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| **Coordination and analysis of GSO satellite networks** | |

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Summary

The purpose of this document is to provide an overview of the different criteria used to evaluate the compatibility of geostationary satellite networks, identifying those with which coordination is required and introducing methods which may be used to facilitate coordination and obtain an interference-free operational scenario. It includes the latest updates from WRC-12 and from ongoing studies towards WRC-15.

The document also considers the case in which a notifying administration may submit the characteristics of its satellite network to ITU, illustrating some aspects that may be taken into account when organizing the filing in order to optimize the outcome, while representing the actual scenario as accurately as possible.

At all times, the issues will be approached from both a conceptual and practical standpoint, with some detail but without losing sight of the overall objective.

# 1 Identifying coordination requirements

Appendix 5 to the Radio Regulations indicates the technical criteria to be used in each case, including:

• Regulatory provisions setting out the forms of coordination

• Sharing scenarios associated with different cases

• Frequency band and Region

• Services

• Threshold/condition

• Calculation method

Tables 5-1, 5-2 and Annex 1 to Appendix 5 present a detailed description of the different cases.

In the case of coordination under RR No. 9.7 between GSO networks, the following criteria apply.

## 1.1 Coordination arc

This involves identifying satellite networks with frequency overlap operating in the same direction of transmission inside a window of  7,  8, 12, or 16 degrees (depending on the frequency band, service and region) from the nominal orbital longitude of the incoming network.

This method is utilized by the Bureau to identify the coordination requirements for satellite networks in the unplanned FSS and BSS services, as well as the meteorological satellite service, and their respective associated frequency assignments for space operations, in the specific frequency bands shown in Appendix 5.

A summary of different cases is presented in the table below.

|  |  |
| --- | --- |
| Frequency Band, Region | Services and applicable coordination arc |
| 1) 3 400-4 200 MHz  5 725-5 850 MHz (Region 1)  5 850-6 725 MHz  7 025-7 075 MHz | any network in the **FSS** and any associated space operation functions with a space station within an orbital arc of **± 8°** of the nominal orbital position of a proposed network in the **FSS.** |
| 2) 10.95-11.2 GHz  11.45‑11.7 GHz   11.7-12.2 GHz (Region 2)  12.2-12.5 GHz (Region 3)  12.5‑12.75 GHz (Regions 1 and 3)  12.7‑12.75 GHz (Region 2)   13.75‑14.5 GHz | any network in the **FSS or BSS, not subject to a Plan**, and any associated space operation functions with a space station within an orbital arc of **± 7°** of the nominal orbital position of a proposed network in the **FSS or BSS, not subject to a Plan.** |
| 3) 17.7‑20.2 GHz (Regions 2 and 3) 17.3‑20.2 GHz (Region 1) and 27.5‑30 GHz | any network in the **FSS** and any associated space operation functions with a space station within an orbital arc of **± 8°** of the nominal orbital position of a proposed network in the **FSS**. |
| 4) 17.3‑17.7 GHz  (Regions 1 and 2)  5) 17.7‑17.8 GHz ( No. 5.517 applies in Region 2) | any network in the **FSS** and any associated space operation functions with a space station within an orbital arc of **± 8°** of the nominal orbital position of a proposed network in the **BSS, or vice-versa.** |
| 6) 18.0-18.3 GHz (Region 2)  18.1‑18.4 GHz  (Regions 1 and 3) | any network in the **FSS** or **meteorological-satellite** service and any associated space operation functions with a space station within an orbital arc of **± 8°** of the nominal orbital position of a proposed network in the **FSS** or **meteorological-satellite** service. |
| 6bis) 21.4 - 22 GHz  (Regions 1 and 3) | any network in the **BSS** service and any associated space operation functions with a space station within an orbital arc of **±12°** of the nominal orbital position of a proposed network in the **BSS.**  See also Resolutions 553 and 554 (WRC-12). |
| 7) Bands above 17.3 GHz, except those defined in § 3) and 6) | any network in the **FSS** and any associated  space operation functions with a space station within  an orbital arc of **± 8°** of the nominal orbital position of a proposed network in the **FSS** (see also Resolution 901 (Rev.WRC‑07)). |
| 8) Bands above 17.3 GHz, except those defined in § 4), 5) and 6) bis | any network in the **FSS or BSS, not subject to a Plan**, and any associated space operation functions with a space station within an orbital arc of **± 16°** of the nominal orbital position of a proposed network in the **FSS or BSS not subject to a Plan, except FSS with respect to FSS** (see also Resolution 901 (Rev.WRC‑07)). |

In application of Resolution 901 (WRC-03), and in the light of ITU-R studies and decisions of future conferences, it will be possible to extend coordination arc values to other frequency bands and services.

