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| **Radiocommunication Study Groups** |  |
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| Source: Document 4A/TEMP/204Reference: Documents 4A/278 (Annex 2), 336 and 348Subject: Questions ITU-R 21/6, ITU-R 22-1/6, ITU-R 104/6,WRC-12 Agenda item 1.13 | **Annex 2 toDocument 4A/368-E** |
| **16 April 2010** |
| **English only** |
| Annex 2 to Working Party 4A Chairman’s Report |
| Preliminary DRAFT REVISION of RECOMMENDATION ITU-R BO.1659 |
| Mitigation techniques for rain attenuation for broadcasting-satellite service systems in frequency bands between 17.3 GHz and 42.5 GHz |

Working Party 4A discussed at its meeting held 24 March - 1 April 2010 two contributions (Documents 4A/336 and 4A/348) proposing revisions to Recommendation ITU-R BO.1659 “Mitigation techniques for rain attenuation for broadcasting-satellite service systems in frequency bands between 17.3 GHz and 42.5 GHz”.

The two documents proposed minor corrections to Table 13 and to the associated note and to upgrade the PDRR ITU-R BO.1659 to a DRR. According to the current ITU-R meeting schedule, the next SG 4 meeting will meet after the next WP 4A, therefore WP 4A proposed to not upgrade the PDRR ITU-R BO.1659 at this meeting in order to give a last opportunity to Members of Working Party 4A to contribute at the next meeting.

The Attachment to this document contains the proposed preliminary draft revision of Recommendation ITU-R BO.1659.

Members of Working Party 4A are invited to review the PDRR and submit contributions to the next meeting.

Summary of the proposed revision

In this revision of Recommendation ITU-R BO.1659, values, tables and figures of the Appendix 1 to Annex 3 were amended taken into account the updated rain attenuation model under Recommendation ITU-R P.618-9. In addition, on section 5 of Appendix 1 to Annex 3, new materials were added in order to assess the annual service availability observed in some cities in Region 1 for different values of power flux density at the Earth’s surface.

**Attachment**:1

Attachment

PRELIMINARY DRAFT REVISION OF RECOMMENDATION ITU-R BO.1659

Mitigation techniques for rain attenuation for broadcasting-satellite service systems in frequency bands between 17.3 GHz and 42.5 GHz

(Questions ITU-R 21/6 and ITU-R 22-1/6)

(2003-2010)

*[Editorial note: No change up to Appendix 1 to Annex 3.]*

Appendix 1 to Annex 3

Rain attenuation and absorption due to atmospheric gases in BSS bands between 17.3 GHz and 42.5 GHz and some associated feeder links

# 1 Introduction

A significant characteristic of the BSS bands between 17.3 GHz and 42.5 GHz is the larger propagation loss in comparison to the 12 GHz band. The elevation angle is a critical factor for both the rain attenuation and the atmospheric absorption in these high frequency bands. Appropriate mitigation techniques may be chosen depending on the propagation loss to be overcome. In this Appendix, a preliminary comparison of the propagation loss is shown in terms of the frequency and the location of the earth stations.

The cities presented in Tables of Appendix 1 to Annex 3 ofthis Recommendation are selected only as examples.

# 2 Parameters for the calculation

The following Recommendations are used in the calculation:

– Altitude of receiving station: Recommendation ITU-R P.1511 (database)

– Annual mean surface temperature: Recommendation ITU-R P.1510 (database)

– Surface water vapour density (1% of year): Recommendation ITU-R P.836 (database)

– Atmospheric gaseous attenuation model: Recommendation ITU-R P.676

– Cloud attenuation: Recommendation ITU-R P.840– Rainfall rate model: Recommendation ITU-R P.837 (database)

– Specific attenuation: Recommendation ITU-R P.838

– Rain height model: Recommendation ITU-R P.839 (database)

– Rain attenuation model: Recommendation ITU-R P.618

– The orbital position of the satellite: Assumed to coincide with those in the 12 GHz BSS Plans for Regions 1, 2 and 3 (see Appendix 30 of the Radio Regulations).

