Spectrum Frequency Allocation Issues and Concerns for Small Satellites

Morio Toyoshima and Attila Matas

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Abstract

Many small-satellite missions have been launched and many more are planned. Small-satellite projects and missions are becoming very active because of some of their advantageous features, such as low latency. As the development cycle and the mission duration for small satellites are short, the relaxation of the regulation and easy deployment are discussed. The current situation with regard to the regulatory aspects for nanosatellites and picosatellites, especially in terms of frequency allocations, is described in this chapter.

M. Toyoshima (✉)
Space Communications Laboratory, National Institute of Information and Communications Technology, Koganei, Japan
e-mail: morio@nict.go.jp

A. Matas
Senior Satellite Regulatory Consultant, OrbitSpectrum, Geneva, Switzerland
e-mail: am@orbitspectrum.ch

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Keywords

Nanosatellite · Picosatellite · CubeSat · Frequency allocation · International Telecommunication Union (ITU) · International Telecommunication Union Radiocommunication Sector (ITU-R) · Radio Regulations (RR) · Geostationary orbit (GSO) satellite · Non-GSO satellite · Advanced Publication Information (API) · Date of Bringing Into Use (DBIU) · Short Duration Mission (SDM) · Space Operation Service (SOS) · World Radio Conference (WRC) · Master International Frequency Register (MIFR)

1 Introduction

The number of small-satellite missions has increased recently. More than 200 launches were conducted in 2018 and more than 400 nanosatellite launches are forecasted in 2019 (Erik Kulu 2019). As the number of launched small satellites increases, there are some frequency-allocation issues for small satellites. This chapter describes the current situation for spectrum-allocation issues and concerns for small satellites.

2 Characteristics of Small Satellites

Small satellites have advantages such as being faster to build and deploy, lower in cost, and having less path loss as well as transmission delay. Figure 1 shows an 1U-size CubeSat which is standardized with the dimensions of 10 cm × 10 cm × 10 cm. The faster development duration can be less than 1 year. The cheaper development cost can be less than tens of thousands of dollars for simple CubeSats. Faster implementation can be done by using modular and standardized CubeSat equipment, and miniaturized equipment can be used based on the latest technology. On the other hand, there are some drawbacks, such as limited launching opportunity, none or little orbit control, small or unreliable power source, limited lifetime, limited mission types, and limited regulatory certainty. Small satellites, however, provide a means for testing emerging

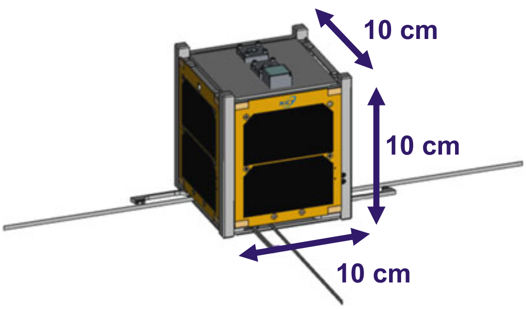

Fig. 1 An example of 1U-size CubeSat

Table 1 Typical characteristics of small satellites

Denomination	Mass (kg)	Max. bus power (W)	Typical cost (USD)	Max. dimensions (m)	Development time (years)	Mission duration (years)
Smallsat (Minisat)	100–500	1000	30–200 M	3–10	3–10	5–10
Microsat	20–100	150	10–150 M	1–5	2–5	2–6
Nanosat (1U-6U CubeSat)	1–20	20	100 k–10 M	0.1–1	1–3	1–3
Picosat	0.1–1	5	50 k–2 M	0.05–0.1		

Note: There are various definitions of small-satellite categories that are used and development times and mission durations vary to a degree around the world

technologies, offer opportunities for new satellite operators that might not otherwise have considered or been able to afford the use of satellite technologies, and operation or demonstration in a variety of practical space-based applications according to the satellite mass categorized as shown in Table 1 (Report ITU-R SA.2312 2019). Moreover, small satellites are easy to be launched with a larger host satellite as piggy-back.

