

ITUEvents

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Carrier to Interference (C / I ratio) Calculations



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Section B3, Part B of the Rules of Procedure

- Rules concerning the C/I calculation methodology for interference assessment under No.11.32A
- Coordination of networks under No. 9.7
- GSO vs GSO satellite networks

When No.11.32A is applied?

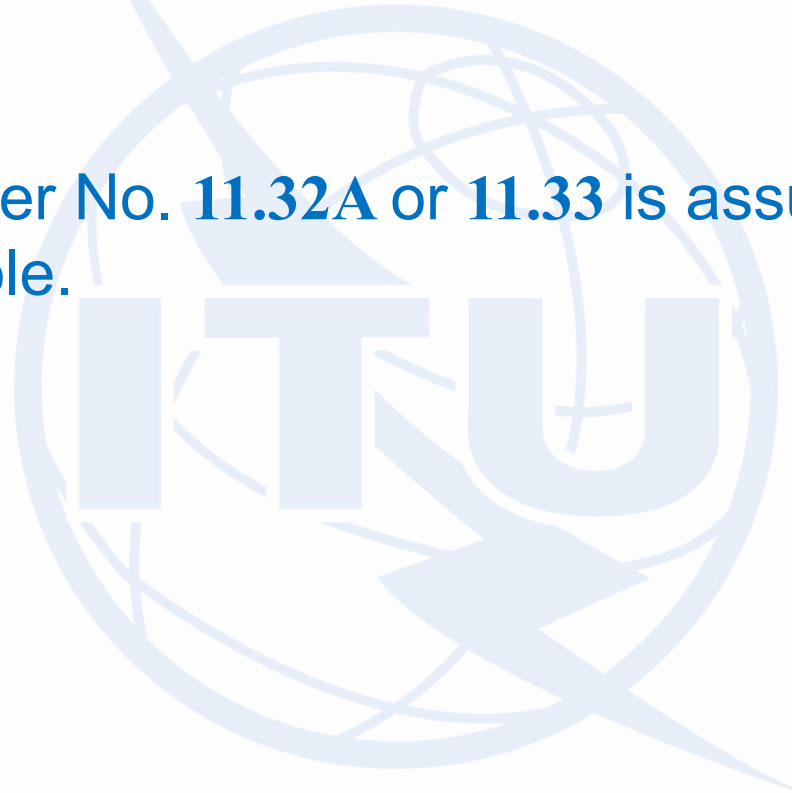
Each notice shall be examined:

11.32A c) with respect to the probability of harmful interference that may be caused to or by assignments recorded with a favourable finding under Nos. 11.36 and 11.37 or 11.38, or recorded in application of No. 11.41, or published under Nos. 9.38 or 9.58 but not yet notified, as appropriate, for those cases for which the notifying administration states that the procedure for coordination under Nos. 9.7, 9.7A, 9.7B, 9.11, 9.12, 9.12A, 9.13 or 9.14, could not be successfully completed (see also No. 9.65);

9.65 If, at the date of receipt of a notice under No. 9.64 above, the Bureau has been informed of a continuing disagreement, the Bureau shall examine the notice under Nos. 11.32A or 11.33 and shall act in accordance with No. 11.38.

11.35 In cases where the Bureau is not in a position to conduct the examination under No. **11.32A** or **11.33**

- finding under No. **11.32A** or **11.33** is assumed unfavourable.





WRC-15 – Resolution 762

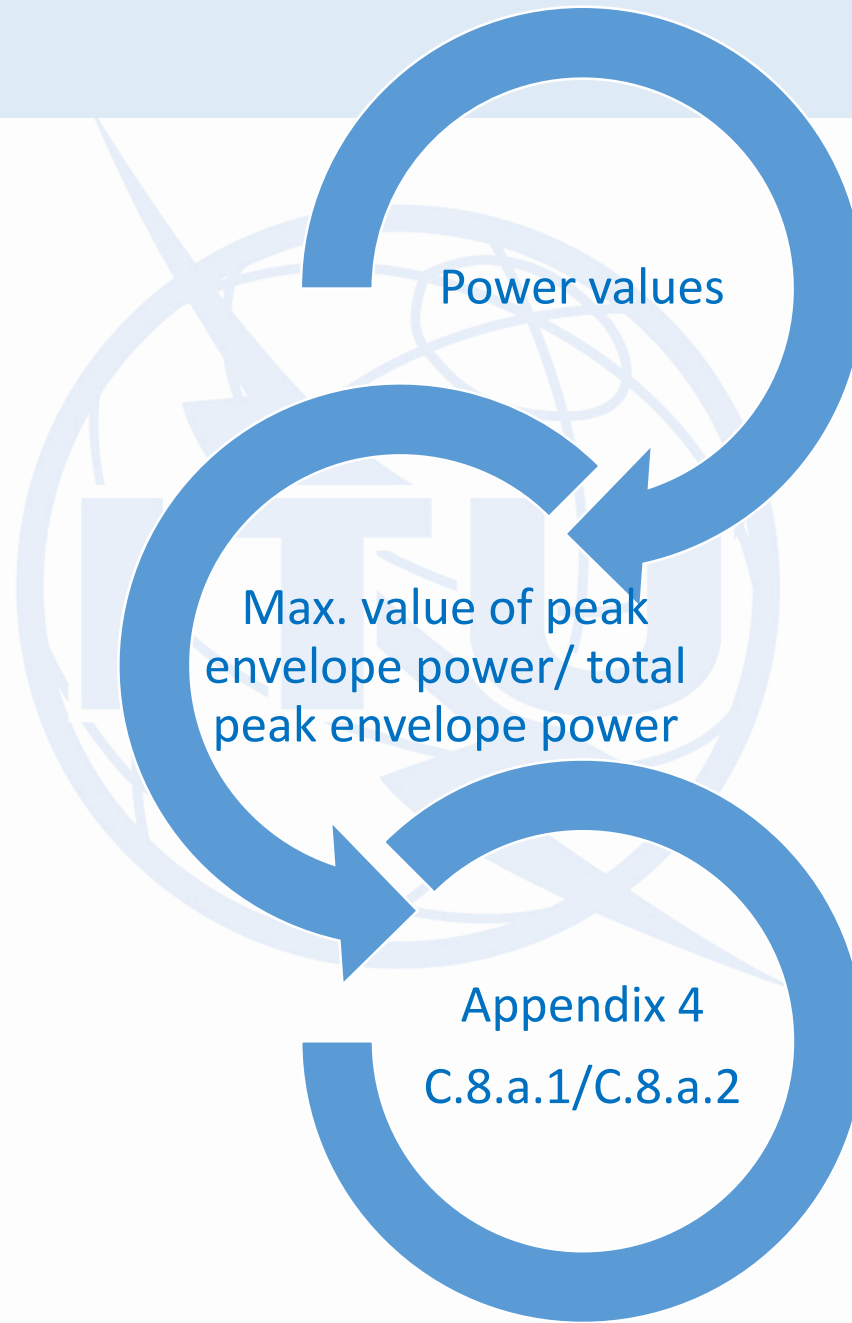
Frequency bands	Space services
Earth-to-space 5 725-5 850 MHz (Region 1) 5 850-6 725 MHz 7 025-7 075 MHz	FSS vs FSS networks Orbital separation > 7°
space-to-Earth 10.95-11.2 GHz 11.45-11.7 GHz 11.7-12.2 GHz (Region 2) 12.2-12.5 GHz (Region 3) 12.5-12.7 GHz (Regions 1 and 3) 12.7-12.75 GHz (space-to-Earth)	FSS or BSS (not subject to a Plan) vs FSS or BSS (not subject to a Plan) Orbital separation > 6°
13.75-14.5 GHz (Earth-to-space)	FSS vs FSS Orbital separation > 6

