Drones, UTM and Spectrum – A review

The drone industry is expanding rapidly worldwide, led by the European Union and others that have proactively tried to ensure regulations and legal impediments are addressed rapidly.

Spectrum, which is coordinated at the EC level and allocated to each state, along with the standards and technology development that accompany its use, are areas where industry stakeholders, regulators and other policymakers should focus attention to ensure that drone access is contemplated at an appropriate time in the development process.

As EASA and the European Commission develop a European regulatory framework for drone operations, that work will have an impact on the existing spectrum frameworks. It will be incumbent on the drone industry to find ways to co-exist with existing spectrum frameworks.

This paper provides information on spectrum policy and standard/technology setting approaches that should help promote UAS opportunities. The annex sets out more specific areas and bands which will require attention.

In summary, we recommend policymakers consider the following:

- Policymakers need to ensure flexibility, capacity and reliability and take into account the wide range of opportunities and use cases that are emerging in this dynamic market.
- The EU should continue to support innovation and technology leadership throughout the Single Digital Market by continuing to pursue flexible use licensed, unlicensed, and spectrum sharing opportunities.
- Standards developed for the use of spectrum by drones should be flexible both operationally and technically, designed at the outset to accommodate the emerging uses to which drones will put spectrum.
- As entities continue to explore ways to overcome limitations in ADS-B, solutions such integration with other spectrum (like commercial LTE) and dynamic channelisation, which allows for the dynamic assignment of frequency channels based on the channel conditions and traffic load, will play a critical role to ensuring access to scarce spectrum resources.
- For commercial and other mission critical applications, dedicated spectrum with quality of service (QoS) standards is more likely to be the appropriate reliability solution.

DRONE ALLIANCE EUROPE

Spectrum Management:

Spectrum is an essential input to the drone industry, providing positioning through Galileo, GLONASS, GPS, and other satellite-based systems; sense and avoid capability; vehicle control; and traffic management. These uses can be performed in licensed and license-exempt spectrum bands.

In 2015, the European Union adopted a flexible use spectrum policy framework that does not mandate specific uses; instead it ensures that the finite resources that is spectrum is put to its most efficient use by allowing service providers to use the spectrum in the way they need, relying on technical standards to protect against harmful interference.

In addition to flexible use, the EU, along with the United States, has been pursuing spectrum sharing opportunities. As spectrum needs increase and vacant spectrum becomes more scarce, regulators around the globe are focusing on ways to meet the growing spectrum demand.

Shared use of spectrum allows multiple users the right to certain spectrum frequencies, which in effect makes additional spectrum resources available. As the EC noted in a report to the European Parliament, spectrum sharing has the potential to create significant net economic benefits for the EU, with a net increase in the value to the European economy of several hundred billion Euros by 2020."[1] At the same time, the risks of spectrum sharing must also be addressed.

The Alliance encourages the EU to continue to support innovation and technology leadership through the Single Digital Market by continuing to pursue flexible use licensed, unlicensed, and spectrum sharing opportunities.

Standards and Technology:

A key component to spectrum policy and its usage is the development of standards that determine the technical and operational parameters by which services and technology operating in spectrum bands are governed. The challenge for emerging technologies such as drones is that standards can be developed and adopted for certain spectrum bands that inadvertently make those bands unavailable or more difficult to use because they did not contemplate drone operations. It is incumbent on the drone industry to ensure that these

[1] *See* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Promoting the Shared Use of Radio Spectrum Resources in the Internal Market*; available at https://ec.europa.eu/digital-single-market/sites/digital-agenda/files/com-ssa.pdf (2012).

issues are made clear and as far as possible, addressed, to allow for sharing to extend to drone usage.

Policymakers and standards bodies should ensure, much like spectrum policy, that standards developed for the use of spectrum are sufficiently flexible and are designed at the outset to accommodate the emerging uses to which drones will put spectrum.

As noted above, spectrum is needed to ensure commercial, safety and policy objectives, such as wireless control links, tracking, diagnostics, payload communications, and collaborative collision avoidance, including vehicle-to-vehicle communications, are achieved. The annex starts to look at the spectrum that is available and what may be required for safe, efficient drone operations.

Below are a few key thoughts to consider as policymakers and standards bodies move forward with their work.