## 1.2 The criterion 🛆T/T > 6 % (Appendix 8 to the Radio Regulations )

This method is used by BR to establish coordination requirements under No. 9.7 of the Radio Regulations for any other scenario in which the coordination arc criterion is not applied. It is also utilized by administrations when requesting BR to include or exclude their names or satellite networks in the coordination process under No. 9.41 of the Radio Regulations.

It involves defining a threshold beyond which harmful interference may occur. If that threshold is not exceeded, compatibility between the related frequency assignments is ensured.

The method is based on measurement of the increase in noise temperature at the receiver due to interference.

It is very important to note that in the case where 🛆T/T > 6 %, further analysis is needed to be sure that the assignments under study are not compatible**.** This is because the🛆T/T criterion does not take into account the wanted signal and the interfering spectrum shape (for example). Other methods, for example, using the *C*/*I* criterion, are more accurate.

The figures below describe the general concept, different possible scenarios and the applicable equations.

General concept

🛆T/T Case I : Frequency overlap is co-directional

🛆T/T Case II: Frequency overlap is in opposite direction of Tx. (inter-satellite)

ηS = Direction from interfering satellite S’ of wanted satellite S δS = Direction from wanted satellite S of interfering satellite S’

**2 *C*/*I* criterion**

Even though this method is not used in the Radio Regulations to establish coordination requirements, it is applied by the Bureau during examination of notifications of satellite networks in order to perform a more detailed examination of the probability of harmful interference in accordance with RR No. 11.32A when this is requested by the notifying administration. This criterion is often used by satellite operators during coordination meetings.

Examination by BR is based on methodology and protection criteria defined by Recommendations ITU-R S.740 and ITU-R S.741-2 and the associated Rules of Procedure of the Radio Regulations Board, or those informed by common agreement between administrations.

Among other data, it takes into account the wanted signal (level and type of carrier modulation), interfering signal (level and spectrum shape) and overlapped bandwidth, making it more accurate than the simple I/N or 🛆T/T criteria presented previously, particularly when inter-network sharing analysis requires compliance with certain quality and availability objectives.

The following figure represents the typical carrier levels and degradation with reference to the receiver noise power (N) caused by the interference.

Without going into the sequence of the *C*/*I* analysis, which is presented in separate documents, some characteristics and advantages are described here, as mentioned in the preceding paragraphs, in order to provide some guidelines to the reader.

The general concept is expressed by:

*C*/*I* = *C*/*N* + K

where:

K = protection ratio (generally, between 12.2 and 14 dB, depending on the carrier type)

*C*/*N* = result of the link budget (considering objectives like S/N or BER, availability, and so on)

*C*/*I* = protection required to ensure compatibility between networks

The result of the above equation can be improved by considering the bandwidth advantage factor, which is the ratio of the interfering carrier power contained in the desired signal bandwidth to the total interfering carrier power.

In principle, the analysis can be performed assuming clear sky conditions and then considering additional factors like propagation loss (Recommendations ITU-R P.676-8 and ITU-R SF.766 may be very useful).

Feeder and de-pointing losses may also be considered in order to obtain more realistic results.

When **multiple interference sources** are considered, it can be expressed in terms of *C*/*I* as:

# 3 Study Group contributions

New proposals or updates to the current interference criteria and associated regulatory procedures are constantly studied by ITU-R Study Group 4, in particular Working Party 4A.

In preparation for WRC-12, under Agenda item 7, analyses have been carried out with a view to proposing:

a) a reduction in the size of the coordination arc for the 6/4 GHz band and of the 10/11/12/14 GHz band;

b) mechanisms to ensure adequate protection of satellite networks outside the coordination arc or with different coverages in the 6/4 GHz and 10/11/12/14 GHz bands, with a reasonable range of technical parameters, without the need for bilateral coordination.

WRC-12 reduced the coordination arc in these bands somewhat but did not decide on mechanisms to make coordination unnecessary outside the coordination arc or for networks with different coverages.

In Resolution 756 (WRC-12), the World Radiocommunication Conference resolved to invite ITU‑R:

1 to carry out studies to examine the effectiveness and appropriateness of the current criterion (ΔT/T > 6%) used in the application of No. **9.41** and consider any other possible alternatives (including the alternatives outlined in Annexes 1 and 2 to this Resolution, such as pfd masks or *C*/*I*, as appropriate), for the bands referred to in *recognizing e)*;

2 to study whether additional reductions in the coordination arcs in RR Appendix 5 (**Rev.WRC-12**) are appropriate for the 6/4 GHz and 14/10/11/12 GHz frequency bands, and whether it is appropriate to reduce the coordination arc in the 30/20 GHz band.

