The effect of the criterion value of single entry interference on the efficiency of use of the Geostationary satellite orbit resource

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Resolution 756 (WRC-12) *resolves* to invite **ITU-R**: " 1) to carry out studies to examine the effectiveness and appropriateness of the current criterion used in the application of RR No. **9.41** …"

The information of the Radiocommunication Bureau on the status of **FSS** frequency assignments in the bands 1**4-14.5 GHz, 10.95-12.75 GHz, 17.7-20.2 GHz** and **27.5-30 GHz** currently within the **MIFR** (e.g. initially recorded under **RR No. 11.38** or **No. 11.41**, currently recorded provisionally or definitively).

FSS Groups in MIFR as on 20.07.2012: 32,348 (10.95-12.75 GHz, 14-14.5 GHz, 17.7-20.2 GHz, 27.5-30 GHz)	
Recorded in MIFR with coordination completed: **15,415 (47.7%)**	**Recorded in MIFR in application of RR No. 11.41 (coordination is not completed):** **16,933 (52.3%)**

The total number of groups of FSS assignments in the MIFR as at 20 July 2012, in all the bands listed above, is 32,348 and a break-up of the number of groups recorded with and without the need for application of RR No. 11.41 are shown below:

1. No. of Groups without application of RR No. 11.41   (coordination completed):   15,415
2. No. of Groups for which RR No. 11.41 has been applied (coordination is not completed):   16,933

Reference: Document 4A/79 (BR) - Survey of status of FSS assignments in the MIFR in the 10.95-30.0 GHz bands, 4 September 2012

The factors defining the necessary angular separation between adjacent GSO satellites

The value of criteria for permissible interference between **GSO FSS** networks in non-planned frequency bands is defined by Recommendation **ITU-R S.1323**, as well as Recommendations **ITU-R S.1432, ITU-R S.523, ITU-R S.739, ITU-R S.740, ITU-R S.741** and **Appendices 5** and **8** of the Radio Regulations.

Recommendation ITU-R S.1323 has defined that the power of permissible **single entry interference** should not exceed *6%* of the total system noise power with the tolerance to **aggregate interference** no more than *20-25%*.

The criterion of single entry interference $\Delta T/T > 6\%$ is applied during coordination of a new network with an earlier filed or registered network.

Value **6%** of criterion $\Delta T/T$ has been adopted many years ago under the conditions of extremely scarce power budget of communication networks with **GSO** satellites and a small number of actually operating networks, when the maintenance of low interference level was determined by an actual necessity.

Assessment of the orbital-frequency resource used by a GSO satellite communication network

The Russian Administration carried out the analysis to assess the effect of the value of permissible single entry interference (ΔT/T) on the GSO capacity.
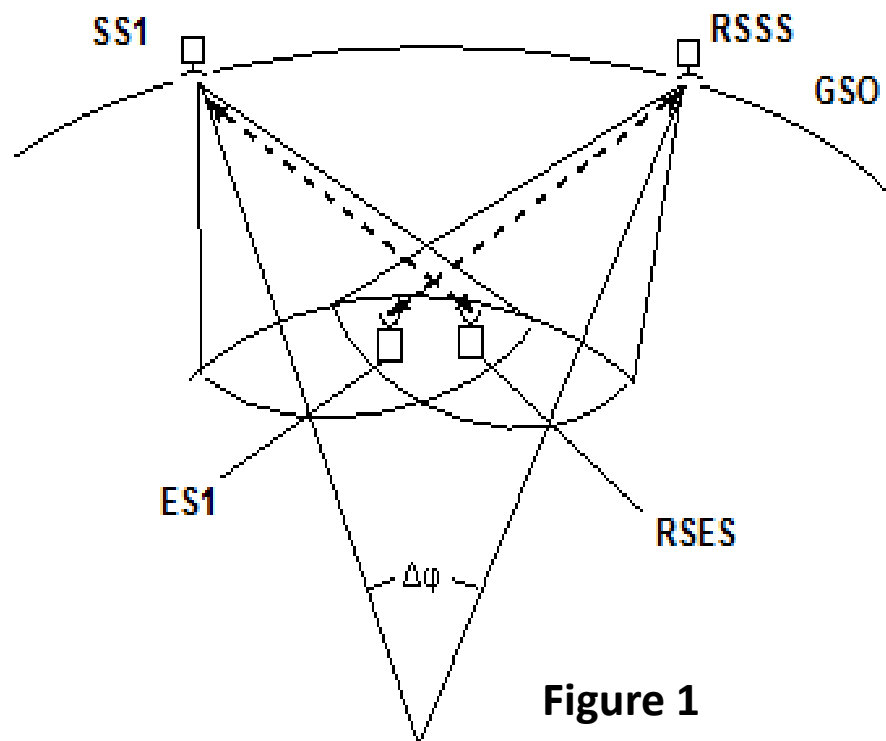

