REPORT ITU-R M.1185-1

Technical aspects of coordination among mobile satellite systems using the geostationary satellite orbit

(Question ITU-R 83/8)

(1990-2006)

1 Introduction

1.1 Objectives and scope

Before an administration notifies the Radiocommunication Bureau (BR) of new or revised frequency assignments for a mobile satellite system, it must first comply with its obligations under the advance publication and coordination procedures specified in Article 9 of the Radio Regulations (RR). The objective of these procedures is to ensure that the proposed assignments will not cause or suffer unacceptable interference with existing and planned space and terrestrial systems.

The RR Article 9 procedures prescribe the sequence of interactions between the applicant administration and affected administrations and with BR; they do not address the technical aspects of coordination. The purpose of the present Report is to deal with the technical aspects of coordination by describing those system design and operational parameters that can be adjusted to achieve the objective of the RR Article 9 procedures and by illustrating how these parameters might be adjusted in practical cases.

The discussion and the illustrations are confined to systems designed to use the mobile-satellite service (MSS) allocations in the 1 525-1 559 MHz (downlink) and 1 626.5-1 660.5 MHz (uplink) bands and do not deal with the coordination of such systems with terrestrial stations..

1.2 Summary of RR Article 9 – Advance publication and coordination procedures

The advance publication procedure described in Section I of RR Article 9 takes place before the formal coordination procedure described in Section II of that Article. It requires the administration proposing new or revised frequency assignments for a satellite system to supply BR with the information about the network characteristics listed in RR Appendix 4 so that it can be published for review and comment by any administration as to the effect on its space radiocommunication services.

The RR stipulate that if such comments are received within a period of four months from publication, the administration proposing the new or revised assignments is obligated first to explore all possible means of reducing interference to acceptable levels by adjusting the design and deployment of the proposed system. If no such means can be found, it may then seek the cooperation of the potentially affected administrations in finding a solution.

The coordination procedure and the conditions under which it must be applied are given in Section II of RR Article 9. The principal condition is that coordination is required if interference from the new system would increase the equivalent noise temperature T in another satellite system beyond an amount ΔT under worst-case conditions defined in RR Appendix 8. The interference power threshold which triggers coordination under RR Appendix 8 may be lower than that considered acceptable by a particular service provider. Hence, it may still not be necessary to modify the design and operating characteristics of that system to accommodate reduction of the received interference.

If system adjustments are necessary in order to meet the criteria for acceptable interference agreed to by the administrations involved, the available options are then identified during the coordination process. They include relocation of one or more space stations or changing the emissions, frequency usage, or other technical and operational characteristics of the systems as described in § 2.

1.3 Importance of satellite system development stage

Before discussing how adjustment of the design and operating parameters of the systems involved can reduce intersystem interference, it should be noted that the extent to which the parameters of a given system can be adjusted depends on the specific characteristics of that system and on its stage of development. Four stages in the development of a satellite system can be distinguished:

– *Initial concept and design*: The design plan for the system has proceeded to the point where preferred values of the technical parameters required by RR Appendix 4, including orbital location and frequency, have been decided.

– *Implementation*: This stage includes the detailed design and construction of the satellite and its associated earth stations and ends with the launch of the satellite. Several years are normally required.

– *Operation*: At this stage, the satellite has been built, launched, and is operating from a particular orbital location with its associated Earth segment.

– *Second generation or replacement satellite system*: During the useful life of the first-generation satellite in a system, a replacement satellite is normally designed and constructed. By the time it is launched, an extensive array of earth stations is in place, and a number of associated transmission parameters may have to be retained in order to preserve continuity of service.

The greatest opportunity for adjusting any of the design and operating parameters exists during the initial concept and design stage. Often, an applicant's network may already have entered its implementation stage before the coordination procedure has reached the point where agreements can be made. The other potentially affected systems may be in any of the four stages.

Systems in the implementation stage may still afford opportunities for the adjustment of their planned design and operating parameters to reduce interference, but these opportunities diminish as the launch date approaches.

