RESOLUTION 770 (WRC-19)

Application of Article 22 of the Radio Regulations to the protection of geostationary fixed-satellite service and broadcasting-satellite service networks from non-geostationary fixed-satellite service systems in the frequency bands 37.5-39.5 GHz, 39.5-42.5 GHz, 47.2-50.2 GHz and 50.4-51.4 GHz

The World Radiocommunication Conference (Sharm el-Sheikh, 2019),

considering

a) that geostationary-satellite (GSO) and non-geostationary-satellite (non-GSO) fixed-satellite service (FSS) networks may operate in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space);

b) that this conference has adopted Nos. **22.5L** and **22.5M**, which contain single-entry and aggregate limits for non-GSO FSS systems in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) to protect GSO networks operating in the same frequency bands;

c) that the ITU Radiocommunication Sector (ITU-R) has developed a methodology, contained in Recommendation ITU-R S.1503, that results in the equivalent power flux-density (epfd) generated by any one non-GSO FSS system considered and a GSO location that corresponds to the worst-case geometry that generates the highest levels of epfd into potentially affected GSO earth stations and satellites,

recognizing

a) that, in accordance with calculations utilizing Recommendation ITU-R S.1503, verification of the worldwide epfd interference of any one non-GSO system can be carried out by a set of generic GSO reference link budgets having characteristics that encompass global GSO network deployments that are independent of any specific geographic locations;

b) that Resolution **769 (WRC-19)** addresses the protection of GSO networks from aggregate emissions from non-GSO systems,

resolves

1 that during the examination under Nos. **9.35** and **11.31**, as applicable, of a non-GSO FSS satellite system with frequency assignments in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space), the technical characteristics of generic GSO reference links contained in Annex 1 to this Resolution shall be used in conjunction with the methodology in Annex 2 to this Resolution to determine compliance with No. **22.5L**;

2 that frequency assignments to non-GSO FSS systems referred to in *resolves* 1 shall receive a favourable finding with respect to the single-entry provision given in No. **22.5L** if compliance with No. **22.5L** is established under *resolves* 1, otherwise the assignments shall receive an unfavourable finding;

3 that, if the Radiocommunication Bureau (BR) is unable to examine non-GSO FSS systems subject to the single-entry provision given in No. **22.5L** due to a lack of available software, the notifying administration shall provide all necessary information sufficient to demonstrate compliance with No. **22.5L** and send BR a commitment that the non-GSO FSS system complies with the limits given in No. **22.5L**;

4 that frequency assignments to non-GSO FSS systems that cannot be assessed under *resolves* 1 shall receive a qualified favourable finding under No. **9.35** with respect to No. **22.5L** if *resolves* 3 is satisfied, otherwise the assignments shall receive an unfavourable finding;

5 that, if an administration believes that a non-GSO FSS system for which the commitment referred to in *resolves* 3 was sent has the potential to exceed the limits given in No. **22.5L**, it may request additional information from the notifying administration with regard to compliance with these limits and No. **22.2**, and both administrations shall cooperate to resolve any difficulties, with the assistance of BR, if so requested by either of the parties;

6 that *resolves* 3, 4 and 5 shall no longer be applied after BR has communicated to all administrations via a circular letter that validation software is available and BR is able to verify compliance with the limits in No. **22.5L**,

invites the ITU Radiocommunication Sector

1 to study and, as appropriate, develop a functional description that could be used to develop software for the procedures outlined in *resolves* 1 above;

2 to review and, as appropriate, provide updates to the generic GSO reference links in Annex 1 to this Resolution under Resolution **86 (Rev.WRC-07)**,

instructs the Director of the Radiocommunication Bureau

to review, once the validation software as described in *resolves* 3 is available, BR's findings made in accordance with Nos. **9.35** and **11.31**.

ANNEX 1 TO RESOLUTION 770 (WRC-19)

Generic GSO reference links for evaluation of compliance with single-entry requirements for non-GSO systems

The data in this Annex are to be regarded as a generic range of representative technical characteristics of GSO network deployments that are independent of any specific geographic location, to be used only for establishing the interference impact of a non-GSO system into GSO networks and not as a basis for coordination between satellite networks.