Flexibility: As with spectrum, standards should provide operational and technical flexibility. For example, LTE, which is a wireless data communications standard, was developed to ensure speed of delivery of data, increased capacity, and reduced latency. These are just the types of attributes that one may look for in a standard where collision avoidance relying on vehicle-to-vehicle communications and traffic management are needed. For the standard to be developed, as noted in the annex, studies will be required. These need to start as soon as practicable.

Capacity: While it is unclear whether any spectrum allocation or standard could have anticipated the opportunity and rapid growth of the drone sector, it is important for all standards bodies, given the pace of technological change and innovation, to anticipate the potential need to handle a large number of devices. ADS-B is an example of a technology that a number of entities are looking at as a potential alternative but are increasingly aware of its limitations for drones. These entities have identified capacity and coverage as two limitations that may hinder use of ADS-B.

ADS-B is the clear preferred solution for manned aircraft, having been adopted in numerous jurisdictions across Europe, Asia, Australia and the Americas. It is actively being deployed in manned aircraft and companies like Flightradar24 currently use it for mapping.

There are indications, however, that the capacity of the ADS-B system, as originally designed, is limited and the lack of ubiquitous coverage needs to be addressed in order to make it relevant for many UAS use cases, particularly agriculture. A recent MITRE study found that the technology "was not designed to handle hundreds of thousands of flights."[2]

[2] Obstacles Appear to be Extending GPS-Based ADS-B for UAV Operations, Inside Global Navigation Satellite Systems (May 16, 2016).

As entities continue to explore ways to overcome these limitations, solutions such integration with other spectrum (like commercial LTE) and dynamic channelisation, which allows for the dynamic assignment of frequency channels based on the channel conditions and traffic load, will play a critical role to ensuring access to scarce spectrum resources. Again, it is important that studies on these issues start as soon as possible. Those studies may also need to look at alternatives to ADS-B to handle the large amounts of traffic represented by drones.

Reliability: While reliability for commercial or mission critical uses may need to be extremely high, other uses including recreational uses, may be sufficiently addressed by systems that do not focus on reliability but are instead developed to promote low access costs. For example, the IEEE 802.11 standards are designed to operate in the unlicensed spectrum bands and are designed to operate in a manner that creates no harmful interference and accepts interference. These are ideal for recreational users as they offer a very low-cost solution for drones to operate. The possibility of delay in signal transmission is also more tolerable for this sort of use.

For commercial and other mission critical applications, dedicated spectrum with quality of service (QoS) standards is more likely to be the appropriate solution. So, for example, LTE networks operated by commercial wireless providers offer a baseline QoS that ensures communications are connected and maintained. Some offer the capability for network management that ensures mission critical communications are prioritized with an enterprise-level business agreement.

Differing levels of reliability allow users to tailor their needs and costs according to the activities they are engaged in and policymakers need to remain mindful as they establish requirements for operations. Ideally, given the economic importance that drones are likely to represent to Europe, it is also appropriate to investigate dedicated spectrum.

Conclusion

There have been policies adopted in the allocation of spectrum that should help ease access to spectrum for drones. There are, however, obstacles that remain and will continue to challenge policymakers concerning future spectrum allocations and standards-making processes. These issues require studies to be commenced in order for the spectrum allocation process through the World Radio Conference to proceed in a timely fashion.

Policymakers need to ensure flexibility, capacity and reliability take into account the wide range of opportunities and use cases that are emerging in this dynamic market. Continued and deeper engagement on these issues is particularly important at this point in the market's development.

ANNEX 1 – Policy concerns to consider in the 2019 World Radio Conference

Spectrum is controlled by each state, which is in turn coordinated through the International Telecommunications Union (ITU), a UN body. In the case of spectrum, the states meet at the ITU to agree allocations of particular spectrum bands for use by particular technologies or users at the ITU's four-yearly World Radio Conference (WRC). The last WRC was late 2015.

Even in 2015, and certainly as the work was done in the four years leading up to the WRC15, the focus in the remotely operated vehicle area was on providing spectrum for driver-less cars and autonomous road vehicles. The ITU have produced some recommendations related to wireless connectivity for road transport systems and the ISO is involved in developing some standards. To date, certainly at the ITU level, there appears to be a need for further work into the development of UAS control systems. The ITU has considered control links for RPAS, and is starting to look at LTE options for UAVs, but this work is far from definitive.

Going forward, as EASA and the European Commission develop a European regulatory framework for the operation of UAS, that work will have an impact on the existing national spectrum frameworks. The impact of this possible new framework has not been examined. There could be implications related to spectrum usage.