# 3 Rain attenuation and gaseous absorption in BSS downlink bands

Comparison of rain attenuation and gaseous absorption in the bands with those in the 12 GHz band was carried out for several cities in Regions 1, 2 and 3.

Atmospheric water vapour and oxygen cause absorption, and water vapour density is not constant over the year. In this study, the values exceeded for 1% of the year extracted from the ITU database were used to estimate gaseous absorption.

As shown in Tables 3 and 4, the gaseous absorption at 21.7 GHz is ranging from 1.2 to 2.0 dB compared with about 0.2 dB at 12.0 GHz. The rain attenuation at 21.7 GHz is approximately four times as large as those at 12.0 GHz, in decibels.

TABLE 3

Atmospheric gaseous absorption and rain attenuation in some cities in Region 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Moscow | London | Paris | Istanbul | Alexandria |
| Longitude/latitude (degrees) | 37.6 E/55.8 N | 0.1 E/51.5 N | 2.3 E/48.9 N | 29.0 E/41.0 N | TBD |
| Satellite orbital position (degrees) | 36.0 E | 33.5 W | 7.0 W | 42.0 E | TBD |
| Elevation angle (degrees) | 26.5 | 23.2 | 33.2 | 40.7 | TBD |
| *R*0.01 (mm/h) | 31.7 | 30.8 | 34.0 | 38.8 | TBD |
|  | Annual time percentage | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz | TBD | TBD |
| Atmospheric absorption | – | 0.2 dB | 2.0 dB | 0.2 dB | 2.0 dB | 0.2 dB | 1.6 dB | 0.1 dB | 1. 5 dB | TBD | TBD |
| Rain attenuation | 0.3% | 1.0 dB | 3.4 dB | 1.0 dB | 3.4 dB | 0.9 dB | 3.1 dB | 1.0 dB | 3.5 dB | TBD | TBD |
| 0.1% | 1.9 dB | 6.4 dB | 1.9 dB | 6.3 dB | 1.7 dB | 5.8 dB | 1.9 dB | 6.5 dB | TBD | TBD |

TABLE 4

Atmospheric gaseous absorption and rain attenuation in some cities in Region 3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Tokyo | Kuala Lumpur | Seoul | Bangkok |
| Longitude/latitude (degrees) | 139.8 E/35.7 N | 101.7 E/3.2 N | 127 E/37.6 N | 100.5 E/13.8 N |
| Satellite orbital position (degrees) | 110.0 E | 91.5 E | 116.0 E | 98.0 E |
| Elevation angle (degrees) | 38.0 | 77.4 | 44.9 | 73.5 |
| *R*0.01 (mm/h) | 48.0 | 93.9 | 50.6 | 86.7 |
|  | Annual time percentage | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz | 12.0 GHz | 21.7 GHz |
| Atmospheric absorption | – | 0.2 dB | 1.9 dB | 0.1 dB | 1.2 dB | 0.2 dB | 1.8 dB | 0.1 dB | 1.4 dB |
| Rain attenuation | 0.3% | 1.5 dB | 5.5 dB | 3.7 dB | 14.7 dB | 1.4 dB | 5.2 dB | 3.0 dB | 12.2 dB |
| 0.1% | 2.8 dB | 10.0 dB | 6.6 dB | 24.7 dB | 2.7 dB | 9.4 dB | 5.5 dB | 20.9 dB |

The propagation losses at 17.5 GHz were compared with those at 12.5 GHz in Table 5 for the cities in Region 2. The rain attenuations at 17.5 GHz were up to 2.5 times larger than those at 12.5 GHz, in decibels.