Systems in the operation stage have many parameters that are either fixed or can only be changed at significant cost. Nevertheless, some systems are designed to have built-in flexibility during operation such as beam repointing, transponder gain settings, programmable passbands, etc. In general, mobile satellite systems have significant flexibility to resolve interference problems through adjustments to frequency plans, as a minimum, regardless of where the system is in the development cycle from concept to operation.

Replacement satellites for an existing system have some of the flexibilities of the preceding three stages. Although a number of transmission parameters may have to be retained, the opportunity does exist to incorporate design changes to reduce potential interference. Adjustments to earth stations are practical only over a substantial period of time, in conjunction with schedules for maintenance, refurbishment, or replacement or termination of obsolete services.

1.4 Link inhomogeneities in mobile-satellite systems

The adjustment of system parameters to meet interference criteria may be made more complex when there are large inhomogeneities among the MSS links to be considered. For example, between links operating with Earth-coverage satellite antennas and links operating with spot beam satellite antennas.

In addition to these link inhomogeneities, mobile satellite systems may have to accommodate a range of RF carriers reflecting differences in message type, message data rate or baseband bandwidth, modulation method, multiple access technique and other parameters.

2 Coordination parameters

The system design and operating parameters to be considered in the course of coordination include virtually any parameter that may affect the interference between systems. The parameters reviewed in this section are as follows:

– criteria for permissible and accepted interference;
– transponder frequency and polarization plans;
– carrier frequency plans;
– satellite antenna coverage and service areas;
– earth station antenna discrimination;
– earth station power control;
– transponder gains and satellite e.i.r.p.;
– satellite positions;
– operational schedule.

2.1 Criteria for permissible and accepted interference

Two types of interference levels are defined in the RR for use in the coordination of frequency assignments between administrations. “Permissible interference” is that which complies with quantitative interference and sharing criteria contained in the RR or in ITU-R Recommendations or in special agreements as provided for in the RR. “Accepted interference” is interference at a higher level than that defined as permissible interference and which has been agreed upon between two or more administrations without prejudice to other administrations. Report ITU-R M.1179 presents a method for determining permissible levels of interference.

When used as the “interference objectives” in overall system planning, the interference criteria of interest apply to the total or aggregate interference from all sources, both intrasystem and intersystem. However, since coordination is usually carried out on a bilateral basis, the interference criteria used in coordination is for single entries of intersystem interference. The single-entry criteria should be chosen so that, if they are met individually by each interfering system, the total interference will not exceed the levels specified by the aggregate interference criteria for intersystem interference.

In the absence of ITU-R Recommendations specifying single-entry interference criteria for permissible intersystem interference, each administration in a coordination action is free to specify the levels of permissible and accepted interference it believes are necessary to protect the channels of its system. However, these levels may be subject to reconsideration during the coordination. Coordination will be facilitated by flexibility in two areas: the ratio of the aggregate to the single-entry level of interference, and the difference between the criteria for accepted interference and the criteria for permissible interference.

It may be possible to relax the single-entry interference criteria in situations where the assumed ratio of aggregate-to-single-entry interference power is conservatively high, as long as the aggregate interference criteria are met.

In the case of accepted versus permissible interference, the actual links in some systems may provide larger performance margins than the representative links upon which permissible interference is based. This could enable later acceptance of higher aggregate levels of interference while still meeting link performance objectives. However, peak capacities or link margins in power-limited satellites are reduced as aggregate interference is increased. Acceptance of relaxed criteria for aggregate interference power is of course strictly a matter to be decided during coordination and should not be relied upon when planning systems prior to coordination.

2.2 Transponder frequency and polarization plan

The transponder frequency and polarization plan for a satellite system describes the passbands of the transponders and the polarization of the receiving and transmitting antennas to which each of the transponders is, or can be, connected. The transponder passbands may partially overlap (e.g. for non-overlapping beams in a multibeam satellite). In principle, transponder frequency/polarization plans can be chosen to facilitate both intrasystem and intersystem frequency reuse.

In practice, however, there is no regular or standard transponder frequency/polarization plan for the MSS. Moreover, although polarization discrimination may provide some reduction in interference in certain cases, mobile earth stations cannot usually be designed to take advantage of this theoretical improvement due to a number of factors, including antenna performance deficiencies, depolarization associated with multipath and requirements for interoperability among systems.