Section B3, Part B of the Rules of Procedure

➤ The ROP defines

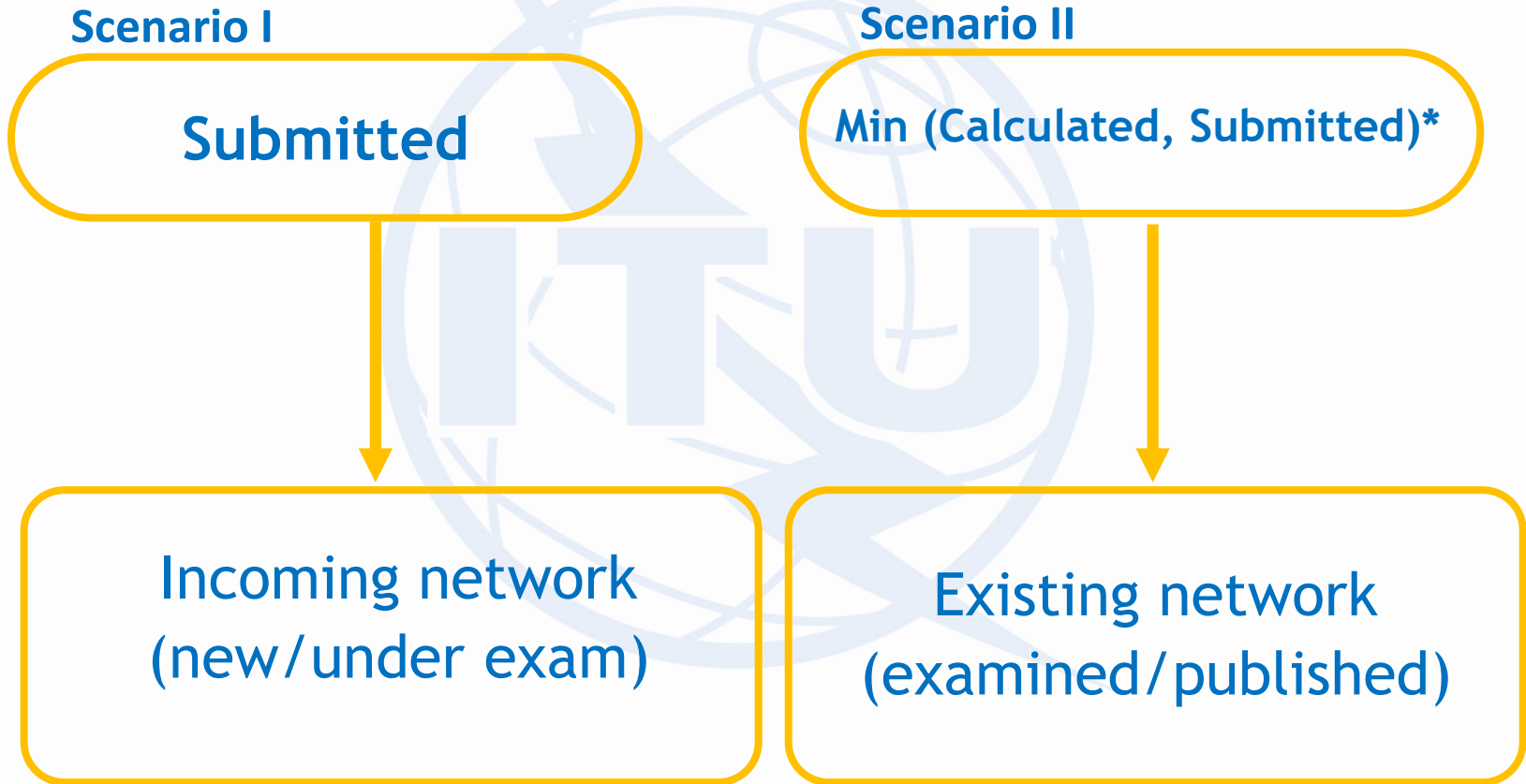
- power values to use
 - how the different type of carriers are categorized according to the class of emission (item C.7 a Annex 2 in Appendix 4)
 - criteria to apply for different combinations of carrier types
 - interference adjustment factor to consider for different combinations of carrier types
 - when C/N objective (submitted in accordance with Appendix 4(Annex 2 item C.8.e.1) or Calculated C/N is used
 - assumptions to make when dealing with composite interference from a number of narrow band carriers
-

Section B3, Part B of the Rules of Procedure



Section B3, Part B of the Rules of Procedure

C/N used



*If no C/N objectives are submitted(not a requirement in the past),
calculated C/N will be used

Section B3, Part B of the Rules of Procedure

- C/N defined as “ratio (dB) of carrier to total noise power which includes all internal system noise and interference from other systems in REC ITU-R S.741-2”
- No. 1.174 noise temperature excludes “the noise due to interference coming from satellite links using other satellites and from terrestrial system”

Section B3, Part B of the Rules of Procedure

- To comply with definition, additional margin added to the margins calculated on the basis of the internal system noise temperature
- Attachment 2 of ROP
- Wanted emissions other than Analog TV - 1.87 dB
- Wanted Analog TV - 0.46 dB

Section B3, Part B of the Rules of Procedure

- For the identification of the required C/I with respect to networks received on or after 1 January 2005
 - whenever the submitted C/N objective is used
 - no additional margins should be added
 - Appendix 4 (rev.WRC-03)
 - C/N objective submitted should already include a margin to account for inter-system interference.

Section B3, Part B of the Rules of Procedure

Extracted from the Rules of Procedure

Scenario I

Before 1 January 2005:

$$\left(\frac{C}{N_{tot}}\right) = \left(\frac{C}{N}\right)_{obj} - X$$

On and after 1 January 2005:

$$\left(\frac{C}{N_{tot}}\right) = \left(\frac{C}{N}\right)_{obj}$$

Scenario II

Before 1 January 2005:

$$\left(\frac{C}{N_{tot}}\right) = \text{MIN}\left(\frac{C}{N_i}, \left(\frac{C}{N}\right)_{obj}\right) - X$$

On and after 1 January 2005:

$$\left(\frac{C}{N_{tot}}\right) = \text{MIN}\left(\frac{C}{N_i} - X, \left(\frac{C}{N}\right)_{obj}\right)$$

C/I methodology

- More complex than delta T/T and more detailed
- Used by Bureau for No.11.32A examination*
- Widely accepted method for assessment of interference especially between geostationary satellite networks
- Widely used by Administrations for coordination of their satellite networks

*No.9.7 - GSO vs GSO satellite networks

COORDINATION MEETING

- Occasion for information exchange
- Agreement of Assumptions
- Agreement of Criteria
- Agreement of Operating or Desired C/Ns
- Agreement of Calculation Method
- Agreement of set of parameters to be used
- More detailed information on service areas, type of carriers, antenna radiation patterns, implementation dates, transponder plan, etc.
- Radio Regulations and ITU Recommendations are often used as the main reference



WHAT'S IMPORTANT?

- **Understanding the basics and concepts of C/I facilitates**
 - C/I generation
 - Development of C/I calculation tool
 - Summarization and interpretation of results
 - Analysis and finding interference mitigation solutions

Calculating Margin

$$\text{Margin} = \boxed{C/I} - \boxed{C/I_{\text{required}}} \quad (\text{dB})$$

