

## Radio Frequency Provision and International Legal Protection of Frequency Assignments for Small Satellites

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**Abstract.** The article deals with the issues related to the allocation and assignment of radio frequencies, the procedure of their international legal protection, which should be performed by the head developer of a small satellite (SSL) during research, development and production of elements of space systems and complexes.

The analysis of radio frequency ranges of service and target radio lines of well-known Russian SSL is carried out. The data on the radio frequency bands of command and telemetric systems (CTS) and the target information radio line (TIRL) of small satellites developed by Russian companies are presented.

It is noted that the radio frequency bands currently used for the SSL operation impose rather strict restrictions on the construction of a space segment and/or cluster on their basis, which will inevitably have a negative impact on the possibilities of their extended use. Proposed are alternative frequency bands and radio link designs to meet the requirements of the Table of Distribution of Frequency Bands between radio services of the Russian Federation and the Radio Regulations.

**Keywords:** small satellite, space platform, frequency range, Radio Regulations

## Introduction

The number of launched small spacecraft (SSC) [1] of the mini-, micro- and nano- (CubeSat) class [2-5] today reaches several dozens per year, and the demand for them is constantly growing. During the creation of the SSC, the issues of radio-frequency support for the functioning of radio-electronic equipment (REE) and its electromagnetic compatibility, are not always timely and fully solved by developers today due to their complexity and volume. In this regard, those issues become more relevant.

Consider the regulatory framework for the allocation and assignment of radio frequencies, as well as the radio frequency bands used today for the operation of service and target radio links of the SSC.

## Legal framework for frequency assignments

All issues related to the allocation and assignment of radio frequencies are regulated by the Federal Law "On Communications" [6] and a number of other legal documents. The law defines the permissive procedure for access to the radio frequency spectrum. The right to use the radio frequency spectrum is granted through the official allocation of radio frequency bands and the assignment of radio frequencies or radio frequency channels. Use of the radio frequency spectrum without permission is not permitted.

An application for the allocation of radio frequency bands should be prepared and submitted during the planning of implementation, development, production, modernization, research, development and experimental work for a period of more than 6 months [7].

The allocation of radio frequency bands is carried out by the State Commission on Radio Frequencies (SCRF) in accordance with the procedure for reviewing materials and making decisions on the allocation of radio frequency bands, rescheduling and amending them [7].

It should be noted that the application for the allocation of radio frequency bands for the development of REE of space complexes and/or systems is submitted by the applicant (lead contractor) no later than the stage of completion of the preliminary or outline technical design [7].

The assignment of a radio frequency or radio frequency channel for civilian electronic equipment is carried out by the federal executive body in the field of

communications on the basis of applications, taking into account the results of the radio-frequency examination service, of the possibility of using the declared electronic equipment and its electromagnetic compatibility with existing and planned electronic equipment (expert examination of the electromagnetic compatibility). Consideration of materials and decision making by the State Committee for Radio Frequencies on the assignment (designation) of radio frequencies or radio frequency channels within the allocated radio frequency bands is carried out in accordance with the approved Examination Procedure [8].

The SCRF decision on the assignment (designation) of radio frequencies is not always positive [9, 10], and sometimes it contains significant limitations.

As an example: the applicants were denied the allocation of the radio frequency band 1610.115-1621.185 MHz, 2483.773-2494.845 MHz (space-to-space) for using the GLOBALSTAR ASP satellite modem, intended for installation on the AIST-2D SSC in 2015 [9] and the radio frequency bands 432-433 MHz for the REE of the space complex 197KS of the Aist-2 SSC in 2016 [10] on the basis of negative conclusions about the possibility of allocating radio frequency bands submitted by the members of the state commission on radio frequencies.

At the same time, the SCRF allowed the use of the radio frequency band 8025-8393 MHz (space-to-Earth) by the earth station of the monitoring and control system TsPOI-SAMARA (radio frequency band of shared use by REE of any purpose), provided that no claims are made for possible unintentional interference from governmental and special purpose REE and development of technical measures to ensure electromagnetic compatibility with military REE and coordination with the Ministry of Defense of Russia [10, 12].

