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Current practice and procedures for notifying space networks currently applicable to nanosatellites and picosatellites

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R SA.2348-0

Current practice and procedures for notifying space networks currently applicable to nanosatellites and picosatellites

(2015)

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1 Introduction

This Report presents an overview of current practice for filing, notifying and deploying satellite networks, applicable to all satellites and on how they impact nanosatellites and picosatellites. Furthermore, this report presents an overview of the particular challenges in coordination between different communication systems which may arise as a result of the operational and technical characteristics of nanosatellites and picosatellites. Report ITU-R SA.2312 provides characteristics, definitions and spectrum requirements of nanosatellites and picosatellites as well as systems composed of such satellites.

2 Applicable regulatory procedures

2.1 Regulatory considerations

For all space radiocommunication services, since the use of a frequency assignment may cause harmful interference to a service of another administration, it is clear that the space station is required to be notified.

It should be noted that while on the one hand, some of the following discussions apply to nanosatellites and picosatellites as particular cases, on the other, some apply universally to all satellite networks or systems that are not subject to coordination of Article **9** of the Radio Regulations.

2.2 Requirement to notify and record frequency assignments to satellite networks or systems

Nanosatellites and picosatellites using frequency assignments, including those operating in the amateur-satellite service, fall into the category of a space radiocommunication service and are required to be notified under RR Article **11**. Prior to notification, in accordance with RR No. **9.1**, the notifying administration of such networks is required to send to the BR the advance publication information (API) not earlier than 7 years and preferably not later than 2 years before the date of bringing into use.

The requirement to notify frequency assignments to the BR is stated in No. **11.2** of the Radio Regulations, and the data to be submitted for the notification of the space station is specified in RR Appendix **4**.

There is an exception for stations in the amateur service and earth stations in the amateur-satellite service:

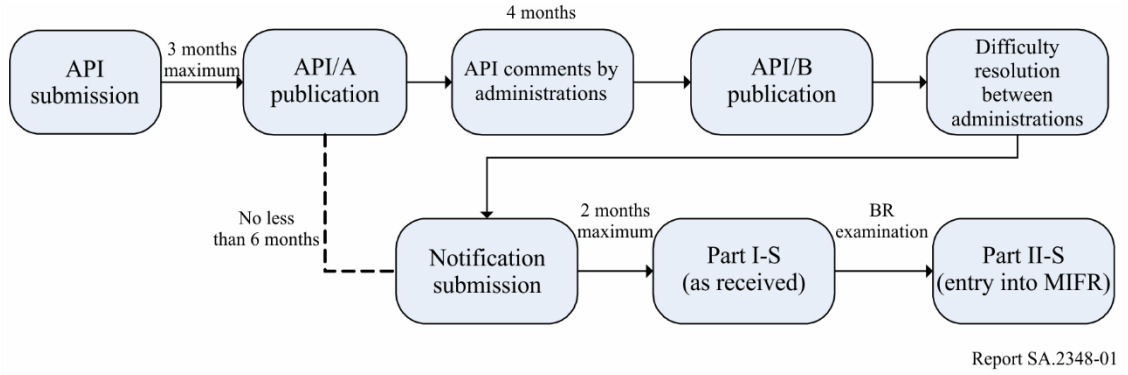
11.14 Frequency assignments to ship stations and to mobile stations of other services, to stations in the amateur service, to earth stations in the amateur-satellite service, and those to broadcasting stations in the high-frequency bands allocated to the broadcasting service between 5 900 kHz and 26 100 kHz which are subject to Article **12** shall not be notified under this Article.

It should be noted, however, that while stations in the amateur service as well as earth stations in the amateur-satellite service are not required to be notified, space stations in the amateur-satellite service are not exempt from the notification procedure under RR Article **11**.

Important events during the course of the regulatory procedure can be found in Fig. 1 below:

FIGURE 1

Important events for satellite networks/systems that are not subject to coordination



2.3 Requirement to resolve difficulties

Following the publication of the API/A special sections, in accordance to RR No. **9.3**, any administration who believes that there may be unacceptable interference caused to its existing or planned satellite networks or systems shall communicate its comments to the publishing administration.

