FEATURE ARTICLE

Radio Spectrum Access For UAS

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Remotely piloted air vehicles have been used by the military for some considerable time and this technology is now finding applications within the civil environment. In a large number of countries there are now significant civil development programmes for these UAS with the intention of development systems that operate seamlessly with existing piloted aircraft in non-segregated airspace.

The variation of systems is expected to be considerable, ranging from very light devices weighing a few hundred grams to those that equate to current civil air transport aircraft and it is expected that these sytesm will want to operater in all types of airspace.

The latest World Radio Conference (WRC-07) which took place in October and November 2007 in Geneva recognised the progress made in the development of UAS and the need for spectrum support. WRC-07 therefore decided the issue was of sufficient merit to warrant the inclusion of an item on the agenda of the next WRC, which will take place in 2011 (WRC-11). WRC-07 gave further explanation on the nature of the agenda item in Resolution 421 (see annex) This article shows the preliminary understanding of this agenda item (AI), including Resolution 421, of the United Kingdom, Germany and France. It also considers and precises the intermediate necessary steps for an efficient work.

Main Lines of the Agenda Item

The baseline of the agenda item is the need of unmanned aircraft to use airspace seamlessly with conventional manned aircraft. It seems to be clear that no other technical solution besides radio links including satellite link would be practicable for the monitoring and controlling of unmanned aircraft.
Resolution 421, which is part of the agenda item, asks to determine the spectrum requirement «to support the remote pilot in commanding and controlling the unmanned aircraft and in relaying the air traffic control communication» (resolves 1). This gives the priority to those functions that are essential for the operation an unmanned aircraft. The challenge in this respect is the fact that a radio link will be part of the interface between pilot and aircraft. Therefore it seems logical that the radio link has to be taken into account in the airworthiness certification process.
In addition Resolution 421 asks as a separate issue (resolves 2) to consider the spectrum requirements for systems «to detect and track nearby aircraft, terrain and obstacles to navigation in order to ensure the UAS avoids these objects in a manner equivalent to that achieved by manned aircraft»
The two issues mentioned above will hopefully result in the allocation of spectrum to support the command and control as well as sense and avoid functionality of a UAS at WRC11. However Resolution 421 also invites ITU-R «to produce a report or a recommendation, as appropriate, on how to accommodate the radiocommunication requirements for UAS payloads». With this the consideration on payload communication in ITU will stay inside the responsible Study Group (SG 5) and its Working Party 5B.
Without any limitation in terms of frequency band and amount of spectrum to be looked at by WRC11 this agenda item gives the maximum of flexibility to find appropriate solutions. The only limitation recognised by WRC07 is the need to protect existing allocation in the bands identified for allocation.

Understanding & Detailed Scope of the Agenda Item

The following considerations aim at helping to fill in a typical table representing the synthesis of the spectrum needs in each category. An example of such a table is given in Table 1 in the annex. Scenarios of the different countries will help to gain global values in a unique table.

Different classes of air spaces: The aim of the WRC-11 AI 1.3 is to allow the safe operation of all kinds of UAS in non-segregated airspace. To date, operations have been limited to segregated airspace such as those designated as''R'' (Restricted), ''D'' (Dangerous) or ''P'' (Prohibited). Through the use of segregated airspace it si clear that separation between manned aircraft (outside this airspace) and unmanned aircraft (inside this airspace) is achieved.

- New unused air volumes such as internal buildings caves and other very specific aeronautical volumes as the very high altitude aeronautical layers above the current controlledairspace currently used by manned aircraft and below the satellite levels. In these specific volumes the rules for the operation of unmanned aircraft only depends on the requirements of the UAS and its transitting arrangements, whilst in other volumes the requirements of manned aircraft have to be respected.
- The current aeronautical areas of responsibility under the overview of the national aeronautical authorities. For the issue of the safe operation of the UAS outside the segregated airspaces, two sub categories of airspaces have to be considered :
  - Controlled airspace, were Air Traffic Control (ATC) maintains a constant surveillance of the traffic and is responsible for the separation of aircraft. A majority of traffic is operated under instrument Flight rules.
  - Uncontrolled airspace, were no ATC is provided and the separation of Aircraft is in the responsibility of the pilots. The operation of aircraft follows the visual flight rules (VFR). It is anticipated that the collision avoidance in this kind of airspace must guaranty a level of efficiency at least as the human ''see and avoid'' principle followed by the current piloted light aircraft.