TABLE 5

Atmospheric gaseous absorption and rain attenuation in some cities in Region 2

|  |  |  |
| --- | --- | --- |
|  | Miami | Rio de Janeiro |
| Longitude/latitude (degrees) | 80.2 W/25.8 N | 43.2 W/22.9 S |
| Elevation angle (degrees) | 51.8 | 63.1 |
| Satellite orbital position (degrees) | 101.2 W | 45.2 W |
| R0.01 (mm/h) | 89.1 | 56.5 |
|  | Annual time percentage | 12.5 GHz | 17.5 GHz | 12.5 GHz | 17.5 GHz |
| Atmospheric absorption | – | 0.1 dB | 0.4 dB | 0.1 dB | 0.3 dB |
| Rain attenuation | 0.3% | 2.7 dB | 5.8 dB | 2.0 dB | 4.4 dB |
| 0.1% | 4.9 dB | 10.4 dB | 3.7 dB | 7.9 dB |

The rain attenuations in the 12 GHz band and 17/21 GHz bands were calculated for the capital cities of all ITU member countries for 0.1% and 0.3% time of an average year. Results are shown in Figs. 6, 7 and 8 as histograms for each Region. Compared with Region 1, the rain attenuation in the capital cities in Region 3 is distributed over a wider range at 21.7 GHz.

The band 40.5-42.5 GHz is allocated to the BSS in all three Regions. Atmospheric absorption and rain attenuation at 41.5 GHz are shown in Tables 6, 7 and 8. The rain attenuation in the 42 GHz band is considerably higher than in the 17/21 GHz band.

TABLE 6

Atmospheric gaseous absorption and rain attenuation in some cities in Region 1 at 41.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Annual time percentage** | Moscow | London | Paris | Istanbul | Alexandria |
| 41.5 GHz |
| Atmospheric absorption | – | 1.7 dB | 1.7 dB | 1.3 dB | 1.2 dB | TBD |
| Rain attenuation | 3.0% | 2.4 dB | 2.3 dB | 2.1 dB | 2.5 dB | TBD |
| 1.0% | 4.9 dB | 4.8 dB | 4.5 dB | 5.2 dB | TBD |
| 0.3% | 10.1 dB | 9.9 dB | 9.2 dB | 10.6 dB | TBD |
| 0.1% | 17.9 dB | 17.6 dB | 16.4 dB | 18.7 dB | TBD |

TABLE 7

Atmospheric gaseous absorption and rain attenuation
in some cities in Region 2 at 41.5 GHz

|  |  |  |  |
| --- | --- | --- | --- |
|  | Annual time percentage | Miami | Rio de Janeiro |
| 41.5 GHz |
| Atmospheric absorption | – | 1.1 dB | 1.0 dB |
| Rain attenuation | 3.0% | 6.2 dB | 4.6 dB |
| 1.0% | 12.5 dB | 9.4 dB |
| 0.3% | 27.0 dB | 21.6 dB |
| 0.1% | 45.4 dB | 36.5 dB |

TABLE 8

Atmospheric gaseous absorption and rain attenuation
in some cities in Region 3 at 41.5 GHz

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Annual time percentage | Tokyo | Kuala Lumpur | Seoul | Bangkok |
| 41.5 GHz |
| Atmospheric absorption | – | 1.4 dB | 0.9 dB | 1.3 dB | 1.0 dB |
| Rain attenuation | 3.0% | 4.0 dB | 8.0 dB | 3.8 dB | 7.6 dB |
| 1.0% | 8.1 dB | 15.9 dB | 7.7 dB | 15.2 dB |
| 0.3% | 16.3 dB | 45.2 dB | 15.5 dB | 38.1 dB |
| 0.1% | 28.3 dB | 72.6 dB | 26.9 dB | 62.2 dB |

# 4 Rain attenuation and gaseous absorption in BSS feeder-link bands

A similar calculation was carried out for the 18 and 28 GHz bands, which are candidates for the feeder links in all Regions, as well as for the 25 GHz band, which is another candidate in Regions 2 and 3. The results are shown in Tables 9, 10 and 11.

