



Small satellite TT&C allocations below 1 GHz: outcome of ITU WRC-19

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Abstract

As hundreds of new small satellites are being launched each year, the RF spectrum for satellite communication becomes increasingly occupied. The International Telecommunication Union recognized this problem at World Radiocommunication Conference 2015 (WRC-15) and invited study groups to investigate the utilization of frequency allocations. The studies followed a three-step approach: first, the TT&C spectrum requirements of small satellites, being a new class of satellites, were assessed. Second, the utilization of existing TT&C frequency allocations and their potential to incorporate the future number of satellites was studied. Third, the study groups investigated new potential TT&C frequency allocations in the frequency ranges 150.05–174 MHz and 400.15–420 MHz. The studies were completed for WRC-19. This paper presents the results of the study groups. A study of the spectrum requirements of small satellites has been completed. The required spectrum for TT&C was estimated to be less than 2.5 MHz for downlink and less than 1 MHz for uplink. Consequently, the study groups conducted sharing studies in various bands which yield that no new allocations are suitable for small satellite TT&C on a co-channel sharing basis. However, regulatory measures are proposed that in the study groups' view will satisfy the small satellite developers' needs. The paper will summarize the regulatory measures taken after WRC-19 along with a personal appraisal of the author.

Keywords Frequency coordination · ITU · WRC · Small satellites · Short duration missions · TT&C

1 Introduction

After the Cubesat design standard was introduced in 1999 and first satellites of this new class have been launched in the subsequent years, small satellites have become increasingly popular in the past 5 years. Today not only universities use small satellite platforms for education and technology demonstration but also commercial operators started to develop and deploy satellites with masses of typically less than 50 kg and reasonably short development times. Currently hundreds of new satellites are launched into space per year. The increase of launches was recognized by the International Telecommunication Union (ITU) which is responsible for the coordination of the shared use of frequencies. As the first Cubesats were mainly launched by new entrants into the space sector, mandatory regulatory procedures like

frequency coordination were omitted or underestimated by the developers. Additionally, the new developers complained that the existing regulatory procedures are too complicated and time consuming for satellites with short development times. The ITU, therefore, decided at the WRC-12 to study the characteristics of picosatellites and nanosatellites and their current practice in filing satellites to the ITU. The studies were concluded in 2015 with two reports on the characteristics [1] and current filing practice [2]. In these reports, it was identified that the characteristics that define small satellites (low mass, small dimensions, low power, etc.) are not relevant from a frequency coordination perspective and that the short development times are still long enough to properly file the systems to the ITU. As a result, it was stated that small satellites fit into the regulatory framework (the ITU Radio Regulations [3]) and that nothing needs to be changed. However, it was found that the bare number of new satellites, irrespective of their size and mass, poses potential harm to existing satellite systems in the respective frequency allocations. The ITU, therefore, decided at WRC-15 to study the spectrum needs of small satellites and the

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potential necessity of new frequency allocations for their TT&C (Tracking, telemetry & control).

As mentioned before, the characterizing properties of small satellites (mass, dimensions) do not have significance for frequency coordination and another characteristic had to be found that has relevance for coordination. This characteristic was found in the typically short mission lifetime which can be directly linked to the “period of validity” of ITU filing procedures. For this reason, ITU study groups refer to “satellites with short duration missions” rather than “small satellites” when this class of satellites is discussed. The mission lifetime (or period of validity) is defined as not more than 3 years. Obviously, this opens the floor for large satellite systems as well; however, it is not expected that large, expensive satellites will be deployed for a mission lifetime of only three years.

The most utilized and at the same time, most crowded bands for short-duration missions have so far been bands below 1 GHz. In these bands, the satellites typically conduct their TT&C. Payload data downlink is usually transferred in higher bands (S band or X band). Therefore, the studies were focused on bands below 1 GHz that are available for satellite TT&C, which is defined as “Space Operation Service” (SOS) in ITU terminology.