Figure 1
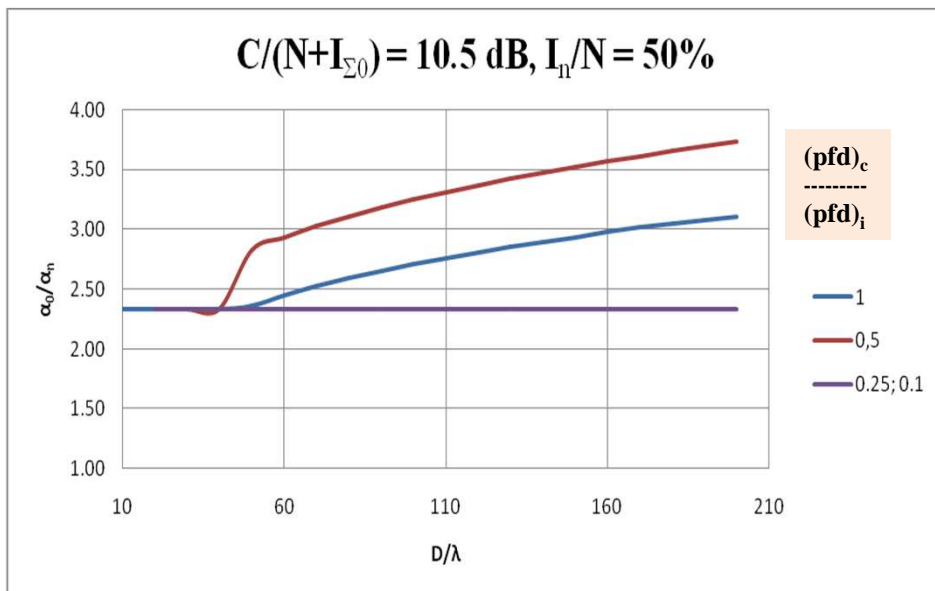
On Figure 1:
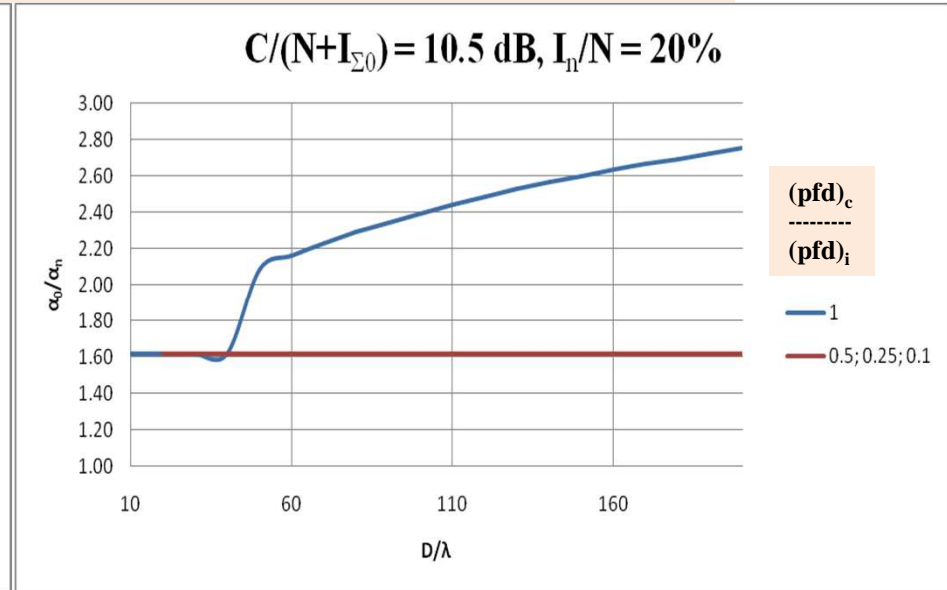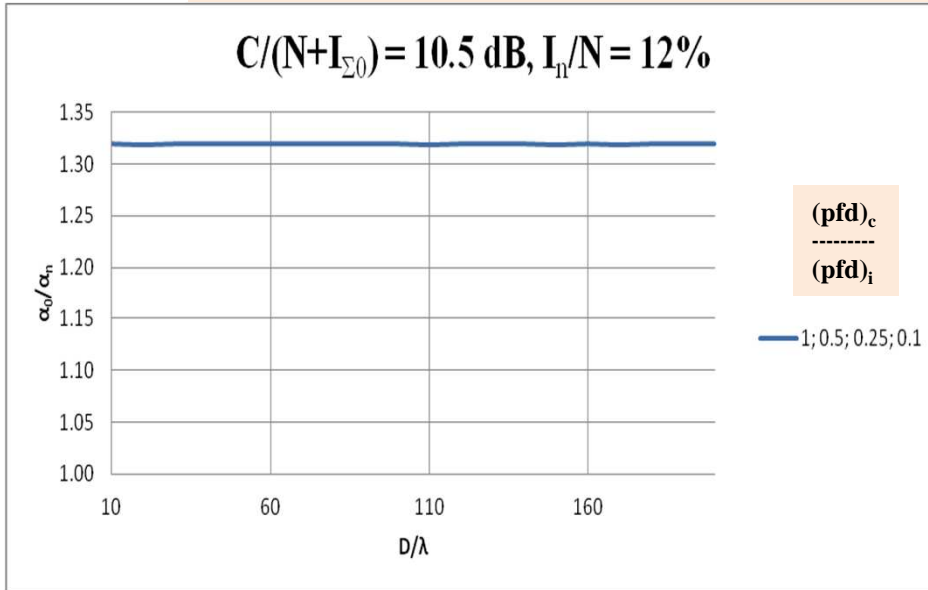**SS1** – space station of the assessed system
ES1 – earth station of the assessed system
RSSS – space station of reference system
RSES – earth station of reference system