TABLE 9

Atmospheric gaseous absorption and rain attenuation in some cities in Region 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Annualtimepercentage | Moscow | London | Paris | Istanbul | Alexandria |
| 18.1 GHz | 27.8 GHz | 18.1 GHz | 27.8 GHz | 18.1 GHz | 27.8 GHz | 18.1 GHz | 27.8 GHz | 18.1 GHz | 27.8 GHz |
| Atmosphericabsorption | – | 0.6 dB | 1.1 dB | 0.6 dB | 1.1 dB | 0.5 dB | 0.9 dB | 0.4 dB | 0.8 dB | TBD | TBD |
| Rain attenuation | 0.3% | 2.4 dB | 5.4 dB | 2.4 dB | 5.3 dB | 2.2 dB | 4.9 dB | 2.5 dB | 5.6 dB | TBD | TBD |
| 0.1% | 4.5 dB | 9.8 dB | 4.5 dB | 9.7 dB | 4.1 dB | 9.0 dB | 4.6 dB | 10.2 dB | TBD | TBD |

TABLE 10

Atmospheric gaseous absorption and rain attenuation in some cities in Region 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Annualtimepercentage | Miami | Rio de Janeiro |
| 18.1 GHz | 25.0 GHz | 27.8 GHz | 18.1 GHz | 25.0 GHz | 27.8 GHz |
| Atmosphericabsorption | – | 0.5 dB | 1.1 dB | 0.8 dB | 0.4 dB | 1.0 dB | 0.7 dB |
| Rain attenuation | 0.3% | 6.2 dB | 12.0 dB | 14.6 dB | 4.7 dB | 9.2 dB | 11.3 dB |
| 0.1% | 11.1 dB | 20.9 dB | 25.1 dB | 8.5 dB | 16.2 dB | 19.6 dB |

TABLE 11

Atmospheric gaseous absorption and rain attenuation in some cities in Region 3

|  |  |  |  |
| --- | --- | --- | --- |
|  | Annualtimepercentage | Tokyo | Kuala Lumpur |
| 18.1 GHz | 25.0 GHz | 27.8 GHz | 18.1 GHz | 25.0 GHz | 27.8 GHz |
| Atmosphericabsorption | – | 0.5 dB | 1.4 dB | 1.0 dB | 0.3 dB | 0.9 dB | 0.6 dB |
| Rain attenuation | 0.3% | 3.8 dB | 7.2 dB | 8.7 dB | 9.9 dB | 19.6 dB | 24.0 dB |
| 0.1% | 7.0 dB | 12.9 dB | 15.5 dB | 17.0 dB | 32.6 dB | 39.5 dB |
|  |  | Seoul | Bangkok |
| 18.1 GHz | 25.0 GHz | 27.8 GHz | 18.1 GHz | 25,0 GHz | 27.8 GHz |
| Atmosphericabsorption | – | 0.5 dB | 1.3 dB | 0.9 dB | 0.4 dB | 1.0 dB | 0.7 dB |
| Rain attenuation | 0.3% | 3.6 dB | 6.8 dB | 8.3 dB | 8.2 dB | 16.3 dB | 20.0 dB |
| 0.1% | 6.6 dB | 12.2 dB | 14.8 dB | 14.3 dB | 27.6 dB | 33.5 dB |

# 5 Downlink service availability in the 21 GHz band

The service availability of the BSS system was calculated assuming various PFD values. A receiving antenna diameter of 45 cm was assumed. DVB-S, DVB-S2 and ISDB-S signal with modulation schemes of QPSK, 8-PSK and 16-QAM are the candidates for the system in this study. The required *C*/*N* of the system has a variation depending on the modulation and coding which involves a trade‑off between service availability and frequency-use efficiency.