3 Definition of Small Satellites

There is no regulatory definition for small satellites in the International Telecommunication Union Radio Regulations (RR). There are only definitions for geostationary (GSO) and non-GSO satellites. Most of small satellites will be launched in the low earth orbit (LEO); therefore, small satellites belong to non-GSO satellites (ITU-R WP7B 2019; Matas 2018). The characteristics and spectrum requirements of satellite systems using nano- and picosatellites in ITU-R were studied and reported in ITU-R SA.2312 characteristics, definitions, and spectrum requirements of nanosatellites and picosatellites, as well as systems composed of such satellites and ITU-R SA.2348 current practice and procedures of notifying space networks currently applicable to nanosatellites and picosatellites (Report ITU-R SA.2312 2019; Report ITU-R SA.2348 2019). The small-satellite community was interested in relaxation of the RR and easy deployment of their non-GSO satellites. The regulatory aspects for nanosatellites and picosatellites in Resolution 757 at World Radiocommunication Conference 2012 (WRC-12) of the ITU resolves to invite WRC-18 to consider whether modifications to the regulatory procedures for notifying satellite networks are needed to facilitate the deployment and operation of small (nano- and pico) satellites and to take the appropriate actions. But the quick decision made at WRC-15 was that there was no need for any special regulatory procedures to facilitate the deployment and operation of nano- and picosatellites.

4 Small Satellite with Short Duration Mission

Small satellites with short duration mission (SDM) are discussed in terms of technical characteristics and spectrum requirements in ITU-R Study Group 7 – Working Party 7B (ITU-R WP7B) (Report ITU-R SA.2312 2019) and the results of these studies are presented in the Report ITU-R SA.2425 studies to accommodate spectrum requirements in the space operation service for non-geostationary satellites with short duration missions and Report ITU-R SA.2426 technical characteristics for telemetry, tracking, and command in the space operation service below 1 GHz for non-GSO satellites with short duration missions (Report ITU-R SA.2425 2019; Report ITU-R SA.2426 2019). WRC 15 decided about a new RES 659 Studies to accommodate requirements in the Space Operation Service (SOS) for non-GSO satellites with SDM and invited the ITU-R to study the spectrum requirements for tracking, telemetry, and command (TT&C) in the SOS for the growing number of non-GSO SDM satellites. A new term "short duration mission (SDM)" as stated in the Resolution 659 is used for the first time in the ITU-R, which refers to a non-GSO satellite system having a limited period of validity of not more than typically 3 years. There is currently no particular regulatory definition for non-GSO SDM satellites. The ITU-R Study Group 7 – Working Party 7B (ITU-R WP7B) developed at the CPM19- Report to the WRC-19 (CPM Report 2019) four methods to satisfy WRC-19 Agenda Item 1.7 (*to study the spectrum needs for telemetry, tracking, and command in the space operation service for non-GSO satellites with short duration missions, to assess the suitability of existing allocations to the space operation service and, if necessary, to consider new allocations, in accordance with Resolution 659 (WRC-15))* and two new reports (Report ITU-R SA.2425 2019; Report ITU-R SA.2426 2019) how to satisfy this action item:

1. Method A proposes no change to the RR.
2. Method B1 proposes a new SOS (Earth to space) allocation for non-GSO SDM systems in the frequency range 403–404 MHz.
3. Method B2 proposes a new SOS (Earth to space) allocation for non-GSO SDM systems in the frequency range 404–405 MHz.
4. Method C proposes to use the SOS allocation in the frequency band 137–138 MHz for downlink and the band 148–149.9 MHz for uplink and to provide appropriate associated regulatory provisions in the RR for non-GSO SDM TT&C links.

Since the existing RR does not take into account the short development cycle and the short lifetimes of non-GSO SDM, a simplified regulatory regime and recording procedures for non-GSO SDM is required. Based on missing regulatory regime for non-GSO SDM, the ITU-R Study Group 4 – Working Party WP4A developed a method as described in the CPM19 Report to the WRC-19 (CPM Report 2019) Agenda Item 7-Issue I – to address this issue that consists of modifications to the existing regulatory procedures for Advanced publication information (API) and Notification of satellite networks and systems that are not subject to Section II of

RR Article 9, to facilitate the recording of non-GSO SDM systems in the MIFR. The most important aspects of the new draft Resolution Simplified regulatory regime for non-GSO SDM satellite systems proposed by the ITU-R WP4A are:

- SDM satellites, operating under any space service not subject to ART 9 Section II (ITU Radio Regulations 2016), shall follow the RR with the exceptions stipulated in this resolution.
- The application of the simplified regulatory regime shall have no impact, as compared to networks not applying the simplified regulatory regime, on the regulatory sharing status of the allocations to services, both terrestrial and space.
- SDM satellites using spectrum allocated to the amateur radio service shall operate under ART 25 (ITU Radio Regulations 2016).
- The total number of satellites in a SDM satellite constellation shall not exceed 10 (t.b.d. by WRC 19) satellite;
- The maximum period of operation and validity of frequency assignments of a SDM satellite shall not exceed 3 years from the date of bringing into use (DBIU), which is equal to the satellite launch date, without any possibility of extension.
- SDM satellite systems shall have a single launch date associated with the first launch (in the case of systems with multiple launches).
- SDM satellites for which the regulatory regime in this resolution is applied will not accrue any special or additional rights under the RR over those satellite systems not applying this regime.