- **C/I: Carrier to Interference (dB)**

- **Single-entry interference protection criteria**

Margin



No harmful
interference

Potential for
harmful
interference



Finding C/I Required

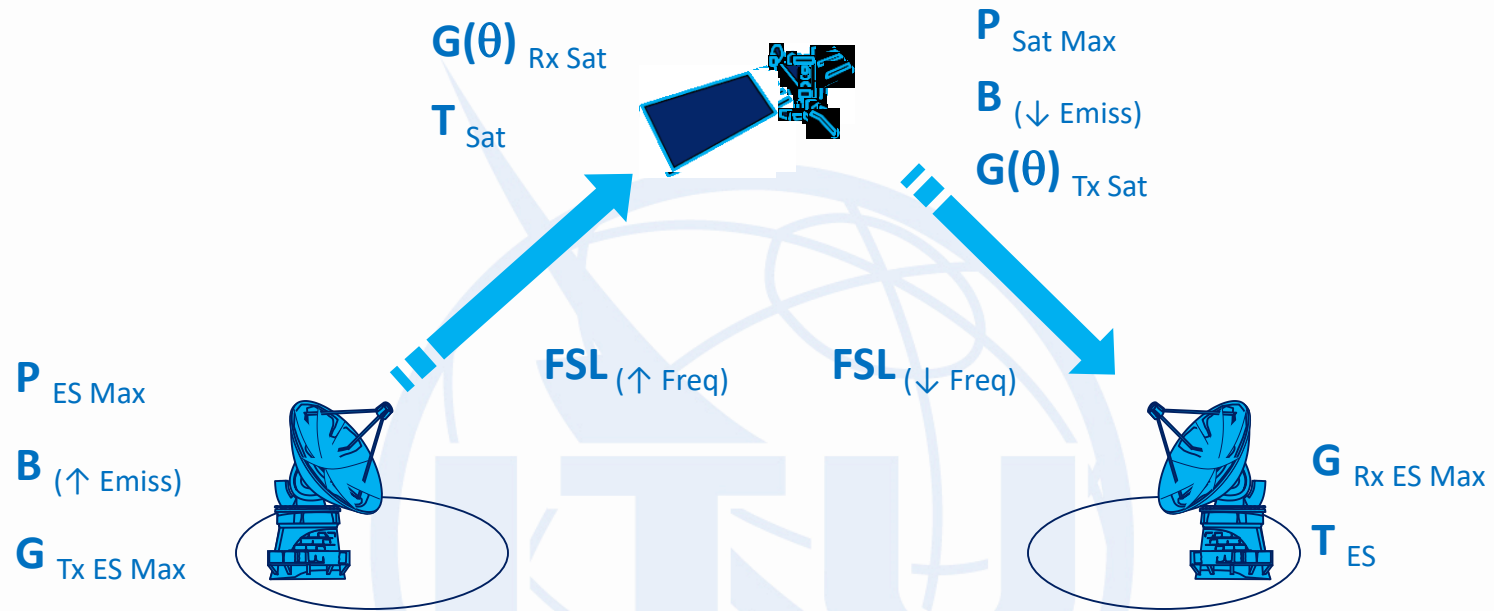


$$\text{Margin} = \text{C/I} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

1. C/N: Carrier to Noise (dB)
2. Type of Carrier

- Single-entry interference protection criteria
- §3.1 of Section B3 of Rules of Procedure

Finding C/I Required Calculate C/N



Maximum Peak Power

Necessary Bandwidth of Emission

Maximum Earth Station Antenna Gain

Free Space Loss (assigned frequency)

Off-axis Satellite Antenna Gain

Receiver System Noise Temperature

Service Area

P_{Max}

B

$G_{ES Max}$

FSL

$G(\theta)_{Sat}$

T

Where to get these information?



SECTION SPECIALE / SPECIAL SECTION / SECCION ESPECIAL CR/C/45

A 41a Sat Network A1f1 Notifying adm. A1f2 Inter. sat. org. BR1 Date of receipt BR20/BR21 IFIC no./part C1UR R

B **Beam Level** BR3a/BR3b Provision reference C BR2 Adm. serial no.

A4a A4a3 Long. tolerance A4a4 Inclination accuracy

A4a3 Visibility arc A4a4 Service arc A4a5 Reason for arc diff.

B1a/B1b Beam designation B2 Emi-Rcp B3a1/B3b1/B3b2a Max. ant. gain B3d Pointing accuracy

B3a **Group Level** B3f Ant. gain vs orbit long. diag.

B3e B3e3 Coef. A B3e4 Coef. B

B7a/BR7b Group id. BR14 Special Section

C4a Class of station C3a Assigned freq. band C5a Noise temperature

C4b Nature of service C6a Polarization type C6b Polarization angle C8d/C8g Max. pwr

C1f1 C1f1a3 Service area diagram

A5/A **Sub-Group or Frequency Assignment Level** BR17 Reason for C8c/C8e absent

C2a Assigned frequency													
5945	MHz	6065	MHz	6185	MHz	6305	MHz	6445	MHz	6565	MHz	6685	MHz
5985	MHz	6105	MHz	6225	MHz	6345	MHz	6485	MHz	6605	MHz		
6025	MHz	6145	MHz	6265	MHz	6385	MHz	6525	MHz	6645	MHz		

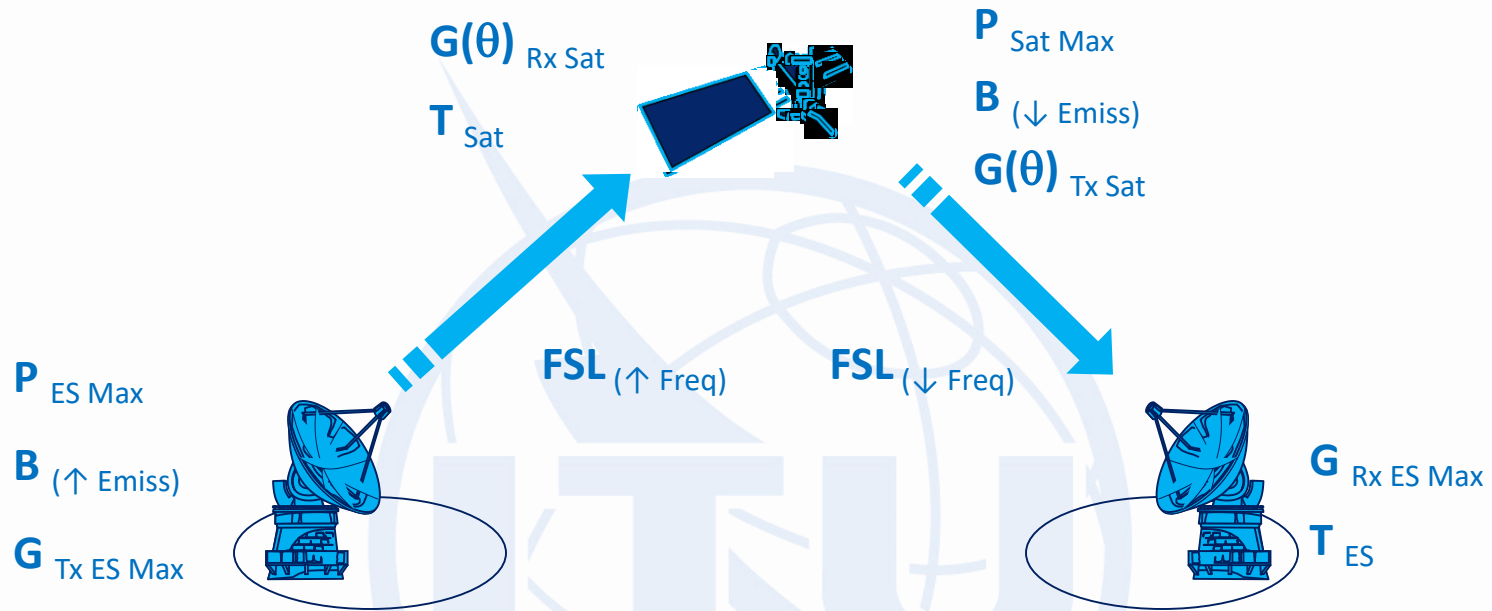
A13 Ref. to Special Sections		C7a Design. of emission		C8a1/C8b1 Max. peak pwr	C8a2/C8b2 Max. pwr dens.	C8c1 Min. peak pwr	C8c2 Min. pwr dens.	C8e C/N ratio	
1	AR11/A	393	1	38K4G7E--	9.1	-35.6	5.1	-39.6	9.4

C10b1 Assoc. earth station id.	C10b4 Ctry	C10b3 Type	C10b5 Geographical coord.	C10c1a/C10c1b Cls. / Nat.	C10c2 Max. iso. gain	C10c3 Bmwidth	C10c4a Ref. pattern	C10c4b Rad. diag.	C10c4c				
									Coef A	Coef B	Coef C	Coef D	Phi1
TYPICAL-1.8M		T		1 TC CP	39.2	2.08	29-25LOG (PI)						

Findings 2D Date 13A Conformity with RR 13B1 Provision 13B2 Remarks 13B3 Date of Review

13C Remarks

Finding C/I Required Calculate C/N



- Maximum Peak Power
- Necessary Bandwidth of Emission
- Maximum Earth Station Antenna Gain
- Free Space Loss (assigned frequency)
- Off-axis Satellite Antenna Gain
- Receiver System Noise Temperature
- Service Area