The time percentages of an average year for which the C/N exceeds 5.6 dB, 7.5 dB, 10.7 dB and 17.0 dB are shown with an example of PFD equal to -105 dB(W/(m2 · MHz)),
-115 dB(W/(m2 · MHz)) and ‑120 dB(W/(m2 · MHz)) in Table 12 and equal to
-105 dB(W/(m2 · MHz)) in Table 13.

The link budget includes rain attenuation, clouds attenuation, gases attenuation, scintillation and antenna pointing loss.

TABLE 12

Annual service availability of 21 GHz band BSS downlink in some cities
in Region 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Moscow | London | Pretoria  | Istanbul | Alexandria |
| Elevation angle (degrees) | 26.5 | 23.2 | 59.9 | 40.7 | 35.8 |
| pfd (dB(W/(m2 · MHz))) | −105.0 | −115.0 | −120.0 | −105.0 | −115.0 | −120.0 | −105.0 | −115.0 | −120.0 | −105.0 | −115.0 | −120.0 | −105.0 | −115.0 | −120.0 |
| Overall *C*/*N* | 5.6 dB | 99.99% | 99.96% | 99.89% | 99.99% | 99.97% | 99.90% | 99.97% | 99.87% | 99.69% | 99.99% | 99.96% | 99.88% | 99.99% | 99.99% | 99.99% |
| 7.5 dB | 99.99% | 99.95% | 99.81% | 99.99% | 99.95% | 99.84% | 99.97% | 99.84% | 99.50% | 99.99% | 99.94% | 99.79% | 99.99% | 99.99% | 99.99% |
| 10.7 dB | 99.98% | 99.89% | 99.38% | 99.99% | 99.90% | 99.53% | 99.95% | 99.67% | 98.63% | 99.98% | 99.88% | 99.30% | 99.99% | 99.99% | 99.94% |
| 17.0 dB | 99.93% | 98.48% | NA[[1]](#footnote-1) | 99.92% | 99.04% | NA1 | 99.82% | 95.80% | NA1 | 99.94% | 98.35% | NA1 | 99.99% | 99.60% | NA1 |
| R0.01 (mm/h) | 31.7 | 30.9 | 31.8 | 38.9 | 5.4 |
| Rain attenuation[[2]](#footnote-2) (dB) | 6.5 | 6.6 | 5.8 | 6.7 | 1.4 |
| NOTE – The locations presented in Table 12 give only examples of the service availability in Region 1. Service availability is depending on the elevation angle and also dependant of the location within Region 1. Hence, a pfd value lower than −120 dB(W/(m2 · MHz)) may also be used in areas with very low rain attenuation than those in Table 12. |

TABLE 13

Annual service availability of 21 GHz band BSS downlink in some
cities in Region 3

|  | Tokyo | Kuala Lumpur | Seoul | Bangkok | Wellington |
| --- | --- | --- | --- | --- | --- |
| Elevation angle (degrees) | 38.0 | 77.4 | 44.9 | 73.5 | 42.3 |
| pfd (dB(W/(m2 · MHz))) | –105.0 | –105.0 | –105.0 | –105.0 | -105.0 |
| Overall *C*/*N* | 5.6 dB | 99.98% | 99.81% | 99.98% | 99.88% | 99.99% |
| 7.5 dB | 99.97% | 99.77% | 99.97% | 99.85% | 99.99% |
| 10.7 dB | 99.95% | 99.68% | 99.95% | 99.78% | 99.99% |
| 17.0 dB | 99.80% | 99.36% | 99.83% | 99.44% | 99.94% |
| R0.01 (mm/h) | 48.0 | 93.6 | 50.6 | 87.1 | 41.7 |
| Rain attenuation[[3]](#footnote-3) (dB) | 10.0 | 26.3 | 14.2 | 21.5 | 6.4 |

NOTE – The cities presented in Table 13 give only examples of the service availability in Region 3. Service availability is depending on the elevation angle and also dependant of the location within Region 3

The more frequency-efficient modulation schemes such as 16-QAM may be applicable to future BSS systems. The required *C*/*N* of the modulation schemes is, however, higher than TC8-PSK. Furthermore, it is susceptible to the non-linearity of the satellite transponders. Tentatively, a required *C*/*N* of 17.0 dB is assumed.