TABLE 1

Parameters of generic GSO reference links to be used in examination of the downlink (space-to-Earth) impact from any one non-GSO system

1	Generic GSO reference link parameters - service					Parameters
	Link type	User #1	User #2	User #3	Gateway	
1.1	E.i.r.p. density (dBW/MHz)	44	44	40	36	*eirp*
1.2	Equivalent antenna diameter (m)	0.45	0.6	2	9	D_m
1.3	Bandwidth (MHz)	1	1	1	1	B_{MHz}
1.4	ES antenna gain pattern	S.1428	S.1428	S.1428	S.1428	
1.5	Additional link losses (dB) This field includes non-precipitation impairments	3	3	3	3	L_o
1.6	Additional noise contribution including margin for inter-system interference (dB)	2	2	2	2	M_{0inter}
1.7	Additional noise contribution including margin for intra-system interference (dB) and non-time varying sources	1	1	1	1	M_{0intra}

2	Generic GSO reference link parameters - parametric analysis	Parametric cases for evaluation						
2.1	E.i.r.p. density variation	−3, 0, +3 dB from value in 1.1						$\Delta eirp$
2.2	Elevation angle (deg)	20			55		90	ε
2.3	Rain height (m) for specified latitude in item 2.4	5 000	3 950	1 650	5 000	3 950	5 000	h_{rain}
2.4	Latitude* (deg. *N*)	0	± 30	± 61.8	0	± 30	0	Lat
2.5	ES noise temperature (K)	340						*T*
2.6	0.01% rain rate (mm/hr)	10, 50, 100						$R_{0.01}$
2.7	Height of ES above mean sea level (m)	0, 500, 1 000						h_{ES}
2.8	Threshold *C*/*N* (dB)	−2.5, 2.5, 5, 10						$\left(\frac{C}{N}\right)_{Thr,i}$

NOTE – For items 2.2, 2.3 and 2.4, these three groups of data are be considered as unique sets of data to be used in the larger, overall set of total possible permutations. For example, 20 degrees of elevation angle will consider three different latitudes of 0, 30 and 61.8 degrees while 90 degrees of elevation will only consider a latitude of 0 degrees and one possible rain height 5 km. The above parameters are chosen as representative propagation parameters for purposes of calculations of precipitation fade statistics. These precipitation fades are representative of other geographic locations.

* Latitude is evaluated as a single value representing the absolute value of the latitude

TABLE 2

Parameters of generic GSO reference links to be used in examination of the uplink (Earth-to-space) impact from any one non-GSO system

1	Generic GSO reference link parameters - service					
	Link type	Link #1	Link #2	Link #3	Gateway	
1.1	ES e.i.r.p. density (dBW/MHz)	49	49	49	60	$eirp$
1.2	Bandwidth (MHz)	1	1	1	1	B_{MHz}
1.3	Half-power beamwidth (deg)	0.2	0.3	1.5	0.3	
1.4	ITU-R S.672 sidelobe level (dB)	−25	−25	−25	−25	
1.5	Satellite antenna peak gain (dBi)	58.5	54.9	38.5	54.9	G_{max}
1.6	Additional link losses (dB) This field includes non-precipitation impairments	4.5	4.5	4.5	4.5	L_o
1.7	Additional noise contribution including margin for inter-system interference (dB)	2	2	2	2	M_{0inter}
1.8	Additional noise contribution including margin for intra-system interference (dB) and non-time varying sources	1	1	1	1	M_{0intra}

2	Generic GSO reference link parameters - parametric analysis	Parametric cases for evaluation						
2.1	E.i.r.p. density variation	−6, 0, +6 dB from value in 1.1						$\Delta eirp$
2.2	Elevation angle (deg)	20			55		90	ε
2.3	Rain height (m) for specified latitude in item 2.4	5 000	3 950	1 650	5 000	3 950	5 000	h_{rain}
2.4	Latitude* (deg. *N*)	0	± 30	± 61.8	0	± 30	0	Lat
2.5	0.01% rain rate (mm/hr)	10, 50, 100						$R_{0.01}$
2.6	Height of ES above mean sea level (m)	0, 500, 1 000						h_{ES}
2.7	Satellite noise temperature (K)	500, 1 600						T
2.8	Threshold *C*/*N* (dB)	−2.5, 2.5, 5, 10						$\left(\frac{C}{N}\right)_{Thr,i}$

NOTE – For items 2.2, 2.3 and 2.4, these three groups of data are be considered as unique sets of data to be used in the larger, overall set of total possible permutations. For example, 20 degrees of elevation angle will consider three different latitudes of 0, 30 and 61.8 degrees while 90 degrees of elevation will only consider a latitude of 0 degrees and one possible rain height 5 km. The above parameters are chosen as representative propagation parameters for purposes of calculations of precipitation fade statistics. These precipitation fades are representative of other geographic locations.