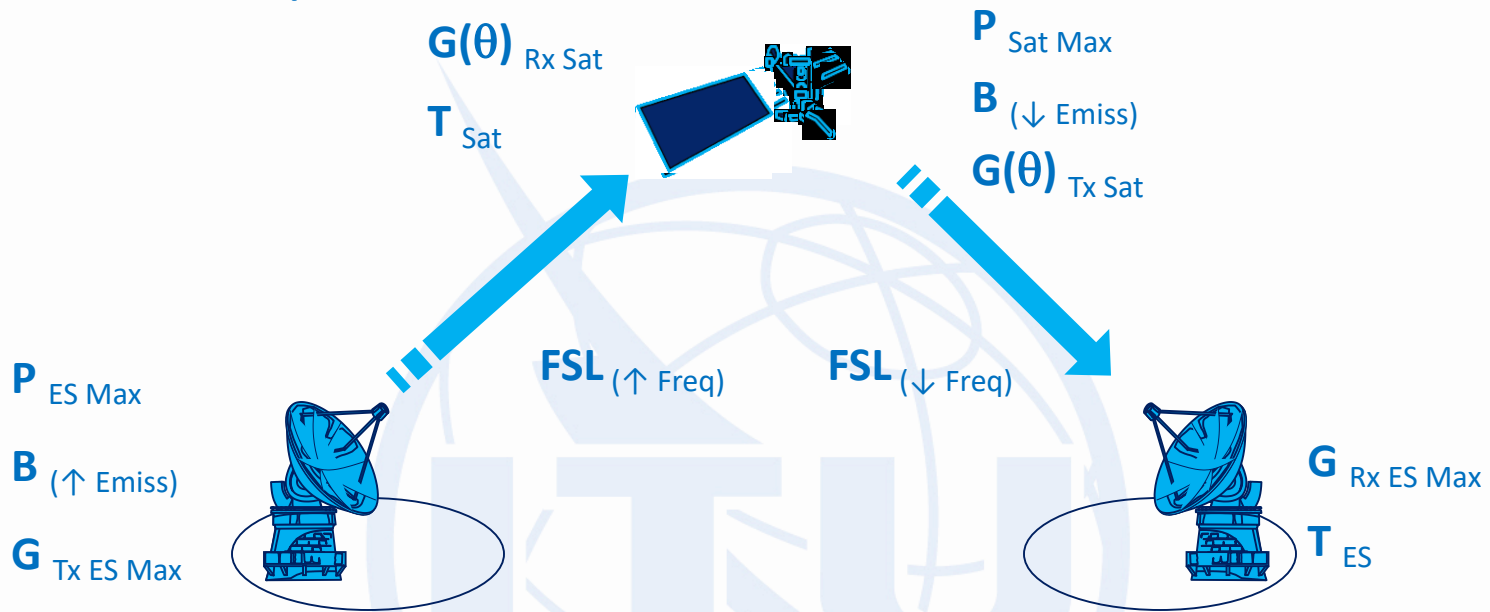
- P_{Max}
- B
- $G_{\text{ES Max}}$
- FSL
- $G(\theta)_{\text{Sat}}$
- T

- C8a1/C8b1
- C7a
- C10d3
- C2a1
- B3a + B3b
- C5a/C10d6
- C11a

Appendix
4

Finding C/I Required

Calculate C/N



C, Carrier power

N, Noise power

$$C/N = P_{Max} + G_{ES Max} + G(\theta)_{Sat} - FSL_{(Freq)} - (k + T + B_{(Emiss)}) \text{ (dB)}$$

$$FSL = 10 \log_{10} (4\pi d f / c)^2$$

k, Boltzmann constant = -228.6 dBW/K/Hz



Free Space Loss (Annex II of AP8)

$$\text{FSL} = 20 (\log f + \log d) + 32.45 \text{ dB}$$

where :

f : frequency (mHz)

d : distance (km)

where:

$$d = 42644(1 - 0.2954 \cdot \cos \psi)^{0.5}$$

where:

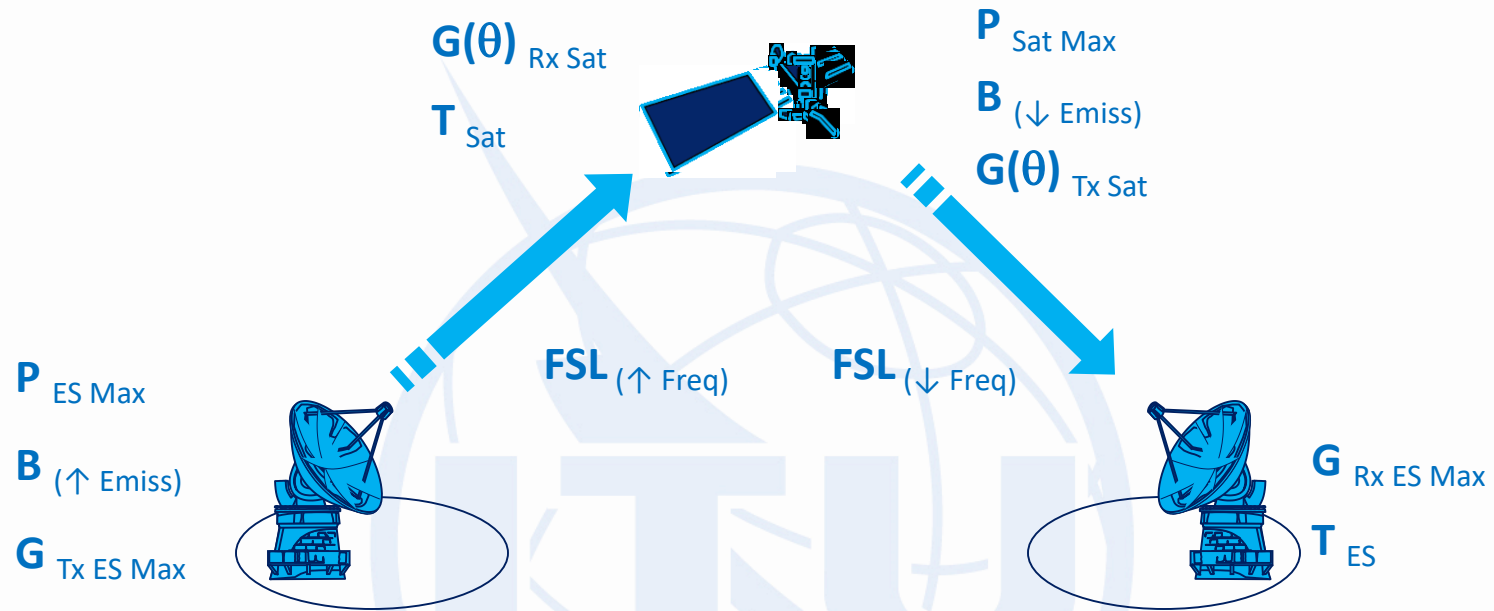
$$\cos \psi = \cos \zeta \times \cos \beta$$

where :

ζ = latitude of earth station

β = difference in longitude btw satellite and earth station

Finding C/I Required Calculate C/N



Uplink C/N

$$C/N \uparrow = P_{ES\ Max} + G_{Tx\ ES\ Max} + G(\theta)_{Rx\ Sat} - FSL_{(\uparrow\ Freq)} - (k + T_{Sat} + B_{(\uparrow\ Emiss)}) \text{ (dB)}$$

Downlink C/N

$$C/N \downarrow = P_{Sat\ Max} + G(\theta)_{Tx\ Sat} + G_{Rx\ ES\ Max} - FSL_{(\downarrow\ Freq)} - (k + T_{ES} + B_{(\downarrow\ Emiss)}) \text{ (dB)}$$

Finding C/I Required



Interfering \ Wanted	TV/FM or Other	Digital	Analogue (Other than TV/FM)
TV/FM	$C/N + 14$ (dB)		
Digital	If $BW_w \leq BW_{eqi}$ then $C/N + 5.5 + 3.5 \cdot \log(BW_w)$ (dB) else if $BW_w > BW_{eqi}$ then $C/N + 12.2$ (dB)	$C/N + 12.2$ (dB)	
Analogue (Other than TV/FM)	$11.4 + 2 \cdot \log(BW_w)$ (dB)	$C/N + 12.2$ (dB)	
Other	$11.4 + 2 \cdot \log(BW_w)$ (dB)	$C/N + 14$ (dB)	

