REPORT ITU-R BT.2075*

Protection requirements for terrestrial television broadcasting services in the 620-790 MHz band against potential interference from GSO and non-GSO broadcasting-satellite systems and networks

(2006)

Background

The band 620-790 MHz is heavily used in Regions 1, 2 and 3 for the analogue terrestrial television broadcasting service (BS) in many countries. Moreover, digital BS have been developed in a number of countries in this frequency range. The simulcast transmission period is foreseen for 20-25 years to come and requires careful planning to minimize disruption of services. A satellite filing was received by the BR before WRC-03 for the use of the band 620-790 MHz in accordance with former Radio Regulation (RR) No. 5.311, this footnote was modified by WRC-03 clarifying the sharing conditions. Frequency sharing between BSS transmissions and BS in the band 620-790 MHz is stipulated by RR No. 5.311 (as modified by WRC-03), Recommendation 705, and Resolution 545 (WRC-03) of the ITU Radio Regulations. RR No. 5.311 was modified at WRC-03 and further studies, already called for by Recommendation 705, were invited to be urgently carried out on sharing criteria for the protection of terrestrial services in particular television broadcasting services from potential BSS systems operating in the band 620-790 MHz (under WRC-07 agenda item 1.11).

In this regard, ITU-R has undertaken technical studies to identify the protection requirements in terms of the maximum power flux-density (pfd) not to be exceeded at the site of the television receiving station to protect from interference from existing and planned analogue and digital terrestrial BSS in the band 620-790 MHz. This Report provides a methodology for the protection requirements for BS, as well as the results of numerical applications of this methodology for terrestrial analogue and digital (fixed, portable outdoor, portable indoor and mobile) BS.

It is worth noting that RRC-06 adopted Resolution 1 (RRC-06) which resolves to invite WRC-07 to take appropriate and necessary measures to effectively protect the broadcasting Plans adopted by RRC-06 and their subsequent evolution from the GSO-BSS and/or non-GSO BSS networks/systems which were not brought into use prior to 5 July 2003.

It is noted the planning for the band 620-790 MHz arising from the GE-06 plan will not apply to administrations beyond Region 1 and neighbouring countries.

1 Introduction

This Report gives the protection requirements for terrestrial broadcasting services in the 620-790 MHz band against potential interference from broadcasting BSS (GSO, non-GSO) satellite systems. This Report focuses on potential future GSO and non-GSO BSS systems assumed to use

* The administrations of Syria, Lebanon and United Arab Emirates in conformity with the Arab States position in WRC-03, RRC-04 and in RRC-06 continue to object to any consideration of the broadcasting from non-GSO so called "HEO" satellite systems, noting that RR No. 5.311 currently does not allow such broadcasting and the need to protect fully the output Plans and their subsequent evolutions of RRC-06 and hence they are not bound by the content of this Report and will not allow any application in accordance of RR Article 23 for their territories to be covered by any new satellite system of both GSO and non-GSO.

digital transmissions and circular polarization and to operate with elevation angles (in the BSS coverage areas) above 60° only. Annex 1 presents information on these BSS systems which can use both GSO and non-GSO orbits, transmit signals with uniform spectral distribution, which are significantly different from typical analogue BSS emissions. It should be noted the BSS systems considered in this report do not include terrestrial re-transmission facilities. The protection requirements have been derived from published information about the needs for the broadcasting service (CPM Report to WRC-97, ITU Digital Terrestrial Television Handbook, Recommendations ITU-R BT.417, ITU-R BT.419, ITU-R BT.655 and ITU-R BT.1368). However, only those broadcasting systems which are currently using frequencies in the 620-790 MHz band or which are expected to use it in the near future have been included. BSS systems currently introduced include the Russian networks, Statsionar-T and Statsionar-T2, and a proposal for a highly elliptical orbit (HEO) system using a digital modulation and circular antenna polarization.

Digital television services have already commenced operation in a number of countries in this frequency range. It is expected that digital television services will be deployed in an even higher number of countries in the near future and it is expected that analogue television services will continue in many countries for many, possibly 20 to 25 years. Protection of the analogue services is likely to be rather more difficult than is the case for digital services. This is especially true for those countries or parts of countries where the television networks have not yet been fully developed, or in areas where the man-made noise levels are low and where the protection requirements are more stringent simply because the noise and the existing interference levels are low.

In Recommendation 705 (WARC-79) in *considering* e) the following qualification is provided to administrations in calculating minimum field strengths when referencing Recommendation ITU-R BT.417:

a) that with terrestrial television receiving systems using current technology, the minimum field strength to be protected may in some cases be less than the values included in Recommendation ITU-R BT.417;

b) that account may have to be taken of ground reflections;

c) that energy dispersal techniques may reduce the required protection ratio and should be used if shown to be effective.

While Recommendation ITU-R BT.417 Annex 1 states the boundaries of the television service in rural districts having a low population density, where television services are to be provided for a sparsely populated region, in which better receivers and antenna installations are likely to be employed, administrations may find it desirable to establish the appropriate median field strength for which protection against interference is planned.

It should be noted that Recommendation ITU-R BT.417 was last reviewed in 1992 by the ITU-R and may not reflect the performance of today’s television receivers and antennas.

Recommendation ITU-R BT.417 gives values obtained from median field-strength investigations at the edge of the coverage area and picture quality assessments for Bands I and III in rural districts of Australia, India and Italy and for Bands IV and V at both rural and urban locations in Italy and the United Kingdom. It may be noted that in Bands IV and V where man-made noise is not generally a problem, the field-strength values quoted for rural areas may also be applied in urban areas.

A key element in planning of terrestrial television services is the consideration given to the point where the television service becomes unwatchable. In some administrations the reception quality of the analogue service is matched to the point where reception of the digital signal would just “fail”. In this way the gradual failure characteristic of the analogue signal is matched to the more sudden failure of the digital signal. One administration has adopted in Band V for digital planning minimum median field strength values of 10 dB below the current analogue values.

Because it is certain that terrestrial analogue and digital television services will continue to be deployed over a period of very many years, it is extremely important that the possible existence of satellite-based television transmission and reception in the same band should not in any way interfere with such deployment. In particular, it will be necessary to ensure that if satellite-based services were to become operational, they cannot claim protection of their reception as a reason to prevent the installation of new terrestrial analogue and digital television transmitters or the change of analogue or digital frequency assignments to facilitate the transition period.

The satellite service could be considered to be a 100% of the time co-channel continuous interference source. In Recommendations ITU-R BT.655 and ITU-R BT.1368, the values of protection ratio quoted apply to interference produced by a single source. Except where otherwise stated, the ratios apply to tropospheric, *T*, interference and correspond closely to a slightly annoying impairment condition. They are considered to be acceptable only if the interference occurs for a small percentage of the time, not precisely defined but generally considered to be between 1% and 10%. For substantially non-fading unwanted signals, it is necessary to provide a higher degree of protection and ratios appropriate to continuous, *C*, interference should be used. If the latter are not known, then the tropospheric, *T*, values increased by 10 dB can be applied.

2 Minimum field strengths for the terrestrial television broadcasting service

It should be the minimum field strength value which is the starting point for the discussion. However, this is not usually the case and the minimum median value is taken as a starting point and the resultant discussion becomes rather convoluted as a result. The reason for the shift in the starting point is partly historic and partly convenience.

At the time when the concept and the relevant values were being developed (during the 1950s), it was not known how far equipment development could go and this was especially true for the band 470 to 862 MHz. Certainly the equipment available at that time could not achieve the performance which was implied by the values adopted. Since then performance has continued to improve and nowadays exceeds that expected. Consequently the real minimum field strength is now even less than that used in planning.

It was a matter of convenience to relate all of the planning work to the minimum median field strength values as this:

– provided a fixed reference which did not depend on television receiver development and thus did not change with time;
– provided a link with any coverage measurements which were made;
– provided an approach which simplified the development of international plans and simplified discussions on an international basis.

As a result, it has become current practice to start with the minimum median field strength values and, when necessary, "work backwards" to the minimum field strength values which are the real basis for planning. In fact, it is only very rarely that it is really necessary to do this reverse engineering and this could help to explain why it is always so difficult to do it and to understand it, even though the basics seem to be very simple.

It is interesting to note that adopting the minimum median field strength values as the reference and then deriving the minimum field strength values from them has the result that these minimum field strength values are somewhat higher than they would be if derived directly from the performance of modern television receivers. In other words, the protection requirements placed on other services are lower than they could reasonably be argued to be.

One case where it is necessary to consider the basic numbers and their derivation is where some limiting values must be taken into account. This is particularly true for the case of areas where interference levels are low and listeners/viewers may be expected to use better than average receiving installations. Such areas exist in most countries, but are particularly relevant to developing countries where transmission networks may not attempt to cover the whole country and viewers are expected to make extra efforts to obtain satisfactory reception quality, for example by using high gain, low noise pre-amplifiers and low loss feeder cable.

However, it must not be assumed that such considerations apply only to developing countries. For example, the broadcasting coverage model applied in one administration seems to concentrate attention on the urban areas and many people living in rural areas need to install special receiving equipment in order to obtain satisfactory reception. In addition, it should be noted that the reference value for digital television reception adopted in another administration seems to include the requirement to use a low noise pre-amplifier wherever necessary. In both of these cases, the impact is to make it necessary to provide protection against interference for signal levels which are lower than those normally adopted in Europe.

3 Protection against interference

Although not directly related to the derivation of minimum field strength and minimum median field strength values, it is necessary to add some words about protection against interference as there is often confusion between the two topics. This is particularly true as the overall treatment in the case of protection of digital television is quite different from that adopted for protection of analogue television.

In some countries the allotment planning for terrestrial television broadcasting services has not included any margin(s) for interference from any other sources other than the adjacent or co-frequency broadcasting service in the band 620-790 MHz. As a result no provisions or co-frequency coordination requirements have been included in the regulatory provisions of many administrations for sharing between broadcasting and other services where broadcasting is the Primary service.

The basis for protection of a wanted signal against interference from some other signal (usually referred to as an "unwanted" signal) is basically very simple and can be considered in terms of a "protection margin". The protection margin at the input to the receiver is given by:

Protection margin = Wanted signal level – Impact of interfering signal

The term "impact of interfering signal" takes account of the fact that the affect of the interfering signal is increased by the relevant protection ratio. In practice, it is usually found to be more convenient to deal with field strength values and this then necessitates taking account of the relative gain of the receiving antenna in the direction of the interfering signal. It can be assumed that the feeder cable loss and any frequency dependence either of the receiving antenna or of the feeder cable may be disregarded as they affect the wanted signal and the interfering signal equally – this simplification cannot be made in all interference situations, but applies in the case under consideration here.

In the case where the protection margin is positive, the wanted signal is taken to be protected against interference and is defined to be acceptable. This means that the reception and protection conditions must be clearly defined. This is why, for example, in the case of analogue television, different protection ratios are defined, relevant to the visibility of interference present for different percentages of the time.

Clearly, the limiting value of the wanted signal to be protected is the minimum field strength. It may be less clear what value should be taken for the interfering signal (the latter is usually referred to as the "nuisance" signal if the impact of the receiving antenna and the protection ratio have been taken into account), especially in the case where it is necessary to consider variation of signal level with location. This is even more true if it is desired to relate protection to median signal levels as these are generally predicted directly.

In the general case, the wanted and interfering signals vary independently and each has its own standard deviation. In such a case, the definition of protection margin needs to be changed to become:

Protection margin = Median wanted signal level – (Impact of median interfering signal level + Combined location correction factor)

where the combined location correction factor is given by standard statistical theory as:

q * square root (sum of the squares of the two standard deviations), and

q is the statistical multiplying factor relevant to the percentage of locations to be protected.

In practice, it is conventional to protect analogue television reception at only 50% of locations and so there is no requirement to take this additional combined location correction factor into account. In the case of digital television reception, however, this margin must be considered. This is true regardless of the values of the standard deviations of the wanted and interfering signals.

In the case of potential interference arising from a satellite-based signal, the standard deviation of the interfering signal is assumed to be zero and as a result, it becomes possible to simplify the calculations by using only the minimum field strength for the wanted signal, the actual signal level of the interfering signal and location correction factor.

When considering protection requirements for terrestrial fixed reception, antenna discrimination is factored into the calculation. In some cases, BS fixed receiver antennas are sometimes up-tilted in hilly environments to receive TV signals and these tilt angles have been considered to some degree in this Report.

4 Protection criteria for BS reception

With free space propagation conditions for BSS signals, the protection criteria for the BS can be derived from the following equation:

– For analogue BS:

$$E_{max\ int} = E_{min} - PR - IM + D_{dir} + D_{pol} = \Phi_{max\_int} + 145.8 \quad (1a)$$

– For digital BS:

$$E_{max\ int} = E_{med} + q\sqrt{(\sigma_w^2 + \sigma_i^2)} - PR - IM + D_{dir} + D_{pol} = \Phi_{max\_int} + 145.8 \quad (1b)$$

where:

E_{max_int}: maximum allowable BSS field strength at the wanted receiving antenna (dB(μV/m))

E_{min}: minimum wanted analogue BS field strength at the wanted receiving antenna as per Recommendation ITU-R BT.417-5 $E_{min} = 62 + 20\log(f/474)$ (dB(μV/m)). (f = 700 MHz)

E_{med}: median wanted digital BS field strength at the wanted (BS) receiving antenna (dB(μV/m)), and $E_{med} = E_{min} - q\sigma_w$

σ_w: standard deviation of the normal distribution of the wanted signal level (digital BS signals)

σ_i: standard deviation of the normal distribution of the interfering signal (digital BSS signals). It should be noted that, in the calculations undertaken in this Report, σ_i is assumed to be 0 dB

q: correction factor obtained from the complementary cumulative inversed normal function $Q(x\%)$, where $x\%$ represents the locations where a certain field strength is present (here, E_{min})

$q\sigma_w$: "location correction factor" (Recommendation ITU-R P.1546)

$q\sqrt{(\sigma_w^2+\sigma_i^2)}$: "propagation correction factor" (Recommendation ITU-R P.1546)

PR: appropriate BS protection ratio with an additional interservice sharing margin (dB)

IM: allowance for interservice sharing (dB)

D_{dir}: BS receiver antenna directivity discrimination with respect to BSS signal (dB)

D_{pol}: BS receiver polarization discrimination with respect to BSS signal (dB)

Φ_{max_int}: maximum BSS pfd at receiving antenna in dB(W/m^2) per 8 MHz channel (8 MHz being the BS channel bandwidth in the band 620-790 MHz).

This method is in accordance with the method described Recommendation ITU-R BT.1368-6.

The system parameters for the GSO and non GSO BSS considered in this Report are found in § 3.3 of Annex 1.

In other studies in the ITU-R, a clear distinction is made between the allowance for "intra system" noise/interference and "external" or inter system interference, with the allowance for external interference typically significantly far less than the internal allowance. This is reasonable because intra-system interference can be taken into account as part of fundamental BS network planning and so is under the control of the BS, whereas other than by means of regulatory protection, no control can be exercised over external interference and any external interference will erode the margin set aside for intra system interference.