Possible reduction of angular separation (α_0/α_n) between adjacent GSO satellites with the ΔT/T increased up to 12%, 20% and 50% - Approach 1

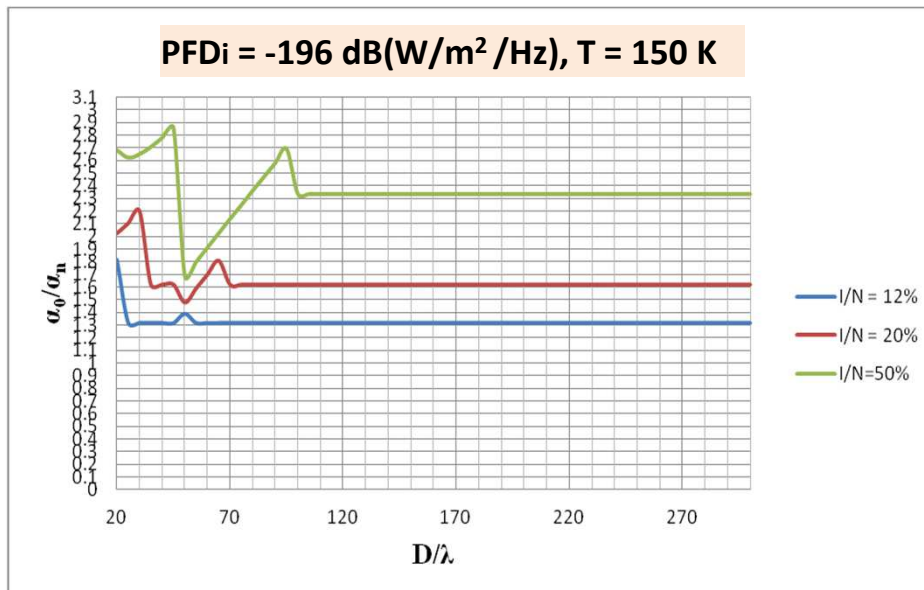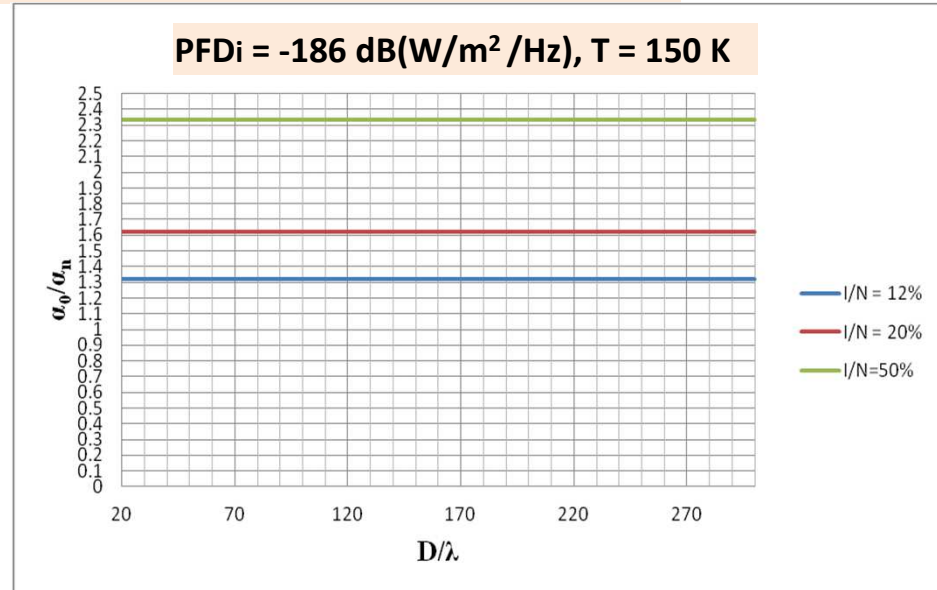