In accordance with Article 23 of the Federal Law "On Communications" and Decree of the Government of the Russian Federation dated December 21, 2011 No. 1049-34 SCRF, a Table for the Allocation of Radio Frequency Bands between the Radio Services of the Russian Federation [13] has been developed. The Table is the main document governing the distribution and conditions of use of radio frequency bands in the Russian Federation by citizens of the Russian Federation and Russian legal entities who order, develop or import electronic equipment into the territory of the Russian Federation, as well as plan the use and operation of electronic equipment.

The procedure for using the 144-146 MHz and 435-438 MHz frequencies of the amateur-satellite service (AMSAT) in the Russian Federation is determined by the Decision of the State Committee for Radio Frequencies "On the Allocation of Radio Frequency Bands for Radio-Electronic Means of the Amateur and Amateur Satellite Services" dated 07.15.2010 No. 10-07-01, taking into account the changes approved by the Decision of the State Committee for Radio Frequencies dated 04.16.2018 No. 18-45-02, in accordance with which it is not required to issue separate Decisions of the State Committee for Radio Frequencies and permits for the use of frequencies, subject to the fulfillment of technical and operational restrictions (limitation of the power of radio lines, radiation classes and radio frequency bands, and others.).

The international legal protection of frequency assignments for radio electronic means is carried out in order to ensure the national interests of the Russian Federation in the international regulation of the use of the radio frequency spectrum, international recognition of frequency assignments for radio electronic means, as well as to create favorable conditions for the development and use of radio electronic means, various radio services in the Russian Federation [14].

In the Russian Federation, the procedure of international legal protection of the assignment (designation) of radio frequencies or radio frequency channels, including work related to the declaration, coordination and registration with the International Telecommunication Union of such radio frequencies or radio frequency channels and the corresponding positions of satellites in geostationary orbit or corresponding characteristics of satellites in other orbits, is defined in the following rules introduced by the Decree of the Government of the Russian Federation of November 14, 2014 No. 1194 [14]:

- "Rules for conducting work on international legal protection of the assignment (designation) of radio frequencies or radio frequency channels in the Russian Federation";

- "Rules for the use in the territory of the Russian Federation of satellite communications networks under the jurisdiction of foreign states".

Thus, in the Russian Federation, issues related to the assignment and designation of radio frequencies, the procedure for their international legal protection, which should be carried out by the lead contractor in carrying out scientific research, development and production of elements of space systems and SSC complexes, are normatively fixed and strictly regulated.

## Characteristics of the service and target SSC radio links

To analyze the radio-frequency ranges of the service and target radio links of the SSC, let us consider the radio frequencies used in the space-to-Earth and Earth-to-space directions as their main parameter.

Table 1 shows the radio frequency bands of the command-telemetry system (CTS), as well as the radio links for the exchange of target information (RLTI) of small spacecraft designed to solve the following problems:

- operational optical-electronic surveillance of water areas, water bodies of the earth's surface, various emergencies, as well as for operational monitoring of the state of engineering facilities: AIST-2D [9, 10, 15], Kanopus-V [16, 17];

- scientific experiments: Universitetskiy-Tatyana-2 [18], Yubileiny-2 [19, 20], Chibis-M (AI) [10, 21, 22], Baumanets-2 [10], SamSat-218 [10, 23].

SSC for communication, relay, and radio surveillance tasks for detecting, identifying, determining the location and course of movement of ships, rivercraft, and aircraft by the radiation of their radio electronic equipment were not considered in this table.

In accordance with the above data, the frequency range of the CTS operation is within the primary distribution of the AMSAT of 435–438 MHz and 144–146 MHz [13, 24–26]. Note that the frequency range 144-146 MHz is quite heavily loaded, since amateur and airborne mobile communications are also in this range [13, 26].

The amateur, radar services, as well as the Earth exploration-satellite service (EESS) (active) are also in the 435–438 MHz frequency range [13, 26].

The radio frequency band 435–438 MHz can be used by AMSAT stations on a secondary basis, provided that interference with other services is eliminated [13, 24, 25]. This radio frequency band is used by military and special purpose radio electronic equipment, which may impose restrictions on its usage and create unacceptable interference for the operation of other radio links in these frequency bands, so protection against interference when using this range cannot be guaranteed.