The following chapters will review the studies that have been conducted to investigate potential new allocations for small satellites. Chapter 2 summarizes the technical work that was done by the ITU study group. The author was part of this study group; however, it has to be noted that great parts of the study work have been done by other authors. Study group contributions are submitted to the ITU on behalf of national administrations; therefore, there are no publications available that allow reference to a certain author. The author of this paper, therefore, wants to express that the studies that are described in chapter 2 are only partly the original work of the author. These parts are identified accordingly. The rest of the chapter summarizes the study group work for which the references [4–6] are recommended for further reading. Chapter 3 describes the conclusions of the work of the study group, while chapter 4 presents the outcome of ITU WRC-19.

2 Study work

The work that was assigned to one of the ITU study groups (ITU-R Working Party 7B) was defined in ITU-R Resolution 659 (WRC-15) [7] as follows: The study group shall study between WRC-15 and WRC-19

1. the spectrum requirements of satellites with mission durations for TT&C.

2. the suitability of existing allocations to the space operation service in the frequency range below 1 GHz, taking into account the current use.

If studies of the current TT&C allocations indicate that small satellite requirements cannot be met, they shall further study

3. sharing and compatibility studies to consider possible new allocations or an upgrade of the existing allocations for small satellite TT&C within the frequency ranges 150.05–174 MHz and 400.15–420 MHz.

2.1 Spectrum requirements of satellites with short-duration missions for TT&C

To analyze if existing frequency allocations for TT&C are sufficient to accommodate satellites with short-duration missions, an investigation of the actual spectrum requirements of these satellites was required. The spectrum requirements were assessed based on the report that was published in 2015 [1]. A new report [4] was drafted as the new term “short-duration missions” needed to be included and some parameters had to be corrected or further specified. This report defines typical characteristics of short-duration missions, e.g. a bandwidth of up to 25 kHz, orbits between 300 and 1000 km and satellite EIRP (equivalent isotropically radiated power) of not more than 3 dBW. It should be noted that these reports do not incorporate minimum (worst-case) values that would be needed for a positive link margin, but rather aim to include all kinds of small satellites that have been launched in the past. Accordingly, these values have not been optimized for sharing studies, which was later found to be not favorable for further analyses.

The spectrum needs were derived by simulating 300 satellite–ground station pairs and their interference potential against each other. The number was set to 300 pairs as this value was expected to represent the number of co-existing short duration mission systems that will need to use spectrum for TT&C below 1 GHz. The ground stations (Fig. 1) and the satellites were distributed based on the current distribution. Two studies (one of which was conducted by the author [8]) yield that the required spectrum for the space-to-Earth direction (Downlink) is less than 2.5 MHz, while the required spectrum for the Earth-to-space direction (Uplink) is less than 1 MHz. The evaluation of existing SOS (TT&C) allocations was based on these estimates. The results are summarized in a report [5].

2.2 Suitability of existing SOS (TT&C) allocations below 1 GHz

The existing frequency allocations that can be used for TT&C below 1 GHz are summarized in Table 1. The table



Fig. 1 Distribution of ground stations as defined in the study group work [8]

Table 1 Existing allocations to the Space Operation Service below 1 GHz

| Frequency band (MHz) | Status | Direction | Allocated bandwidth (MHz) | Special obligations/constraints |
|----------------------|-----------|----------------|---------------------------|---------------------------------|
| 30.005–30.010 | Primary | N/A | 0.005 | Satellite identification |
| 137–138 | Primary | Space-to-Earth | 1.0 | – |
| 148–149.9 | Primary | Earth-to-space | 1.9 | RR No. 9.21 applies |
| 267–272 | Secondary | Space-to-Earth | 5 | RR No. 9.21 applies, NATO band |
| 272–273 | Primary | Space-to-Earth | 1 | NATO band |
| 400.15–401 | Secondary | Space-to-Earth | 0.85 | |
| 401–402 | Primary | Space-to-Earth | 1 | |
| 449.75–450.25 | Primary | Earth-to-space | 0.5 | RR No. 9.21 |

shows the allocated bands, the protection status, the direction of the allocation, the bandwidth and if special obligations apply. The status is either primary or secondary. Primary allocations are protected against secondary services and only have to coordinate with other primary services. Accordingly, primary services are preferable. The direction depicts if the band can be used for uplink or downlink.