If an administration considers that assignment(s) in the API has the potential to affect assignments under its responsibility, under No. **9.3** of the Radio Regulations, it has the right to comment within 4 months upon publication of the proposed assignments. Comments to API/A special sections should be sent to the other administration and a copy to the BR submitted using SpaceCom under Resolution **55 (Rev.WRC-12),** and published by the BR in API/B special sections.

Thereafter, both administrations shall endeavour to cooperate in joint efforts to resolve any difficulties, with the assistance of the BR if so requested by either of the parties, and shall exchange any additional relevant information that may be available.

A further consultation process is provided for under RR No. **11.28.1** in the event that the data submitted in the notification is different from the data submitted in the API (except for modifications concerning addition of a frequency band, direction of transmission or reference body).

2.4 Cessation of emissions

In general, space stations are required under RR No. **22.1** to be equipped with devices to ensure immediate cessation of their radio emissions by telecommand. For space stations in the amateur-satellite service, there is an additional requirement in RR No. **25.11** to ensure that sufficient earth command stations are established before launch to ensure that the emissions can be terminated immediately.

Although the above general requirements are laid out in the Radio Regulations, matters still arise as to how the BR could make sure that they are met. However, should the BR require a certification from the administration in the form of an attachment or should the BR develop a mandatory requirement to submit notification information of earth stations under Resolution **642 (WRC-79)**, this would place additional regulatory burden on satellite operators.

3 Current experience in notifying nanosatellites and picosatellites

The following sections summarize the experience of various relevant parties on the current practice and procedures for notifying nanosatellite and picosatellite networks.

3.1 Filing data analysis performed by the nanosatellite and picosatellite community

In order to define and analyse the characteristics of picosatellites and nanosatellites, an extensive database containing known satellites with masses less than 20 kg was set up. Satellites that were launched more than 10 years ago were neglected only to allow focus on current experiences. Most of the values were derived from information that was published online. Missing values were obtained by contacting the satellite system's developers. The database contains 293 satellite systems (393 satellites, as of August 2014) operated by 33 countries. Table 1 shows the increase of launches in the last ten years. From this table it is evident that nanosatellites and picosatellites are not a rare side issue anymore. Of these satellite systems only 107 have applied for an ITU API, whereas 43 have reached notification status (it should be noted that for some systems, the notification is still pending). The average time between the date when the ITU receives the API application and the actual launch is only 19.9 months. It is possible and desirable that the percentage of systems notified will increase due to the improving awareness of mandatory regulatory procedures.

TABLE 1

Nanosatellite and picosatellite launches and ITU filings

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Launches	6	8	3	22	14	7	16	20	14	26	92	113	**341**
API	2	3	1	11	1	3	8	4	3	8	38	25	**107**
Notification	2	3	1	4	-	2	7	2	2	2	14	4	**43**

The analysis along with feedback from nanosatellite and picosatellite developers showed that one part of the problem is the lack of knowledge and manpower on the part of the developers which are often universities which provide training in mission planning and operations to students. Often the universities and other academic institutions, etc. did not have previous space programs. Accordingly, the knowledge of mandatory procedures like frequency management is often insufficient. Abbreviations, terms and definitions are often unfamiliar to inexperienced university groups and to some administrations as well. More experienced universities, with the help of their administrations, tend to manage these difficulties once they know what needs to be done and how to meet regulatory deadlines. Table 2 presents the challenges that nanosatellite and picosatellite developers experience during the coordination process.