Source: Table 2 in Section B3 of Rules of Procedures, ITU-R S.741-2

BW_w : Necessary bandwidth of wanted carrier (MHz)

BW_{eqi} : Equivalent bandwidth of interfering carrier (MHz)

C/N: Carrier to Noise ratio (dB)

Finding C/I Required
Check Carrier Type



Example:

36M0G7W--

Necessary bandwidth

Class of Emission

1st Symbol: Type of modulation of the main carrier

2nd Symbol: Nature of signal(s) modulating the main carrier

3rd Symbol: Type of info to be transmitted

Finding C/I Required

$$\text{Margin} = \text{C/I} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

To summarize:

- From Appendix 4 data, find C/N
- From emission, find carrier type
- From Table 2 in Section B3 of Rules of Procedure, find C/I Required

Finding C/I

$$\text{Margin} = \boxed{\text{C/I}} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

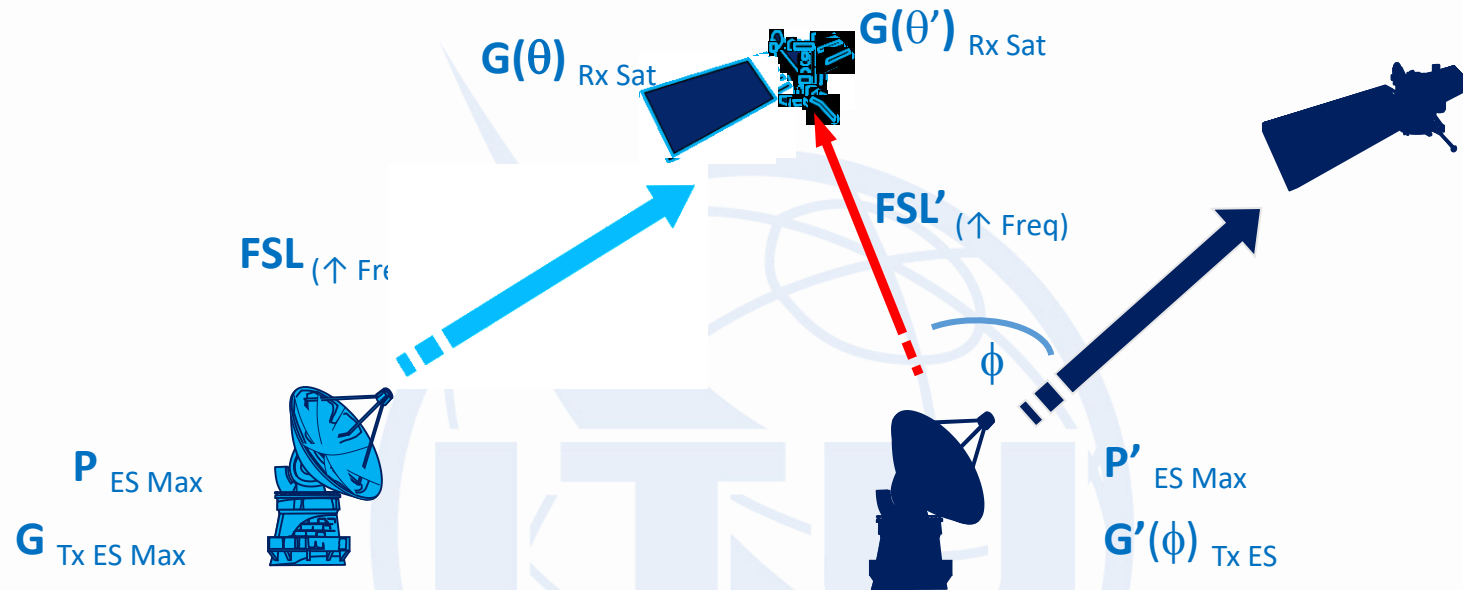
C/I: Carrier to Interference (dB)

$$\text{C/I} = \text{C/I}_b - I_a$$

1. C/I_b : Basic calculated C/I (dB)
2. I_a : Interference adjustment factor (dB)

Finding C/I

Calculate C/I basic



$$C \uparrow = P_{ES \text{ Max}} + G_{Tx \text{ ES Max}} + G(\theta)_{Rx \text{ Sat}} - FSL_{(\uparrow \text{ Freq})} \text{ (dBW)}$$

$$I \uparrow = P'_{ES \text{ Max}} + G'(\phi)_{Tx \text{ ES}} + G(\theta')_{Rx \text{ Sat}} - FSL'_{(\uparrow \text{ Freq})} \text{ (dBW)}$$

$$C/I \uparrow = C \uparrow - I \uparrow \text{ (dB)}$$

Topocentric Angular Separation Between Two Satellites

(Annex I of AP8)

$$\theta_t = \arccos \left[\frac{d_1^2 + d_2^2 - (84332 \sin(\theta_g/2))^2}{2d_1 \cdot d_2} \right]$$

Where

d1 and d2 are the distances (km),
from earth station to the two
satellites separately

θg is the geocentric angular
separation in degrees between
the two satellites, taking the
longitudinal station-keeping
tolerances into account