5 Frequency Allocation for Small Satellites

Main purposes of small satellites are used for amateur satellite, space operation, Earth observation satellite, space exploration satellite, weather monitoring satellite, and so on. There are some instances where 1U-6U satellites are used for commercial purposes and such uses and spectrum allocations are consistent with the processes related to such services for telecommunications, remote sensing, RF Geolocation, etc. As an example, the frequency band for nanosatellites is shown in Fig. 2 (Erik Kulu 2019). As can be seen from W-band and laser/optical in Fig. 2, the higher frequency bands will be used more in future small-satellite missions. The typical frequency allocated for small satellites are shown in Table 2 (Matas 2016). For the allocation of frequencies, the world on the Earth has been divided into three "radiocommunication" regions as described in provision No. 5.2 of the ITU Radio Regulations (Timmerman 2018): exclusive allocations, which are favored in cases that involve broad international use of equipment; shared frequency allocations, which are applied to maximize the use of the available spectrum when two or more radiocommunication services can effectively utilize the same frequency band. A shared frequency band can be allocated to more than one service (primary or secondary). Stations of a secondary service shall not cause harmful interference to stations of primary service, cannot claim protection from harmful interference from stations of a primary service, and can claim protection, however, from harmful

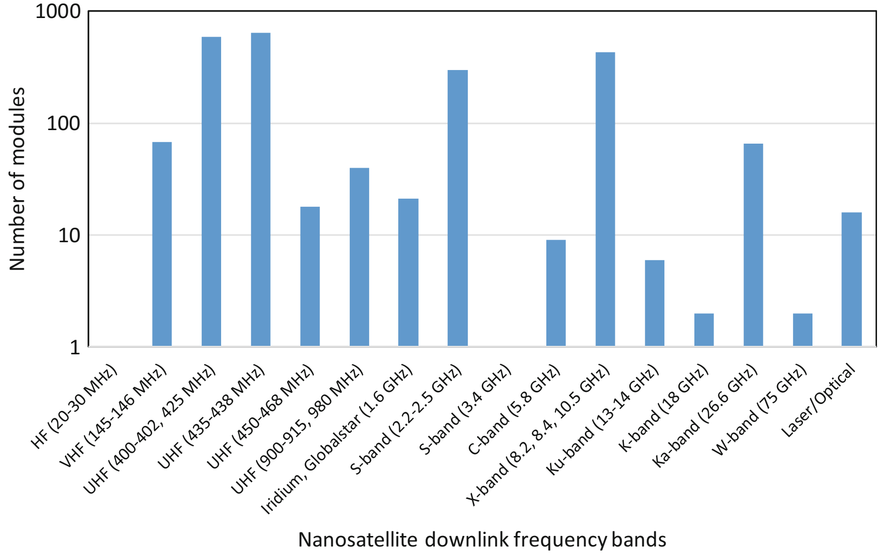

Fig. 2 An example of frequencies allocated for nanosatellite downlink bands

interference from stations of the same or other secondary service(s) to which frequencies may be assigned later (Timmerman 2018).

According to No. 4.4 of the RR (Timmerman 2018) Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention, and these Regulations.

The determination of whether or not a frequency assignment to a transmitting station is capable of causing harmful interference to the stations of another administration operating in accordance with the Radio Regulations does not lie only on the side of the administration operating the transmitting station that may be producing the interference and other administrations should have information about a use under No. 4.4 to assess its interference potential or identify the source of harmful interference. For this reason, an administration intending to use a frequency assignment to a transmitting station under No. 4.4 has to notify to the Bureau this frequency assignment, pursuant to Article 11 (Timmerman 2018), if possible prior to bringing it into use.