In other contexts where systems are homogeneous (e.g. between two point-to-point links in the fixed service) an I/N requirement of –6 dB (or sometimes –10 dB) is commonly adopted, however where non-homogeneous services or intraservice interference is involved (and where the spectrum regulator implicitly has less ability to separately manage interference between services) an I/N of –10 dB (or more) may be adopted. An additional "interservice interference margin" of 10 dB has therefore been added to the BS-BS protection ratio values currently included in Table 1 and Tables 3 to 7. A figure of –9.1 dB has been used in Table 2.

It should be noted that, for the case of the protection of analogue reception, the use of minimum median field strength values from Recommendation ITU-R BT.417-5 have been used. Annex 1 to Recommendation ITU-R BT.417-5 provides minimum median field strength values for which protection against interference may be planned for sparsely populated regions. The minimum median field strength specified for such areas is 6 dB below the minimum median field strength specified for Band V in *recommends* 1 of Recommendation ITU-R BT.417-5. This 6 dB factor has been used in differentiating the minimum median field-strength values used for analogue BS nominal coverage area and fringe coverage area cases.

5 Definition for the fixed, portable and mobile reception

The definition for the fixed, portable and mobile reception give some bases to the understanding of the class of service referred to in the Report. It is considered important to have a common understanding about the same type of reception/service in the different regions and to clearly stipulate the correspondence of each type of reception. It is considered useful and important to define each of them and avoid misunderstanding when comparing different implementations, for example portable which is a stationary reception and not a mobile reception type or a hand held[1] reception type.

5.1 Fixed reception

Fixed reception is defined as reception where a directional receiving antenna mounted at roof level is used.

It is assumed that near-optimal reception conditions (within a relatively small volume on the roof) are found when the antenna is installed.

In calculating the field strength for fixed antenna reception, a receiving antenna height of 10 m above ground level is considered to be representative for the broadcasting service. Other heights might be used for other services.

5.2 Portable reception

Portable reception is defined as:

– Class A (outdoor), which means reception where a portable receiver with an attached or built-in antenna is used outdoors at no less than 1.5 m above ground level;
– Class B (ground floor, indoor), which means reception where a portable receiver with an attached or built-in antenna is used indoors at no less than 1.5 m above floor level in rooms with the following characteristics:
  – on the ground floor;
  – with a window in an external wall.

Portable indoor reception on the higher floors will be regarded as Class B reception with signal level corrections applied, although indoor ground floor reception is likely to be the most common case.

In both Classes A and B, it is assumed that:

– optimal receiving conditions will be found by moving the antenna up to 0.5 m in any direction;
– the portable receiver is not moved during reception and large objects near the receiver are also not moved;
– extreme cases, such as reception in completely shielded rooms, are disregarded.

5.3 Mobile reception

Mobile reception is defined as reception by a receiver in motion with an antenna situated at no less than 1.5 m above ground level. This could for example be a car receiver or handheld equipment.

The dominant factor with regard to local reception effects is thought to be due to fading in a Rayleigh channel. Fade margins are intended to offset these effects. Fade margins depend on the frequency and the velocity.

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[1] Handheld devices are personal wireless devices, normally of a very small size similar to that of a mobile phone or personal digital assistant (PDA), with the capability of receiving audiovisual streams and data service, and often with facilities for bidirectional voice/data communication.

6 Assumptions made for this Report

a) *Protection requirements for terrestrial analogue reception in the 620-790 MHz band*

– It is assumed the values in Recommendation ITU-R BT.419 can be used in both horizontal and vertical planes.

– It is assumed that potential GSO and non-GSO BSS systems and networks under consideration in this Report would benefit from having service areas served with high elevation angles.

– It is also assumed that BS signals are linearly polarized, and in the band 620-790 MHz the potential GSO and non-GSO BSS systems are circularly polarized.

– It has been assumed that the potential interfering GSO and non-GSO BSS satellite signal will use digital modulation and in that case it can be considered as a white-noise like signal, and Recommendation ITU-R BT.1368 is taken as a basis to derive the relevant protection ratios.

– It is assumed that the maximum degradation in BS C/N margin that can be tolerated, due to co-frequency sharing with other services including the potential BSS, is 0.5 dB of the available margin.

– The potential GSO and non-GSO BSS systems and networks under consideration in this Report do not have any return channel or terrestrial retransmission requirements.

b) *Protection requirements for terrestrial digital fixed reception in the 620-790 MHz band*

– It is assumed that Recommendation ITU-R BT.419 can be used in both horizontal and vertical planes.

– As a receiving antenna is situated at around 10 m above the ground the most important contribution to the received signal comes from the line-of-sight signal from the satellite. Although there may exist shadowing and multipath contributions, they are believed to be insignificant. Therefore, the satellite signal standard deviation, σ_t, is assumed to be 0 dB and the propagation correction factor, $q\sqrt{\sigma_w^2+\sigma_i^2}$, equals the location correction factor, $q\sigma_w$.

– It is assumed that potential BSS systems under consideration in this Report would benefit from having service areas served with high elevation angles.

– It is also assumed that BS signals are linearly polarized, and BSS systems circularly polarized. The receiver antenna polarization discrimination is determined by the low elevation angle case.

– It is assumed that the maximum degradation in BS C/N margin that can be tolerated, due to co-frequency sharing with other services including BSS, is 0.5 dB of the available margin.

– The potential GSO and non-GSO BSS systems and networks under consideration in this Report do not have any return channel or terrestrial retransmission requirements.

7 Protection requirements for terrestrial analogue reception in the 620-790 MHz band

The maximum allowable interfering field strength for angles of arrival from the potential BSS for the terrestrial analogue television broadcasting service in the 620-790 MHz band is listed in Table 1.

In some administrations planning consideration is given to the minimum field strengths required for the terrestrial television broadcasting service in fringe coverage areas. This is a worst case example for single entry pfd's.

TABLE 1

Protection requirements for analogue service (fixed reception)

	BS nominal coverage areas (Note 1)		**BS fringe coverage areas (Note 1)**	
	$\delta \leq 20° + x°$[a] (Note 2)	**$\delta \geq 60° + x°$ (Note 2)**	**$\delta \leq 20°$**	**$\delta \geq 60°$**
Nominal bandwidth (MHz)	8[b]	8	8	8
Minimum median field strength (dB(μV/m)) (Note 1)	65.4[c]	65.4	59.4[d]	59.4
Derived power flux-density (dB(W/m^2)) (Note 3)	–80.4	–80.4	–86.4	–86.4
Receiving antenna directivity discrimination (dB) (Note 4)	0	16	0	16
Receiving antenna polarization discrimination (dB) (Note 5)	1.25	0	1.25	0
Required protection ratio (dB) (Note 6)	44	44	44	44
Allowance for interservice interference (Note 6*bis*) (dB)	10	10	10	10
Maximum interfering single entry pfd (dB(W/m^2)) (Note 7)	–133.15	–118.4	–139.15	–124.4
Maximum interfering field strength (dB(μV/m)) (Note 7)	12.65	27.4	6.65	21.4

[a] For values between 20° + x° and 60° + x° a mask may be derived by linear interpolation.

[b] The channel bandwidth of 8 MHz is listed and it should be noted that some administrations use 6 MHz and 7 MHz channelling.

[c] Derived from the median figures as specified in Tables 1 and 2 of Recommendation ITU-R BT.417 with a 6 dB margin compared to the minimum field strength values given in this Recommendation.

[d] In some administrations lower minimum field strength levels are planned.

NOTE 1 – *BS nominal coverage areas* are the areas with typical man-made noise levels. The minimum field strength to be protected at the edge of the coverage area is derived from Recommendation ITU-R BT.417-5. Current BS planning in many administrations has been undertaken in total isolation of interference margins for a source of interference other than adjacent and co-frequency BS.

BS fringe coverage areas are areas where the television broadcasting networks are relatively sparse and viewers are expected to use high gain antennas and low noise preamplifiers. In some fringe areas interference from man-made interference is very low. Therefore, the value of minimum field strength to be protected given for 582-960 MHz band is often reduced by 6 dB. In such cases the derived pfd and maximum interfering signals must also be reduced by 6 dB. Such values are expected to apply in a relatively large number of developing countries, in particular, and in rural areas in other countries (see Annex 1 to Recommendation ITU-R BT.417).

NOTE 2 – The receiving antenna discrimination is obtained using directly Recommendation ITU-R BT.419. Investigations have shown that this assumption does not remain valid in hilly environments. Annex 2 concludes that a representative average tilt angle of $x° = 10°$ can be used although one Administration stated that a representative tilt angle of $x° = 15°$ is more appropriate to cover this phenomenon.

NOTE 3 – The conversion between pfd (φ) and minimum field strength (E) is by means of the formula $E = \varphi + 145.8$, where E is in dB(μV/m) and φ is in dB(W/m^2).

NOTE 4 – Terrestrial television applications use directional antennas, but these are very often horizontally polarized and have relatively wide beams in the vertical plane, thus there is no discrimination against interfering signals originating in a satellite for $\delta \leq 20° + x°$. It is assumed that Recommendation ITU-R BT.419 can be used in both horizontal and vertical planes. It has been also assumed that linear interpolation may be used for values of δ between $20° + x°$ and $60° + x°$.

NOTE 5 – It is assumed that potential GSO and non-GSO BSS systems and networks under consideration in this Report would benefit from having service areas served with high elevation angles. It is also assumed that BS signals are linearly polarized, and potential GSO and non-GSO BSS systems circularly polarized. As a consequence, polarization discrimination situation will experience two situations:

– for angles of arrival ≥ $60° + x°$, the potential BSS interferer transmits in its main beam, and the BS victim receives in its side and back lobes: in this case, Recommendation ITU-R BT.419 indicates that polarization discrimination is already taken into account;

– for angles of arrival between 20º + x° and 60º a mask may be derived by linear interpolation;

– for angles of arrival ≤ $20° + x°$, the victim BS receives in its main lobe, and the potential BSS interferer transmits in the worst case in its first sidelobe, resulting in a BSS/BS polarization discrimination of 1.25 dB.

NOTE 6 – It has been assumed that the potential interfering non-GSO BSS satellite signal will use digital modulation and in that case it can be considered as a white-noise like signal, and Recommendation ITU-R BT.1368 is taken as a basis to derive the relevant protection ratios. This Recommendation contains a 41 dB protection ratio (PR) value for the case of continuous interference for intra service planning, although for the purpose of this Recommendation the term “continuous” means 50% of time. As interference is present for 100% of the time, in the case for satellite based interfering signals, 3 dB has been added to the relevant PR values given in Recommendation ITU-R BT.1368.

NOTE 6*bis* – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 10 dB lower to ensure the degradation in C/N margin is limited to approximately 0.5 dB of the available margin.

NOTE 7 – The quoted pfd is the single entry value tolerable within the nominal bandwidth of a television channel. If there are multiple interfering satellite signals in the same pass band, their interfering pfd must be combined. The study contained in Section 9 of Annex 1 can be used to determine an allowance for the aggregate pfd case if required.

8 Protection requirements for terrestrial digital fixed reception in the 620-790 MHz band

Tables 2, 3 and 4 address the respective protection requirements for fixed reception of the digital television broadcasting systems; System A (ATSC), System B (DVB-T) and System C (ISDB-T). The system characteristics and protection requirements can be found in Recommendations ITU-R BT.1306 and ITU-R BT.1368 respectively. Further information on these systems can be found in the ITU Digital Terrestrial Television Handbook.

While a nominal bandwidth has been specified in the following Tables for representative channelling it should be noted that many administrations use the other channelling within their terrestrial television broadcasting.

TABLE 2

Protection requirements for digital System A (ATSC) (fixed reception)

	δ ≤ 20°	**δ ≥ 60°**
Nominal bandwidth (MHz)	6	6
Minimum field strength (dB(μV/m)) (Note 10)	39[(1)]	39
Derived pfd (dB(W/m^2)) (Note 4)	–106.8	–106.8
Receiver antenna directivity (dB) (Note 5)	0	16
Receiver antenna polarization (dB) (Note 7)	1.25	0
Required PR (dB)	19.5	19.5
Allowance for interservice interference (Note 8*bis*) (dB)	9.1	9.1
Maximum interfering single entry pfd (dB(W/m^2)) (Note 10)	–134.15	–119.4
Maximum interfering field strength (dB(μV/m))	11.65	26.4

(1) These are indicative values for minimum field strength for digital System A.

TABLE 3

Protection requirements for digital System B (DVB-T) (fixed reception)

	16-QAM, Code rate 2/3		**64-QAM, Code rate 2/3**	
	δ ≤ 20° + *x*° (Note 1)	**δ ≥ 60° + *x*°** (Note 1)	**δ ≤ 20° + *x*°** (Note 1)	**δ ≥ 60° + *x*°** (Note 1)
Nominal bandwidth (MHz)	8	8	8	8
Required *C*/*N* ratio (dB) (Note 2)	14.6	14.6	20.1	20.1
Minimum field strength (dB(μV/m)) (Note 3)	41.4	41.4	46.9	46.9
Location correction factor (dB) (Note 6.1)	−9	−9	−9	−9
Minimum median field strength (dB(μV/m))	50.4	50.4	55.9	55.9
Derived median pfd (dB(W/m^2)) (Note 4)	–95.4	–95.4	–89.9	–89.9
Receiving antenna directivity discrimination (dB) (Note 5)	0	16	0	16
Receiving antenna polarization discrimination (dB) (Note 7)	1.25	0	1.25	0
Required PR (dB) (Note 8)	14.6	14.6	20.1	20.1
Allowance for interservice interference (Note 8*ter*) (dB)	10	10	10	10
Propagation correction factor (dB) (Note 6.2)	−9	−9	−9	−9
Maximum interfering single entry pfd (dB(W/m^2)) (Notes 9 and 11)	–127.75	–113.0	–127.75	–113.0
Maximum interfering field strength (dB(μV/m)) (Notes 9 and 11)	18.05	32.8	18.05	32.8

TABLE 4

Protection requirements for digital System C (ISDB-T) (fixed reception)

	64-QAM, Code rate 3/4					
	δ ≤ 20° + *x*° (Note 1)	δ ≥ 60° + *x*° (Note 1)	δ ≤ 20° + *x*° (Note 1)	δ ≥ 60° + *x*° (Note 1)	δ ≤ 20° + *x*° (Note 1)	δ ≥ 60° + *x*° (Note 1)
Nominal bandwidth (MHz)	6	6	7	7	8	8
Minimum field strength (dB(μV/m)) (Note 13)	45.5	45.5	46.2	46.2	46.7	46.7
Location and time-correction factor (dB) (Note 12)	−9	−9	−9	−9	−9	−9
Minimum median field strength (dB(μV/m))	54.5	54.5	55.2	55.2	55.7	55.7
Derived median pfd (dB(W/m^2)) (Note 4)	–91.3	–91.3	–90.6	–90.6	–90.1	–90.1
Receiving antenna directivity discrimination (dB) (Note 5)	0	16	0	16	0	16
Receiving antenna polarization discrimination (dB) (Note 7)	1.25	0	1.25	0	1.25	0
Required PR (dB) (Note 8)	21	21	21	21	21	21
Allowance for interservice interference (Note 8*ter*) (dB)	10	10	10	10	10	10
Propagation correction factor (dB) (Note 12)	−9	−9	−9	−9	−9	−9
Maximum interfering single entry pfd (dB(W/m^2)) (Note 9)	–130.05	–115.3	–129.35	–114.6	–128.85	–114.1
Maximum interfering field strength (dB(μV/m)) (Note 9)	15.75	30.5	16.45	31.2	16.95	31.7

NOTE 1 (Tables 3, 4) – The receiving antenna discrimination is obtained using Recommendation ITU-R BT.419. Investigations have shown that this assumption does not remain valid in hilly environments. Annex 2 concludes that a representative average tilt angle of *x*° = 10° can be used although some Administrations stated that a representative tilt angle of *x*° = 15° or some other value may be more appropriate to cover this phenomenon.