There are various European and national organisations active in the UAS area and little attention has been paid to the spectrum implications of that work.

However, there are a number of issues and usages that need to be addressed. These include:

- Wireless control links
- Tracking
- Diagnostics
- Payload communications
- Collaborative collision avoidance, including vehicle-to-vehicle communications

This paper will look at each of these in turn. It then looks at the requirements a coordinated UAV Traffic Management system (UTM) may require.

1 Wireless Control Links

1.1 General

WRC-12 allocated the frequency band 5030 – 5091 MHz to be used for the terrestrial RPAS control links.

Subsequently, WRC-15 identified the following spectrum to be used by satellite systems controlling drones. However, it was also noted that ICAO is to develop the relevant SARPS before the spectrum can be used and there will be a progress report to WRC-19 and WRC-23 will review the effectiveness of the allocation. There are power limits associated with some of these frequency bands.

Region 1	Region 2	Region 3
12.5 – 12.75 GHz space to Earth	10.95 – 11.2 GHz space to Earth	12.2 – 12.75 GHz space to Earth
14.0 – 14.47 GHz Earth to space	11.45 – 11.7 GHz space to Earth	14.0 – 14.47 GHz Earth to space
19.7 – 20.2 GHz space to Earth	11.7 – 12.2 GHz space to Earth	19.7 – 20.2 GHz space to Earth
29.5 – 30.0 GHz Earth to space	14.0 – 14.47 GHz Earth to space	29.5 – 30.0 GHz Earth to space
	19.7 – 20.2 GHz space to Earth	
	29.5 – 30.0 GHz Earth to space	

Region 1 covers Europe, Africa and parts of the Middle East
Region 2 covers the Americas
Region 3 covers Asia and the Pacific

1.2 LTE (Cellular)

It is important to note that LTE is a specific technology and is not interchangeable with other cellular technologies. LTE is a specific generation of cellular technology but other generations remain in use. Generations of technology below 4G are unable to be used reliably. Coverage of 4G around Europe remains a work in progress.

The ITU acknowledges that LTE in the frequency range 800 - 900 MHz could be used for the control of UASs and would have a range of up to one mile. As this frequency band will mainly be used for traditional mobile services it begs a question as to how the UAS control systems will be classified. This is important as the UAS systems may require protection from interference to ensure safe and reliable operations.

Further, this band is also used for legacy GSM systems. Work is therefore required to ensure that there is no significant interference to the UAS system. Some European countries are developing plans to switch off GSM and use the spectrum for LTE. The implications of that move may need to be taken into account.

An ITU report looking at what the Tactile Internet (a low latency version of the Internet of Things) means for the transport sector focuses on road transport. As an afterthought it refers to the control of UASs. The outstanding question is whether the latency of LTE is sufficiently low for that technology to be used for the control of UAS. If so, it might represent a long term solution to the issue.

1.3 802.11p

This is a technology closely associated with Intelligent Transport Systems (ITS), a concept most normally associated with road transport. That is not to say that it cannot be used in the UAS environment. However, at this stage, no work has been done on ensuring if this allocated spectrum could be used in the drone environment.

The technology uses the 5.9 GHz band in Europe and the USA but a different frequency band is used in Japan. There are problems with the use of the 5.9 GHz band in some countries. Australia is an example where usage of this band causes interference to road tolling systems operating in an adjacent band. If there is a significant take-up of driver-less cars then this could increase the road transport use of ITS which may impact on its use for aviation purposes.

2 Tracking

The ITU allocated spectrum for a satellite-based global ADS-B tracking system at WRC15. This was in response to the MH370 mystery and the ensuing uproar. Given that the spectrum is available the drone industry could start to use it. There is nothing stopping this technology tracking drones as well as manned aircraft. The question is what would be required on the UAVs to make that possible.

2.1 ADS-B

To date, ADS-B is the clear preferred solution. However, note that it is being installed first over land, so at least for the short to medium term it is likely the terrestrial version rather than the satellite version will be deployed. There are also indications that the capacity of the ADS-B system is limited so there may be a need to examine the impact of the extra demand drones will create.

ADS-B data could nevertheless be used to develop maps that operators base their decisions on. This is in effect what Flightradar24 does today. This concept is, in effect, being developed and demonstrated in the driverless car environment today.