Nonetheless, the opportunity exists during advance publication and coordination, for administrations to redefine the transponder plan of a system in order to reduce interference with respect to other systems. Likewise, it may be possible to negotiate constraints on the use of the existing transponder plan of an operating system in order to meet the criteria for accepted interference.

For example, when it is foreseen that unwanted signals from another system might unacceptably load the feeder down-link transmitters, it may be possible to negotiate carrier frequency plan constraints (see § 2.3) for the interfering system or transponder plan constraints for the interfered-with systems to alleviate the problem. The loading level statistics can be predicted and used to determine the degree to which it is necessary to constrain the carrier or transponder frequency plans.

For transponders equipped with programmable passbands, it may be possible to accept constraints on passband settings to remedy transponder loading problems. This is a particularly promising technique for multiple-beam satellites insofar as the constraints may be needed only for some of the beams. Another advantage is that programmable passbands allow changes to be made in the transponder plan even in the operational stage.

2.3 Carrier frequency plans

The carrier frequency plan of a satellite system designates which frequencies within the passbands of the transponders are to be used for each type of carrier to be provided by the system. Mobile satellite systems typically use several types of carriers for several types of earth stations. Consequently, when interference between two such systems is analysed, there are a large number of link combinations to be considered.

For example, some satellites will support on the order of greater than ten different types of carriers, some of which will be transmitted by more than one type of mobile earth station. This task of evaluating interactions between all links may be facilitated by the use of computer software.

In a typical sharing situation, some of the possible co-channel interactions between links may be found to comply at the outset with criteria for permissible levels of interference. If the number of problem links is small (e.g. one or two) carrier frequency planning is an option to be strongly considered.

As an example, consider a co-channel sharing difficulty between a single link and some of the links in the other system. A simple operational constraint may be accepted where problematic interactions are avoided by agreeing to observe the necessary channel assignment constraints. This can be accomplished in systems using demand assigned multiple access (DAMA) by implementing appropriate frequency assignment safeguards in the DAMA software.

Links that cannot share frequencies on a co-channel basis will require adherence to carrier frequency plans that assure prescribed amounts of frequency offset with respect to their problematic counterparts. Again, the solution may be implemented in the form of channel assignment software controls within the system frequency plan.

2.4 Satellite antenna coverage and service areas

The service area(s) of a satellite system are the geographic areas within which the earth stations associated with the system are intended to operate with specified signal-to-noise performance and specified protection against interference from other systems. The coverage area is the geographic area within which the signal-to-noise performance meets specifications. In single-beam satellite systems, the coverage area generally encompasses the entire service area. In multiple beam systems, the individual beam coverages will be smaller than the service area but collectively will encompass it.

The discrimination available from satellite antennas in cases of systems with non-overlapping service areas may be sufficient to allow unconstrained co-channel sharing. In other cases, the interactions between each beam in one system and the various types of links and mobile earth stations in the other system must be individually considered. The satellite antenna beam(s) of one system are considered against the service area(s) of the other.

Reference radiation patterns for representative antennas are often used in interference analyses; however, in many cases, actual radiation patterns may offer greater discrimination than reference patterns. In some cases, it may be possible to design satellite antennas that have substantially reduced side-lobe levels in the direction of the non-overlapping service areas of other systems.

Multiple-beam satellites may also offer opportunities for obtaining higher satellite antenna discrimination to facilitate coordination. The increased discrimination can be achieved for systems in the following ways:

– rearrangement or repositioning of beams, so long as the composite service area remains properly covered;
– decreasing the beam dimensions so as to accelerate the fall-off of gain with increasing off-axis angle;
– repositioning the entire beam array through scan angle or rotational angle adjustments;
– repositioning beams and decreasing their numbers, possibly with some sacrifice to performance at the fringe of the composite service area;
– minimization of gain specifically towards the affected service area(s) of the other system through optimization of the antenna design.