NOTE 2 (Table 3) – The required *C*/*N* values are stated in the ITU Digital Terrestrial Television Handbook for fixed and portable digital television reception (Rice and Rayleigh channels, respectively). In fact, it is not really critical which values of *C*/*N* ratio are used here as the same value must be used as the PR in a later part of the calculations.

NOTE 3 (Table 3) – The minimum field-strength values for digital terrestrial television have been calculated for the frequency of 700 MHz as per methodology in Recommendation ITU-R BT.1368-5. The usage of this voltage method stipulates that the value for the maximum interfering field strength does not depend on the variant of the digital terrestrial broadcasting systems. However, in the case of DVB-T, two variants are listed in the Table 3 for demonstration purpose.

NOTE 4 (Tables 2, 3, 4) – The conversion between pfd (φ) and minimum field strength (E) is by means of the formula $E = \varphi + 145.8$ where E is in dB(μV/m) and φ is in dB(W/m^2).

NOTE 5 (Tables 2, 3, 4) – Terrestrial analogue and digital television applications for fixed reception use directional antennas, but these are very often horizontally polarized and have relatively wide beams in the vertical plane, thus there is no discrimination against interfering signals originating in a satellite for $\delta \leq 20° + x$. It is assumed that Recommendation ITU-R BT.419-3 can be used in both horizontal and vertical planes. It has been assumed that linear interpolation may be used for values of δ between $20° + x°$ and $60° + x°$.

NOTE 6.1 (Table 3) – As described in Recommendation ITU-R P.1546, broadband digital DVB-T signals follow a log-normal law distribution, with a standard deviation, σ_w, of 5.5 dB. In order to ensure a coverage of 95% of locations, q becomes $Q(95\%) = –1.64$. The location correction factor for the wanted signal equals $q\sigma_w = -1.64*5.5 = -9$ dB.

NOTE 6.2 (Table 3) – As described in Recommendation ITU-R P.1546, broadband digital DVB-T signals follow a log-normal law distribution, with a standard deviation of 5.5 dB. In order to ensure a coverage of 95% of locations, q becomes $Q(95\%) = –1.64$. As a receiving antenna is situated at around 10 m above the ground the most important contribution to the received signal comes from the line-of-sight signal from the satellite. Although there may exist shadowing and multipath contributions, they are believed to be insignificant. Therefore, the satellite signal standard deviation, σ_i, is assumed to be 0 dB and, in this case, the propagation correction factor, $q\sqrt{\sigma_w^2 + \sigma_i^2}$, thus equals $q\sigma_w = -9$ dB.

NOTE 7 (Tables 2, 3, 4) – It is assumed that potential BSS systems under consideration in this Report would benefit from having service areas served with high elevation angles. It is also assumed that BS signals are linearly polarized, and potential BSS systems circularly polarized. As a consequence, polarization discrimination situation will experience two situations:

– for angles of arrival $\geq 60° + x°$, the potential BSS interferer transmits in its main beam, and the BS victim receives in its side and back lobes: in this case, Recommendation ITU-R BT.419 indicates that polarization discrimination is already taken into account;

– for angles of arrival between $20° + x°$ and $60° + x°$a mask may be derived by linear interpolation;

– for angles of arrival $\leq 20° + x°$, the victim BS receives in its main lobe, and the potential BSS interferer transmits in the worst case in its first sidelobe, resulting in a BSS/BS polarization discrimination of 1.25 (refer Annex 1).

NOTE 8 (Tables 3, 4) – The PR for terrestrial digital signals has been taken from the Recommendation ITU-R BT.1368, corresponding to the PR ratio for co-channel interference from a digital signal to the digital signal. Because of the very rapid transition to failure for digital signals, there is no need to distinguish between different percentages of time. The same PR values apply to all percentages of time.

NOTE 8*bis* (Table 2) – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 9.1 dB lower to ensure the degradation in C/N margin is limited to 0.5 dB of the available margin.

NOTE 8*ter* (Tables 3, 4) – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 10 dB lower to ensure the degradation in C/N margin is limited to approximately 0.5 dB of the available margin.

NOTE 9 (Table 2, 3, 4) – The quoted pfd is the single entry value tolerable within the nominal bandwidth of a television channel. If there are multiple interfering satellite signals in the same passband, their interfering pfd's must be combined. The study contained in § 9 of Annex 1 can be used to determine an allowance for the aggregate pfd case if required.

NOTE 10 (Table 2) – The broadcasting coverage model applied in one administration provides attention to urban areas. However, many people living in the rural areas need to install special receiving equipment in order to obtain satisfactory reception. Furthermore, it should be noted that the planning of digital television services in another administration is based on the use of low noise amplifiers in rural areas. In both of these cases, it is necessary to provide protection against interference for field strength levels that are lower than those normally adopted elsewhere.

NOTE 11 (Table 3) – From these calculations, it can be seen that the maximum interfering field strength and pfd values are identical for the DVB-T modulations in the Table. This is to be expected as the relationship between *C*/*N* ratio and minimum field strength is independent of the type of modulation. Consequently, these results will also be valid for other DVB-T modulations.

NOTE 12 (Table 4) – The location and time-correction factor has been calculated to be −9 dB taking into account both location variability and time variability. As a receiving antenna is situated at around 10 m above the ground the most important contribution to the received interfering signal comes from the line-of-sight signal from the satellite. Although there may exist shadowing and multipath contributions, they are believed to be insignificant. Therefore, the satellite signal standard deviation is assumed to be 0 dB and the propagation correction factor equals the location and time-correction factor.

NOTE 13 (Table 4) – The minimum field-strength values for digital terrestrial television have been calculated for the frequency of 700 MHz as per the voltage method included in Recommendation ITU-R BT.1368-5. The usage of the voltage method stipulates that the value for the maximum interfering field strength does not depend on the ISDB-T system variant.

9 Protection requirements for terrestrial digital portable reception in the 620-790 MHz band

For the case of portable reception for digital television broadcasting System B (DVB-T) and System C (ISDB-T), two different scenarios are considered, one addressing the case of outdoor reception (Table 5) and one addressing the case of indoor reception (Table 6).

The system characteristics and protection requirements for digital television broadcasting Systems B and C can be found in Recommendations ITU-R BT.1306 and BT.1368 respectively. Further information on these systems can be found in the ITU Digital Terrestrial Television Handbook.

9.1 Case of terrestrial digital portable outdoor reception

TABLE 5

Protection requirements for digital Systems B and C (portable outdoor reception)

	16-QAM, Code rate 2/3		**64-QAM, Code rate 2/3**	
	δ ≤ 20°	**δ ≥ 60°**	**δ ≤ 20°**	**δ ≥ 60°**
Nominal bandwidth (MHz)	8	8	8	8
Required *C*/*N* ratio (dB) (Note 1)	17.2	17.2	22.3	22.3
Minimum field strength (dB(μV/m)) (Note 2)	51.0	51.0	56.1	56.1
Location correction factor (dB) (Note 6)	−9	−9	−9	−9
Minimum median field strength (dB(μV/m))	60.0	60.0	65.1	65.1
Derived pfd (dB(W/m^2)) (Note 3)	–85.8	–85.8	–80.7	–80.7
Receiving antenna directivity discrimination (dB) (Note 4)	0	0	0	0
Receiving antenna polarization discrimination (dB) (Note 5)	1.25	1.25	1.25	1.25
Location correction factor (dB) (Note 6)	−9	−9	−9	−9
Required PR (dB) (Note 7)	17.2	17.2	22.3	22.3

TABLE 5 (*end*)

	16-QAM, Code rate 2/3		64-QAM, Code rate 2/3	
	δ ≤ 20°	**δ ≥ 60°**	**δ ≤ 20°**	**δ ≥ 60°**
Allowance for interservice interference (Note 7*bis*) (dB)	10	10	10	10
Propagation correction factor (dB) (Note 6)	−9	−9	−9	−9
Maximum interfering single entry pfd (dB(W/m^2)) (Notes 8, 9)	–120.75	–120.75	–120.75	–120.75
Maximum interfering field strength (dB(μV/m)) (Notes 8, 9)	25.05	25.05	25.05	25.05

NOTE 1 – The required *C*/*N* values are stated in the ITU Digital Terrestrial Television Handbook for fixed and portable digital television reception (Rice and Rayleigh channels, respectively). In fact, it is not really critical which values of *C*/*N* ratio are used here as the same value must be used as the PR in a later part of the calculations.

NOTE 2 – The minimum field strength values for digital terrestrial television have been calculated for the frequency of 700 MHz as per the method as per methodology in Recommendation ITU-R BT.1368-5. The usage of this voltage method stipulates that the value for the maximum interfering field strength does not depend on the system variant. However, a few variants are listed in the Table for demonstration purpose.

NOTE 3 – The conversion between pfd (φ) and minimum field strength (*E*) is by means of the formula $E = \varphi + 145.8$ where *E* is in dB(μV/m) and φ is in dB(W/m^2).

NOTE 4 – For the case of portable reception, omnidirectional antennas are used. Therefore no directivity discrimination has been considered.

NOTE 5 – It is assumed that potential BSS systems under consideration in this Report would benefit from having service areas served with high elevation angles. It is also assumed that BS signals are linearly polarized, and potential BSS systems circularly polarized. A BSS/BS polarization discrimination of 1.25 dB has been applied. Refer to Annex 3.

NOTE 6 – As described in Recommendation ITU-R P.1546, broadband digital signals follow a log-normal law distribution, with a standard deviation of 5.5 dB for outdoor reception (fixed and portable outdoor). In order to ensure a coverage of 95% of locations, *q* becomes *Q* (95%) = –1.645, and the location correction factor $q\sigma_w$ equals −1.645*5.5 = −9 dB. The signal distribution is a combination of log-normal, Rice and Rayleigh statistics at mobile terminals. The log-normal shadowing has a standard deviation, which can be estimated using empirical or statistical modelling equations and lies in the range of 0-5.5 dB depending on the elevation angle. In the case of portable outdoors terminals, a BSS signals standard deviation, σ_w, of 0 dB is assumed for simplicity and is also felt representative given the nature of the BS and potential BSS systems envisaged here. Therefore, the propagation correction factor, $q\sqrt{\sigma_w^2 + \sigma_i^2}$, equals qσw = –9 dB.

NOTE 7 – The PR for terrestrial digital signals has been taken from Recommendation ITU-R BT.1368, corresponding to the PR ratio for co-channel interference from a digital signal to the digital signal. Because of the very rapid transition to failure for digital signals, there is no need to distinguish between different percentages of time. The same PR values apply to all percentages of time.

NOTE 7*bis* – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 10 dB lower to ensure the degradation in *C*/*N* margin is limited to approximately 0.5 dB of the available margin.

NOTE 8 – The quoted pfd is the single entry value tolerable within the nominal bandwidth of a television channel. If there are multiple interfering satellite signals in the same pass band, their interfering pfd's must be combined. The study contained in § 9 of Annex 1 can be used to determine an allowance for the aggregate pfd case if required.

NOTE 9 – From these calculations, it can be seen that the maximum interfering field strength values are identical for both the 16-QAM and 64-QAM modulation schemes in the Table. This is to be expected as the relationship between *C*/*N* ratio and minimum field strength is independent of the type of modulation. Consequently, these results will also be valid for other system variants.

9.2 Case of terrestrial digital portable indoor reception

TABLE 6

Protection requirements for digital Systems B and C (portable indoor reception)

	16-QAM, Code rate 2/3		**64-QAM, Code rate 2/3**	
	δ ≤ 20°	**δ ≥ 60°**	**δ ≤ 20°**	**δ ≥ 60°**
Nominal bandwidth (MHz)	8	8	8	8
Required *C*/*N* ratio (dB) (Note 1)	17.2	17.2	22.3	22.3
Minimum field strength (dB(μV/m)) (Note 2)	51.0	51.0	56.1	56.1
Location correction factor (dB) (Note 6)	–13	–13	–13	–13
Minimum median field strength (dB(μV/m))	64.0	64.0	69.1	69.1
Derived median pfd (dB(W/m^2)) (Note 3)	–81.8	–81.8	–76.7	–76.7
Receiving antenna directivity discrimination (dB) (Note 4)	0	0	0	0
Building penetration loss (dB)	8	8	8	8
Receiving antenna polarization discrimination (dB) (Note 5)	1.25	1.25	1.25	1.25
Location correction factor (dB) (Note 6)	–13	–13	–13	–13
Required PR (dB) (Note 7)	17.2	17.2	22.3	22.3
Allowance for interservice interference (Note 7*bis*) (dB)	10	10	10	10
Propagation correction factor (dB) (Note 6)	–13	–13	–13	–13
Maximum interfering single entry pfd (dB(W/m^2)) (Notes 8, 9)	–112.75	–112.75	–112.75	–112.75
Maximum interfering field strength (dB(μV/m)) (Notes 8, 9)	33.05	33.05	33.05	33.05

NOTE 1 – The required *C*/*N* values are stated in the ITU Digital Terrestrial Television Handbook for fixed and portable digital television reception (Rice and Rayleigh channels, respectively). In fact, it is not really critical which values of *C*/*N* ratio are used here as the same value must be used as the protection ratio in a later part of the calculations.

NOTE 2 – The minimum field-strength values for digital terrestrial television have been calculated for the frequency of 700 MHz as per the method as per methodology in Recommendation ITU-R BT.1368-5. The usage of this voltage method stipulates that the value for the maximum interfering field strength does not depend on the system variant. However, two variants are listed in Table 6 for demonstration purpose.

NOTE 3 – The conversion between pfd (φ) and minimum field strength (E) is by means of the formula $E = \varphi + 145.8$ where E is in dB(μV/m) and φ is in dB(W/m^2).

NOTE 4 – For the case of portable reception, omnidirectional antennas are used. Therefore no directivity discrimination has been considered.

NOTE 5 – It is assumed that potential BSS systems under consideration in this Report would benefit from having service areas served with high elevation angles. It is also assumed that BS signals are linearly polarized, and potential BSS systems circularly polarized. A BSS/BS polarization discrimination of 1.25 dB has been applied. Refer to Annex 3.