TABLE 2

Challenge Matrix

Source	Effect	Concern
Launch as piggyback	Orbital elements are not known until late in the satellite system design	More specific orbital elements may be needed for frequency coordination
No thrusters	Uncontrolled orbital changes during satellite operation, inability to hold exact orbital position	Movement of radiation pattern with time, (most of this class use omni-directional antennas)
Short development process	Specific spectral parameters desirable at the beginning of design process and can be hard to change later	Coordination too long; expense of changes if required by coordination
Low onboard power	Low RF transmission power	Still has potential to cause interference due to narrow bandwidth and resulting potentially high power spectral density
No or ineffective attitude control	Omni-directional antennas commonly used	Potential interference to other satellites in orbit and terrestrial systems

3.2 Radiocommunication Bureau

3.2.1 Experience in processing of filings under Articles 9 and/or 11 of the RR for non-GSO satellite systems that may be characterised as nanosatellite and picosatellite networks

The BR has so far encountered no difficulties in processing under Articles **9** and/or **11** of the RR for non-GSO satellite systems that may be characterised as nanosatellite and picosatellite networks, even though clarification was required for some cases. The most frequent cases of clarification requested by the BR involve incorrect use of frequency bands and emissions and missing mandatory RR Appendix **4** data elements.

Several administrations have expressed concerns to the BR that there are some commenting administrations who do not respond to requests to resolve difficulties, and have consequently requested the BR to assist in forwarding communications to the commenting administrations.

Without full participation in the commenting period (which is a typical situation with regard to all satellite network filings), these administrations and operators are left unsure if their nanosatellite or picosatellite will finally operate in a mutually interference free environment. However this does not prevent the notifying administration of the nanosatellite or picosatellite to submit the frequency assignments for notification and recording in the Master Register.

The BR accepts satellite network filings only when submitted by an administration. However, the BR has received some API filings directly from universities, without going through the administration. The BR has responded to universities that it is necessary to submit filings through the national administration. In some cases, nothing further was received from the administration or the university concerning that satellite.

As some of the administrations deploying nanosatellites and picosatellites are new to satellite filings, they may not be experienced in the procedure required for submitting satellite filings to the BR. It is therefore important to educate the administrations to be aware of their obligations to submit all satellite filings to the BR, as discussed in § 2 of this document.

Furthermore it is to be noted that an increased knowledge and awareness of the applicable regulatory procedures among nanosatellite and picosatellite operators is required. As an example of guidance on a domestic level, in the United States of America, the Federal Communications Commission issued a Public Notice with further information on "Guidance On Obtaining Licenses For Small Satellites"[1].

Although the ITU is providing comprehensive materials (seminar documents, workshop documents, online e-learning centre etc.) such as for example the "Guidance on Space Object Registration and Frequency Management for Small and Very Small Satellites" developed by the UN Office for Outer Space Affairs and the ITU[2] with a view to alleviating the difficulties experienced by operators, nonetheless difficulties may still exist due to the complexity of the procedures.

The BR encourages new satellite operators to become members of the ITU. The BR also encourages administrations to register these new satellite operators as operating agencies to be inserted into the Preface.

3.2.2 Publication numbers

With the background of the regulatory requirements outlined in section 2, the number of filings (API and notification) for NGSO satellite networks received by the BR since 2008 is shown below:

TABLE 3

API for NGSO satellite network filings received since 2008

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
NGSO (amateur-satellite service)	5	7	8	14	26	24
NGSO (not amateur-satellite service)	31	31	33	37	36	31
NGSO (all)	36	38	41	51	62	55

Looking at the numbers for API's, an increase in the number of APIs for the amateur-satellite service can be seen over the period 2008-2013. However, the numbers for other NGSO filings have actually been quite stable over the same years. Therefore, the growth in the overall number of API filings is largely due to filings for the amateur-satellite service.

TABLE 4

Notifications for NGSO satellite network filings received since 2008

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
NGSO (amateur-satellite service)	2	7	4	1	6	13
NGSO (not amateur-satellite service)	13	30	19	37	35	26
NGSO (all)	15	37	23	38	41	39

For notifications, some increase in number of notifications of NGSO for the amateur-satellite service in 2012 and 2013 can be seen. Despite this increase in the number of notifications, the number is still significantly less than the number of nanosatellites and picosatellites actually

[1] http://www.fcc.gov/document/guidance-obtaining-licenses-small-satellites.