* Latitude is evaluated as a single value representing the absolute value of the latitude

ANNEX 2 TO RESOLUTION 770 (WRC-19)

Description of parameters and procedures for the evaluation of interference from any one non-GSO system into a global set of generic GSO reference links

This Annex provides an overview of the process to validate compliance with the single-entry permissible interference of a non-GSO system into GSO networks using the generic GSO reference link parameters in Annex 1 and the interference impact using the latest version of Recommendation ITU-R S.1503. The procedure to determine compliance with the single-entry permissible interference relies on the following principles.

Principle 1: The two time-varying sources of link performance degradation considered in the verification are link fading (from rain) using the characteristics of the generic GSO reference link and interference from a non-GSO system. The total *C/N* in the reference bandwidth for a given carrier is:

$$C/N = C/(N_T + I) \tag{1}$$

where:

C: wanted signal power (W) in the reference bandwidth, which varies as a function of fades and also as a function of transmission configuration

N_T: total system noise power (W) in the reference bandwidth

I: time-varying interference power (W) in the reference bandwidth generated by other networks.

Principle 2: The calculation of spectral efficiency is focused on satellite systems utilizing adaptive coding and modulation (ACM) by calculating the throughput degradation as a function of *C/N*, which varies depending on the propagation and interference impacts on the satellite link over the long term.

Principle 3: During a fading event in the downlink direction the interfering carrier is attenuated by the same amount as the wanted carrier. This principle results in slight underestimation of the impact of the downlink interference.

Implementation of verification algorithm

The generic GSO reference link parameters described in Annex 1 should be used as described in the following algorithm to determine if a non-GSO FSS network is compliant with No. **22.5L**.

Within the parametric analysis there are a range of values for each of the following parameters in Section 2 of Tables 1 and 2:

– e.i.r.p. density variation

– elevation angle (degree)

– rain height (m)

– latitude (degree)

– 0.01% rain rate (mm/hr)

– height of ES (m)

– ES noise temperature (K) or satellite noise temperature (K), as appropriate.

A set of generic GSO reference links should be created using one per service case identified in Section 1 of Tables 1 and 2 and one value from each of the parametric analysis parameters in Section 2 of Tables 1 and 2. Then, with this set of generic GSO reference links, the following process should be undertaken:

Determine the frequency that should be used in the analysis, f_{GHz}, by applying the methodology in Recommendation ITU-R S.1503 to the non-GSO system filed frequencies and the frequency bands for which No. ***22.5L*** *applies*

For each of the generic GSO reference links

{

Step 0: Determine if this generic GSO reference link is valid and select the appropriate threshold

If the generic GSO reference link is valid, then

{

Step 1: Derive the probability density function (PDF) of the rain fade to use in the convolution

Step 2: Recommendation ITU-R S.1503 should be used to derive the PDF of the EPFD from the non-GSO FSS system

Step 3: Perform a modified convolution (space-to-Earth) or convolution (Earth-to-space) with the PDF of the rain fade and the PDF of the EPFD. This convolution yields a PDF of C/N and C/(N+I)

Step 4: Use the C/N and C/(N+I) PDFs to determine compliance with No. ***22.5L***

}

}

If the non-GSO system under examination is found to comply with No. ***22.5L*** *with respect to all generic GSO reference links, then the result of the evaluation is pass otherwise it is an unfavourable finding.*

Each of these steps are described further in Appendices **1** and **2** to this Annex for the space-to-Earth and Earth-to-space procedures, respectively.