NOTE 6 – As described in Recommendation ITU-R P.1546, broadband digital signals follow a log-normal law distribution, with a standard deviation, σ_w, of 7.8 dB (including the statistical variation of building penetration loss) for indoor reception (portable indoor). In order to ensure a coverage of 95% of locations, q becomes Q (95%) = –1.645, and the location correction factor, $q\sigma_w$, equals −1.645*7.8 = −13 dB. The signal distribution is a combination of log-normal, Rice and Rayleigh statistics at mobile terminals. The log-normal shadowing (outdoors) has a standard deviation, which can be estimated using empirical or statistical modelling equations and lies in the range of 0-5.5 dB depending on the elevation angle; the standard deviation of the building penetration loss must also be taken into account to arrive at σ_w = 7.8 dB. In the case of portable indoors terminals, a BSS signals standard deviation of 0 dB is assumed for simplicity and is also felt representative given the nature of the BS and potential BSS systems envisaged here. Therefore, the propagation correction factor, $q\sqrt{\sigma_w^2 + \sigma_i^2}$, equals $q\sigma_w = -13$ dB.

NOTE 7 – The PR for terrestrial digital signals has been taken from Recommendation ITU-R BT.1368, corresponding to the PR ratio for co-channel interference from a digital signal to the digital signal. Because of the very rapid transition to failure for digital signals, there is no need to distinguish between different percentages of time. The same PR values apply to all percentages of time.

NOTE 7*bis* – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 10 dB lower to ensure the degradation in *C*/*N* margin is limited to approximately 0.5 dB of the available margin.

NOTE 8 – The quoted pfd is the single entry value tolerable within the nominal bandwidth of television channel. If there are multiple interfering satellite signals in the same pass band, their interfering pfd's must be combined. The study contained in § 9 of Annex 1 can be used to determine an allowance for the aggregate pfd case if required.

NOTE 9 – From these calculations, it can be seen that the maximum interfering field strength values are identical for both the 16-QAM and 64-QAM modulation schemes in the Table. This is to be expected as the relationship between *C*/*N* ratio and minimum field strength is independent of the type of modulation. Consequently, these results will also be valid for other system variants.

10 Protection requirements for terrestrial digital mobile reception in the 620-790 MHz band

Table 7 addresses the protection requirements for mobile reception of digital television broadcasting System B (DVB-T) and System C (ISDB-T). The system characteristics and protection requirements can be found in Recommendations ITU-R BT.1306 and BT.1368 respectively. Further information on these systems can be found in the ITU Digital Terrestrial Television Handbook.

TABLE 7

Protection requirements for digital Systems B and C (mobile reception)

	16-QAM, Code rate 1/2	
	δ ≤ 20°	δ ≥ 60°
Nominal bandwidth (MHz)	8	8
Required *C*/*N* ratio (dB) (Note 1)	12.5	12.5
Minimum field strength (dB(μV/m)) (Note 2)	46.3	46.3
Location correction factor (dB) (Note 6)	−13	−13
Minimum median field strength (dB(μV/m))	59.3	59.3
Derived median pfd (dB(W/m^2)) (Note 3)	–86.5	–86.5
Receiving antenna directivity discrimination (dB) (Note 4)	0	0
Receiving antenna polarization discrimination (dB) (Note 5)	1.25	1.25
Required PR (dB) (Note 7)	12.5	12.5
Allowance for interservice interference (Note 7*bis*) (dB)	10	10
Propagation correction factor (dB) (Note 6)	−13	−13
Maximum interfering single entry pfd (dB(W/m^2)) (Notes 8, 9)	–120.75	–120.75
Maximum interfering field strength (dB(μV/m)) (Notes 8, 9)	25.05	25.05

NOTE 1 – The required *C*/*N* values are stated in the ITU Digital Terrestrial Television Handbook for fixed and portable digital television reception (Rice and Rayleigh channels, respectively). In fact, it is not really critical which values of *C*/*N* ratio are used here as the same value must be used as the PR in a later part of the calculations.

NOTE 2 – The minimum field strength values for digital terrestrial television have been calculated for the frequency of 700 MHz as per the method as per methodology in Recommendation ITU-R BT.1368-5. The usage of this voltage method stipulates that the value for the maximum interfering field strength does not depend on the system variant. Consequently, the results in the Table obtained from the 16-QAM 1/2 are valid for the other few variants.

NOTE 3 – The conversion between pfd (φ) and minimum field strength (*E*) is by means of the formula $E = \varphi + 145.8$ where *E* is in dB(μV/m) and φ is in dB(W/m^2).

NOTE 4 – For the case of mobile reception, omnidirectional antennas are used. Therefore no directivity discrimination has been considered.

NOTE 5 – It is assumed that potential BSS systems under consideration in this Report would benefit from having service areas served with high elevation angles. It is also assumed that BS signals are linearly polarized, and potential BSS systems circularly polarized. A BSS/BS polarization discrimination of 1.25 dB has been applied. Refer to Annex 3.

NOTE 6 – As described in Recommendation ITU-R P.1546, broadband digital signals follow a log-normal law distribution, with a standard deviation of 5.5 dB for outdoor reception (fixed, portable and mobile). In order to ensure a coverage of 99% of locations, *q*. becomes *Q*(99%) = –2.32, and the location correction factor equals −2.32*5.5 = −13 dB. The signal distribution is a combination of log-normal, Rice and Rayleigh statistics at mobile terminals. The log-normal shadowing has a standard deviation, which can be estimated using empirical or statistical modelling equations and lies in the range of 0-5.5 dB depending on the elevation angle. In the case of mobile terminals, a BSS signals standard deviation, σ_i, of 0 dB is assumed for simplicity and is also felt representative given the nature of the BS and potential BSS systems envisaged here. Therefore, the propagation correction factor, $q\sqrt{\sigma_w^2 + \sigma_i^2}$, equals $q\sigma_w = -13$ dB.

NOTE 7 – The PR for terrestrial digital signals has been taken from Recommendation ITU-R BT.1368, corresponding to the PR ratio for co-channel interference from a digital signal to the digital signal. Because of the very rapid transition to failure for digital signals, there is no need to distinguish between different percentages of time. The same PR values apply to all percentages of time.

NOTE 7*bis* – Beyond the PR required for BS-BS intraservice interference that is built into the PRs in Recommendation ITU-R BT.1368, interference contributions arising from interservice sharing (between the BS and interference from other services including potential BSS) need to be 10 dB lower to ensure the degradation in *C*/*N* margin is limited to approximately 0.5 dB of the available margin.

NOTE 8 – The quoted pfd is the single entry value tolerable within the nominal bandwidth of television channel. If there are multiple interfering satellite signals in the same pass band, their interfering pfd's must be combined. The study contained in § 9 of Annex 1 can be used to determine an allowance for the aggregate pfd case if required.

NOTE 9 –The relationship between *C*/*N* ratio and minimum field strength is independent of the type of modulation. Consequently, these results will also be valid for other system variants.

11 Potential for interference

11.1 pfd from the GSO BSS

WARC-79 Recommendation 705 provides provisional limits on the pfd from the existing GSO BSS system: –129 dB(W/m^2) for arrival angles below 20°, –113 dB(W/m^2) for arrival angles above 60° and a linear interpolation for arrival angles between 20° and 60°. It further calls for additional studies on whether these pfd limits are appropriate.

It should be noted that Resolution 545 (WRC-03) suspends the application of RR No. 5.311, which governs use of the band 620-790 MHz by the broadcasting-satellite service, until the end of WRC-07, to allow further studies under Recommendation 705.

11.2 Antenna discrimination in directivity and polarization

This Report assumes that the gain of the fixed receiving television antenna is at its maximum value over all azimuth angles at elevations up to 20° and is 16 dB less than maximum at elevations above 60°, with a linear interpolation at elevations between 20° and 60°. This is consistent with Recommendation ITU-R BT.419-3 and simplifies the evaluation of maximum allowable interference.

Measurements of 12 commercially available terrestrial BS antennas were performed by one administration. The overall conclusion from this study is that a real antenna, even a reasonably low-gain one, has better directivity discrimination in the horizontal plane than the simple mask in Fig. 1 of Recommendation ITU-R BT.419-3, but that the elevation relationship is a reasonable approximation of a real antenna.

For polarization discrimination, this Report assumes, based on the study in Annex 3, that it is a maximum of 1.25 dB for all elevation angles up to 20° + *x*°. According to Recommendation ITU-R BT.419-3, polarization discrimination is already taken into account for potential BSS transmissions arriving at angles above 60° + *x*° and so no polarization discrimination factor is used for higher angles.

11.3 Summary of calculated maximum interfering pfd

Calculations of the potential maximum interfering pfd are provided in this report for a range of cases for analogue and digital terrestrial television broadcasting systems. The key results of the studies as summarized in Table 8 converted to a reference bandwidth of 1 MHz and rounded to the nearest whole number. (Refer to the Tables mentioned in column 2 for pfd values in the nominal system bandwidth for each system.)

TABLE 8

Summary of calculated maximum interfering single entry pfd

BS system to be protected from potential BSS	Reference	Maximum interfering pfd (dB(W/(m² · MHz))) $\delta \leq 20°+x°$ (1)	Maximum interfering pfd (dB(W/(m² · MHz))) $\delta \geq 60°+x°$ (1)
Analogue television service – nominal coverage area (fixed reception)	Table 1	–142	–127
Analogue television service – fringe coverage area (fixed reception)	Table 1	–148	–133
Digital System A (ATSC) (fixed reception)	Table 2	–142	–127
Digital System B (DVB-T) (fixed reception)	Table 3	–137	–122
Digital System C (ISDB-T) (fixed reception)	Table 4	–138	–123
Digital Systems B and C (DVB-T and ISDB-T) (portable outdoor reception)	Table 5	–130	–130
Digital Systems B and C (DVB-T and ISDB-T) (portable indoor reception)	Table 6	–122	–122
Digital Systems B and C (DVB-T and ISDB-T) (mobile reception)	Table 7	–130	–130

(1) The factor $x°$ is indicated here as a reminder that the receiving antenna discrimination is obtained using directly Recommendation ITU-R BT.419., hence assuming a typical tilt angle of 0° for these antennas. Investigations have shown that this assumption does not remain valid in hilly environments. Annex 2 concludes that a representative average tilt angle of $x° = 10°$ can be used although some Administrations stated that a representative tilt angle of $x° = 15°$ or some other value may be more appropriate to cover this phenomenon. In the case of Digital System A (ATSC) no tilt angle is specified ($x° = 0°$)

12 Conclusion

The analysis provided in the Report has dealt with the protection requirements of the terrestrial broadcasting service from GSO and non GSO BSS networks/systems for a wide range of fixed analogue and digital scenarios, including fringe area reception as well as mobile, and portable. The results that detail the required protection levels in terms of maximum interfering field strength for each of the scenarios are provided in Tables 1 to 7.

The summary in Table 8 shows that analogue television systems and Digital System A require greater protection (i.e. lower pfd limits) from both low and high elevation angles of arrival.

The tables also show the results of calculation where the maximum interfering field strengths are translated to an equivalent maximum single entry pfd for a range of elevation angles which would be required from GSO and non GSO BSS networks/systems. Table 8 provides a summary of those results.

The protection requirements for fixed reception of digital Systems B and C are approximately equivalent to the proposed BSS pfd levels, however, greater protection (i.e. lower pfd limits) is required by digital Systems B and C in the portable outdoor and mobile reception cases for high elevation angles.

It should be noted that the frequency range 620-790 MHz has been planned by the RRC-06 for maximum utilization by terrestrial television broadcasting with no allowance for additional future BSS interference. RRC-06 adopted Resolution 1 (RRC-06) to be submitted to WRC-07 decision and appropriate action at the 2007 World Radiocommunications Conference:

"**1** to take appropriate and necessary measures to effectively protect the broadcasting Plans adopted by this Conference and their subsequent evolution from the GSO-BSS and/or non-GSO BSS networks/systems which were not brought into use prior to 5 July 2003;

2 to take appropriate and necessary measures in order that the ground terminals of GSO and/or non-GSO BSS networks/systems which were not brought into use prior to 5 July 2003 shall not claim protection from the Plans adopted by this Conference and their subsequent evolution, nor put any constraint on the operation of the assignments of the Plans and their subsequent evolution,"

This Report only covers a range of services either proposed or in service. It will need to be updated as new systems are proposed.

To fully cover the Resolution 1 (RRC-06) terrestrial television service receiving antenna beam tilt needs to be incorporated as detailed in this Report.

Annex 1

Consolidated characteristics of potential GSO and non-GSO systems intended to operate in the 620-790 MHz band

1 Introduction

The purpose of this Annex is to provide some information on this topic concerning potential GSO and non-GSO BSS systems proposed by France in 2002 to the ITU-R. Information is coming from documents submitted to ITU-R since 2002, based on RR No. 5.311 and Recommendation 705 of the RR before WRC-03.

A careful review of this Annex generated several questions and comments about its content. The more important include:

– the practicality of the satellite antenna and applicability of the reference antenna pattern from RR Appendix 30; and

– the link budget with respect to mobile antenna terminal gain and fade margin.

2 System overview

The purpose of the system is to offer a BS on national or regional basis.

A wide range of contents will be delivered through the system towards mobile terminal in a mass-market environment thanks to the use of highly efficient compression, coding and multiplexing techniques.

The system will consist of:

– a user segment with low cost user terminals (receive only);
– a gateway station interconnected with terrestrial networks for the transfer of information to the user terminal via the satellite segment;
– a constellation of satellites potential GSO and non-GSO. Two satellite configurations have been considered:
  – a potential GSO system covering low latitude zones (equatorial regions);
  – a constellation of potentially three satellites in non-GSO covering higher latitude zones (medium and high latitude regions).

The frequency bands and associated service type are given in Table 9.

TABLE 9

Frequency bands and service type

Link	Service type	Frequency band
Gateway to satellite	FSS (Earth-to-space)	27.7-27.870 GHz
Satellite to terminals	BSS	620-790 MHz

It should be noted that user terminals in the band 620-790 MHz are only capable of receiving and as a consequence, the only BSS transmissions in that band are space to Earth. There is no return channel in that band.

3 Main characteristics of potential GSO BSS and non GSO BSS systems

3.1 Macro-diversity principle

BSS receivers will intensively use signal-processing techniques in order to cope with the specific terminal environment, including mobile propagation and interfering environment.

Thanks to optimized multiplexing, interleaving and coding techniques, the receiver will take benefit of the time- and frequency-diversity of the received signal to autonomously mitigate interferences from BS transmitters operating in the same frequency band. This is mainly due to the fact that:

– interfering signals cause harmful interferences on only a fraction of the data due to time and frequency diversity;
– long time interleaving can be envisaged in broadcasting systems.

Moreover, these techniques will also allow spreading the signal power in order to limit possible interference towards terrestrial broadcasting services.

3.2 BSS reception in an interfered environment

Figure 2 shows an example of power spectrum at BSS receiver input in typical BS interfering environment. We can see that channels used by the closest BS transmitters are heavily interfered whereas interferences in channels used by farthest transmitters are attenuated due to the largest propagation losses.