The 30.005–30.010 MHz slot can be neglected as it is very small and not feasible for small satellite antenna sizes. The remaining allocations sum up to 2.4 MHz in the uplink and to 8.85 MHz for the downlink. In general, these numbers should be sufficient to incorporate short-duration missions; however, special obligations exist that make the use of the bands not possible or at least difficult. Radio Regulations

Article No. 9.21 states that “before an administration notifies to the [ITU] Bureau or brings into use a frequency assignment [...], it shall effect coordination, as required, with other administrations [...] for any station of a service for which the requirement to seek the agreement of other administrations is included in a footnote to the Table of Frequency Allocations referring to this provision” [3]. This statement is as difficult to understand as it is dangerous for potential users of the band; all potential users must search agreement from other administrations before the band can be used. The other administrations can refuse agreement without a reason. Consequently, even if sharing would be technically feasible, the sharing can be prohibited, e.g. for political reasons. For this reason, ITU-R Resolution 659 states that “that the existing

allocations to the space operation service below 1 GHz, where No. 9.21 applies, are not suitable". In the space-to-Earth direction, the portions 267–273 MHz are part of a NATO harmonized band and coordination needs agreement of military administrations, at least in NATO countries.

At the same time as developers and operators of satellites with short-duration missions tried to identify potential new frequency allocations, other operators of "traditional" satellites sought to limit the use of certain bands around 400 MHz to limit the interference potential for data collecting systems operating in these bands. More details can be found in ITU-R Resolution 765 [9] and the final acts of WRC-19 which put power limits in these bands [10].

Irrespective of the parallel developments mentioned in the paragraph above, the studies on potential new allocations for TT&C yielded that, in general, the existing downlink allocations are sufficient, while uplink allocations are not feasible, given the existing constraints.

2.3 Potential new frequency allocations for SOS (TT&C)

ITU-R Resolution 659 states that if the existing SOS allocations are not sufficient to accommodate satellites with short-duration missions, other frequency ranges between 150.05 and 174 MHz as well as between 400.15 and 420 MHz shall be studied. Obviously, these bands have incumbent services that use the bands, either globally or regionally harmonized. Tables 2 and 3 summarize the incumbent services for each band portion. Capitalized service names refer to primary status while uncapitalized refers to secondary status. Footnotes in form 5.XXX add special obligations to many of the band portions but are not included in this paper.

Sharing studies on each of the bands 150–174 MHz and 400.15–420 MHz have been done and the results are sobering. Almost all bands have been identified as not feasible for co-channel sharing. The sharing analyses have been based on characteristics of the incumbent services and their protection criteria as well as the short-duration missions' parameters. A report of more than 150 pages [6] was written, and the results clearly state that co-channel sharing is not possible. Only in the band that is currently mainly used by radiosonde systems (403–406 MHz), the studies show two different results. Some administrations state that sharing with radiosondes would be possible under certain circumstances and proposed a new allocation in these bands.

2.4 Upgrade of existing SOS allocations

During the ITU study group meetings between 2015 and 2019, it was proposed to change the constraints of existing TT&C bands instead of finding new allocations. As stated above, the space-to-Earth bands were considered to

be sufficient, while the Earth-to-space bands are blocked for short-duration missions by Radio Regulations Article No. 9.21. As a simple solution, it was proposed to delete the reference to Article No. 9.21. Most study group participants agreed that this would solve the problem and render the need for new allocations unnecessary.

3 Short-duration missions at WRC-19

The study group and a subsequent conference preparatory meeting (CPM) proposed three possible methods to solve the agenda item on short-duration missions at WRC-19:

- a) Method A proposes to not change anything, since some administrations thought that changes are not needed for short duration missions.
- b) Methods B1 and B2 propose a new Earth-to-space allocation either between 403 and 404 MHz or 404 and 405 MHz. These bands are the before-mentioned radiosonde bands and it was expected that this proposal will be difficult for many administrations.
- c) Method C was to use 137–138 MHz for the downlink and make available 148–149.9 MHz for the uplink by removing the footnote regarding Article No. 9.21 and with that remove the dependency on the goodwill of other administrations.