The Director of BR is instructed to include the results of these studies in his Report to WRC-15.

Ongoing studies are considering:

a) which frequency bands would be subject to the new coordination criterion;

b) whether the new threshold would be based on single-entry or multiple sources of interference;

c) whether to apply different criteria for each combination of interfering and interfered-with carrier type, noting that Recommendation ITU-R S.741 may not take into account some modulation-coding schemes currently in use, as well as the difficulties of identifying them using the current RR Appendix 4 parameters;

d) the possibility of defining a reasonable range of technical parameters (e.g. uplink G/T, downlink noise temperature, antenna sizes);

e) identifying provisions and situations where the new criteria should be applied.

Contributions based on homogenous networks, separation of two and three degrees, possible levels of permissible interference and associated loss of energy margin and capacity, are also under study.

The background to discussions, relevant technical and operational studies, and various other details, may be found under Annex 13 to the report of the Working Party 4A Chairman.

The progress with regard to the aforementioned proposals warrants close follow-up in the forthcoming meetings, as the outcome of discussions may require modifications to the current criteria and procedures explained in previous sections.

# 4 Methods of facilitating coordination and sharing scenarios between GSO networks

At this stage of the text, having introduced the methods of identifying satellite networks requiring coordination and the criteria applied to determine the level of interference to be mitigated, the remaining question is what to do to make the networks mutually compatible.

A few of the methods that are generally used to achieve the desired compatibility and may be helpful to the reader are presented below, it being understood that there are many others. Recommendation ITU-R SM.1132-2 provides further information on this subject.

In principle, the choice of the method used will depend on the stage of the satellite project.

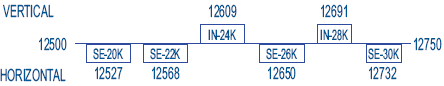
At an early stage of a spacecraft’s design, it is possible to implement modifications to aspects related to space station beams and associated antenna gain contours.

On the other hand, if the satellite has already been manufactured, the choices will be limited to the ground segment and possible modifications may be focused on the Earth stations (for example).

Typical methods are as follows:

## 4.1 Frequency separation (either band segmentation or channelling plan )

Satellite 1

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## Satellite 2

## 4.2 Polarization advantage

## 4.3 Improving antenna system spatial discrimination

• Redesign or specification of antenna gain contours, spill-off and service areas associated with satellite beams

• Modification of antenna diameters in the ground segment

• Improvements to earth station radiation pattern

Space segment

The figure below shows how two or more different areas can be isolated by using zone or spot beams rather than a hemispheric one. In this case, if coordination with other networks is more difficult in a certain area, it does not impact on the rest of the service area. It will also allow frequency re-use and improve the use of the spectrum-orbit resource.

Ground segment

The following figures show the impact, in terms of reduction of interference to neighbouring satellites, if the antenna radiation pattern associated with the earth stations is modified:



The following diagram shows how the main lobe is modified when the antenna diameter is changed, with a reduction in interference of approximately 5 dB to a satellite located at one degree of separation while increasing the antenna diameter from 1.2 to 13 metres.

## 4.4 Modifying orbital separation between adjacent satellites

The following example illustrates an interference reduction of 4.8 dB if two satellites are separated by between two and three degrees.

Assuming D/λ = 100 ; ES Antenna Patterns REC 465-5 / REC 580-6

Interference reduction:

If - Ii = 25.log (φi / φf)

where φf: minimum final separation between satellites

φi: minimum initial separation between satellites

Scenario 1

Ө1n-Ө2n = 2˚ 🡪 Nominal orbital separation

ΔӨ1 = ΔӨ2 = ± 0.1˚ 🡪 E-W station keeping

Scenario 2

Ө1n-Ө2n = 3˚

ΔӨ1 = ΔӨ2 = ± 0.1˚

Interference reduction with respect to scenario 1

If - Ii = 25.log (1.8 / 2.8 ) = –4.8 dB

Even though this seems to be a good solution in some cases from the technical point of view, it must be emphasized that today, in most of the classic services and frequency bands like FSS in the C and Ku bands, the impact of shifting a satellite’s orbital location will cause an increment in interference (measured in terms of 🛆T/T) to certain satellite networks sharing the same frequency band and located in the direction towards which the first satellite is shifted.

From the regulatory point of view, according to the Rules of Procedure of the Radio Regulation Board (§ 2), relating to No.9.27 and considering the current high level of satellite congestion in the geostationary orbit for the above cases, such an increment in interference will generate new or modified coordination requirements. This is not always desirable and should be evaluated with caution.