FIGURE 1

Waveform concept tailored to cope with the specific propagation conditions affecting mobile receivers in UHF

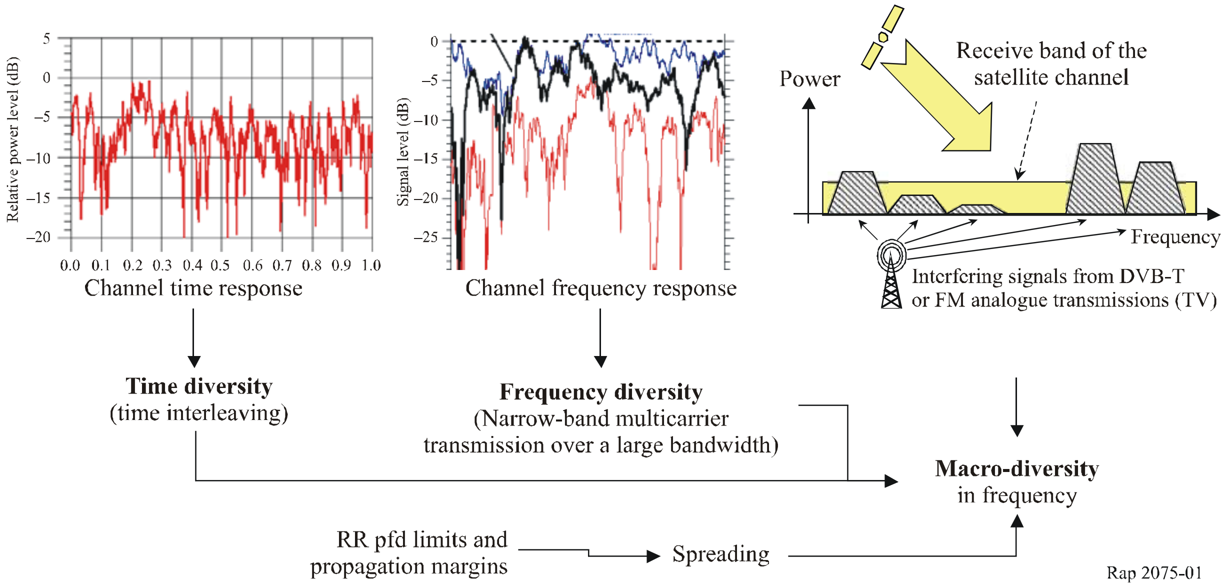
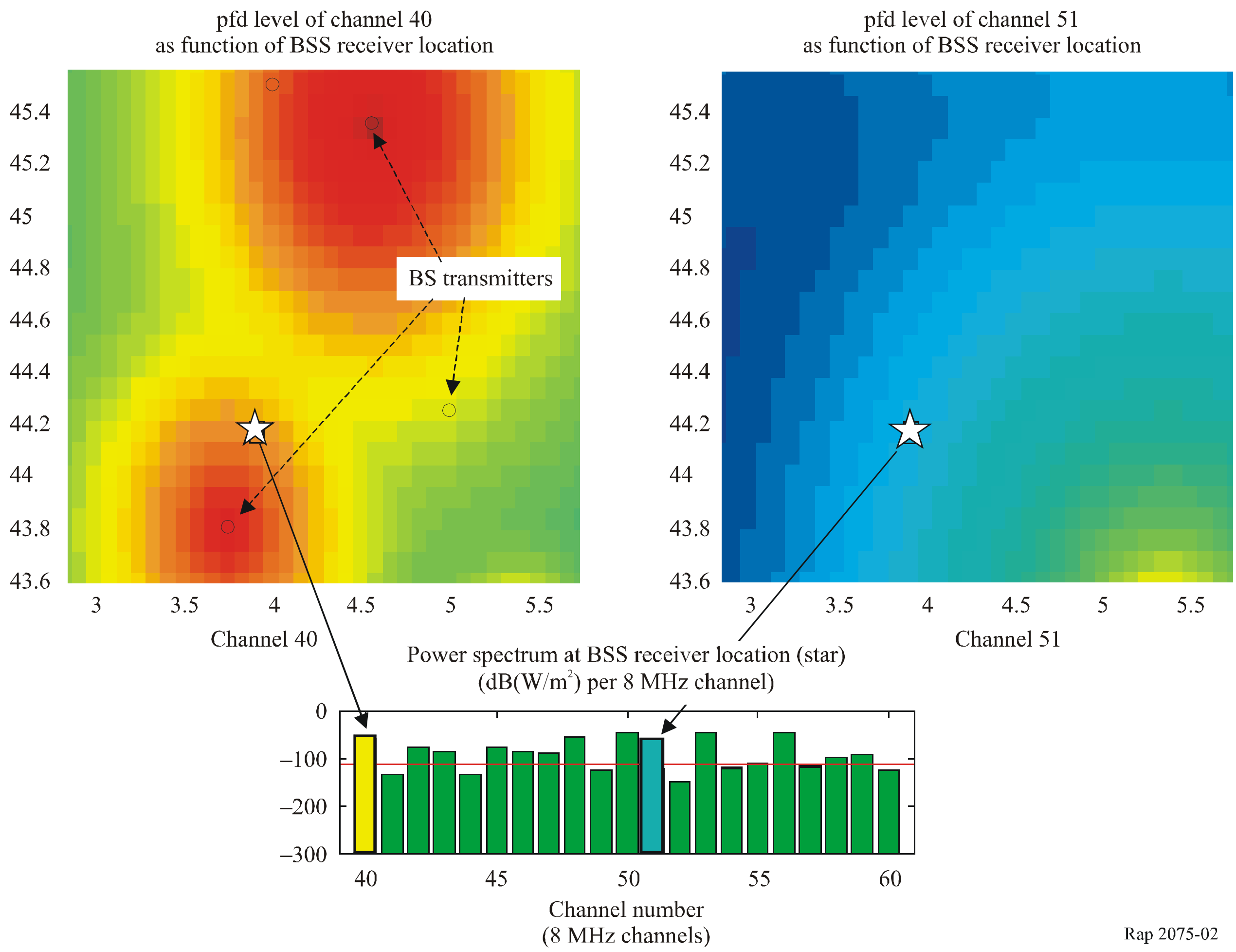


FIGURE 2

Typical interference scenario at BSS receiver input



Because of the specific receiver design, the interfering environment shall thus be characterized by the distribution of I_0/N_0 over the entire BSS signal bandwidth:

– *Number of blocked channels*

At first order, channels heavily interfered by BS transmitters will not be used by the receiver to recover the data stream.

– *I/N on "usable" channels*

At receiver input, a number of channels will be less interfered by the BS systems. A given BS channel will be considered as "usable" when the I/N ratio will not exceed a given threshold.

The specific spectrum spreading and coding scheme of the BSS signal allows a BSS receiver to dynamically recover the transmitted data stream thanks to the part of the BSS signal where the interference level (I_0/N_0) is the lowest.

It means that the demodulation performances of the BSS receiver in the heavy interfering environment caused by the BS transmitters is basically driven by the ratio of spectrum where the interference level (I_0/N_0) does not exceed a certain threshold.

In view of this adaptive demodulation scheme, BSS receivers will be able to accept the current and future interfering environment from terrestrial broadcasting systems (analogue and digital).

3.3 Potential GSO and non-GSO BSS systems main parameters

Broadcasting towards portable/mobile terminals from satellite received at high elevation represents an optimized use of the UHF band by BSS when considering the existing regulatory constraints in this band. GSO BSS systems will be used to cover low latitude zones where the geostationary arc is at elevation angles higher than 60°. Non-GSO BSS systems are suitable for covering medium and high latitude zones within the service area, to be able to always operate at elevation angles higher than 60°.

These BSS systems will intensively use coding, spreading spectrum to distribute power and interference mitigation techniques in order to cope with the specific terminal interfering environment from BS. Moreover, these techniques will also allow reducing the signal power density in order to limit possible interference towards terrestrial broadcasting services.

In order to optimize the power requirements and to keep constant the pfd on ground within the service area, both GSO and non-GSO satellites use isoflux transmitting antennas and non-GSO satellites adjust the power and the shape of the beam as a function of the altitude (beam zooming). All GSO and non-GSO satellites produce the same pfd on ground within their service area, which corresponds to the maximum single entry interference to BS receivers. Only one satellite (GSO or non-GSO) will transmit at any time over the service area (see § 5.1).

The main characteristics of proposed GSO and non-GSO BSS systems are summarized in Table 10.

3.4 Polarization discrimination

The BSS signal will be circularly polarized while the BS receivers in some cases are linearly polarized; hence, in these cases, a polarization discrimination of antennas in the reception of television broadcasting has to be taken into consideration.

According to Recommendation ITU-R BT.419-3, for a given transmitter power, a circularly polarize transmitting antenna will result in a field strength lower by 3 dB in the horizontal or vertical plane than that provided using a linearly polarized transmitting antenna.

TABLE 10

GSO and Non GSO systems characteristics

	GSO satellites	Non-GSO satellites
Type of orbit		3 satellites apogee altitude 47 103 km
Service area diameter (km)	3 500	3 800
Minimum elevation angle (degrees)	60	60
Periods of satellite activity	Only ONE satellite transmitting at any time	Only ONE satellite transmitting at any time
Frequency bands		
Uplink (feeder link) (GHz)	27.500-27.670	27.500-27.670
Downlink (user link) (MHz)	620-790	620-790
Downlink beacon (for feeder U/L power control) (GHz)	27.500-27.501	27.500-27.501
Signal parameters		
Modulation	Multicarrier (OFDM)	Multicarrier (OFDM)
Bandwidth (MHz)	Up to 170	Up to 170
UHF band parameters		
e.i.r.p. density at Nadir angle dB(W/MHz)	40	42 at apogee
Maximum pfd on ground ($dB(W/m^2)$)[(1)]	–113	–113
On-board antenna	Isoflux on service area	Isoflux + beam zooming on service area
Antenna pattern outside service area[(2)]	RR AP 30 – Fig. 9	RR AP 30 – Fig. 9
Service area	Equatorial regions	Medium to high latitude regions
Service area angular width (degrees)	~ 6 x 3	< 8.7
Polarization	Circular	Circular
UHF only receiving user terminal G/T (dB/K)	–25	–25
Minimum $C_0/(N_0+I_0)$	0 dB on non-heavily interfered spectrum	0 dB on non-heavily interfered spectrum
Ka band parameters		
Edge of coverage G/T (dB/K)	5 EOC	5 EOC
Beacon e.i.r.p. (dBW)	Typical 40	Typical 40
Antenna radiation pattern	Rec. ITU-R S.1528	Rec. ITU-R S.1528

(1) pfd limit included in Recommendation 705 of the RR for elevation angles higher that 60°. This limit is considered to be applied in the worst case of the victim BS bandwidth, that is to say, in 8 MHz.

(2) There is presently no antenna pattern recommended for BSS in UHF. Isoflux constraint should entail a fast roll off outside the service area as achieved with RR AP 30 satellite transmit antenna pattern.

As explained in the study included in Appendix 3 to Annex 6(Rev.1) of Document 6E/211 (Chairman's Report), a value of 1.25 dB is proposed to be used as the polarization discrimination for compatibility assessment from BSS systems to broadcasting services in the 620-790 MHz band.

4 Constellation parameters for non GSO system

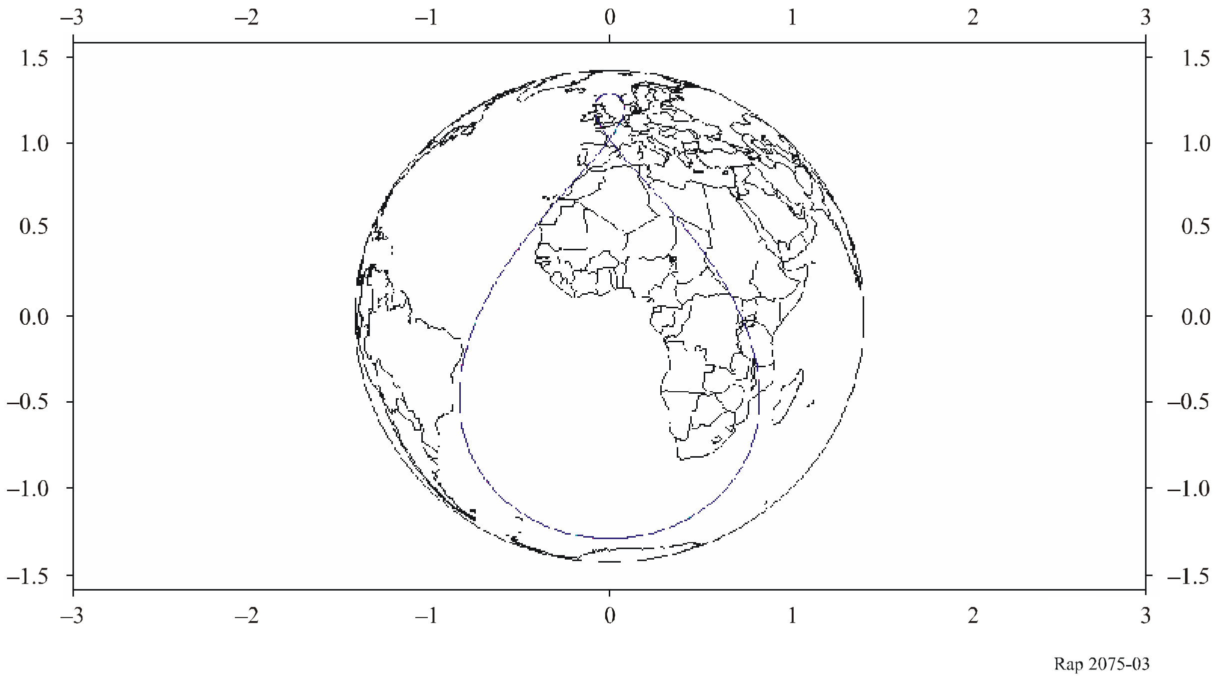
The constellation parameters are optimised to offer satisfactory visibility conditions to any users within the service area. The example below illustrates the case of a Tundra constellation covering Western European countries with three satellites orbiting in a 24-h period:

– Semi-major axis: 42 164 km
– Eccentricity: 0.2684
– Inclination: 63.4°
– Argument of perigee: 270°
– Right ascension of ascending node: 110°, 230° and 350°
– Mean anomaly: 340°, 220° and 100°

Figure 3 illustrates the satellite ground track on the Earth's surface.