[2] http://www.unoosa.org/pdf/misc/2015/Handout-on-Small-SatellitesE.pdf.

launched. As an illustration, 88 nanosatellites and picosatellites had been reported launched in 2013 as compared to 6 notified in 2012 and 13 notified in 2013.

There is no clear increase in the number of notification of other NGSO satellite networks over the period.

3.3 International Amateur Radio Union

3.3.1 Frequency coordination requests for amateur-satellite service space stations

Nanosatellite and picosatellite systems operating in amateur and amateur-satellite spectrum are not subject to the coordination procedure in Section II of Article **9** of the RR. To resolve any potential difficulties the process described at http://www.iaru.org/amateur-radio-satellite-frequency-coordination.html is used.

Frequency Coordination Requests for amateur-satellite service space stations are being made using the Amateur Satellite Frequency Coordination Request form. The form is available at: http://www.iaru.org/uploads/1/3/0/7/13073366/iaru_amateur_satellite_coordination_requestv34.doc.

During the last two years there has been a similar clear and significant growing interest for nanosatellite and picosatellite stations operating in the amateur-satellite service as indicated by the BR. For 2013 (situation as of 25 August 2013) 23 coordination requests have been completed, and 17 coordination requests are still in process.

The status of current applications can be seen at http://www.amsat.org.uk/iaru.

With the IARU coordination team meeting every two weeks, the typical processing time for coordination requests could be less than four weeks, provided that all necessary information is being made available.

3.3.2 Reference to Advance Publication Information

Characteristics of satellite networks, earth stations or radio astronomy stations are submitted as described in Annex 2 to RR Appendix **4**.

Nanosatellites and picosatellites are not exempted from the API notification to ITU. To remind the operators of the requirement that administrations have to complete the API notification, the IARU Amateur Satellite Frequency Coordination Request form has a field for filling in the API number as received from ITU when performing the notification. If the information is not available at the time of filing in the IARU form, it should be forwarded when available.

4 Identification of regulatory challenges

As described in Report ITU-R SA.2312, specifications and technical characteristics such as programmatic timeline, launches, deployment mechanisms, and manoeuvring and propulsion of nanosatellite and picosatellite missions may present difficulties in regulatory filing procedures and coordination of satellite systems. This chapter identifies the relevant regulatory aspects and the nanosatellite and picosatellite characteristics which may cause difficulties in the application of these aspects.

4.1 General regulatory aspects

Communications equipment used in nanosatellites and picosatellites is generally commercial off-the-shelf (COTS), with the ability to either set the frequency on build or set it prior to acceptance testing of the unit. The time within which this can and must be completed requires that the

frequencies for the operation of the satellite are known quite early in the program. Changing frequencies late in the program can have significant cost and schedule impacts.

Due to limitations in the availability of low cost technologies the vast majority of nanosatellites utilize frequency bands ranging from 100 MHz to 10 GHz.

Many nanosatellite and picosatellite operations to date have been non-conforming to the Radio Regulations and were thus operating on an unprotected basis and subject to not causing harmful interference (RR No. **4.4**). As an example, some administrations have used frequency bands allocated to the amateur or amateur-satellite service. However, the use of amateur or amateur-satellite service spectrum, under the amateur service, is only appropriate if the definition of the amateur service (RR No. **1.56**) is met: "A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest." A number of applications and operations in these frequency bands may not comply with all the requirements for amateur use and have therefore been authorized only for experimental operation.