APPENDIX 1 TO ANNEX 2 TO RESOLUTION 770 (WRC-19)

Algorithm steps to be applied in the space-to-Earth direction to determine compliance with No. 22.5L

By applying the following steps, the single-entry interference impact from a non-GSO system on the availability and spectral efficiency of a generic GSO reference link is determined. The generic GSO reference link parameters of Annex 1 to this Resolution are used, considering all possible parametric permutations, in conjunction with the worst-case geometry ("WCG") epfd output of the latest version of Recommendation ITU-R S.1503. The output of Recommendation ITU-R S.1503 is a set of interference statistics that a non-GSO system creates. These interference statistics are then used to determine the effect of the interference into each generic GSO reference link.

Step 0: Verification of the generic GSO reference link and selection of *C*/*N* threshold

The following steps should be used to determine if the generic GSO reference link is valid and if so, which of the thresholds $\left(\frac{C}{N}\right)_{Thr,i}$ should be used. It is assumed that R_s = 6 378.137 km, R_{geo} = 42 164 km and k_{dB} = −228.6 dB(J/K). Note that the term "cumulative distribution function" is meant to include the concept of the complementary cumulative distribution function depending upon context.

1) Calculate the peak gain of the ES in dBi using:

for $20 \leq D/\lambda \leq 100$

$$G_{max} = 20 \log \left(\frac{D}{\lambda}\right) + 7.7 \qquad \text{dBi}$$

for $D/\lambda > 100$

$$G_{max} = 20 \log \left(\frac{D}{\lambda}\right) + 8.4 \qquad \text{dBi}$$

2) Calculate the slant distance in km using:

$$d_{km} = R_s \left(\sqrt{\frac{R_{geo}^2}{R_s^2} - \cos^2(\varepsilon)} - \sin(\varepsilon) \right)$$

3) Calculate the free-space path loss in dB using:

$$L_{fs} = 92.45 + 20\log(f_{GHz}) + 20\log(d_{km})$$

4) Calculate the wanted signal power in the reference bandwidth in dBW accounting for additional link losses:

$$C = eirp + \Delta eirp - L_{fs} + G_{max} - L_o$$

5) Calculate the total noise power in the reference bandwidth in dBW/MHz using:

$$N_T = 10\log(T \cdot B_{MHz} \cdot 10^6) + k_{dB} + M_{ointra} + M_{ointer}$$

6) For each threshold $(C/N)_{Thr,i}$, derive the margin available for precipitation for that case in dB:

$$A_{rain,i} = C - N_T - \left(\frac{C}{N}\right)_{Thr,i}$$

7) If for each threshold $(C/N)_{Thr,i}$ the margin $A_{rain,i} \leq A_{min}$, then this generic GSO reference link is not valid.

8) For each of the thresholds $(C/N)_{Thr,i}$ for which $A_{rain,i} > A_{min}$, undertake step 9:

9) Using the precipitation model in Recommendation ITU-R P.618 together with the selected rain rate, ES height, rain height, ES latitude, elevation angle, frequency, calculated rain fade margin and an assumed polarization of vertical, calculate the associated percentage of time, $p_{rain,i}$.

10) If for each threshold $(C/N)_{Thr,i}$ the associated percentage of time is not within the range:

$$0.001\% \leq p_{rain,i} \leq 10\%$$

then this generic GSO reference link is not valid.

11) If at least one threshold meets the criteria in steps 7 and 10, then the lowest threshold, $(C/N)_{Thr}$ that meets these criteria is used in the analysis.

NOTE – A_{min} is 3 dB.

Step 1: Generation of precipitation fade PDF

The precipitation fade PDF should be generated using Recommendation ITU-R P.618 from the selected rain rate, ES height, ES latitude, rain height, elevation angle, frequency and an assumed polarization of vertical as follows:

1) Calculate the maximum fade depth A_{max} using $p = 0.001\%$

2) Create a set of 0.1 dB bins of precipitation fade A_{rain} between 0 dB and A_{max}

3) For each of the bins, determine the associate probability p to create a cumulative distribution function (CDF) of A_{rain}

4) For each of the bins, convert this CDF into a PDF of A_{rain}

When using Recommendation ITU-R P.618, the precipitation attenuation should be 0 dB for time percentages above p_{max} where p_{max} is the minimum value of a) 10% and b) the probability of rain attenuation on a slant path calculated from § 2.2.1.2. of Recommendation ITU-R P.618-13.