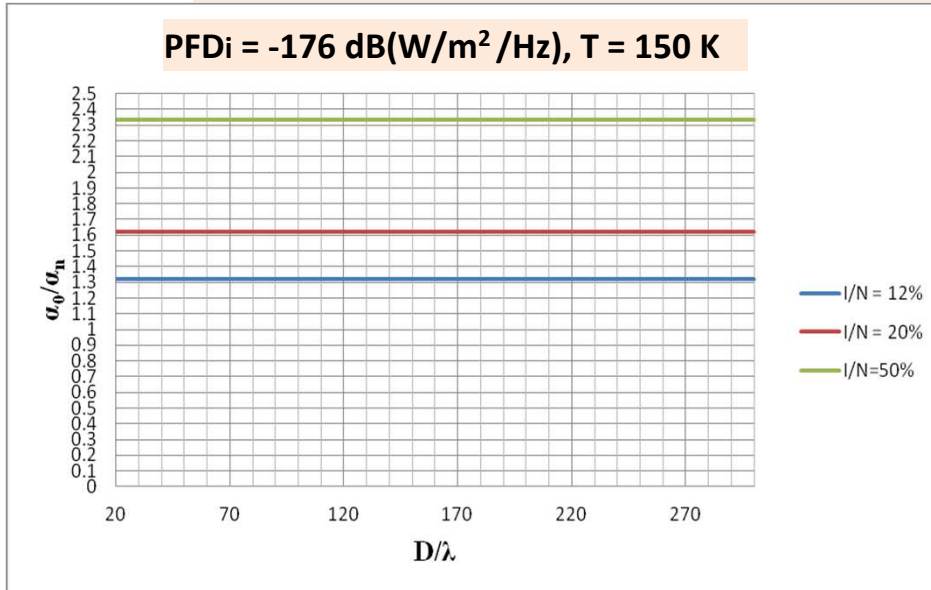

$$G(\alpha_n) = G_{max} - C/N + I_n/N + (pfd)_c/(pfd)_i$$

C/N – carrier-to-noise ratio in the victim link

$I_n/N = \Delta T/T$ – value of criterion for permissible single entry interference