FIGURE 3

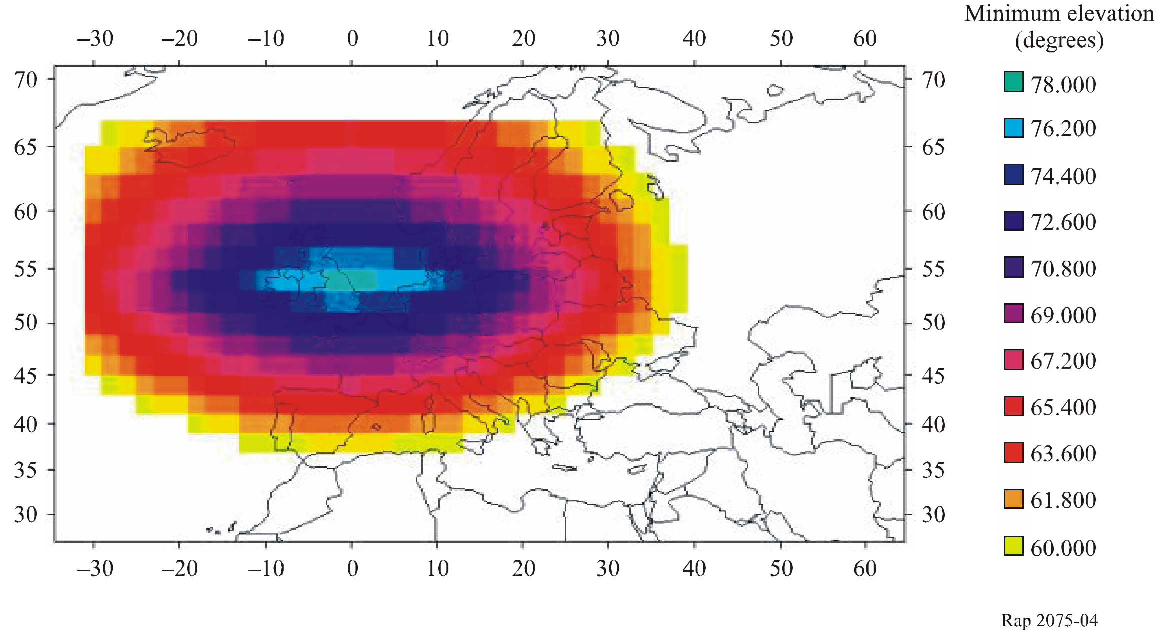
Non-GSO constellation ground track



The use of highly elliptical orbit non-GSO is particularly suited to the coverage of medium to high latitude regions. As shown in Fig. 4, any user within the coverage area is in visibility of a satellite with an elevation angle greater than 60°.

FIGURE 4

Minimum elevation angle as function of the user location



5 Non-GSO satellite operational characteristics

5.1 Times of satellite activity

With the orbital parameters of a non-GSO constellation, a given satellite is in visibility of the service area with an elevation angle better than 60° only 1/3 of the time:

– Over its 24-h orbit period, the satellite will be in visibility of the service area with an elevation angle better than 60° during 8 h, and then 16 h will be spent in "non-visibility".

Satellites will be programmed to be inactive (amplifiers switched-off) during periods of "non-visibility" (16 h). It means that only one satellite will be transmitting towards the service area at a given time.

5.2 Satellite antenna and power management

The satellite antenna will be designed to meet a number of requirements during the active transmissions periods:

– *Isoflux coverage*

The satellite will use an isoflux antenna to optimise its power requirements and to cope with in-coverage pfd limits. It means that the satellite antenna gain within the service area will be such that the pfd on ground will be kept constant whatever the position of a terminal within the service area.

– *Beam zooming*

As the satellite altitude varies with time in non-GSO, the solid angle with which a satellite sees the service area will vary with time, as function of its altitude. In order to cope with this "beam zooming effect" and to reduce the overall power requirements, the satellite will also adjust the power and the shape of the beam as function of its altitude.

Consequently, the satellite design will ensure that the pfd on ground will be kept constant whatever the time and the terminal location within the service area.

5.3 Example of link budget for non-GSO BSS system

The required satellite e.i.r.p. and consequently pfd on ground is mainly dependent upon the interfering scenario at the BSS receiver location and the target capacity of the system (aggregate data bit rate).

As a sizing example, Table 11 provides the link budget for a BSS receiver in the following environment hypothesis:

– *Level of interference in "usable" channels:* the system is dimensioned to support an interference level from BS transmitters in "usable" channels equal to the BSS receiver noise floor, i.e. $I_0/N_0 = 0$ dB.

– *Proportion of "usable" channels:* the ratio of spectrum with satisfactory I_0/N_0 levels (>0 dB) is assumed to be equal to 25% of the 170 MHz, i.e. 75% of the total spectrum at the BSS receiver location is heavily interfered by BS emissions.

The e.i.r.p. and pfd requirements are then provided for a total system capacity of 10 Mbit/s after decoding, which is in line with the capacity performances of satellite systems providing broadcasting services to mobile users.

TABLE 11

Link budget example for typical BSS receiving terminal

	Downlink frequency	**0,705 GHz**	*Centre frequency of BSS allocation in UHF (620-790MHz)*
Orbital parameters		**Toundra orbit**	
	Apogee altitude	47 103 Km	
	Minimum Elevation angle	60,0°	*edge of service area*
	Satellite path range	**47 862 Km**	*satellite at apogee, user station at edge of service area*
BSS Satellite RF parameters			
	Total satellite EIRP	**64,8 dBW**	*Ground station at edge of coverage, satellite at apogee*
	Signal bandwith	170 MHz	
	Equivalent PFD on ground [per 8 MHz]	-113,1 dBW/m²	*and pfd < -129 dBW/m² for elevation angles below 20°*
Downlink propagation			
	Free Space Loss	183,0 dB	
	Fading Loss	3,0 dB	*Rec. P.681-5, "tree shadowing", 800MHz, 95% of time, 60° elevation*
BSS Receiving Terminal			
	Terminal antenna gain	2,0 dBi	
	Receiver noise temperature	500 K	
	Receiver G/T	-25,0 dB/K	
Intra-system C/No budget			
	Dowlink C/No	**82,4 dBHz**	
	C/No degradation due to feeder uplink contribution	0,4 dB	
	Overall C/No	**82,0 dBHz**	
	Overall C/No	-0,3 dB	*without external interference*
Aggregate Capacity of BSS system in heavily-interfered environment			
	Io/No allowance for interference from BS transmitters	0,0 dB	*on "usable" channels, at receiver input*
	Overall C/(No+Io) in usable channels	79,0 dBHz	
	Required Eb/(No+Io)	3,0 dB	*BER = 2e-4 after Viterbi decoder*
	Assumed ratio of "usable" spectrum	25%	*total spectrum with satisfactory I/N ratios at any BSS receiver location*
	Max aggregate bit rate	**10 Mbps**	

5.4 Aggregate system capacity

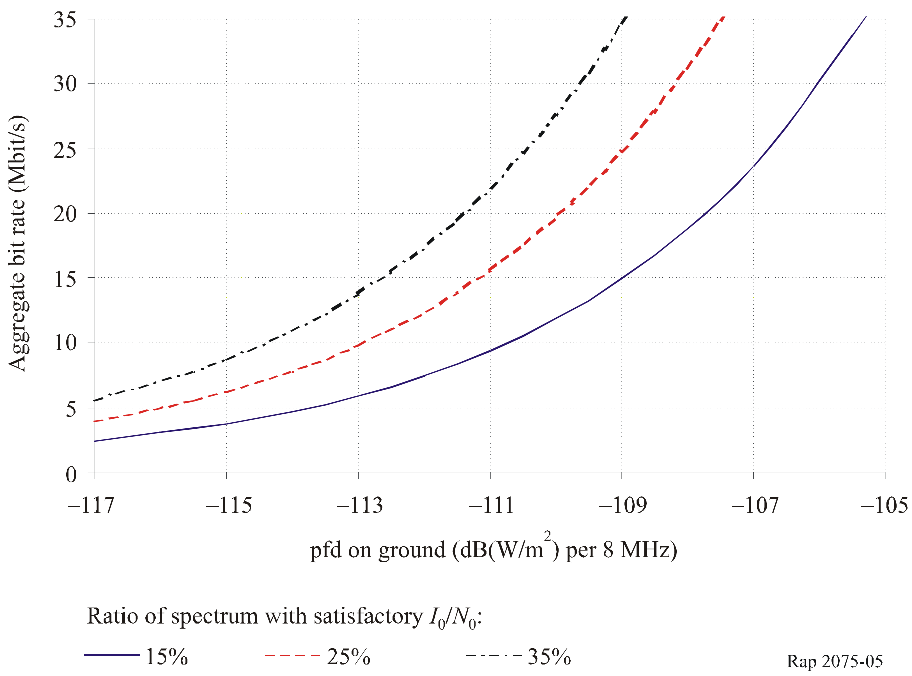
More generally, the previous link budget computation can be varied with the pfd.

The capacity of a BSS system is a function of the pfd level received on ground and of the ratio of spectrum with satisfactory I_0/N_0 levels. The pfd level received on ground will be always less than the limits included in RR No. 5.311 and RR Recommendation 705 taking into account that GSO and non-GSO BSS systems will operate with elevation angles greater than 60°. Figure 5 shows that, even with a heavy usage of spectrum by terrestrial services (e.g. less than 15% of spectrum having satisfactory interference levels), a significant broadcasting capacity can be provided by a BSS system.

In the case of GSO and non-GSO BSS with elevation angles below 60° advice is being sought from Radiocommunication Working Party 6S.

FIGURE 5

Aggregate capacity a BSS system as function of the PFD on ground



6 Information about multiple BSS systems in the band 620-790 MHz

Information about multiple BSS systems in the band 620-790 MHz is presented in Document 6E/299 (Doc. 6S/311) from March 2003.

7 Characteristics of an example BSS GSO/non-GSO system/network concept for possible use in the 620-790 MHz band

In March 2006 Radiocommunication Working Party 6S provided Working Party 6E with the characteristics on BSS systems under consideration for possible operation in the frequency band 620-790 MHz. It consolidated the available information concerning these systems in particular with respect to those aspects relating particularly to studies of sharing BSS operation with that of the terrestrial services to which this band is also allocated.

7.1 Space station characteristics

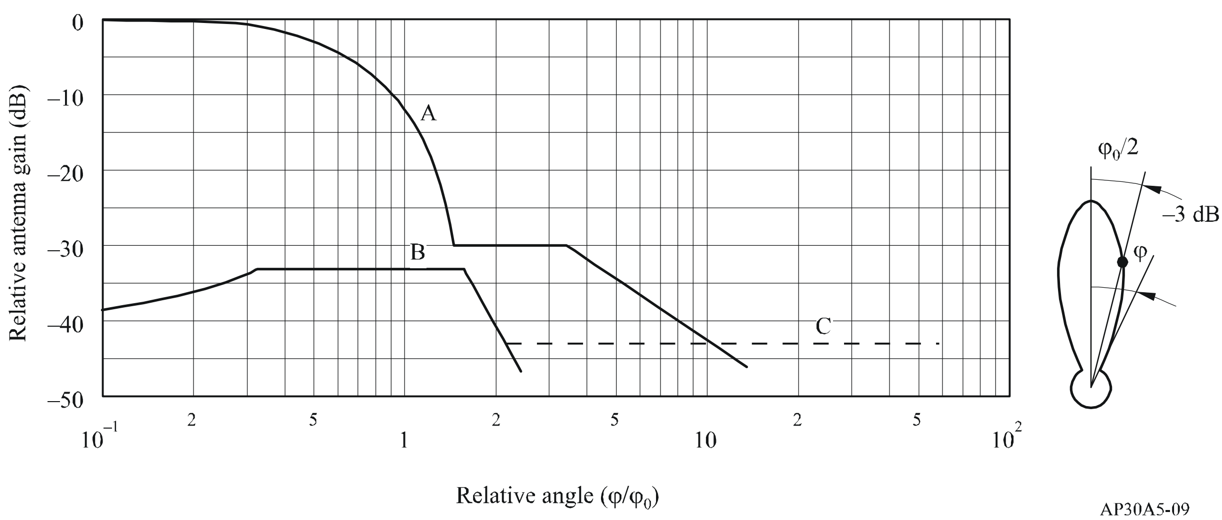
TABLE 12

Operating power levels	Space station emissions would comply with the pfd mask given in *recommends* 1 of RR Recommendation 705, namely: -129 dB(W/m^2) for $\delta \leq 20°$ $-129 + 0.4\ (\delta - 20)$ dB(W/m^2) for $20° < \delta \leq 60°$ -113 dB(W/m^2) for $60° < \delta \leq 90°$ when applied to an 8 MHz bandwidth, and where δ is the angle of arrival above the horizontal plane (degrees)
Off-axis space station antenna gain	There is presently no antenna pattern recommended for BSS in UHF. The isoflux design constraint (see Document 6E/299 from the 2000-2003 ITU-R study period) should entail a fast roll off outside the service area. The space station antenna pattern outside the serviced area has been assumed to be consistent with the satellite transmit antenna pattern given in Fig. 9 of RR Appendix 30. This pattern is reproduced in §7.2 below.
Service area	In all cases (GSO or non-GSO) the service area is defined as the contour representing an elevation angle of 60°. This service area limit corresponds to the –3 dB relative gain value in Fig. 9 of RR Appendix 30.
Polarization	Circular

7.2 Satellite transmitting antenna pattern, for use outside the service area – Fig. 9 from Appendix 30

FIGURE 9

Reference patterns for co-polar and cross-polar components for satellite transmitting antennas in Regions 1 and 3



Curve A: Co-polar component (dB relative to main beam gain)

$-12\left(\frac{\varphi}{\varphi_0}\right)$ for $0 \leq \varphi \leq 1.58\ \varphi_0$

-30 for $1.58\ \varphi_0 < \varphi \leq 3.16\ \varphi_0$

$-\left[17.5+12\log\left(\frac{\varphi}{\varphi_0}\right)\right]$ for $\varphi > 3.16\ \varphi_0$

after intersection with Curve C: as Curve C

Curve B: Cross-polar component (dB relative to main beam gain)

$-\left(40+40\log\left|\frac{\varphi}{\varphi_0}-1\right|\right)$ for $0 \leq \varphi \leq 0.33\ \varphi_0$

-33 for $0.33\ \varphi_0 < \varphi \leq 1.67\ \varphi_0$

$-\left(40+40\log\left|\frac{\varphi}{\varphi_0}-1\right|\right)$ for $\varphi > 1.67\ \varphi_0$

after intersection with Curve C: as Curve C

Curve C: Minus the on-axis gain (Curve C in this Figure illustrates the particular case of an antenna with an on-axis gain of 43 dBi).

7.3 Earth station characteristics

TABLE 13

Receiving earth station maximum antenna gain	2.0 dBi
Off-axis antenna pattern	Antenna is quasi-omnidirectional
Receiving system noise temperature	500 K

8 Maximum number of possible BSS systems

The maximum number of BSS systems has been established by use of the RR Appendix 5 criterion for establishing the need for coordination between GSO satellite networks. This is that the increase in noise temperature in the wanted BSS reception downlink caused by an interfering network should not exceed 6% when expressed as a ratio $\Delta T/T$ where T is the receiving system noise temperature in the wanted link. As T is 500 K, the value of ΔT would then be 30 K. This methodology was developed to cover the case of GSO/GSO interference but it can also be used for the GSO/non-GSO and non-GSO/non-GSO cases as the location of the operating non-GSO satellite can be considered fixed.