2.5 Earth station antenna discrimination

Reference radiation patterns for representative earth station antennas are often used in coordination. However, measured patterns may be used but with some caution because the distortion of the far-field radiation pattern that may be caused by objects near the antenna (e.g. cars and trucks) must be taken into account. In coordination, it is necessary to consider the service area for each type of mobile earth station with respect to the beam(s) in the other system.

2.6 Earth station power control

Some types of mobile earth stations may implement power control, such that their uplink e.i.r.p. levels are under the control of the system in which they are working. Systems that also utilize linear transponders could possibly accept some constraints in the algorithms for commanding mobile earth station power levels. In some cases, transponder gain can be adjusted to compensate for this constraint. It may be possible to identify modest constraints on e.i.r.p. that can effectively reduce the interference that is either caused or received. This assessment is made on a carrier-by-carrier and beam-by-beam basis.

2.7 Transponder gains and satellite e.i.r.p.

In cases where total power levels from unwanted signals from mobile earth stations operating in other systems might load the satellite return link as a result of overlap in the carrier frequency plans, it may be necessary to constrain transponder gain settings in order to minimize the power drain caused by that loading. However, routine practices for adjusting transponder gain may preclude the option of special adjustments.

Similarly, in order to assure adequate reception at mobile earth stations, the satellite e.i.r.p. levels used in the service down links in the forward direction should be maintained at or above predetermined levels. However, when the traffic level through the satellite is far below the peak system capacity level, unnecessarily high downlink e.i.r.p. levels can occur. Downlink interference can be limited by adjusting the gain settings to constrain the maximum e.i.r.p. used in the downlink carriers. For a given type of down link, the range between minimum and maximum e.i.r.p. cannot be reduced below a certain amount due to the need for tolerances in the control of feeder uplink e.i.r.p. levels and transponder gain.

2.8 Satellite positions

Interference on the links to and from mobile earth stations is not greatly reduced as the satellite spacing is increased, until the spacing is greater than one-half the half-power beamwidth of the earth stations. Nonetheless, it may be possible to eliminate problem interactions involving medium- or high-gain earth station antennas by adjusting orbital spacing. For low gain earth stations, clearly the ability to do this is much more limited.

Orbital position can also improve satellite isolation under the following exceptional circumstances:

– for a satellite using an earth-coverage antenna beam, it may be possible to maintain coverage of the service area from alternate orbital positions while reducing the coverage area overlap with the other system's service area(s);

– for planned satellites using multiple beams, it may be possible to reduce or eliminate overlaps between the coverage area(s) of one system and the service area(s) of another to the extent that coverage can be varied with changes in satellite position.

2.9 Operational schedule

If peak traffic loads in two systems do not occur at the same time, it may be possible to accept time-shared access to common segments of the spectrum. This may be facilitated by the use of an interconnecting communications link between the two systems.

3 Coordination methodology

As noted earlier, the RR Article 9 procedures for advance publication and coordination only provide methods for determining when the procedures are to be applied, which administrations are affected, the kinds of information to be exchanged, and the sequence and timing of the information exchanges. The methodology for deciding whether it is necessary to adjust the technical and operational parameters of the systems involved in the coordination process is left to the discretion of the participating administrations. This section illustrates possible methodologies for use during the technical coordination.

3.1 Assumptions

It is assumed that at least some frequency assignments proposed for a new mobile satellite system "B" must be coordinated with those of a mobile satellite system "A" already in coordination or operation. Although system "B" may have to be coordinated with more than one other system, and occasionally multilateral coordination meetings may be held, the coordinations are usually carried out on a bilateral basis.

It is also assumed that both the mandatory and the more detailed information on system characteristics listed in RR Appendix 4 have been furnished for system "A" and that corresponding information for system "B" has also been published. Flexibility for the adjustment of these system characteristics during the coordination process will depend on the stage of development of the system as described in § 1.3.

System "B" is assumed to be in either the late concept and design or early implementation stage, whereas system "A" is assumed to be in either the late implementation or operative stage. Thus, the administration responsible for system "B" (the "applicant administration") will generally have more flexibility for parameter adjustment than the administration for system "A" (the "affected administration"). Even so, the affected administration also has responsibilities to make feasible adjustments.