Note that the SamSat-218 SSC radio link developed by the SSAU is not compatible in the direction of transmission with the rest of the given radio links.

As an alternative, the use of radio frequency bands 267-273 MHz (space-to-Earth) specially allocated for the Space Operation Service (SOS) can be considered [13, 24, 25].

Table 1 - the Main characteristics of the SSC radio lines [34]

Organization	SSC (launch date)	Bus	RLTI (space-to-Earth) MHz	CTS (space-to-Earth) (Earth-to-space) MHz
JSC "RSS" Progress	AIST-2D (28.04.2016)	AIST-2 [15]	8025-8393 [10, 12]	435.3065-435.3235 435.3556-435.3735/ 145.831-145.849 145.861-145.879 [9,10]
JSC VNIIEM Corporation	<i>Kanopus-V</i> (22.07.2012)	Kanopus-V [17]	8066.3-8189.7 8258.3-8381.7 [16]	2205.44-2224.06/ 2031.52-2048.23 [16]
JSC VNIIEM Corporation	Universitetskiy – Tatyana-2 (17.09.2009)	UMP-70 [18]	1.7 GHz, [18, 31, 32]	435.3-435.6/ 145.8-146.0 [18, 31, 32]
JSC ISS	Yubileiny-2 (28.07.2012)	Yubileiny [19, 20]	2.4 GHz, [19, 20, 33]	435.3-435.6/ 145.8-146.0 [19, 20, 33]
SRI RAS	Chibis-M (30.10.2011)	Chibis-M [21]	2.27 GHz, [21]	435.3-435.6/ 145.8-146.0 [21]
SRI RAS	Chibis-AI (project)	Chibis-M [21]	2269.5-2270.5, 8395-8400 [10, 22]	435.2065-435.2235 435.3065-435.3235/ 145.804-145.816 145.849-145.861 [10, 22]
MSTU named after Bauman	Baumanets-2 (28.11.2017)	—	8195-8255 94980-95020 [10]	435.395-435.435/ 145.815-145.835 and 145.845-145.865 [10]
SSAU	SamSat-218 (28.04.2016)	CubeSat (3U).	—	145.85-145.89/ 435.59-435.61 [10, 23]

Thus, in the 145-146 MHz and 435-438 MHz radio frequency bands, the sources of interference will increase over time, and, as a result, the electromagnetic environment in the area of operation of ground-based control and reception of information from the SSC will only worsen over time. It is necessary to work out an option of switching to a different frequency range.

As an option, the 258-261 MHz (Earth-to-space) radio frequency bands can be used to build a CTS, while consumers should not cause harmful interference to systems in the mobile-satellite service [13, 24, 25].

The frequency bands used by the RLTI are assigned in accordance with the requirements of the table of the distribution of radio frequency bands of the Russian Federation (given in table 1) and do not require changes.

It should be noted as an unfortunate choice of 2.4 GHz by the Information Satellite Systems JSC for its SSC [19, 20], because the radio frequency band 2300-2450 MHz [13, 24, 25] is the radio frequency band of primary use of radio electronic equipment intended for the needs of state administration, including presidential communications, government communications, the needs of the country's defense, state security and the rule of law, and for fixed, mobile, amateur, radar services. Also, the frequencies 2300-2400 MHz and 2500-2690 MHz or parts of these bands are identified for use by administrations wishing to implement the International Mobile Telecommunications (IMT) in accordance with Resolution 223 (Rev. WRC-15) [13, 26].

In addition, the frequency of 2.4 GHz (Earth-to-space) on a secondary basis [13, 24, 25] can only be used for space communications, subject to the development and coordination with the Russian Ministry of Defense of organizational and technical measures to ensure electromagnetic compatibility with REE of special and military purpose. The above conditions for the use of the 2.4 GHz frequency impose serious restrictions on the possibility of obtaining permission and using this frequency in the construction of space systems and complexes of spacecraft.