It is expect that the insertion of the UAS in the airspace used by manned aircraft will require amendments to the existing internationally agreed rules of the air. The conditions under which unmanned aircraft are allowed to use the airspace together with manned aircraft may influence the spectrum requirement and the quality of spectrum required to satisfy this requirement.

Components of UAS: The components of a typical UAS could be the following ones :

- UAS: (Unmanned Aircraft System) consists of the UA

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and an associated control station;
- UA: Unmanned aircraft: All types of unmanned aircraft can be considered. This includes the potential non piloted aircraft, as it is considered by some countries that in a transition period a pilot could be aboard some UA. (see UK proposal below);
- GS (control station): this is the station where operators command and control in real time the UA;
- OPAC (Operational Payload Analysing Centre): this is the remote centre where data from the UA is analysed and brings a particular importance for all the missions related to surveillance purposes. As the processing resources would be greater in these remote stations, it would be very interesting for the gross UA weight consideration to send massive rough data (and video in particular) to these centres. On the other hand, such method would require important bandwidths.
  Another interesting question is to consider the interest to integrate, or not, in the security flux the possible video streams data.
- ATC: (Air Traffic Control) for the UA flying in volumes described in section B above. ATC is mandatory in controlled airspace.

All these components are not necessarily based in the same premises. Therefore, direct communications between these actors could also be considered.

''Command and control'' (C/C or C^2): This is the typical link between the remote operator piloting and the UA. Two ways of communications can be consider :
- The uplink to send orders to the aircraft. This is the ''Command'' link that would probably necessitate low data rate of around kbits/s per UA.
- The downlink to send the flight status of the UA to the remote pilot. This is called the ''Control'' function. It is anticipated that in some flight conditions, or in specific airspaces, that it could be necessary to downlink video. This consideration is of a first importance for the work of the ITU-R related to the Resolution ITU-R 421 and must also be appreciated with the similar requirement that can occur for the S&A function (see below). Such a requirement would lead to a necessary bandwidth of several hundreds of kbit/s per UA.

The C^2 link of an UA is part of the mechanism used to control the aircraft. These functionalities are subject to the airworthiness certification of an aircraft. It has to be studied in which way the radio link has to be taken into account during the certification of a UAS.

''Sense And Avoid'' (S&A): This functionality is equivalent to the piloting principle ''see and avoid'' used in all volumes. The electro-magnetic equipments designed to collect rough data related to the ''sense'' function will have specific requirements in ITU-R services. For example, the evaluation of the close proximity of the UA using radar equipment will lead to operate in radionavigation service bands. It has to be studied how far these functionality can be realised by using existing systems such as radar, ACAS, ADS-B and UAT. The data derived by the sensors could either be directly processed inside the UA or be transmitted to the GC. The transmission of data from the S&A sensors and the control of these sensors is considered to be part of the C^2 link.
Similarly to the C^2 considerations, it is expected that the ''S&A'' electro-magnetic requirements will have to be compliant with the requirement established by international accepted rules developed by all international aeronautical organisations, such as ICAO and EUROCONTROL.