Antenna reference patterns

Annex 3 of Appendix 7 of the Radio regulations

ITU-R S.580-6

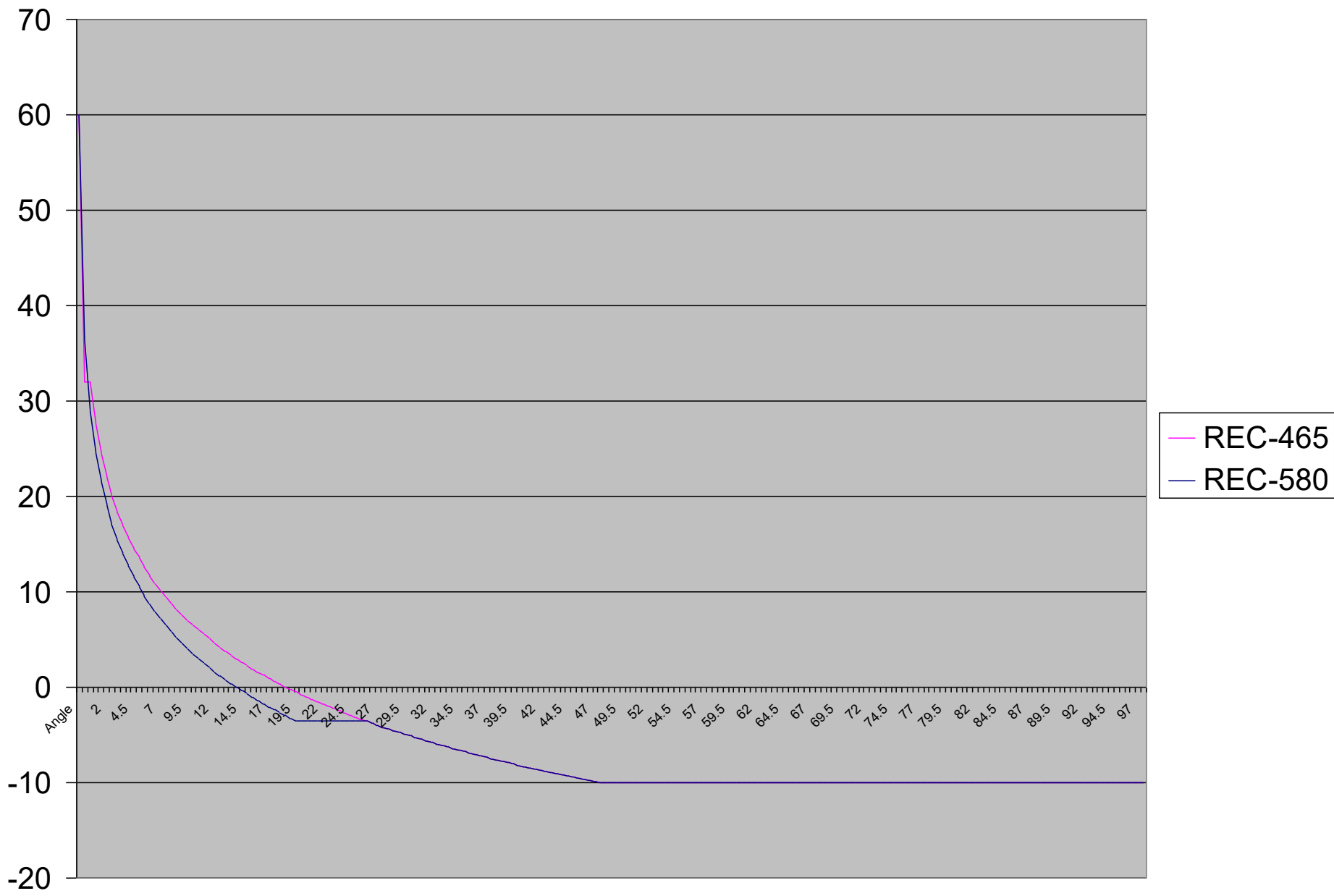
ITU-R S.465-6

ITU-R BO.1900

ITU-R M.694-1

ITU-R BO.1213-1

ITU-R BO.1295



Pattern1	Pattern2	Freq (MHz)	Gmax (dBi)
REC-465	REC-580	7265	60

Finding C/I

Calculate C/I basic

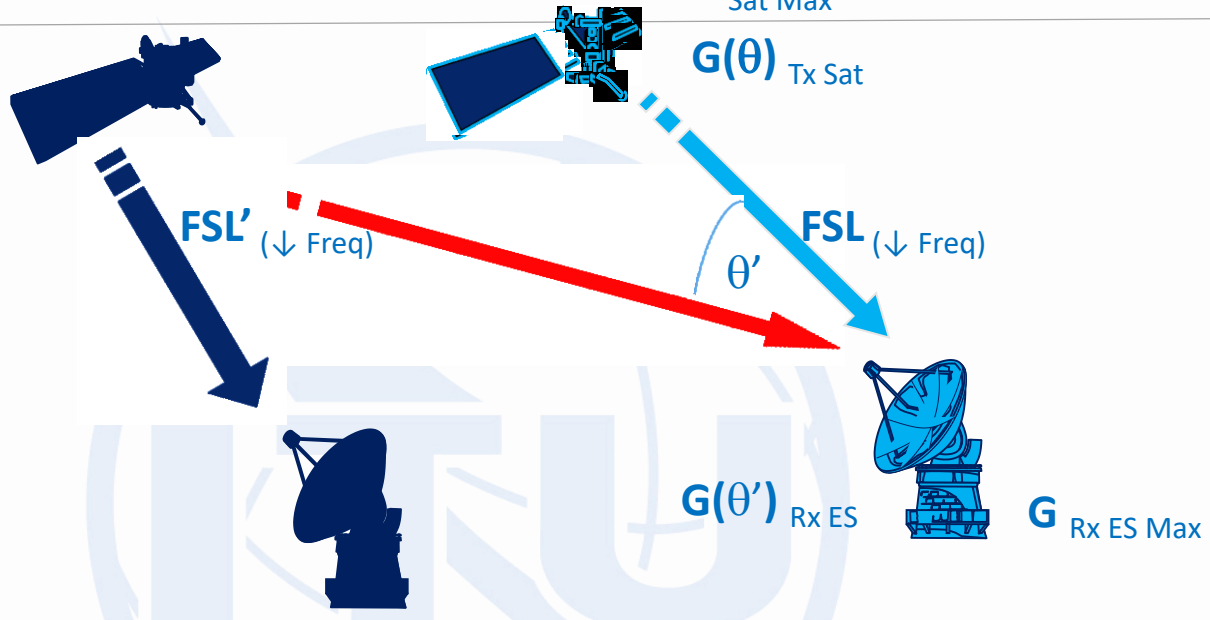


$P'_{\text{Sat Max}}$

$G'(\phi)_{\text{Tx Sat}}$

$P_{\text{Sat Max}}$

$G(\theta)_{\text{Tx Sat}}$



$$C \downarrow = P_{\text{Sat Max}} + G(\theta)_{\text{Tx Sat}} + G_{\text{Rx ES Max}} - FSL_{(\downarrow \text{Freq})} \text{ (dBW)}$$

$$I \downarrow = P'_{\text{Sat Max}} + G'(\phi)_{\text{Tx Sat}} + G(\theta')_{\text{Rx ES}} - FSL'_{(\downarrow \text{Freq})} \text{ (dBW)}$$

$$C/I \downarrow = C \downarrow - I \downarrow \text{ (dB)}$$

Finding C/I



$$\text{Margin} = \boxed{\text{C/I}} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

C/I: Carrier to Interference (dB)

$$\text{C/I} = \text{C/I}_b - I_a$$

1. C/I_b : Basic calculated C/I (dB)
2. I_a : Interference adjustment factor (dB)

Finding C/I Get Adjustment Factor



Wanted Interfering	Digital	Analogue (Other than TV/FM)	Other	TV/FM
Digital	METHOD 1: Wanted Bandwidth (BW) to Interfering BW Overlapping Ratio Adjustment			
TV/FM	METHOD 2: Wanted BW to Interfering Equivalent BW Overlapping Ratio Adjustment		METHOD 1: Co-freq.	
Analogue (Other than TV/FM)			METHOD 3: Non co-freq. (Relative Protection Ratio)	
Other			METHOD 2	

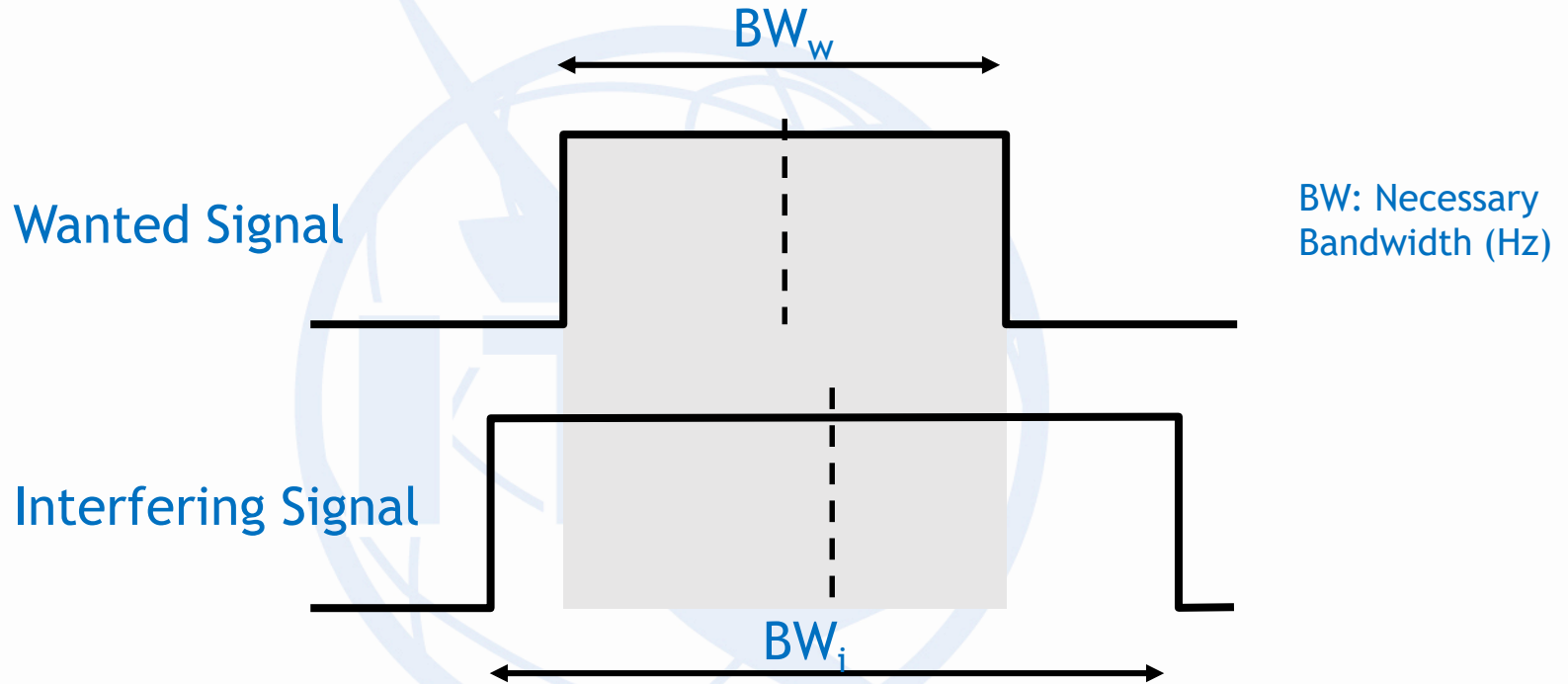
Source: Table 1 in Section B3 of Rules of Procedures, ITU-R S.741-2