## 4.5 Reorganizing the distribution of different carrier types

This basically involves the following steps:

– Identifying different types of carrier such as:

– TT&C;

– Analogue TV/FM;

– Digital data.

– Considering their diversity characteristics in terms of BW, maximum power and spectral density distribution.

– Grouping them in the frequency domain, taking into account the distribution of similar carriers used by neighbouring satellites.

– Off-axis e.i.r.p. masks associated with type of carrier and frequency bands, as well as operational restrictions or relaxations, may be agreed during the coordination process.

## 4.6 Use of advanced modulation/FEC technologies (e.g. DVB-S2), signal coding and processing techniques (such as spread spectrum or CDMA).

## 4.7 Re-engineering the link budget, including modulation-FEC, power density levels, and adjusting performance and availability objectives in order to tolerate higher levels of interference.

# 5 Optimizing a filing for submission to ITU

## 5.1 The current situation

Thus far we have shown how coordination requirements are identified, a number of interference criteria for evaluating compatibility between GSO satellite networks, and possible methods of facilitating coordination and sharing scenarios between GSO networks.

The entire process set out in the Radio Regulations with the principal goal of recording frequency assignments in the MIFR and obtaining international recognition, protection, and associated rights and obligations, is described in RR Articles 9 and 11. It comprises three stages:

• Advance publication of information;

• Coordination; and

• Notification.

The Radiocommunications Bureau has developed several software tools to implement these procedures including submission of notices.

Each notice has a structure for compiling the full set of characteristics of frequency assignments associated with the subject satellite network, either for coordination or notification submissions.

These characteristics include:

• Space station beam

• Service area

• Frequency band

• Power density levels

• Associated Earth station.

These characteristics and some others are organized in **groups** of frequency assignments, which are then used by administrations to coordinate and finally to notify the satellite network to ITU.

Each administration is free to choose the manner in which it organizes the full set of frequency assignments in groups. However, the aim of every notification is as far as possible to obtain favourable findings with a view to recording the respective assignments in the MIFR. This section is intended to provide the reader with some guidelines in order to make the process more efficient, which may be measured by the number of frequency assignments recorded in the MIFR in relation to the total number of frequency assignments submitted, depending on the structure used to organize the notice.

While acknowledging the freedom of administrations to decide how to group assignments in coordination or notification requests, it should be noted that, if they are submitted in a such a way that the result of the examination at group level is coherent with the actual use of the assignments, not only will this maximize the chances of their being recorded without the need to apply RR No. 11.41, it will also promote more efficient future use of the orbit-spectrum resource by other satellite networks as a result of the improved information available in the MIFR.

With that said, it is also important to understand that during the coordination stage there is a need for greater flexibility in terms of the combinations of characteristics studied, which will be defined only following completion of coordination with other networks and once the final requirements to be satisfied by the satellite project are known.

It is therefore expected that a coordination request could involve a more general approach rather than a specific and precise set of assignments submitted for notification.

## 5.2 Aspects to consider in the organization of the notice

The characteristics mentioned in § 5.1 above may be used to optimize a filing, as follows.

a) Space station beam and service area

During the analysis with respect to neighbouring satellite networks, it may be found that this operation is more feasible in one area than in another. The service areas could therefore be split into different groups or even different beams. This will ensure that the frequency assignments associated with the most favourable service area will be recorded successfully, while the others can continue coordination or may be modified later.

b) Frequency band

The same concept can be used for frequency planning. The segment of a frequency band which has been successfully coordinated could be organized in a different group from the other segment for which coordination has not been completed. Otherwise, the full range of frequency assignments would result in unfavourable findings owing to a small set of assignments within a single group associated with the entire frequency band.

c) Power density levels

Depending on the emission, several power density levels may be found to satisfy the requirements of the desired link budget. Some of these carriers may have been coordinated successfully, while others still require further progress. In this case, again, it is advisable to split the group, taking into account the diversity of power levels.

A typical example might be to separate space operation carriers from digital data or TV-FM analogue carriers, for which maximum power levels could differ by several dBW.

d) Associated Earth station

With respect to earth stations, as shown in § 4 above, the antenna diameter will affect its main lobe and its capacity to interfere with or be affected by interference from closely separated satellites. Consequently, the compatibility scenario for an earth station using a 9 metre antenna will be more favourable than the one associated with a 1.2 metre antenna, for example. Again, the use of different groups depending on the antenna size will ensure that assignments are duly recorded, without being affected by the “worst case” within the same group.

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