Relay of ATC communication: In areas under the responsibility of national aeronautical authorities, a permanent link between the air traffic controller managing the airspace and the pilot of the UA will be necessary. It is supposed that all the communications will be relayed by the UA. A direct link between the ATC and the remote pilot will be useful but not mandatory as this operator could be far from the ATC centre or in maritime or aerial bases where direct links with the ATC would be difficult to implement. Considering these free units involved for this kind of communications two uplinks and two downlinks are expected :
1) ATC uplinks for the communications :
   a. from the ATC to the UAV;
   b. from the RPC to the UAV;
2) ATC downlinks for :
   a. from the UAV to the ATC;
   b. from the UAV to the RPC;

To satisfy these real time voice communications first analyses expected that two channels will be necessary instead of only one for the current communications between the ATC and the pilots of conventional airplanes. As these communications are crucial for a safe management of the airspace, especially in the high density of some terminal approach areas, the requirement for link availability could lead to double some or all these links. Some concepts see the possibility to realise the ATC relay function by embedding digitised audio channels into the C^2 data link.

Payload: In preparation of WRC-07 early estimations of payload requirements were circulated:
- A global short term need (before the Year 2020) of several hundreds of MHz is required for the telemetry and must be found in frequencies below 16 GHz.
- No requirement for the telecommand nor the telemetry long term have been yet quantified.
- All the existing ITU-R MOBILE allocations are potentially useful for the telemetry short term requirement, provided that the shared studies would prove so.
- The frequencies above 16 GHz are not yet suitable for the telemetry requirement as the technology is not yet available.

Resolution 421 invites ITU-R to produce a report or a recommendation, as appropriate, on how to accommodate the radiocommunication requirements for UAS payloads. Furthermore, additional studies lead to consider that the global spectrum required for the payload operation will necessitate:
- The short, medium and long term requirements for the telemetry payload.
- The identical requirements for the telecommand links would probably lead to lower bit rate.
- The efficient use of the UA by the OPAC would involve that the OPAC operator could communicate with the pilot in the GC by means of a specific link. This is useful when the UA mission or flight pattern must be re-oriented, due to the nature of the data analysed by the OPAC. A relative low bit rate communication link between these two units, relayed by the UA could satisfy this requirement.

Other considerations (Relay, redundancies…)
Besides the communications between these actors, the ITU-R resolution let also open the door to consider some other major aspects:
- Relay of communications: The communications between the above actors could be assumed by direct links or re-transmitted communication. The retransmission platform could be a satellite or an another (unmanned)aircraft, or a simple ground or maritime station.
- Redundancy: The level of link availability for the safe operation of future UAS in non-segregated airspace

would probably lead to double or triple some kind of communications.

- UA handover operations : As UAS could operate over long distances, it will be necessary to take into account that during some flights the aircraft could be in communication with more than one ATC, OPAC or GC unit for handover operations.
- All frequencies bands and possible services to be considered : The Resolution does not exclude any frequency band nor any ITU-R service to satisfy the safe use of the UAS in our skies. It also gives WRC-11 the possibility to allocate additional spectrum bands, except for the payload purposes.

Resolution Ambition Limited by 3 Year Working Period

As a principle, the ITU-R Resolution 421 invites to propose answers to all these aspects by 2011. Nevertheless, the scope of this resolution is so wide that it is probable that not all the issues will find satisfactory answers. Therefore, the work of the next years needs to be organised in a manner to reach best results for the short and medium term requirements without compromising the further studies for the long term needs. The workplan related to the spectrum needs for the UAS aims also at identifying the unanswered questions that will be forwarded to other WRC.

Examples of scenario for the short term

A lot of coordination will be necessary to synthesis all the national spectrum needs for the short, medium and long term scenarios. The following sections give examples of the way followed by some CEPT countries to elaborate their scenarios:

- **German Example**
  In Germany some activities between industry and the administration are under way to develope scenarios which may help to estimate the spectrum requirements for UAS. For the time being two cases are being looked at:
  - UAS on a transcontinental flight, this involves communication with several ATC unit and the need to use different communication paths including satellite.
  - UAS used for the surveillance of a well defined area; this involves national flight operation and communication over relatively short distances.