Space research and space operation service bands have also been used by nanosatellites and picosatellites. Frequency bands allocated to the Earth exploration-satellite service, meteorological-satellite service and mobile-satellite service have been used for Earth-to-space links for the purpose of telecommand links. This is confirmed by observations of the Radiocommunication Bureau: the satellite networks identified as nanosatellites or picosatellites were filed under the following station classes and radiocommunication services:

a) Most of the nanosatellite and picosatellite networks are declared under the amateur-satellite service (class of station EA) using frequency bands where EA is a primary service or in the bands where EA is authorized to operate under RR No. **5.282**.

b) Some advanced nanosatellite and picosatellite networks with a camera or a sensor on board which require high speed data download are also operating in bands allocated to the space research service (class of station EH) and use frequency bands allocated to the amateur-satellite service for TT&C.

c) New generation nanosatellites and picosatellites with advanced sensors are also using frequency bands allocated to the land-mobile service (on a non-interference and no protection basis) or the Earth exploration-satellite service (class of station EW).

Also, some nanosatellites and picosatellites have used bands which are designated under footnote No. **5.150** of the Radio Regulations for use by industrial, scientific and medical (ISM) applications. It should be stressed that the definition of ISM does not include radiocommunication, and developers should be aware that nanosatellites and picosatellites do not fall under the definition of ISM applications.

While they cannot operate on the same unlicensed basis as ISM equipment, some administrations consider that they may be eligible for licensing on an experimental basis. No matter what service a nanosatellite or picosatellite frequency assignment operates under, the characteristics of the earth stations used with it need to be documented and the compatibility of its frequency assignments with stations in other radiocommunication services needs to be assessed. It should be recognized that, when frequency assignments that are not in conformance with the Radio Regulations are notified to the ITU, this should be done in accordance with Article **8.4** of the Radio Regulations.

As use of nanosatellite and picosatellite systems expands to support other applications, developers may seek to use additional frequency bands allocated to the appropriate service of operation. Interest in other frequency bands allocated to other radiocommunication services may result from mission specific requirements, availability of terrestrial infrastructure to support a particular mission, or other yet to be identified factors. As the relatively short development cycle and reduced

cost offers easier access to space to new communities (e.g. educational institutes), either through partnerships with civil space agencies or as independent satellite operators, the range of applications will undoubtedly expand. Along with this expansion, there may also be an expansion of the spectrum requirements, which would require further study.

With the continuing miniaturization of technologies and the expansion of innovative applications for nanosatellite and picosatellite systems, bandwidth and data rate requirements are also anticipated to increase over time.

As mentioned earlier, many of the nanosatellites and picosatellites attempt to make use of the very latest in technology. Sometimes, nanosatellites and picosatellites use radio frequency spectrum not in accordance with the Table of Frequency Allocations. Some administrations are considering the use of nanosatellites and picosatellites as experimental stations, however, the appropriateness of the use of this station type is debatable. Experimental stations are defined in RR Article **1** as follows:

> **1.98** *experimental station:* A *station* utilizing *radio waves* in experiments with a view to the development of science or technique.

From the definition, it is clear that experimental stations are meant to be used for experiments using radio waves, not communicating the result of experiments using radio waves. Furthermore, it has to be noted that this definition does not include amateur stations.

Considering the current number of nanosatellites and picosatellites being launched as well as planned, many of them could fit into the description of a station utilizing radio waves in experiments with a view to the development of science or technique. However, some of the nanosatellites and picosatellites being planned or already launched are for commercial use and should not be classified under as experimental stations for purposes of the Radio Regulations.

Specific regulations governing experimental stations are listed in Article **27** of the Radio Regulations:

> **27.5** § 4 1) All the general rules of the Constitution, the Convention and of these Regulations shall apply to experimental stations.

There are exemptions:

> **27.7** § 5 Where there is no risk of an experimental station causing harmful interference to a service of another country, the administration concerned may, if considered desirable, adopt different provisions from those contained in this Article.

However, all space stations, because they orbit the earth and pass over different countries, will in almost all cases present a risk of causing harmful interference to stations of another country.