The diagram in Fig. 6 below and its associated Table 14, taken from Document 6E/299 from the 2000-2003 ITU-R study period, show the locations of three GSO satellite networks and three non-GSO systems along with their associated service areas (the inner contours) as well a contours where the limit value of $\Delta T/T$ equal to 6% is obtained. The locations of the six BSS systems have been chosen so that the $\Delta T/T$ = 6% contours do not overlap into the service areas of adjacent systems. Thus the six systems can operate together with acceptable levels of inter-system interference. Any attempt to introduce additional BSS systems with usable service areas would lead to the need to coordinate between systems which would be extremely difficult, due to the lack of directionality in the BSS receiving terminals.

FIGURE 6

Service areas of the BSS systems

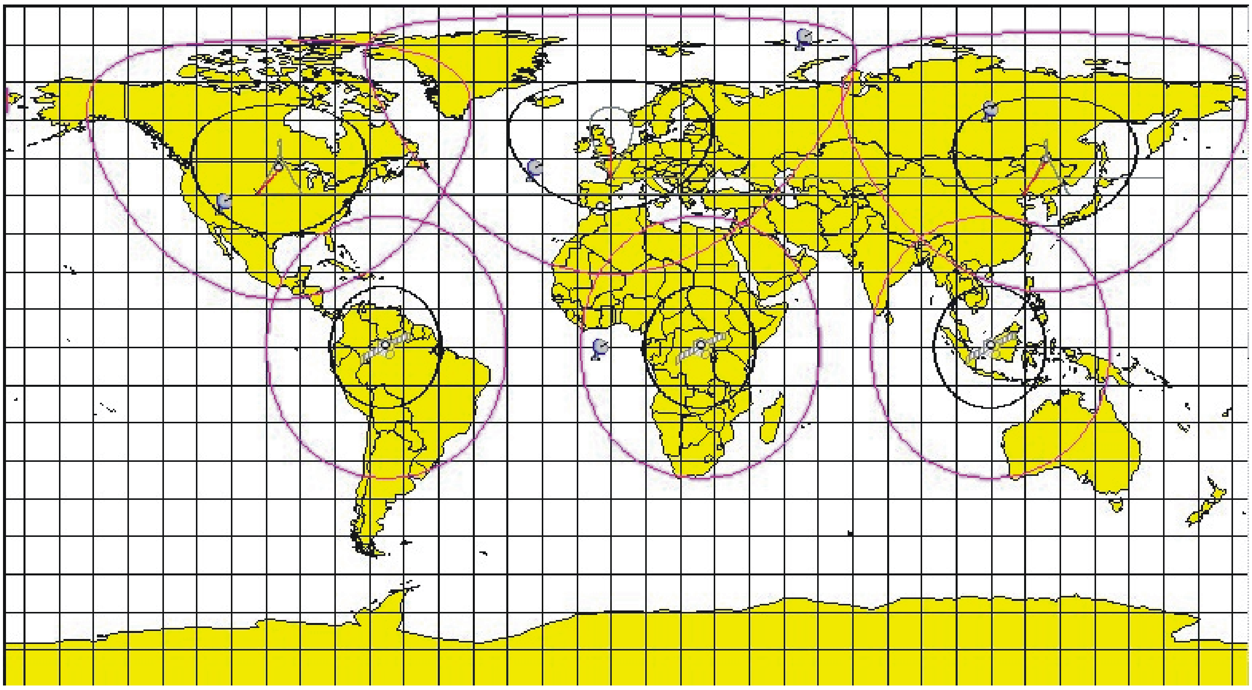


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TABLE 14

BSS systems' orbital characteristics

GSO systems	**GSO 1**	**GSO 2**	**GSO 3**
S/C longitude (degrees)	26 E	110 E	65 W
Service area	Centre Africa	South East Asia	North Latin America
Non-GSO Systems	**Non-GSO 1**	**Non-GSO 2**	**Non-GSO 3**
Semi-major axis (km)	42 164	42 164	42 164
Eccentricity	0.2684	0.2684	0.2684
Inclination (degrees)	63.4	55	55
Service area	Europe	North East Asia	USA/Canada

Each non-GSO system consists of three satellites using a given highly elliptical orbit. The active arc is so defined that service area will receive the active satellite signal with elevation angles greater than 60°. The non-GSO system is designed so that each satellite is transmitting along the active arc of the satellite (1/3 of the 24-h orbit period) and is inactive along the remaining part of the orbit. It means that only one satellite will be transmitting towards the service area at a given time.

9 Aggregate versus single entry interference

Interference into terrestrial receiving stations from transmitting BSS satellites can be assessed either by consideration of single entry or aggregate interference. The aggregate level of interference will always exceed the single entry level. The analysis below (taken from Document 6E/299 from the 2000-2003 ITU-R study period) demonstrates that the difference between the aggregate value and the single entry value is small, when considering interference into terrestrial BS receivers located inside the BSS service area, and consequently, consideration of only the single-entry level in interference studies can be used in this case as a useful simplification. However, if interference into BS receivers located well outside any of the BSS service areas is being assessed, such a simplification would not be appropriate.

For the study the following characteristics of receiving BS stations have been assumed.

TABLE 15

Parameters of BS receivers

Type of BS receiver	Fixed	Portable/mobile
Antenna peak gain(1) (dBi)	12	0
Antenna pattern	Rec. ITU-R BT.419	Omnidirectional

(1) The value of the antenna peak gain has no influence on the difference between aggregate and single entry interference.

Simulations were carried out for 8-h periods (the period when one non-GSO satellite is active) with sampling every 2 s. Aggregate interference is determined for several places and particularly in locations where the unfavourable geometrical configuration of the satellites should lead to the highest level of aggregate interference. For each location, the fixed BS antenna has been given a rotational motion (scan rate 2°/s) so as to determine the aggregate interference corresponding to the worst azimuth angle.

The maximum difference between aggregate and single entry interference are given hereunder in Table 16 for different locations within the service areas of the BSS systems, including the location where the worst case is reached. The data corresponding to the fixed BS receiver are given for the most unfavourable azimuth angle.

TABLE 16

Difference (Δ) between aggregate and single entry interference levels

European service area						
Location	London	Lisbon	Malaga	Naples	St. Petersburg	Reykjavik (worst case)
Δ (Fixed BS Rx) (dB)	0.7	0.8	0.8	0.9	Q	1
Δ (Mobile BS Rx) (dB)	0.1	0.1	0.2	0.2	0.1	0.2
North East Asia service area						
Location	Irkoutsk	Kagoshima	Beijing	Xian (China)	North Hokkaido	Shanghai (worst case)
Δ (Fixed BS Rx) (dB)	0.7	1	1	1.1	0.7	1.2
Δ (Mobile BS Rx) (dB)	0.1	0.3	0.2	0.3	0.1	0.5
North American service area						
Location	Montreal	Regina	Seattle	Denver	El Paso	Atlanta (worst case)
Δ (Fixed BS Rx) (dB)	0.9	0.7	0.5	0.7	0.8	1
Δ (Mobile BS Rx) (dB)	0.2	0.1	0.1	0.1	0.1	0.4

TABLE 16 (*end*)

Centre Africa service area						
Location	Libreville	Lusaka	Dar es Salam	Addis Abeba	Bangui	Adré (Tchad) (worst case)
Δ (Fixed BS Rx) (dB)	0.4	0.3	0.4	0.5	0.5	1.1
Δ (Mobile BS Rx) (dB)	0.1	0.1	0.1	0.1	0.1	0.1
South East Asia service area						
Location	Timor	Brunei	Djakarta	Singapore	Bangkok	Hué (Viet Nam) (worst case)
Δ (Fixed BS Rx) (dB)	0.3	0.7	0.4	0.4	1.2	1.3
Δ (Mobile BS Rx) (dB)	0.1	0.1	0.1	0.1	0.3	0.4
South American service area						
Location	Quito	Lima	Macapa	Trinidad	Caracas	Cartagena (worst case)
Δ (Fixed BS Rx) (dB)	0.5	0.3	0.4	0.6	0.8	1.1
Δ (Mobile BS Rx) (dB)	0.1	0.1	0.1	0.1	0.1	0.2

10 Coordination request and notification submissions to the Radiocommunication Bureau

A review of the Bureau's space radiocommunication stations (SRS) database shows that coordination request and notification information has been submitted for the following BSS systems operation or planned to operate in the 620-790 MHz frequency band.

TABLE 17

Administration	**Space station name**	**Orbital location**	**Type of submission(1)**	**Status**
F	F-SAT-UHF-GEO-10	71° W	CR	Processing suspended (*resolves* 1 of Resolution 545 (WRC-03)
F	F-SAT-UHF-GEO-2	32° E	CR	Processing suspended (*resolves* 1 of Resolution 545 (WRC-03)
F	F-SAT-UHF-GEO-8	120° E	CR	Processing suspended (*resolves* 1 of Resolution 545 (WRC-03)
F	F-SAT-UHF-HEO-2	N/A	N	Processing suspended (*resolves* 1 of Resolution 545 (WRC-03)
RUS	STATSIONAR-T	99° E	N	Recorded in MIFR
RUS	STATSIONAR-T2	99° E	N	Recorded in MIFR

(1) CR: Coordination request (Section II of RR Article 9).
N: Notification (RR Article 11).

The system F-SAT-UHF-HEO-2 covers the European service area.

11 Provisions of RR Article 23

RR Nos. 23.13 to 23.13C provide particular provisions applying to BSS transmissions. They are repeated below for information.

"Section II – Broadcasting-satellite service

23.13 § 4 In devising the characteristics of a space station in the broadcasting-satellite service, all technical means available shall be used to reduce, to the maximum, the radiation over the territory of other countries unless an agreement has been previously reached with such countries.

23.13A If the Bureau receives an indication of a written agreement under No. **23.13**, it shall include reference to that agreement when the assignments to the system are recorded with reference to No. **23.13** in the Remarks column of the Master International Frequency Register or included in the Regions 1 and 3 List. (WRC-2000)

23.13B If, within the four-month period following the publication of the Special Section for a broadcasting-satellite service (except sound broadcasting) network submitted for coordination under Article **9** or Appendix **30**, an administration informs the Bureau that all technical means have not been used to reduce the radiation over its territory, the Bureau shall draw the attention of the responsible administration to the comments received. The Bureau shall request the two administrations to make every effort possible in order to resolve the issue. Either administration may request the Bureau to study the matter and submit its report to the administrations concerned. If no agreement can be reached, then the Bureau shall delete the territory of the objecting administration from the service area without adversely affecting the rest of the service area and inform the responsible administration. (WRC-2000)

23.13C If, after the four-month period mentioned above, an administration objects to remaining in the service area, the Bureau shall delete the territory of the objecting administration from the service area of the broadcasting-satellite service (except sound broadcasting) network concerned without adversely affecting the rest of the service area and inform the responsible administration. (WRC-2000)"

When publishing a Coordination Request Special Section, the Radiocommunication Bureau applies a Rule of Procedure regarding the process given in RR Nos. 23.13 *et seq.*

Annex 2

On the question of the tilt angle problem in a hilly environment

1 Summary

This Annex provides practical information on the potential need to up-tilt TV receiver antennas in hilly environments. These considerations relate to a phenomenon previously pointed out in the context of the WP 6E compatibility studies involving fixed analogue or digital receiver antennas. A value of 10° up-tilt angle would represent an adequate average to take the phenomenon into account.

2 General

According to Recommendation ITU-R BT.419-3, the directivity discrimination values, in function of the angle relative to direction of the main response δ, are given by:

0	dB	for	$\delta \leq 20°$
$0.4\,(\delta - 20)$	dB	for	$20° < \delta \leq 60°$
16	dB	for	$\delta > 60°$

It has been pointed out that, in some cases, the pfd masks obtained from the general equations contained in Annex 8 of Document 6E/39, should additionally take into account a tilt angle $x°$ to reflect the potential up-tilt of a fixed receiving TV antenna in a hilly environment. The equation becomes then:

0	dB	for	$\delta \leq 20° + x°$
$0.4\,(\delta - x° - 20)$	dB	for	$20° + x° < \delta \leq 60° + x°$
16	dB	for	$60° + x° < \delta \leq 90°$

3 Practical study

Investigation has been conducted on Switzerland antenna installation issues by calling experts on this matter.

Some radio and television shops in three different Swiss towns, where the television signal was coming from an extremely elevated point, were contacted and they provided the following results:

– The town Brig is served by the transmitter Gebidem situated ~7 km from the town and at an elevation of ~2 200 m. The terrain profile between the transmitter and the town is shown in Fig. 7. As a consequence, about 30% of the television reception antennas are installed with a tilt angle of about 20°.

– The town Interlaken is served by the transmitter Niederhorn situated ~7.5 km from the town and at an elevation of 1 950 m. The terrain profile between the transmitter and the town is shown in Fig. 8. As a consequence, about 50% of the television reception antennas are installed with a tilt angle of about 10°.

– The town Luzern is served by the transmitter Rigi situated ~14 km from the town and at an elevation of 1 650 m. The terrain profile between the transmitter and the town is shown in Fig. 9. As a consequence, about 10% of the television reception antennas are installed with a tilt angle of about 5-10°.

FIGURE 7

Path profile between the Gebidem transmitter and the town of Brig

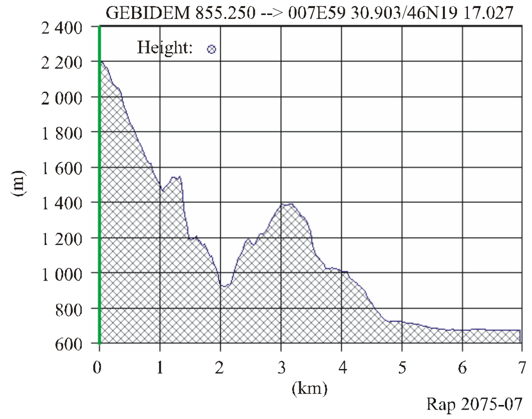


FIGURE 8

Path profile between the Niederhorn transmitter and the town of Interlaken

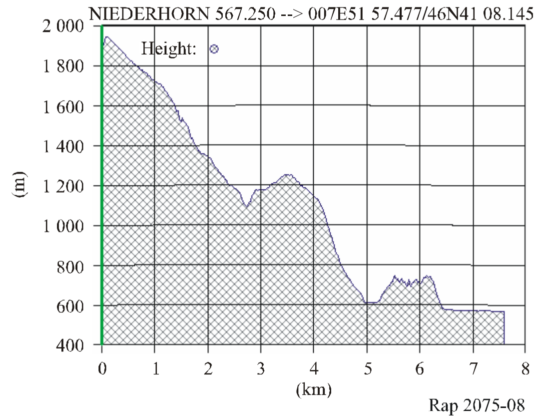
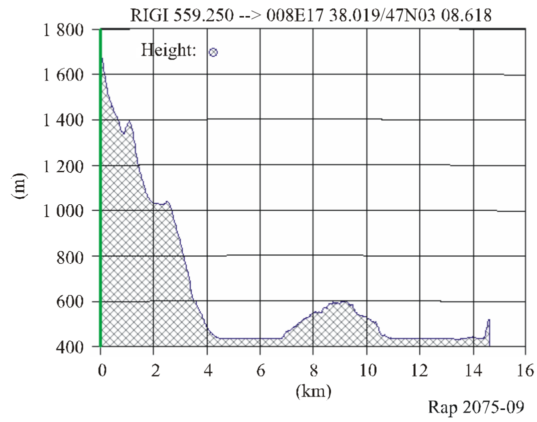


FIGURE 9

Path profile between the Rigi transmitter and the town of Luzern



In general a receiving television antenna needs to be up-tilted when:

– the transmitter is located high above the reception point;

– the signal is coming from far away (no direct sight to the transmitter) and must be caught by diffraction;

– the direct line to the transmitter is covered by mountains. Under certain circumstances, the signal can be caught by an antenna directed to the edge of the highest mountain.