$(pfd)_c / (pfd)_i = (1; 0.5; 0.25; 0.1)$ – signal-to-interference power-flux density ratio

Possible reduction of angular separation (α_0/α_n) between adjacent GSO satellites with the $\Delta T/T$ increased up to 12%, 20% and 50% - Approach 2

PFDi = -176 dB(W/m^2/Hz), T = 150 K

PFDi = -186 dB(W/m^2/Hz), T = 150 K

PFDi = -196 dB(W/m^2/Hz), T = 150 K

$$\Delta T = I = pfd_i + S_{eff}(\alpha) \ (dB)$$
$$S_{eff}(\alpha) = G(\alpha) + 10\log(\lambda^2/4\pi)$$

The gain in the necessary angular separation (α_0/α_n):

$\alpha_0/\alpha_n = 1.32$ for I/N = 12%

$\alpha_0/\alpha_n = 1.619$ for I/N = 20%

$\alpha_0/\alpha_n = 2.335$ for I/N = 50%

Higher permissible interference will lead to some degradation of the link energy budget and decrease in **C/(N+I)** ratio. The calculation **EML** and **ΔEML (dB)** under **Recommendation ITU-R SM.1751** : $EML = 10 \lg(1 + I_{\Sigma n}/N)$, (dB)

I_n/N	EML(dB)	Δ EML(dB)
0.06 (6%)	0.784568	–
0.12 (12%)	1.448854	0.664286
0.2 (20%)	2.201081	1.416513
0.5 (50%)	4.232459	3.447891
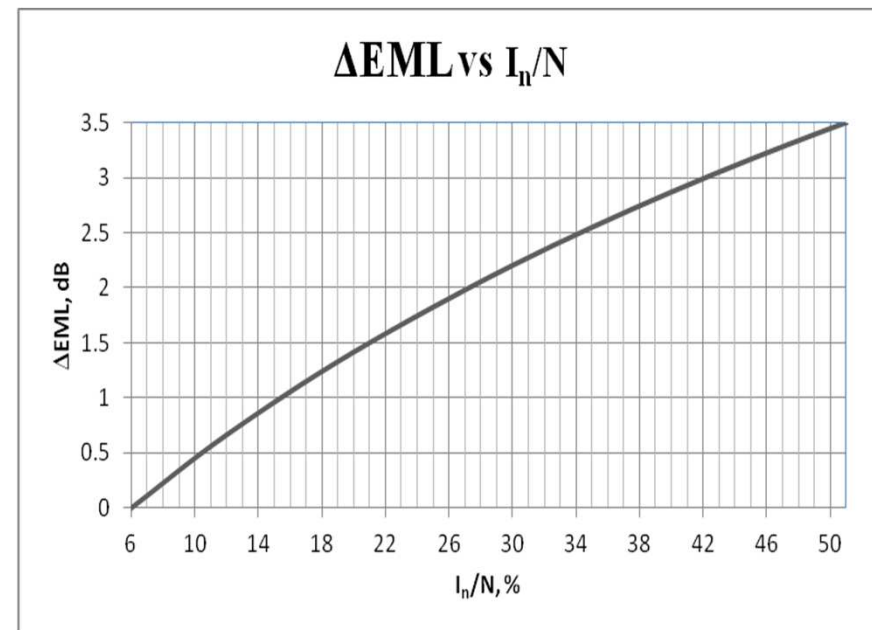
The degraded link energy margin **ΔEML (dB)** value reflects energy margin loss compared to the case of single entry interference **6%**. The **ΔEML (dB)** will not exceed **0.66 – 3.45 dB** corresponding to the typically available energy margin in the current **FSS** networks.

The calculation considers the aggregate interference from all FSS networks based on the ratio of single entry and aggregate interference established by Recommendation ITU-R S.1323.