Finding C/I

Get Adjustment Factor



Method 1:



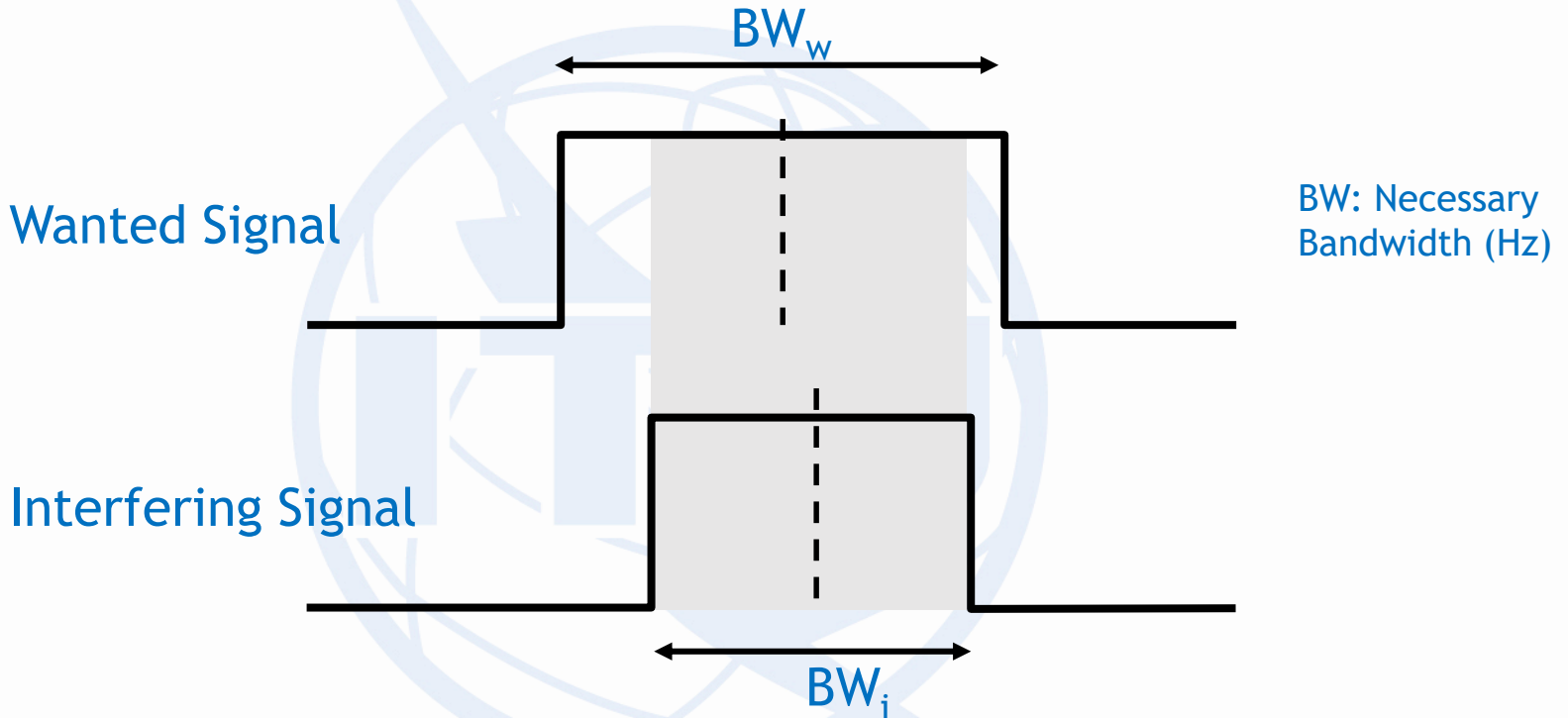
$$\begin{aligned} I_a &= 10\log_{10} (BW_{\text{overlap}} / BW_i) \\ &= 10\log_{10} (BW_w / BW_i) \\ &< 0 = \text{Improvement!} \end{aligned}$$

Finding C/I

Get Adjustment Factor



Method 1:



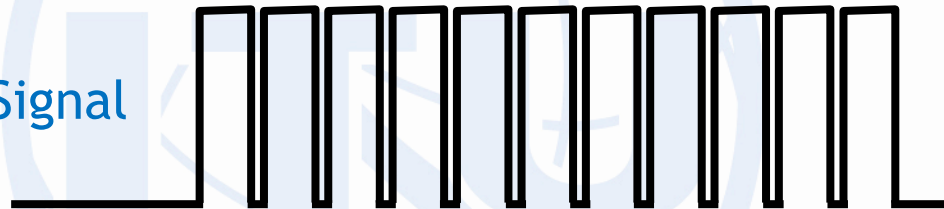
$$\begin{aligned} I_a &= 10\log_{10} (BW_{\text{overlap}} / BW_i) \\ &= 10\log_{10} (BW_i / BW_i) \\ &= 0 = \text{No Improvement!} \end{aligned}$$



Wanted Signal



Interfering Signal



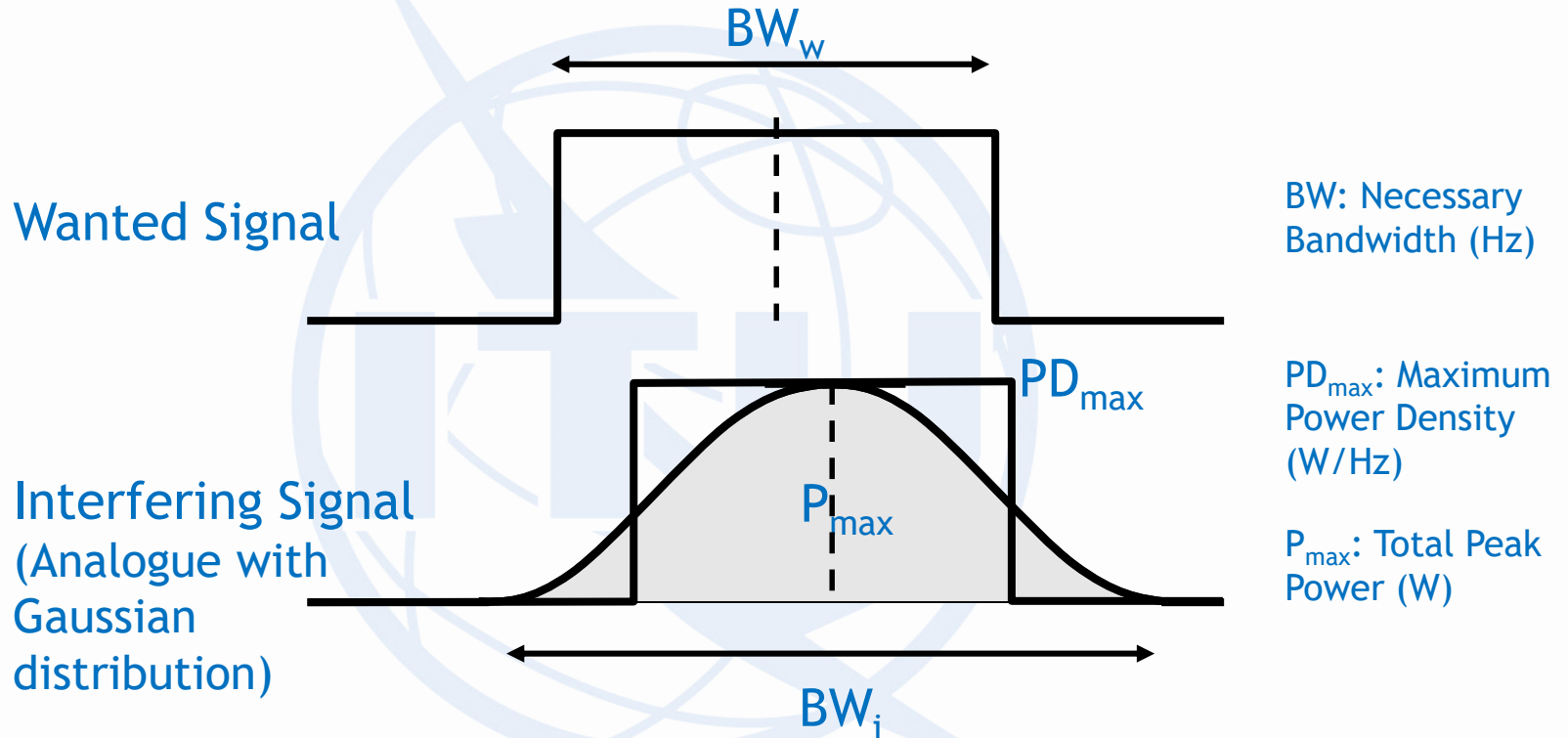
- Interfering transponder fully loaded with N narrowband carriers
- N is maximized by transponder bandwidth (item C.3.a of Appendix 4) and maximum total peak power (item C.8.d.1)