A bin size of 0.1 dB should be used to ensure consistency with the output from Recommendation ITU-R S.1503. Each bin of the CDF contains the probability that the precipitation fade is at least A_{rain} dB. Each bin of the PDF contains the probability that the precipitation fade is between A_{rain} and A_{rain} + 0.1 dB. During implementation, the array of bins can be capped at the minimum of A_{max} and the fade for which the resulting C/N would lead to the link being unavailable or have zero through-put.

Step 2: Generation of epfd PDF

Recommendation ITU-R S.1503 should be used to determine the epfd CDF from the non-GSO FSS parameters and the frequency, dish size and ES gain pattern. The epfd CDF will be calculated at the worst-case geometry from Recommendation ITU-R S.1503.

The epfd CDF should then be converted into a PDF.

Step 3: Creation of *C*/*N* and *C*/(*N*+*I*) CDFs by modified convolution of precipitation fade PDF with epfd PDF

For the selected generic GSO reference link, the *C*/*N* and *C*/(*N*+*I*) PDFs should be generated using the following steps to undertake the modified discrete convolution:

Initialize the C/N and C/(N+I) distributions with bin size of 0.1 dB

Calculate the effective area of an isotropic antenna at wavelength λ using:

$$A_{ISO} = 10\log\left(\frac{\lambda^2}{4\pi}\right)$$

Calculate the wanted signal power accounting for additional link losses and gain at edge of coverage:

$$C = eirp + \Delta eirp - L_{fs} + G_{max} - L_o$$

Calculate the system noise power using:

$$N_T = 10\log(T \cdot B_{MHz} \cdot 10^6) + k_{dB} + M_{ointra}$$

For each value A_{rain} in the precipitation fade PDF

{

Calculate the faded wanted signal power using:

$$C_f = C - A_{rain}$$

Calculate the C/N using:

$$\frac{C}{N} = C_f - N_T$$

Update the C/N distribution with this C/N and the probability associated with this A_{rain}

For each value EPFD in the EPFD PDF

{

Calculate the interference from the EPFD taking into account the precipitation fading using:

$$I = EPFD + G_{peak} + A_{iso} - A_{rain}$$

Calculate the noise plus interference using:

$$(N_T + I) = 10\log\left(10^{N_T/10} + 10^{I/10}\right)$$

Calculate the C/(N+I) using:

$$\frac{C}{N+I} = C_f - (N_T + I)$$

Identify the relevant C/(N+I) bin for this C/(N+I) value

Increment this bin's probability with the product of the probabilities of this precipitation fade and EPFD

}

}

Step 4: Use of *C/N* and *C/(N+I)* distributions with the criteria in No. 22.5L

The *C/N* and *C/(N+I)* distributions should then be used to check against the availability and spectral efficiency criteria in No. **22.5L** as follows:

Step 4A: Check on unavailability increase

Using the selected threshold $\left(\frac{C}{N}\right)_{Thr}$ for the generic GSO reference link, determine the following:

U_R = Sum of the probabilities from all bins for which $C/N < \left(\frac{C}{N}\right)_{Thr}$

U_{RI} = Sum of the probabilities from all bins for which $C/(N+I) < \left(\frac{C}{N}\right)_{Thr}$

Then the condition to be verified for compliance is:

$$U_{RI} \leq 1.03 \times U_R$$

Step 4B: Check on the time-weighted average spectral efficiency decrease

Determine the long-term time-weighted average spectral efficiency, SE_R, assuming precipitation only by:

Set $SE_R = 0$

For all bins in the C/N PDF above the threshold $\left(\frac{C}{N}\right)_{Thr}$

{

Equation 3 of Recommendation ITU-R S.2131-0 should be used to convert the C/N to a spectral efficiency

Increment SE_R *by the spectral efficiency multiplied by the probability associated with this C/N*

}

Determine the long-term time-weighted average spectral efficiency, SE_{RI}, assuming precipitation and interference by:

Set $SE_{RI} = 0$

For all bins in the C/(N+I) PDF above the threshold $\left(\frac{C}{N}\right)_{Thr}$

{

Equation 3 of Recommendation ITU-R S.2131-0 should be used to convert the C/(N+I) to a spectral efficiency

Increment SE_{RI} *by the spectral efficiency multiplied by the probability associated with this C/(N+I)*

}

Then the condition to be verified for compliance is:

$SE_{RI} >= SE_R*(1 - 0.03)$

APPENDIX 2 TO ANNEX 2 TO RESOLUTION 770 (WRC-19)

Algorithm steps to be applied in the Earth-to-space direction to determine compliance with No. 22.5L

By applying the following steps, the single-entry interference impact from a non-GSO system on the availability and spectral efficiency of a generic GSO reference link is determined. The generic GSO reference link parameters of Annex 1 to this Resolution are used, considering all possible parametric permutations, in conjunction with the worst-case geometry ("WCG") epfd output of the latest version of Recommendation ITU-R S.1503. The output of Recommendation ITU-R S.1503 is a set of interference statistics that a non-GSO system creates. These interference statistics are then used to determine the effect of the interference into each generic GSO reference link.

Step 0: Verification of the generic GSO reference link and selection of *C/N* threshold

The following steps should be used to determine if the generic GSO reference link is valid and if so, which of the thresholds $\left(\frac{C}{N}\right)_{Thr,i}$ should be used. It is assumed that R_s = 6 378.137 km, R_{geo} = 42 164 km and k_{dB} = −228.6 dB(J/K). Note that the term cumulative distribution function is meant to include the concept of the complementary cumulative distribution function depending upon context.

1) Calculate the slant distance in km using:

$$d_{km} = R_s\left(\sqrt{\frac{R_{geo}^2}{R_s^2} - \cos^2(\varepsilon)} - \sin(\varepsilon)\right)$$

2) Calculate the free-space path loss in dB using:

$$L_{fs} = 92.45 + 20\log(f_{GHz}) + 20\log(d_{km})$$

3) Calculate the wanted signal power in the reference bandwidth in dBW accounting for additional link losses and gain at edge of coverage:

$$C = eirp + \Delta eirp - L_{fs} + G_{max} - L_o + G_{rel}$$

4) Calculate the total noise power in the reference bandwidth in dBW/MHz using:

$$N_T = 10\log(T \cdot B_{MHz} \cdot 10^6) + k_{dB} + M_{ointra} + M_{ointer}$$

5) For each threshold $(C/N)_{Thr,i}$, derive the precipitation margin for that case in dB:

$$A_{rain,i} = C - N_T - \left(\frac{C}{N}\right)_{Thr,i}$$

6) If for each threshold $(C/N)_{Thr,i}$ the margin $A_{rain,i} \leq A_{min}$, then this generic GSO reference link is not valid.

7) For each of the thresholds $(C/N)_{Thr,i}$ for which $A_{rain,i} > A_{min}$, undertake step 8:

8) Using the precipitation model in Recommendation ITU-R P.618 together with the selected rain rate, ES height, rain height, ES latitude, elevation angle, frequency, calculated precipitation fade margin and an assumed polarization of vertical, calculate the associated percentage of time, $p_{rain,i}$.

9) If for each threshold $(C/N)_{Thr,i}$ the associated percentage of time is not within the range:

$$0.001\% \leq p_{rain,i} \leq 10\%$$

then this generic GSO reference link is not valid.

10) If at least one threshold meets the criteria in steps 6 and 9, then the lowest threshold, $(C/N)_{Thr}$ that meets these criteria should be used in the analysis.

NOTE – A_{min} is 3 dB and the gain relative to peak towards the ES, $G_{rel} = -3$ dB.

Step 1: Generation of precipitation fade PDF

The precipitation fade PDF should be generated using Recommendation ITU-R P.618 from the selected rain rate, ES height, ES latitude, rain height, elevation angle, frequency and an assumed polarization of vertical as follows:

1) Calculate the maximum fade depth A_{max} using $p = 0.001\%$

2) Create a set of 0.1 dB bins between 0 dB and A_{max}

3) For each of the bins, determine the associate probability p to create a cumulative distribution function (CDF) of A_{rain}

4) For each of the bins, convert this CDF into a PDF of A_{rain}

When using Recommendation ITU-R P.618, the precipitation attenuation should be 0 dB for time percentages above p_{max} where p_{max} is the minimum value of a) 10% and b) the probability of rain attenuation on a slant path calculated from § 2.2.1.2. of Recommendation ITU-R P.618-13.