4.2 Timeline

If the API process is not started early enough in the development cycle, the schedule of development for some picosatellite and nanosatellite programs may outpace the existing regulatory timelines associated with the existing satellite network notification process. However, this should not mean in any way that these programs should be allowed a reduction in the filing parameters to be provided and, in general, the requirement to coordinate with other frequency assignments sharing the frequency band. For example, given the requirements for publication of an API of 3 months, plus a commenting period of 4 months, and the additional time required for coordination with other administrations, it can be up to 7 months before a good understanding of the situation for the potential for harmful interference can be achieved. The notification can be submitted 6 months after the publication of the API/A special section, which could be up to 9 months after the date of submission of the API. It is therefore imperative that the API is submitted sufficiently early in the development cycle.

FIGURE 2

Typical Mission Design Timeline

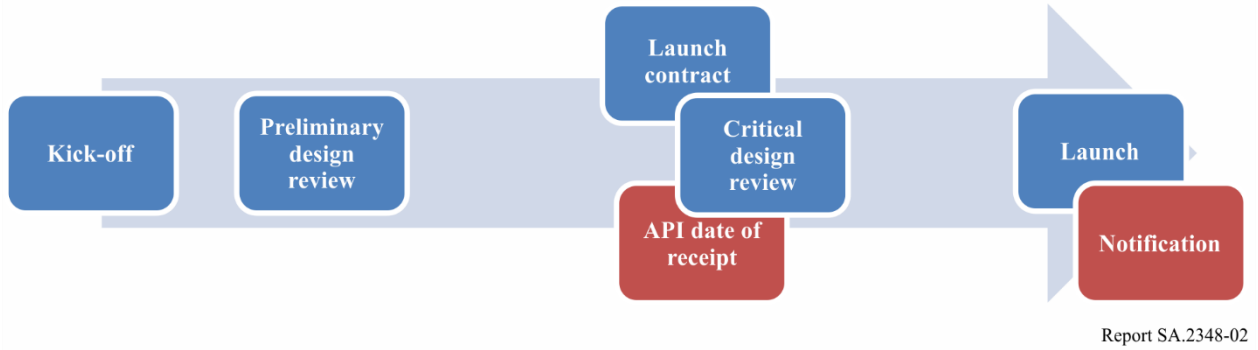


Figure 2 shows the typical timeline for a nanosatellite or picosatellite mission. The chart shown above is a simplified program plan, since the only milestones mentioned are the project kick-off, the preliminary design review (PDR), the critical design review (CDR) and the launch. The key points are when the launch contract is signed and when the important filing steps are undertaken.

The launch contract is usually signed about 12-18 months before launch. In the mission design timeline that is often (but not necessarily) the time when the CDR is held. In some missions, the operator will have final knowledge of the orbital parameters only when the launch contract is signed. Therefore it is important that the operator submit an API at the PDR stage, or at the latest, at the CDR rather than waiting for the launch contract to be signed.

4.3 Orbits, manoeuvring and propulsion

From an operator's perspective, current procedures are challenging for nanosatellites and picosatellites. The most specific parameters are often known only late in the design process, which can present challenges in the filing process.

Nanosatellite and picosatellites often have no or only have limited manoeuvring and propulsion capabilities. Some satellites can perform orbit manoeuvres using differential drag. This will begin to become more common in the coming years. For satellites without manoeuvring capabilities, orbital parameters cannot be maintained. Often, orbits are designed to decay to limit orbital debris after end of mission. For this reason, satellites without propulsion technically have multiple orbital planes (RR Appendix **4** item A.4.b.1), due to precession of the orbital plane as the orbit decays.

Among the crucial parameters in the regulatory procedures are the orbit parameters like apogee, perigee and inclination. For geostationary satellites and traditional satellites (especially Earth observation) these parameters can be mission defining as well. For picosatellites and nanosatellites, however, these values usually are of little importance. Since the mission objective of some of these satellites is some form of technology demonstration like attitude control, tether manoeuvers or simply on orbit verification of materials or electrical components, they are not bound to special orbits, as long as the earth station is reachable on a regular basis. Accordingly, nanosatellite and picosatellite operators are very open to different launch possibilities and flexible in both orbit altitude and inclination.

