 MHz?
2. 2010 – 2110 MHz and 2200 – 2500 MHz (?)
3. 2300-2400 MHz – may not be an option for harmonisation (?)
4. 5000-5010 MHz – limited to internationally standardised aeronautical systems (WRC-12), so do not study further (?)
5. 5030-5091 MHz– limited to internationally standardised aeronautical systems(??), aeronautical mobile (R) service
6. 5091 – 5150 MHz. – limited to internationally standardised aeronautical systems, limited to surface applications at airports, ref. Resolution 748 (WRC-15)
7. 5150 – 5250 MHz – possibility for the drone payload to the ground? May need strict elevation angle related limits to avoid aggregated interference into satellite receiver frontend?
8. Use of existing and future MFCN networks
	1. 700 MHz?
	2. 1.8 GHz ?
9. Other options?

### 8.3 ICAO Spectrum Considerations according to ICAO Doc 10019, “Manual on Remotely Piloted Aircraft Systems (RPAS)”

According to clause 11.3.13 the following bands are potential candidates for RPAS C2 links as of 2012 ITU Radio regulations

1. 960- 1 164 MHz for RLOS
2. 1 545 – 1 555 / 1 646.5 – 1 610 / 1 610 – 1 626.5 MHz for BRLOS
3. 5 030 – 5 091 MHz for RLOS and BRLOS

According to clause 11.3.14 … sharing … 5 030 – 5 091 MHz allocation

According to clause 11.3.15…. 12/14 GHz and 20/30 GHz Fixed Satellite Service (FSS) bands… more study needed…

According to clause 12.3 VOICE AND DATA TO/FROM THE RPS, RELAYED VIA THE RPA



Figur . Figure in ICAO RPAS MANUAL



Figur . Figures in ICAO RPAS MANUAL



Figur . Figure in ICAO RPAS MANUAL



Figur . Figure in ICAO RPAS MANUAL



Figur . Figure in ICAO RPAS MANUAL



Figur . Figure in ICAO RPAS MANUAL

## 8.4 RESOLUTION 155 (WRC-15)

RESOLUTION 155 (WRC-15)

**Regulatory provisions related to earth stations on board unmanned aircraft**

**which operate with geostationary-satellite networks in the fixed-satellite**

**service in certain frequency bands not subject to a Plan of Appendices 30,**

**30A and 30B for the control and non-payload communications of**

**unmanned aircraft systems in non-segregated airspaces**

…

*noting*

*a)* that this conference has adopted Resolution **156** on the use of earth stations in motion

communicating with geostationary FSS space stations in the frequency bands 19.7-20.2 GHz and

29.5-30.0 GHz;

*b)* that Report ITU-R M.2171 provides information on characteristics of UAS and spectrum

requirements to support their safe operation in non-segregated airspace,

…

*resolves*

1 that assignments to stations of geostationary FSS satellite networks operating in the

frequency bands 10.95-11.2 GHz (space-to-Earth), 11.45-11.7 GHz (space-to-Earth), 11.7-12.2 GHz

(space-to-Earth) in Region 2, 12.2-12.5 GHz (space-to-Earth) in Region 3, 12.5-12.75 GHz (spaceto-

Earth) in Regions 1 and 3 and 19.7-20.2 GHz (space-to-Earth), and in the frequency bands

14-14.47 GHz (Earth-to-space) and 29.5-30.0 GHz (Earth-to-space), may be used for UAS CNPC

links in non-segregated airspace\*, provided that the conditions specified in *resolves* below are met;

…

17 that, in order to protect the radio astronomy service in the frequency band

14.47-14.5 GHz, administrations operating UAS in accordance with this Resolution in the frequency

band 14-14.47 GHz within line-of-sight of radio astronomy stations are urged to take all practicable

steps to ensure that the emissions from the UA in the frequency band 14.47-14.5 GHz do not exceed

the levels and percentage of data loss given in the most recent versions of Recommendations

ITU-R RA.769 and ITU-R RA.1513;

..



Figur . Figure in RES 155

Annex A:
Bibliography

Annex B:
Change History

| Date | Version | Information about changes |
| --- | --- | --- |
| *October 2011*  | *1.1.1* | *First publication of the TS after approval by TC SPAN at SPAN#19(30 September - 2 October 2011; Prague)* |
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# History

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