A bin size of 0.1 dB should be used to ensure consistency with the output from Recommendation ITU-R S.1503. Each bin of the CDF contains the probability that the precipitation fade is at least A_{rain} dB. Each bin of the PDF contains the probability that the precipitation fade is between A_{rain} and A_{rain} + 0.1 dB. During implementation, the array of bins can be capped at the minimum of A_{max} and the fade for which the resulting *C*/*N* would lead to the link being unavailable or have zero throughput.

Step 2: Generation of epfd PDF

Recommendation ITU-R S.1503 should be used to determine the epfd CDF from the non-GSO FSS parameters and the frequency, dish size and ES gain pattern. The epfd CDF will be calculated at the worst-case geometry from Recommendation ITU-R S.1503.

The epfd CDF should then be converted into a PDF.

Step 3: Creation of *C*/*N* and *C*/(*N*+*I*) CDFs by convolution of precipitation fade PDF with epfd PDF

For the selected generic GSO reference link, the *C*/*N* and *C*/(*N*+*I*) PDFs should be generated using the following steps to undertake the discrete convolution:

Initialize the C/N and C/(N+I) distributions with bin size of 0.1 dB

Calculate the effective area of an isotropic antenna at wavelength λ using:

$$A_{ISO} = 10\log\left(\frac{\lambda^2}{4\pi}\right)$$

Calculate the wanted signal power accounting for additional link losses and gain at edge of coverage:

$$C = eirp + \Delta eirp - L_{fs} + G_{max} - L_o + G_{rel}$$

Calculate the system noise power using:

$$N_T = 10\log(T \cdot B_{MHz} \cdot 10^6) + k_{dB} + M_{ointra}$$

For each value A_{rain} in the precipitation fade PDF

{

Calculate the faded wanted signal power using:

$$C_f = C - A_{rain}$$

Calculate the C/N using:

$$\frac{C}{N} = C_f - N_T$$

Update the C/N distribution with this C/N and the probability associated with this A_{rain}

For each value EPFD in the EPFD PDF

{

Calculate the interference from the EPFD:

$$I = EPFD + G_{peak} + A_{iso}$$

Calculate the noise plus interference using:

$$(N_T + I) = 10\log\left(10^{N_T/10} + 10^{I/10}\right)$$

Calculate the C/(N+I) using:

$$\frac{C}{N+I} = C_f - (N_T + I)$$

Identify the relevant C/(N+I) bin for this C/(N+I) value

Increment this bin's probability with the product of the probabilities of this precipitation fade and EPFD

}

}

Step 4: Use of *C/N* and *C/(N+I)* distributions with the criteria in No. 22.5L

The *C/N* and *C/(N+I)* distributions should then be used to check against the availability and spectral efficiency criteria in No. **22.5L** as follows:

Step 4A: Check on unavailability increase

Using the selected threshold $\left(\frac{C}{N}\right)_{Thr}$ for the generic GSO reference link, determine the following:

U_R = Sum of the probabilities from all bins for which $C/N < \left(\frac{C}{N}\right)_{Thr}$

U_{RI} = Sum of the probabilities from all bins for which $C/(N+I) < \left(\frac{C}{N}\right)_{Thr}$

Then the conditions to be verified for compliance are:

$$U_{RI} \leq 1.03 \times U_R$$

Step 4B: Check on the time-weighted average spectral efficiency decrease

Determine the long-term time-weighted average spectral efficiency, SE_R, assuming precipitation only by:

Set $SE_R = 0$

For all bins in the C/N PDF above the threshold $\left(\frac{C}{N}\right)_{Thr}$

{

Equation 3 of Recommendation ITU-R S.2131-0 should be used to convert the C/N to a spectral efficiency

Increment SE_R *by the spectral efficiency multiplied by the probability associated with this C/N*

}

Determine the long-term time-weighted average spectral efficiency, SE_{RI}, assuming precipitation and interference by:

Set $SE_{RI} = 0$

For all bins in the C/(N+I) PDF above the threshold $\left(\frac{C}{N}\right)_{Thr}$

{

Equation 3 of Recommendation ITU-R S.2131-0 should be used to convert the C/(N+I) to a spectral efficiency

Increment SE_{RI} *by the spectral efficiency multiplied by the probability associated with this C/(N+I)*

}

Then the conditions to be verified for compliance are:

$$SE_{RI} \geq SE_R * (1 - 0.03)$$