3.2 The coordination process

As in the case of the fixed-satellite service (FSS), the MSS coordination process can be divided into three phases:

Phase 1 – Assessment of the interactions of the transmissions of the involved systems ("A" and "B") against predetermined interference criteria: If unacceptable levels of interference are anticipated, it will be necessary to move ahead to phase 2; otherwise the administrations can agree that no adjustments to the system design parameters are needed.

Phase 2 – Adjustment of technical and operational system parameters which could facilitate a complete or partial resolution to the interference problems identified in phase 1. However, any adjustments made during this phase should not require either system to constrain its current or planned mode of operation, nor its type, distribution or quality of services.

Phase 3 – Consideration and negotiation of further adjustments and constraints of system parameters to either or both systems if interference problems have not been resolved during phase 2. Such changes could affect the operating flexibility and future growth options of either or both systems.

3.3 Identification of significant interactions

To carry out the first phase of the coordination, it is necessary to identify where interference between systems "A" and "B" is most likely to occur. Each band or band segment common to both systems must be examined for each satellite beam in the two space segments. All possible operational configurations must be considered.

In examining the various links in the two systems as defined in § 1.4, it is desirable first to compare their relative vulnerability to interference and the comparative impact on interference levels of adjusting link parameters.

3.3.1 Feeder link versus service link

In principle, the coordination can involve altering various parameters of the feeder links or service links. Generally, it is first desirable to concentrate on coordinating the service links. This is because feeder links generally employ relatively large earth station antennas with higher adjacent satellite discrimination and interference is more highly dependent on the service link parameters.

3.3.2 Forward versus return service link

Because of the large differences in the transmitting and receiving characteristics of a satellite and a mobile earth station, adjustments of most of the parameters described in § 2 may affect the forward and return service links differently. Some will affect only the forward (space station-to-mobile earth station) or the return (mobile earth station-to-space station) link.

3.4 Adjustment of technical and operational parameters

Table 1 summarizes the general practicality and benefit of making parameter adjustments and constraints during the coordination process. Practicality is referred to stage of development, and benefit is described separately for the forward and return links of the two systems.

To illustrate how the parameters for the service links may be adjusted in the second and third phases of coordination, two basic cases are considered:

– non-co-coverage case: the satellite networks serve separate geographical areas;

– co-coverage case: the satellite networks have overlapping service areas.

Based largely on which of these two cases applies to systems "A" and "B", and whether the principal interference is expected to be encountered on the forward or return link, one can make a rough evaluation of the practicality and benefit of the various system parameter adjustment options.

TABLE 1

General practicality and benefit of accepting constraints or adjustments on system parameters

Parameter to be adjusted	Practicality relative to stage of system development				Interference reduction benefit	
	Concept and design	Implement	Operation	2nd gen/ replace satellite	Forward link	Return link
Criteria for acceptable interference	M-H	M-H	M-H	M-H	M	M
Transponder frequency passbands	M-H	M	L*	M-H	L	M
Polarization	M-H	M	L	L	L	L

TABLE 1 (*end*)

Parameter to be adjusted	Practicality relative to stage of system development				Interference reduction benefit	
	Concept and design	Implement	Operation	2nd gen/ replace satellite	Forward link	Return link
Satellite antenna coverage	H	M	L	H	CC:L NCC:M-H	CC:L NCC:M-H
Satellite service areas	L	L	L	L	CC:L NCC:M	CC:L NCC:M
Mobile earth station antenna discrimination	M	L-M	L	L	L	L-M
Earth station e.i.r.p. (power control)	M	M	L-M	M	M	M
Transponder gains and satellite e.i.r.p.	M	M	M	M	M	L
Satellite position	M	L-M	L	L	CC:L NCC:L-M	CC:L NCC:L-M
Operational schedule	L-M	L-M	L-M	L-M	H	H

Key: H = High; M = Moderate; L = Low or None; CC = Co-coverage; NCC = Non-co-coverage

* Only if programmable passbands are used.