When notifying the use of frequency assignments to be operated under No. 4.4, the notifying Administration shall provide a confirmation that it has determined that these frequency assignments meet the conditions and that it has identified measures to avoid harmful interference and to immediately eliminate such in case of a complaint (ITU Rules of Procedure 2018).

Table 2 Typical frequency allocated for small satellites

Frequency band	Service	Symbol	Type of allocation
401–403 MHz	EESS (E-S)	EW	Primary
401–402 MHz	SOS (S-E)	ET	Primary
449.75–450.25 MHz	SOS (E-S) SRS (E-S)	ET EH	No. 5.286-only subject to No. 9.21 (other No. 4.4)
1215–1300 MHz	ESSS (active), SRS	Ex, EH	Nos. 5.330–5.335A protecting RNSS and RL
1427–1429 MHz	SOS (E-S)	ET	Primary
2025–2110 MHz	EESS (E-S, S-S) SOS (S-E, S-S) SRS (E-S, S-S)	EW ET EH	Primary
2200–2290 MHz	EESS (S-E, S-S) SOS (S-E, S-S) SRS (S-E, S-S)	EW ET EH	Primary
2290–2300 MHz	SRS (S-E) (deep space)	EH	Primary
8025–8400 MHz	EESS (S-E)	EW	Primary
8400–8500 MHz	FX, MOB SRS (S-E)	EH	Primary
8550–8650 MHz	(EESS), (SRS) (active)	Ex, EH	Primary
9300–9800 MHz	(EESS), (SRS) (active)	Ex, EH	Primary
9800–9900 MHz	(eess) (active) (srs) (active)	Ex EH	Secondary
10.6–10.7 GHz	(EESS), (SRS) (passive)	Ex, EH	Primary
13.25–13.75 GHz	(EESS), (SRS) (active)	Ex, EH	Primary
22.21–22.5 GHz	(EESS), (SRS) (passive)	Ex, EH	Primary
22.55–23.15 GHz	(ISS), (SRS) (E-S)	ES, EH	Primary (No. 5.338A)
23.6–24 GHz	(EESS), (SRS) (passive)	Ex, EH	Primary

Notes: *EESS* earth exploration-satellite service, *SOS* space operation service, *SRS* space research service, *EW* space station in the earth exploration-satellite service, *ET* space station in the space operation service, *EH* space research space station, *ES* station in the inter-satellite service

Amateur-satellite service (EA) can be used for small satellites. Amateur service is defined as a radiocommunication service for the purpose of self-training, intercommunication, and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest in RR 1.56. Amateur-satellite service is also defined as a radiocommunication service using space stations on earth satellites for the same purposes as those of the amateur service in RR 1.57. The frequency allocation for EA is shown in Table 3 (Timmerman 2018).

Table 3 Frequency allocations for amateur satellite service

Wavelength	Frequency band (MHz)	Applications
10 m	28,000–29,700 (primary)	This band is used primarily in conjunction with an input or output in the 144 MHz band
2 m	144–146 (primary) Satellite: 145.794–146	These bands are in heavy use by numerous amateur satellites for inputs and outputs
70 cm	435–438 (secondary) RR No. 5.282	
23 cm	1260–1270 (secondary) Earth-to-space only RR No. 5.282	These bands are used as alternatives to the 144 MHz and 435 MHz bands because of congestion
13 cm	2400–2450 (secondary) RR No. 5.282	
9 cm	3400–3410 (secondary) Regions 2 and 3 only RR No. 5.282	
5 cm	5650–5670 MHz (secondary) Earth-to-space only RR No. 5.282	These bands are used for experimental amateur satellites
	5830–5850 MHz (secondary) Space-to-earth only	
3 cm	10.45–10.5 GHz (secondary)	These bands are used for experimental amateur satellite communications
1.2 cm	24–24.05 GHz (primary)	
6 mm	47–47.2 GHz (primary)	These bands are used for experimental amateur satellites
4 mm	76–77.5 GHz (secondary)	
	77.5–78 GHz (primary)	
	78–81 GHz (secondary)	
	81.0–81.5 GHz (secondary) RR No. 5.561A	
2 mm	134–136 GHz (primary)	
	136–141 GHz (secondary)	
1 mm	241–248 GHz (secondary)	
	248–250 GHz (primary)	

6 International Frequency Coordination, Notification and Recording in the ITU Master International Frequency Register

An Administration shall send to the Bureau a general description of the network for the Advanced Publication Information (API) not earlier than 7 years and preferably not later than 2 years before the planned DBIU of the satellite network or system as shown in Fig. 3 (Matas 2016). A clear majority of the non-GSO small satellites operates in the frequency bands not falling under formal ART 9