## Conclusions and suggestions

The issues of radio-frequency support for the functioning of the space complex (system) based on the SSC are normatively rather strictly regulated, but the developers are not fully implemented. Currently used radio frequency bands impose rather stringent restrictions for the construction of the space segments and/or clusters based on the SSC, which will inevitably negatively affect their expanded use. The predicted further increase in the number of launched SSCs will complicate the functioning of command-telemetry systems in the (space-to-Earth) and (Earth-to-space) directions, as well as to the loading of the radio links for the exchange of target information (RLTI) in the (space-to-Earth) direction.

Unfortunately, it should be noted that at present there is practically no necessary coordination and interaction regarding the use of the radio frequency band between civil and military radio services.

Under these conditions, it seems preferable to use the following radio frequency bands:

- 258 ... 261 MHz (Earth-to-space) can be used to build the command and telemetry system of the SSC, while consumers should not cause harmful interference to the systems of mobile and mobile satellite services operating in this frequency band, or require protection from them, or limit the use and development of such systems [13, 24, 25];

- 267 ... 273 MHz (space-to-Earth) is allocated for the space operation service, taking into account that this is the band of radio frequencies of primary use for REE intended for the needs of public administration, including presidential communications, government communications, the needs of the country's defense, state security and law enforcement [13, 24, 25] with restrictions of 5.254, 5.257 [26] and 95, 125, 127 [13];

- 2025 ... 2110 MHz used by the space research service (Earth-to-space, space-to-space), the space exploitation service (Earth-to-space, space-to-space), the satellite earth exploration service (Earth-to-space, space-to-space) with the restrictions 5.392 [26] and 193, 200, 211, 219, 221, 222, 223, 224, 225 [13];

- 2200 ... 2290 MHz used by the space research service (space-to-space, space-to-Earth), the space exploitation service (space-to-space, space-to-Earth), the satellite earth exploration service (space to space, space-to-Earth) [13];

- 8025 ... 8400 MHz for the Earth exploration-satellite service (space-to-Earth), meteorological satellite (Earth-to-space), and fixed satellite (Earth-to-space) taking into account the limitation of 5.462A of the radio frequency distribution table [13].

At the same time, it is necessary to consider abandoning the 8400-8500 MHz space research (space-to-Earth) service radio frequency band, designed for the needs of government, including presidential communications, government communications, the needs of the country's defense, state security and law enforcement [13].

Implementation of control and reception of information from spacecraft of satellite communication systems related to the fixed satellite and mobile satellite services (SSSS Turaiya [27], SPSS Iridium [27], multifunctional system of personal satellite communications Gonets-D1M [28, 30], the advanced low-orbit satellite communications system "Gonets-WEB" [29, 30]) will be extremely complicated due to the unresolved issues of frequency assignments and will require amendments to the relevant regulatory documents.

The recommended option for constructing electronic equipment and ensuring the electromagnetic compatibility of this radio electronic equipment for space systems (complexes) based on the SSC is a combined control system for receiving telemetry and information from onboard payloads operating in the radio frequency band allocated for solving a particular objective in accordance with the table of the distribution of radio frequency bands between the radio services of the Russian Federation.

It is proposed to use the radio frequency ranges [13, 26]: 2025-2110 MHz (space-to-space, Earth-to-space) to solve the objectives of operational optical-electronic surveillance of water areas, water bodies of the earth's

surface, emergency situations of various nature, as well as for operational monitoring of the condition of engineering objects, 7190-7250 MHz (Earth-to-space), 8025-8400 MHz (space-to-Earth), 25.5-27.0 GHz (space-to-Earth), 37.5-38.0 GHz (space-to-Earth on a secondary basis), 40.0-40.5 GHz (Earth-to-space), 65.0-66.0 GHz.

For scientific experiments, it is advisable to use the radio frequency ranges [13, 26]: 2025-2100 MHz (space-to-space, Earth-to-space), 7145-7190 MHz (deep space, Earth-to-space), 7190-7235 MHz (Near space, Earth-cosmos), 8400-8450 MHz (Deep space, space-to-Earth), 8450-8500 MHz (space-to-Earth), 22.55-23.15 (Earth-to-space), 31.8-32.3 GHz (Far space, space-to-Earth), 34.2-34.7 GHz (deep space, Earth-to-space), 37.0-38.0 GHz (space-to-Earth), 40.0-40.5 GHz (Earth-to-space), 65.0-66.0 GHz, 94.0-94.1 GHz.

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