3.4.1 Non-co-coverage case

If system "A" and system "B" cover different service areas, and it has been determined that there will nonetheless be an interference problem, administration "B" may want to first concentrate on the design of the spacecraft antenna. The objective would be to alter or constrain the satellite antenna coverage so that it more closely matches the service area and also achieve greater intersystem isolation in the direction of the service area of system "A". This is only practical in the design and perhaps the early implementation stage of system "B". Adjustment of the spacecraft antenna coverage of system "A", whose satellite is assumed to be in the late implementation or operation stage, is generally practical only in the event that the satellite employs programmable or steerable spot beams.

In non-co-coverage cases where unacceptable interference from system "B" to system "A" is predicted only in the forward link, one or both may change its satellite e.i.r.p. in order to achieve satisfactory carrier-to-noise plus interference power ratios without unduly sacrificing performance.

In some of the non-co-coverage cases, discrimination may be improved by changing the proposed position of satellite "B" or the existing position of satellite "A" to increase the orbital spacing between them. Given the limited directivity of most mobile earth station antennas, this option will have only a moderate effect on the interference between systems "A" and "B" and would thus be considered as a last resort. However, to overcome an interference problem, moving the satellite may be attractive in that it might have little impact on the development cost or schedule of system "B".

For the non-co-coverage case some of the options described in § 2 may not be necessary if most of the required isolation can be provided by satellite antenna discrimination. If, however, the interference problem is severe the administrations may have to resort to frequency interleaving or other options.

3.4.2 Co-coverage case

In the co-coverage case, total achievable isolation between systems on the service links is clearly less than that in the non-co-coverage case since the same geographical region (or a portion thereof) will be serviced by both systems "A" and "B". If system "B" is still in the design stage, and unacceptable intersystem interference is expected, it may be decided to consider changes to the frequency/polarization plan in order, for example, to interleave transponder passbands with those of system "A".

Also, changes to carrier frequency plans may be considered to reduce intersystem interference. Channel interleaving can reduce the required protection ratio between systems and carrier placement can be planned so as to reduce intermodulation. Interleaving the two systems' channels (perhaps in conjunction with adjusted satellite e.i.r.p.) may be enough to resolve the interference problem.

In the co-coverage case, design alterations affecting the satellite antenna coverage serve little or no purpose in either the forward or return service links unless an administration chooses to limit or change its service area in the case of partial co-coverage. The benefit of this is low.

4 Impact of technological evolution on future coordinations

Many of the advances in technologies that are being made to improve mobile satellite system performance may also enhance the compatibility between mobile satellite systems and improve coordination outcomes. Hence, the capabilities of the orbit/spectrum resources for accommodating future requirements are generally increasing.

Spectrally efficient modulation methods and low-rate voice codecs should result in reduced channel bandwidths or greater interference tolerance which will allow more flexible frequency planning. Multiple access techniques such as code division multiple access (CDMA) employing spread spectrum modulation may result in higher interference tolerance for mobile satellite systems.

Transponder linearization will reduce intrasystem noise (e.g. intermodulation) and the resulting increase in margins may enable acceptance of higher levels of interference power. Multiple-beam satellite antennas with smaller beams and reduced side-lobe levels will enable better matching of the coverage areas to service areas resulting in increased intersystem isolation. Future flexible spot beam planning concepts should enable dynamic frequency and power allocation to beams while ensuring efficient spectrum usage.

Widespread use of medium-to-high gain mobile earth station antennas may improve compatibility where adequate satellite separation is possible. Although not necessarily aimed at improving coordination, these advances may offer a bonus by enhancing intersystem compatibility. As a result, future coordination may be eased.

5 Conclusions

During advance publication and coordination of frequency assignments for mobile satellite systems, detailed analysis may identify interactions producing unacceptable interference. Several design and/or operating parameters can be adjusted at various stages of development to alleviate the identified interference; however, it should be noted that with existing systems, certain satellite parameters cannot be changed until the replacement stage. The general practicality and benefit of accepting constraints or adjustments on system parameters is summarized in Table 1.

New technology is anticipated to offer greater performance in terms of capacity, and might also improve intersystem compatibility and reduce the need for administrations to make adjustments during coordination. Responsibility rests with all mobile satellite system operators to incorporate flexibility into their designs and operations so as to facilitate the coordination process.