4.4 Spectrum management cost

Many nanosatellite and picosatellite programs are undertaken on programs with a relatively low budget, and by universities, government entities, or companies with minimal or no in-house expertise with spectrum licensing and management processes. A learning curve associated with understanding the requirements for and process of notification can result in delays and errors in filings.

With the exception of the amateur-satellite service, the costs associated with spectrum licensing consultation and licensing costs on national level themselves can be prohibitive. These costs do not end once the licences have been issued; ongoing flight programs incur appreciable costs in ensuring their spectrum is protected.

On the international level, it is also necessary to obtain and review International Frequency Information Circular (IFIC) publications and undertake relevant action if required.

It should be noted that for the amateur satellite service, the BR does not charge cost recovery fees for filing.

4.5 Frequency range

During the API phase, the frequency range is one of the parameters to be supplied as specified in RR Appendix **4**. During the notification, the assigned frequency and bandwidth must be supplied. In the past, the BR has received some filings with a very narrow frequency range in the API, such that at the notification stage, the assigned frequency and bandwidth do not fall within the frequency range submitted in the API, and resulting in a notification filing that is not receivable. The BR advises administrations to file for a broader frequency range at the API stage in order to avoid such getting into difficulties during the notification.

4.6 Carrier frequencies

In addition to the frequency range required in the API for NGSO satellite networks not subject to coordination, it is mandatory to also submit the carrier frequencies of the emissions. Many operators have expressed that it is difficult to provide the exact carrier frequencies during the API stage.

Considering the example of amateur-satellite service, normally the API has to be submitted to the BR before the operator can apply to IARU for the exact frequencies that they can use. Therefore it is not possible for the operator to know at the API stage what the exact carrier frequencies will be. In this case, the carrier frequency should be viewed as an estimate at the time of API, and this value can be modified and made definitive at the notification stage, as long as it fits within the frequency range submitted in the API.

4.7 Antenna radiation patterns

Many operators have difficulty providing the required co-polar antenna radiation patterns for the space and earth station antennas. Some have simply submitted the entire user manual for a commercial off the shelf antenna.

As nanosatellites and picosatellites have limited space for carrying a directional antenna, it is common for these satellites to carry antennas that are non-directional. Therefore it is possible for administrations to submit an antenna pattern “ND-SPACE” which indicates that it is a non-directional space station antenna.

The BR has consolidated some antenna patterns for space and earth station antennas commonly seen in API filings in the amateur satellite service and will be making them available for information at the BR’s website.

5 Conclusions

This report presents an overview of the current practice from various administrations, the BR, the IARU as well as nanosatellite and picosatellite developers in the application of ITU satellite filing rules and procedures (Articles **9** and **11** of the Radio Regulations) to nanosatellites and picosatellites.

It is found that one of the largest challenges in the current practice of filing satellites is the late knowledge of orbital parameters. It is noted that for the initiation of an API, the declaration of the orbital parameters is mandatory. This Report raises the issue of orbital parameters but does not fully propose a solution. Even when the required parameters are known, the schedule and pace at which many nanosatellite and picosatellite programs currently proceed may be more rapid than the regulatory timelines associated with the existing advance publication, coordination and notification process.

The minimum time required for the ITU filing procedures to process the API and corresponding comments before a network can be brought into use is typically about 8 months. In practice, the overall time needed to file a satellite network until entry into the Master International Frequency Register and launch can vary widely from one administration to another.

Furthermore, the time to modify the satellite system parameters to address comments on the API has to be taken into account as well. On occasion, nanosatellites and picosatellites have not completed the regulatory procedures before launch.

Additionally, more familiarity with the applicable rules and procedures is needed by some of those involved in developing and launching nanosatellites and picosatellites, for whom it may be the first time they have had to apply the filing procedures.

Annex 1

List of abbreviations

API – Advance publication information

CDR – Critical design review

COTS – Commercial-off-the-shelf

IARU – International Amateur Radio Union

IFIC – International Frequency Information Circular

ISM – Industrial, scientific and medical

PDR – Preliminary design review

TT&C – Telemetry, Tracking and tele-Command