In the BSS, using the 21 GHz band, the much larger rain fade should be compensated to achieve service availability similar to that of the 12 GHz band. In the conventional satellite design, the e.i.r.p. is determined by considering the attenuation as a margin. Therefore the system needs excessively large-scale satellites and high clear sky pfd, which may be considered uneconomical.Thus to implement a BSS with an affordable satellite system in some specific area, effective measures to compensate for rain attenuation are required.

The annual service availability of the 21 GHz BSS band downlink listed in Table 12 for some cities in Region 1, as example, is considerably greater than the annual service availability for the 12 GHz Plan in Appendix 30 of the Radio Regulations, i.e. 99% of the worst month, equivalent to an annual service availability of 99.7%. Based on satellite operator objectives and service area targeted, if the level of availability with a power flux-density at the Earth’s surface equal to –105 dB(W/(m2.MHz)) is much greater than the expected availability, it could be envisaged to reduce the power flux-density at the Earth’s surface produced by emissions from the space stations in order to reach the required availability. This power reduction could directly impact the satellite design (i.e. more operational transponders with the same power consumption envelope) or the associated cost (i.e. reduction of total power consumption which have a direct impact on the satellite cost)

For Region 1, with respect to a reduced power flux-density at the Earth’s surface:

1) For pfd of −115 dB(W/(m2· MHz)) (i.e. 10 dB of reduction),

 the annual service availability for the C/N of 7.5 and 10.7 dB for some example cities in Region 1 listed in Table 12 is greater than the annual service availability for some other cities in Regions 1 listed in Tables 12 with a power flux-density at the Earth’s surface of −105 dB(W/(m2 · MHz)).

2) For pfd of −120 dB(W/(m2 · MHz)) (i.e. 15 dB of reduction),

 the annual service availability for the C/N of 5.6 dB for some example cities in Region 1 listed in Table 12 is greater than the annual service availability for some other cities in Regions 1 listed in Tables 12 with a power flux-density at the Earth’s surface of −105 dB(W/(m2 · MHz)).

For Region 1, it would be understood that a power flux-density at the Earth’s surface of −105 dB(W/(m2· MHz)) is effective to improve the annual service availability for some cities in Region 1 as shown in Table 12. For example, it would be noted that one city with a rainfall rate, R0.01%, below 31 mm/h in Region 1 shows the possibility to consider a pfd at the Earth’s surface of −105 dB(W/(m2· MHz)) instead of −115 dB(W/(m2· MHz)) to increase the annual service availability for the *C*/*N* of 10.7 dB from 99.90% to 99.99%.

As shown in Tables 12 and 13, the required value of power flux density at the Earth’s surface for a specific satellite network is fully linked to several factors (e.g. total link attenuation observed over the targeted area, required availability, modulation scheme, etc.)

# 6 Conclusion

This Appendix has shown that:

– rain attenuation and atmospheric gaseous absorption in bands between 17.3 GHz and 42.5 GHz are considerably larger than those in the 12 GHz band;

– assuming conventional satellite system design, the e.i.r.p. is determined including the link margin requirements to meet the availability objectives. In some cases, the required e.i.r.p. could be too high to allow for a conventional satellite system;

– given the propagation conditions, appropriate mitigation techniques for rain attenuation may be required to facilitate the introduction of feasible BSS systems in the higher frequency bands.

1. NA: Not Applicable because the level of pfd does not permit to achieve the level of C/N required. [↑](#footnote-ref-1)
2. Rain attenuation calculated for 99.9% of the year. [↑](#footnote-ref-2)
3. Rain attenuation calculated for 99.9% of the year. [↑](#footnote-ref-3)