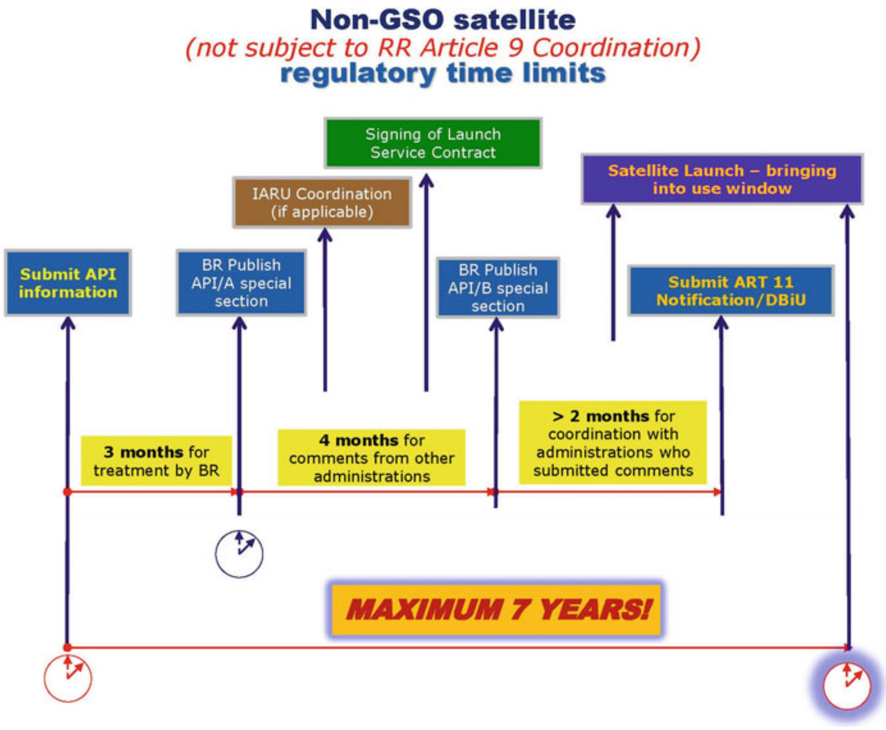

Fig. 3 Basic international frequency coordination procedure for small satellites

coordination procedure. Shortest regulatory limit for non-GSO not subject to coordination from API up to Notification/DBIU is no more than 9 months. The API is published after 3 months through International Frequency Information Circular (IFIC) at the ITU. Following to the publication of the API, comments from other administrations are accepted for 4 months. The international frequency coordination is then conducted with administrations who submitted any comments. The regulatory time-limit represents crucial information for bringing a satellite network into use and submitting notices for recording in the Master International Frequency Register (MIFR). The notified DBIU of any assignment to a space station of a satellite network shall be no later than 7 years following the receipt of the API.

Requirements for administrations to notify satellite frequency assignments and associated orbital positions for recording in the MIFR, declaration of bringing satellite into use, and protection of these assignments from harmful interference are the key pillars of the ITU RR international orbit/spectrum regime.

7 Conclusion

The current situation of the regulatory issue for small satellites was described. There is no regulatory definition for small satellites in ITU-R RR, but in general small satellites belong to non-GSO satellites because most of them are launched into the LEO. A non-GSO satellite system having a limited period of validity of not more than typically 3 years can be referred as SDM. As it is expected that the number of small-satellite missions will increase, the new frequency bands are allocated for non-GSO SDM systems, which corresponds to the relaxation of the regulation for small satellites because of the short development cycle and the SDM. Higher frequency bands will be used more for small-satellite missions in the future.

8 Cross-References

► Flight Software and Software-Driven Approaches to Small Satellite Networks
► High Altitude Platform Systems (HAPS) and Unmanned Aerial Vehicles (UAV) as an Alternative to Small Satellites
► Hosted Payload Packages as a Form of Small Satellite System
► Network Control Systems for Large-Scale Constellations
► Overview of Small Satellite Technology and Systems Design
► Power Systems for Small Satellites
► RF and Optical Communications for Small Satellites
► Small Satellite Antennas
► Small Satellite Constellations and End-of-Life Deorbit Considerations
► Small Satellites and Structural Design
► Stability, Pointing, and Orientation

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