While Method C was seen to be the most probable solution by most members of the ITU study groups, it was highlighted that the compatibility of 137–138 MHz with aeronautical mobile (route) services in the adjacent band below 137 MHz was not yet studied. Therefore, strong opposition was expected at WRC-19. The reason why effects to adjacent bands were not studied is that 137–138 MHz already was an existing allocation for space operation service and as such the need for new compatibility studies was not seen.

Besides the studies on TT&C allocations for short-duration missions, late in the study cycle a modification to the regulatory procedure to file short-duration missions was proposed. In this proposal, it was suggested that the time that is needed to register a short-duration mission with the ITU can be significantly reduced, if the system is only short term and consists of less than ten satellites. This proposal was linked with the studies on potential new TT&C allocations during WRC-19.

As a result, the following changes were agreed upon during the conference:

- The frequency band 137.025–138 MHz shall be used for short-duration missions, if they do not cause harmful interference and if they do not claim protection from

Table 2 Frequency allocation table in the frequency range 150.05–174.00 MHz [3]

| Allocation to services | | |
|--|---|--|
| Region 1 | Region 2 | Region 3 |
| 150.05–153 FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY 5.149 | 150.05–154 FIXED MOBILE 5.225 | 150.05–154 FIXED MOBILE 5.225 |
| 153–154 FIXED MOBILE except aeronautical mobile (R) meteorological aids | | |
| 154–156.4875 FIXED MOBILE except aeronautical mobile (R) 5.225A 5.226 | 154–156.4875 FIXED MOBILE 5.226 | 154–156.4875 FIXED MOBILE 5.225A 5.226 |
| 156.4875–156.5625 MARITIME MOBILE (distress and calling via DSC) 5.111 5.226 5.227 | 156.4875–156.5625 MARITIME MOBILE (distress and calling via DSC) 5.111 5.226 5.227 | 156.4875–156.5625 MARITIME MOBILE (distress and calling via DSC) 5.111 5.226 5.227 |
| 156.5625–156.7625 FIXED MOBILE except aeronautical mobile (R) 5.226 | 156.5625–156.7625 FIXED MOBILE 5.226 | 156.5625–156.7625 FIXED MOBILE 5.226 |
| 156.7625–156.7875 MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.228 | 156.7625–156.7875 MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) 5.111 5.226 5.228 | 156.7625–156.7875 MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.228 |
| 156.7875–156.8125 MARITIME MOBILE (distress and calling) 5.111 5.226 | 156.7875–156.8125 MARITIME MOBILE (distress and calling) 5.111 5.226 | 156.7875–156.8125 MARITIME MOBILE (distress and calling) 5.111 5.226 |
| 156.8125–156.8375 MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.228 | 156.8125–156.8375 MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) 5.111 5.226 5.228 | 156.8125–156.8375 MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.228 |
| 156.8375–161.9375 FIXED MOBILE except aeronautical mobile 5.226 | 156.8375–161.9375 FIXED MOBILE 5.226 | 156.8375–161.9375 FIXED MOBILE 5.226 |
| 161.9375–161.9625 FIXED MOBILE except aeronautical mobile Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 | 161.9375–161.9625 FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 | 161.9375–161.9625 FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 |
| 161.9625–161.9875 FIXED MOBILE except aeronautical mobile Mobile-satellite (Earth-to-space) 5.228F | 161.9625–161.9875 AERONAUTICAL MOBILE (OR) MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) | 161.9625–161.9875 MARITIME MOBILE Aeronautical mobile (OR) 5.228E Mobile-satellite (Earth-to-space) 5.228F |
| 161.9875–162.0125 FIXED MOBILE except aeronautical mobile Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 5.229 | 161.9875–162.0125 FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 | 161.9875–162.0125 FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 |
| 162.0125–162.0375 FIXED MOBILE except aeronautical mobile Mobile-satellite (Earth-to-space) 5.228F | 162.0125–162.0375 AERONAUTICAL MOBILE (OR) MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) | 162.0125–162.0375 MARITIME MOBILE AERONAUTICAL MOBILE (OR) 5.228E Mobile-satellite (Earth-to-space) 5.228F |