2.2 Mobile Telephony

There is research being carried out into using mobile phone activity to map pedestrian movement and the size and locations of crowds. Combining this with what Flightradar24 is doing using ADS-B and a network of antenna might produce a low power, low cost solution.

2.3 The Internet of Things

Flight tracking is a form of connecting aircraft together and the Internet of Things (IoT) is a process of connecting a large number of objects together. Essentially this is what the V-2-V and Sense and Avoid systems seek to achieve.

Despite much talk, there is little information yet available of the application of IoT to aviation systems and this is an issue where research is required. It is possible that the IoT can be used for tracking purposes, as well as for more tactile uses. The Tactile Internet, a low latency form of the IoT, is considered to be the next generation of IoT. There is currently a focus on using it for road transport, amongst other applications, but little attention on using it for aviation purposes.

2.4 4G (LTE)

As part of its specifications, LTE will include IoT. At the 4G stage, LTE will not support full powered IoT connectivity, but the upgrade path to 5G will address many of those concerns. Currently, 5G is scheduled for deployment in 2020, but Japan and Korea are looking at 2018 for first rollout. Europe, on the other hand is looking at 2022. There is considerable discussion now underway about what capabilities 5G will support and the frequency bands it can use.

There is a need to ensure that this aspect of 4G develops in a way appropriate to aviation usage. An aviation IoT system will have special characteristics different to other uses of IoT. We need to develop our requirements for 4G as a matter of urgency.

3 Diagnostics

WRC-15 allocated the frequency band 4200 – 4400 MHz for the purpose of carrying out in-flight diagnostics. This was supported by the Wireless Avionics Intra-Communications allocation for connecting different parts of the system on-board aircraft,

4 Payload

Payload spectrum may be required if the payload itself uses spectrum. The obvious example of this would be using drones to deliver broadband connectivity. Alternatively it might be similar to the satellite earth stations on aircraft used for air-ground connectivity. There is a need to identify what spectrum is required for payload purposes and could any existing spectrum allocations be used to meet this need.

If the drones are used for the provision of broadband connectivity then there is a need to consider the spectrum requirements. It is possible that the spectrum allocated to HAPS could be used for this purpose. HAPS is the ITU term for High Altitude Platforms such as balloons. The

ITU is currently looking at spectrum allocated to HAPS and this will be an agenda item at WRC-19.

It is important to note that the spectrum identified by WRC- 12 and WRC-15 for the control links is specifically excluded from usage for payload purposes.

5 Collision Avoidance and Vehicle to Vehicle Communications

UAS will largely remain connected at all times. That opens up a number of technological possibilities. Both Vehicle-to-Vehicle (V2V) and Sense and Avoid (SAA) technologies are currently being developed.

There are two types of SAA:

- Collaborative, based on V2V
- Non-collaborative, based on sensors to allow separation between equipped and non-equipped vehicles

The ITU has only studied V2V communications in the context of road systems. For road systems it seems that only the 5.9 GHz frequency band is used and the technology is 802.11p. In a road system this has a maximum range of 1,000m. In some road system concepts radar and/or GPS are also used. Some of these road radar systems operate in the 24 GHz band though it appears that other frequency bands are used as well in some states.

Aviation SAA is based on either ADS-B or radar. It is unlikely, due to power or payload capacity that radar and other active sensors would be appropriate for UAVs.

Alternatively, T-CAS and electro-optical cameras could be used. Multiple sensors will be required. T-CAS is a collision detection system based on SSR operating at 1030 MHz with the response at 1090 MHz. The response channel is the same as that used for ADS-B, raising further issues about the capacity of the system.

UAV Traffic Management

The current model of aerospace utilisation will not meet future projected UAS demands. This has implications for spectrum allocations and usage, as well as for how air navigation services will be delivered more generally.

It is possible that a new model will be required for the delegation of responsibility for many traditional air navigation services, from a single supplier to multiple operators operating in a distributed fashion. The individual operators would coordinate operations by following established protocols, using vehicle-to-vehicle, vehicle-to-service and service-to-service data communication and automation, to safely and efficiently manage the shared airspace.

This will throw into question a number of the current spectrum operations. Some of the connectivity requirements would be covered by V2V communications. For connecting the various operators and the central function some sort of mesh network will be required.

The NASA concept is based on a range of technologies including radar, cellular, satellite, unspecified navigation and unspecified communication. The spectrum requirements of this system need to be identified and the implications considered.

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