4 Conclusion

The issue raised in this Annex concerns the tilt angle for terrestrial television receiving antennas. It appears that, in mountainous environment, positive tilt angles, for the BS receiving antennas, are implemented by the antennas fitters to receive the TV signals properly.

In conclusion, the value of the tilt angle for fixed reception of terrestrial television services, must be taken into account in the calculations of compatibility between BSS systems and broadcasting services in the 620-790 MHz band. According to the results, a value of 10° for the tilt angle seems to be a representative and compromise value in this study for "BS nominal coverage areas". For "BS fringe coverage areas", the tilt angle is assumed to be 0°.

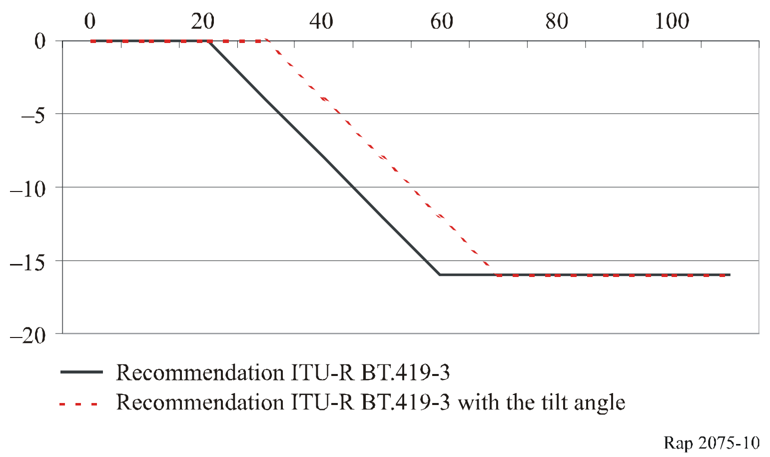
Therefore, based on the Recommendation ITU-R BT.419-3 and the different investigations, the directivity discrimination values for "BS nominal coverage areas", in function of the angle relative to the direction of the main response δ, are given by:

0	dB	for	$\delta \leq 30°$
$0.4\,(\delta - 20)$	dB	for	$30° < \delta \leq 70°$
16	dB	for	$70° < \delta \leq 90°$

This is shown graphically in Fig. 10.

FIGURE 10

Directivity discrimination depending on the angle relative to direction of the main response



Annex 3

Analysis of polarization loss

Summary

This Annex offers a study, which shows that the geometry of potential circularly polarized signals interfering into linearly polarized BS receivers will benefit from 1.25 dB polarization discrimination.

1 Polarization characterization

A general polarization state (ellipse) may be defined in terms of:

– the *voltage axial ratio*, *r*, of the co-polarized and cross-polarized electric-field components;

– the *sense of rotation* of the electric vector, specified by a sign for the axial ratio ("–" for right-hand or "+" for left-hand);

– the *tilt angle*, τ, made by the major polarization axis (generally the co-polar field component) with respect to the local horizontal at the Earth's surface.

For example, the limiting cases are pure circular polarization (CP), for which $r = \pm 1$ and τ is arbitrary, and pure linear polarization (LP), for which $r = \infty$ and $\tau = 0°$ and 90° for horizontal and vertical polarization.

For engineering purposes, the axial ratio is typically expressed in decibel terms: $R(\text{dB}) = 20 \log |r|$. The polarization quality of CP antennas is usually expressed directly in terms of axial ratio, where perfect CP has a voltage axial ratio $r = 1.0$ (or $R = 0$ dB). The cross-polar isolation XPI_C or cross-polarization ratio CPR_C referenced to pure CP are related to the voltage axial ratio by [Stutzman, 1993]:

$$xpi_c(\text{voltage}) = \left[\frac{|r|+1}{|r|-1} \right]^2$$

$$XPI_c(\text{dB}) = -CPR_c = 10 \log(xpi_c) \qquad (2)$$

For example, the XPI_C value of 10 dB assumed in Document 6E/66(Rev.1)/6S/24(Rev.1) for the satellite side lobe corresponds to an axial ratio of 5.7 dB (a very poor CP axial ratio, typical at far off-boresight angles). Because the axial ratio (or equivalently cross-polar isolation) is poor and irregular outside the 3 dB beam-width of most antennas, average values cannot be assumed reliable outside this range.

For linearly polarized antennas, the polarization quality is typically quantified in terms of the degree of isolation (XPI_L) between the co-polar and cross-polar ports. XPI_L can be related to axial ratio with certain reasonable assumptions. If it is assumed that the co-polar and cross-polar ports of the antenna are orthogonal, and the polarization ellipse is referenced to the co-polar antenna axis, the LP axial ratio, *R* (dB), and XPI_L are equivalent in magnitude (the sign may vary depending on convention):

$$XPI_L = R \qquad \text{dB} \qquad (3)$$

For LP polarization states, the higher the axial ratio, the better is the cross-polar isolation. The normal convention of using axial ratio, *R*, for CP and *XPI* (dropping the subscript *L* as it is implicit) for LP will be observed here.

2 Response of an antenna to an incident wave

A general expression in terms of axial ratios for the *polarization efficiency*, *p*, related to the power of a propagating wave (subscript *w*) that is detected by a receive antenna (subscript *a*), valid for any arbitrary polarization states, is [Stutzman, 1993]:

$$p(w,a) = \frac{1}{2} + \frac{4r_w r_a + (r_w^2 - 1)(r_a^2 - 1)\cos 2\Delta\tau}{2(r_w^2 + 1)(r_a^2 + 1)} \tag{4}$$

where:

- r_a: (voltage) axial ratio of the antenna
- r_w: (voltage) axial ratio of the wave
- $\Delta\tau$: angle between the tilt angle of the antenna polarization ellipse and the tilt angle of the incident wave polarization ellipse, both referred to horizontal at the Earth surface.

The efficiency $p(w,a)$ can vary from 0 (antenna detects no wave power) to unity (antenna detects all the incident power).

Polarization loss, L_p (dB), is directly related to polarization efficiency, $p(w,a)$, by:

$$L_p = 10 \log p(w, a) \tag{5}$$

For the interaction between *pure* CP and *pure* LP states, $p(w,a) = 1/2$. Thus, $L_p = 10 \log(1/2) = -3$ dB, and half the incident wave power is detected by the antenna. (For example, this result explains the –3 dB adjustment in Note 7 of Recommendation ITU-R F.1245-1.) This value of loss cannot be applied for practical wave-antenna interactions, however.

In practice, antenna polarization states are never perfectly circular or linear. Proper assessment of polarization loss requires that the polarization states of the incident wave and the antenna be known. Furthermore, for off-boresight incidence, the interaction of an incident wave with the antenna depends on both the co-polar and cross-polar patterns of the antenna, and the latter in particular tends to degrade rapidly with increasing off-boresight angle.

3 Off-boresight incidence

For off-boresight angles, the cross-polar patterns of antennas typically degrade much faster than the co-polar pattern. Hence, the off-boresight axial ratio may be significantly poorer than the axial ratio that corresponds to the sharp cross-polar null that usually exists on boresight.

For the current application, the cross-polar pattern of the terrestrial antenna is the most important consideration. The degradation of *XPI* with increasing off-axis angle varies from antenna to antenna, and is difficult to specify in a general sense. However, based on a review of related technical information, it appears that the provisioning of digital television assumes a cross-polar isolation of 15 dB over the 3 dB beamwidth of terrestrial antennas operating in the bands of current interest. A value of 15 dB will therefore be assumed for nominal “linear polarization” *XPI* in the following section. At off-boresight angles outside the main-beam, the cross-polar pattern varies considerably and the axial ratios become generally poorer.

Based on this review of terrestrial antenna patterns, it appears that polarization loss allowances are applicable across the 3 dB mainlobe of terrestrial antennas. However, polarization loss is less reliably predicted outside this range. There are similar limitations imposed by poor cross-polarization patterns of satellite antennas, such as near the edge of coverage. If the satellite antenna cross-polar isolation is poorer than the isolation corresponding to the limiting axial ratios assumed in this analysis, the corresponding polarization loss is likewise reduced.

4 Practical bounds on polarization loss for imperfect CP – imperfect LP interactions

Practical bounds on polarization loss may be estimated by assuming polarization states for antennas of typical quality. Based on a survey of UHF CP satellite antennas, the polarization quality is good, with axial ratios values typically less than 2 dB. A nominal value of 1.5 dB is assumed over the 3 dB beamwidth of good quality spacecraft antennas for both GSO and non-GSO UHF-band satellites. Values of 1.0 to 2.0 dB are used in the analysis to illustrate the sensitivity to axial ratio.

Due to the large variety of terrestrial UHF LP antenna types and applications, the cross-polar isolation values are more variable, especially for off-boresight incidence. Nevertheless, a review of antenna manufacturer specifications indicates that, even for widebeam antennas, an *XPI* of 15 dB can typically be achieved across the 3 dB beamwidth of most antennas.

XPI is generally superior to 15 dB on boresight. A range of values is assumed in the analysis to demonstrate the dependence on *XPI*. As already surmised, a reduction in polarization loss is expected for interactions that occur outside the 3 dB beamwidth of either the satellite or terrestrial antenna.

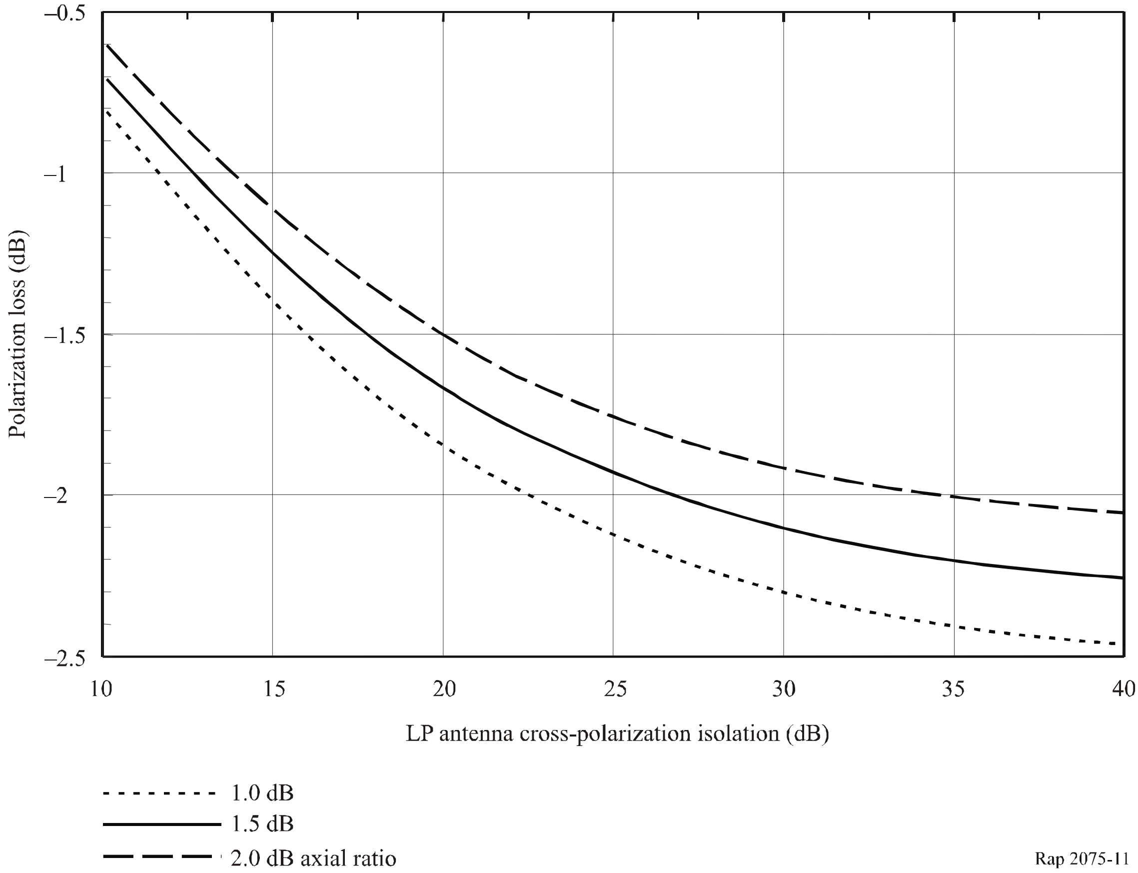
Minimum polarization loss (maximum power exchange) occurs when the polarization states of the incident wave and the receiving antenna have the same sense and their tilt angles are collinear. Both of these conservative conditions will be assumed for the analysis. This scenario has the added advantage of eliminating the necessity to take tilt angle into account in subsequent evaluations, since the worst-case orientation is always assumed to occur. Based on the prior discussion, CP axial ratios of 1.0, 1.5, and 2.0 are assumed, and the polarization loss is calculated with equations (4) and (5) for LP antenna isolations ranging from 10 dB (poorer isolation) to 40 dB (superior isolation).

Figure 11 presents the analysis results. For CP-LP interactions in the case of a typical value of axial ratio of 1.5 dB for the CP satellite antenna and a terrestrial LP antenna having a nominal isolation of 15 dB, Fig. 11 shows that the corresponding polarization loss is –1.25 dB. Recall that worst-case assumptions for relative tilt angle and polarization sense have already been assumed.

FIGURE 11

Polarization loss (dB) as a function of the cross-polarization isolation (dB) of terrestrial LP antennas with representative values of the axial ratio of S-band satellite antennas as parameter

(--- 1.0 dB; — 1.5 dB; – – 2.0 dB axial ratio)



5 Conclusions

Incorporation of polarization loss in interference assessment appears viable if nominal polarization states of the incident wave and the receiving antenna are adequately known. For the particular case of nominal CP-to-LP polarizations, a value of polarization loss of –1.25 dB may be assumed for interactions that occur within the 3 dB main-lobes of both antennas.

The polarization loss that may be assumed for interactions that occur outside the 3 dB main-lobe of either antenna in most instances will be reduced. However, such loss cannot be reliably predicted without specific pattern information for the antennas in question.

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