Table 2 (continued)

| Allocation to services | | |
|-----------------------------------|---------------------|---------------------|
| Region 1 | Region 2 | Region 3 |
| 162.0375–174 | 162.0375–174 | 162.0375–174 |
| FIXED | FIXED | FIXED |
| MOBILE except aeronautical mobile | MOBILE | MOBILE |
| 5.226 5.229 | 5.226 5.229 5.231 | 5.226 5.229 5.231 |

Table 3 Frequency allocation table in the frequency range 400.15–420 MHz [3]

| Allocation to services | |
|------------------------|---|
| 400.15–401 | METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208A 5.208B 5.209 SPACE RESEARCH (space-to-Earth) 5.263 Space operation (space-to-Earth) 5.262 5.264 |
| 401–402 | METEOROLOGICAL AIDS SPACE OPERATION (space-to-Earth) EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Fixed Mobile except aeronautical mobile |
| 402–403 | METEOROLOGICAL AIDS EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Fixed Mobile except aeronautical mobile |
| 403–406 | METEOROLOGICAL AIDS Fixed Mobile except aeronautical mobile 5.265 |
| 406–406.1 | MOBILE-SATELLITE (Earth-to-space) 5.265 5.266 5.267 |
| 406.1–410 | FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY 5.149 5.265 |
| 410–420 | FIXED MOBILE except aeronautical mobile SPACE RESEARCH (space-to-space) 5.268 |

other services. In this case, simplified filing procedures apply.

- For most countries, Art. 9.21 was removed from the uplink band 148–149.9 MHz. Only for some countries (Armenia, Azerbaijan, Belarus, China, Korea (Rep. of), Cuba, Russian Federation, India, Iran (Islamic Republic of), Japan, Kazakhstan, Malaysia, Uzbekistan, Kyrgyzstan, Thailand and Viet Nam) this was linked to power limits and a 1% duty cycle that shall not be exceeded at the country borders.

4 Conclusion and outlook

This chapter is intended to provide the author's conclusions of the work and might diverge from other opinions. Although it could be claimed that with these changes new opportunities have opened for small satellites, the benefits in the author's opinion are marginal. The only changes that have been made are in VHF bands. Even though losses are lower in VHF than in UHF, VHF bands are not desired by many developers because of the bad ratio between antenna size and satellite size. Moreover, there are already existing TT&C downlink allocations in 400.15–402 MHz that might be more favorable than the 137–138 MHz allocation.

The 148–149.9 MHz uplink band has been opened for short-duration missions; however, it is disputable whether this band will be favored by small satellite developers. From a developer's perspective, the results of WRC-19 for new TT&C allocations are not satisfying. New allocations in UHF would have been favored.

The main reason why new allocations have not been opened is because of the way that the compatibility studies are conducted. When potential new allocations were discussed during WRC-15, it was defined that new allocations are only possible if co-channel sharing is possible. This definition of sharing study does not incorporate the fact that some of the bands between 150.05–174 MHz and 400.14–420 MHz are not as heavily used as in recent years. Additionally, the recommendations that were applied to investigate sharing feasibility are at least debatable and, in many cases, outdated. It is believed that small satellites/short-duration missions could have been accommodated in some UHF ranges, if studies could have been oriented at the realistic use instead of co-channel studies which are based on partly outdated recommendations.

Given this personal judgment, it is debatable how future will change the regulatory landscape for small satellites. It is most likely that small satellite developers will move to higher bands in the absence of satisfying solutions in UHF. The few usable allocations will become more crowded and interferences are expected to increase. In preparation for the next WRC in 2023, no agenda items on new allocations below 1 GHz are scheduled.

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