For a good description of such an scenario a good and common understanding of the components (such as C², S&A) have to be developed.
It appeared to be a little problem that the scenarios are dependant on the legal framework under which unmanned aircraft may operate. The development of the legal framework not, only nationally but internationally as well, is just starting. Coming to solutions in time for WRC-11 requires not only nationally close cooperation with those organisations which are responsible for the legal framework.

- **UK Example**
  In the UK a collaborative team has been established between government, aviation authorities, air traffic service providers and UAS operators to investigate the additional spectral requirements UAS have over manned aircraft for flight safety.
  In order to determine this requirement for command and control, the UK has looked at the information (including ATC voice) required by the GC, in order to maintain safe flight of the aircraft along its intended route in accordance with ATC instructions where appropriate. This information is broken down into it's component parts and for each component part the data size and update rate is identified for both normal and fault condition. From this, the data rate for a UAS is then determined smoothing peaks in data throughput requirements where appropriate. Once this has been determined for the various different types of UAS and a model is then used to determine the number of aircraft within a given volume of airspace and hence the capacity requirements of the various links.
  The UK has yet to start deliberations on the amount of spectrum required for sense and avoid or for payload functions.

- **French Short Term Example**
  The French Ministry of Interior, of the Over-seas and terrestrial collectivities (MIOCT) recently began to develop a very preliminary scenario to identify and quantify the spectrum requirements for the use of UAS for security applications. For that purpose, the missions proposed by the USEP (UAS for Security and Environmental-related purposes) study which was conducted by the CGArm (Conseil Général de l'Armement) have been used. The first short term scenario aim at carrying the following missions which are considered to be of a first priority for the MIOCT:
  - General surveillance of massive human gatherings in a limited area in the order of a square kilometre;
  - Complementary fire forest surveillance in a wide area (a few thousands of square kilometres) for the early detection of of fire start-ups;
  - Complementary search & rescue applied to lost people.

  If we suppose that these above missions take place simultaneously at the same area, this leads to a very preliminary global estimation indicated in the following values. It is therefore also supposed that the UAS of the MIOCT will not operate in radio and radar controlled areas. They will only use VFR and not controlled volumes. These values are given only as example and must be compared with other scenarios:
  - C2 up and down links (no video considered)[(1)] : several Mbits/s;
  - S&A up and down links (no video considered)[(1)]: in the order of the Mbits/s;
  - Video for S&A or C2[(1)]: to be further précised – probably necessary for the flight in VFR areas and in non-controlled airspace – in the order of several Mbits/s;
  - ATC [(1)] : several channels necessary;
  - Payload : bandwidth of a few tens of MHz wide;
  - Relay : aeronautical relay is under consideration.

  [(1)] compliant to ICAO standards

These first results for the short term must be added to medium and long term ones in the objective to specify the global spectrum needs for MIOCT.

Conclusion

WRC-11 Agenda Item 1.3 gives a lot of flexibility to find good solution to accommodate the radio links needed for the operation of UAS. It is clear that the operation of UAS has a lot of aspects which are outside the scope of this agenda item and even outside the scope of ITU. This requires a good cooperation between all organisations involved (ITU, ICAO, EUROCAE, RTCA, CEPT, EUROCONTROL; EDA just to mention a few of them). In Europe CEPT has established a Conference Preparatory Group which aims to develop a common proposal for WRC-11. Industry and all other interested parties are invited to participate through there national administration in this process.

ANNEXES

WRC-11 Agenda Item 1.3

Quote from Resolution 805 (Agenda for the 2011 World Radiocommunication Conference):

«WRC-07 resolves to recommend to the Council that a world radiocommunication conference be held in 2011 for a period of four weeks, with the following agenda:

1.3 to consider spectrum requirements and possible regulatory actions, including allocations, in order to support the safe operation of unmanned aircraft systems (UAS), based on the results of ITU R studies, in accordance with Resolution 421 [COM6/8] (WRC 07);

RESOLUTION 421 (WRC07)
Consideration of appropriate regulatory provisions for the operation of unmanned aircraft systems