Possible disadvantages caused by the increase of permissible single entry interference (2)

The capacity losses for the case of digital transmission using spectrum and energy efficiency tables given in **ETSI EN 302307** and known Shannon's equation – for assessment of limiting capacity of the network.

$$T_{sn} = log_2 \left(1 + \frac{c}{(N+I_{\Sigma n})}\right)$$, (bit/s/Hz)

Table 1. Capacity decrease (γ %) and spectrum efficiency (T_{sn} bit/s/Hz)

C/(N+I$_{\Sigma n}$)		I_n/N (%)				
		0%	6%	12%	20%	50%
10,5 дБ	γ (%)	106,67%	100%	94,49%	88,27%	72,12%
	T_{sn} (bit/s/Hz)	3,85	3,61	3,41	3,185	2,602

Capacity decrease described by **γ = (Tsn/Ts0)x100%** (Shannon's equation), and corresponding spectrum efficiency **Tsn (bit/s/Hz)** are shown in Table 1, where **Ts0** – spectrum efficiency corresponding to **single entry interference 6%**.

ΔT/T as a function of orbital separation in respect of different antenna sizes in C-band and Ku-band
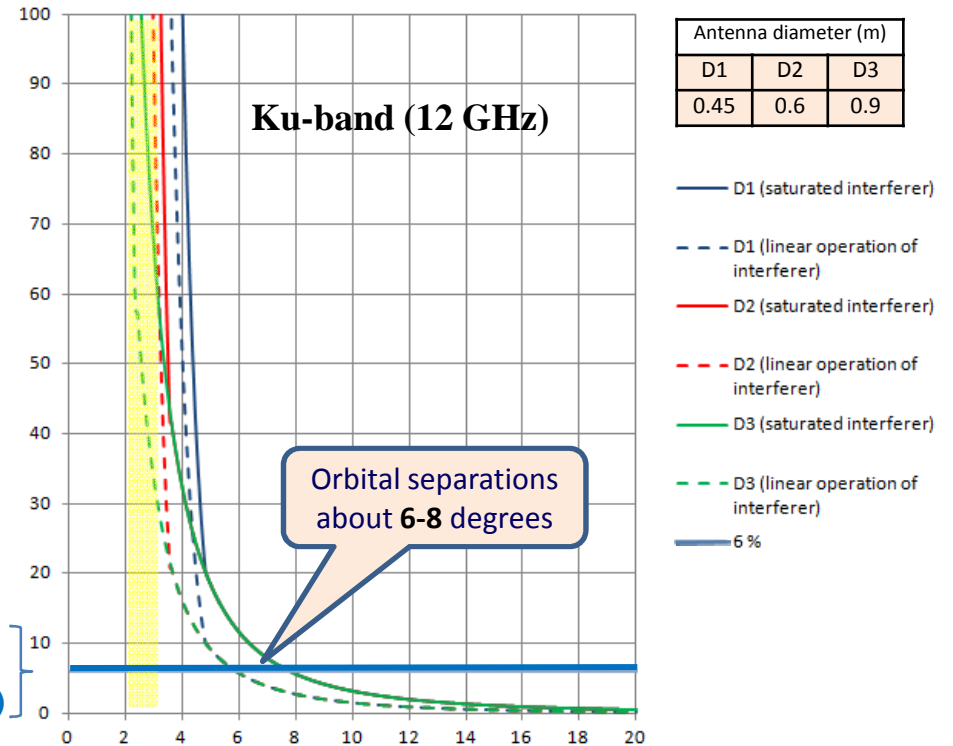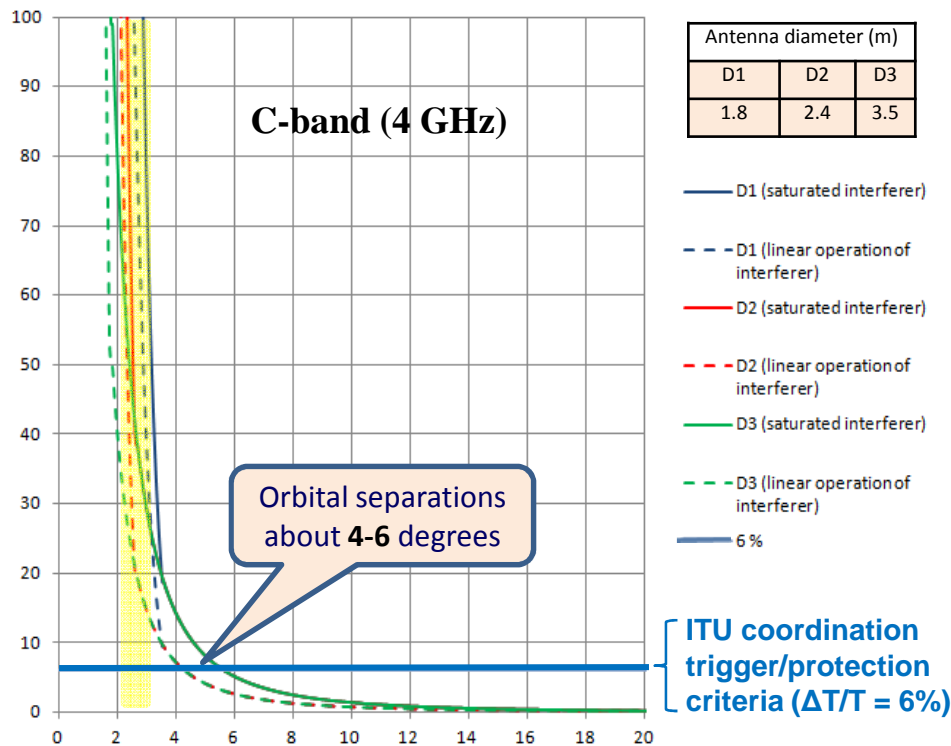
The resulting **ΔT/T > 6%** in **C-band** for orbital separations less than about **4-6 degrees.**