The World Radiocommunication Conference (Geneva, 2007),

considering

a) that worldwide use of unmanned aircraft systems (UAS) is expected to increase significantly in the near future;

b) that unmanned aircraft need to operate seamlessly with piloted aircraft in non-segregated airspaces and that there is a need to provide globally harmonized spectrum for that purpose;

c) that the safe flight operation of UAS needs reliable communication links and associated spectrum, especially for the remote pilot to command and control the flight and to relay the air traffic control communications;

d) that the safe flight operation of UAS necessitates advanced techniques to detect and track nearby aircraft, terrain and obstacles to navigation in order to ensure the UAS avoids these objects in a manner equivalent to that achieved by manned aircraft;

e) that satellite radiocommunications are part of UAS operations, in particular to relay transmissions beyond the horizon and maintain safety of flight;

f) that there is a need to protect existing services;

g) that some applications of UAS involve high data-rate payload transmissions from the aircraft to remote stations,

recognizing

a) that UAS will operate in the same environment as manned aircraft;

b) that some UAS will operate below or above the current conventional air traffic of manned aircraft, including in specific environments not accessible to manned aircraft, such as volcanoes, hurricanes, poisonous or electromagnetic zones;

c) that studies are required to provide a basis for considering regulatory changes, including additional allocations, to accommodate spectrum requirements of UAS consistent with the protection of incumbent services;

d) that any new allocation should not place undue constraints on services to which the frequency bands are allocated;

e) that this agenda item is not intended to be used to identify bands for UAS use, but rather only to propose, as necessary, new allocations or modifications to existing allocations to accommodate UAS,

resolves

that WRC11 consider, based on the results of ITUR studies:

1 the spectrum requirements and possible regulatory actions, including additional allocations, to support the remote pilot in commanding and controlling the unmanned aircraft systems and in relaying the air traffic control communications, as mentioned in *considering c)*;

2 the spectrum requirements and possible regulatory actions, including additional allocations, to support the safe operation of unmanned aircraft systems not covered by *resolves* 1, as mentioned in *considering d)*,

invites ITUR

1 to conduct in time for WRC11 the necessary studies leading to technical, regulatory and operational recommendations to the Conference, enabling that Conference to decide on appropriate allocations for the operation of UAS;

2 that the studies referred to in *invites ITUR* 1 should include sharing and compatibility studies with services already having allocations in those bands;

3 to produce a report or a recommendation, as appropriate, on how to accommodate the radiocommunication requirements for UAS payloads,

further invites

the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), administrations and other organizations concerned to participate in the studies identified in *invites ITU R* above,

requests the Secretary-General

to bring this Resolution to the attention of ICAO.

Table 1: Identification of different categories of spectrum required for the UAS to be studied under the resolution 421. The table also indicates the possible communication standards for these transmissions. The payload spectrum needs must be considered separately.

Types of areas	**Controlled areas**		**Non controlled areas**
Means to control	Radio and radar (secondary) services	Only radio services	No radio No radar service
Examples of areas of flight	TMA, Airways, ''P'', ''R'' and ''D'' areas	VFR areas	All other areas (deep valleys, very high altitudes….)
Video for C2 or S&A	Possible not necessary	Probably necessary (1)	Probably necessary (2)
S&A Uplink	Probably necessary (1)	Probably necessary (1)	Probably necessary (2)
S&A Downlink	Probably necessary (1)	Probably necessary (1)	Probably necessary (2)
ATC	Probably necessary (1)	Probably necessary (1)	Not necessary
C2 Uplink	Probably necessary (1)	Probably necessary (1)	Probably necessary (2)
C2 Downlink	Probably necessary (1)	Probably necessary (1)	Probably necessary (2)
Relays (satellites, aeronautical or terrestrial)	Necessity depending on the scenario (1)	Necessity depending on the scenario (1)	Necessity depending on the scenario (2)

(1) compliant to ICAO standards (2) not necessarily compliant to ICAO standards