The resulting **ΔT/T > 6%** in **Ku-band** for orbital separations less than about **6-8 degrees**.

Currently co-frequency/coverage/polarized satellite networks in **C-** band and **Ku**-band are typically spaced about **2-3** degrees in GSO and receive actual interference from **40%** up to **100%** and more
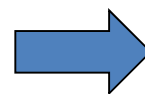
Significant overprotection in ITU criteria:
- Unneccessary coordination
- Complicating coordination
- Complicating access to spectrum orbit resources

The studies carried out by the Administration of the Russian Federation under Resolution 756 (WRC-12) have shown :

1. Increase in criterion **ΔT/T** of permissible single entry interference from **FSS** network from existing **6%** to **12%, 20%** and **50%** will allow the angular separation between adjacent satellites at the **GSO** to be decreased by **1.3, 1.6** and **2.3** times respectively.
    That makes it possible to accommodate additional **FSS or BSS** networks at the **GSO** and facilitate coordination.

2. As a **payment for that**, each network would lose energy margin **(EML)** equal to **0.66, 1.42** and **3.45 dB** respectively (for links with initial **C/(N+I) = 10.5 dB**) or *capacity of each network would decrease by 5.5%, 12%* and **28%**.
    It can be supposed that with the current state of technology, loss in the link energy margin up to **1.5-2.0 dB** in most satellite networks could be compensated without loss in the capacity.

3. The criterion ΔT/T of permissible single entry interference is possible to be increased from **6%** up to **12%–20%**. With the increase in the criterion ΔT/T up to **20%** the total capacity of the **GSO** would increase in **1.4** times.

The studies carried out by the Administration of the Russian Federation under Resolution 756 (WRC-12) have shown :

4. The decision–making to increase the criterion of permissible interference is under the **WRC** jurisdiction, where all the countries have equal rights. However, interests of administrations differ: some administrations are primarily interested in obtaining the resource to establish new **FSS** satellite systems, others – in the protection of operating networks from interference.

5. As an acceptable trade-off, the increased criterion could be introduced for and in respect to new networks only. This decision would, however, postpone the real effect for many (**tens of**) years.

Procedure and terms of transition to the new values of the ΔT/T criterion must be installed by a special Resolution of WRC-15.

Thank you for your attention!

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