Finding C/I

Get Adjustment Factor



Method 2:



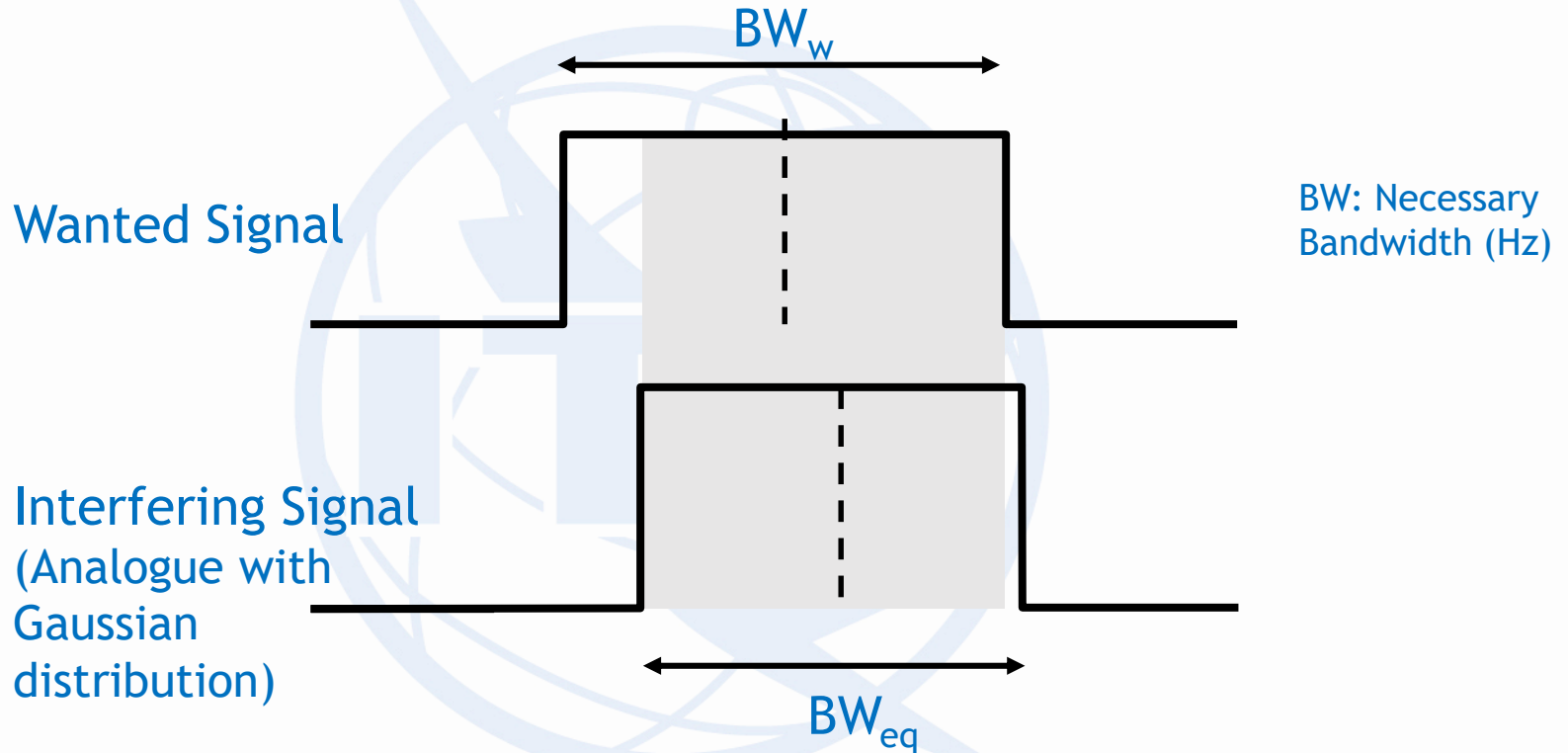
$$BW_{eq} = P_{max} / PD_{max}$$

Finding C/I

Get Adjustment Factor



Method 2:



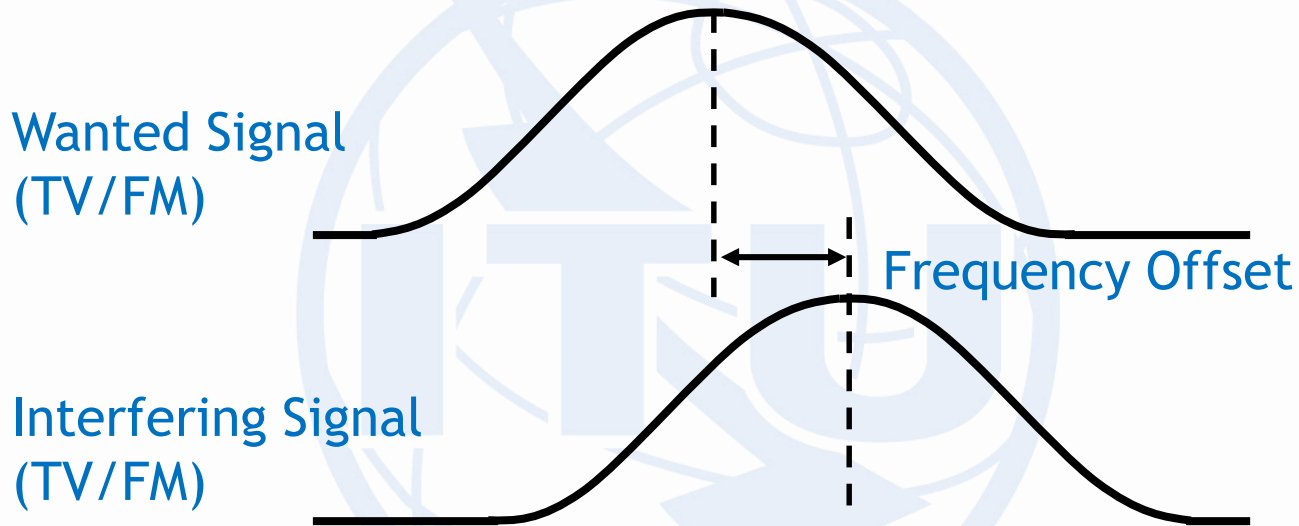
$$I_a = 10\log_{10} (BW_{\text{overlap}} / BW_{\text{eq}})$$

Finding C/I

Get Adjustment Factor



Method 3:



Relative Protection Ratio adjustment factor is

- derived from protection masks using frequency offset
- a function of overlapping bandwidths of wanted and interfering signals

Finding C/I



$$\text{Margin} = \boxed{\text{C/I}} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

To summarize:

- From Appendix 4 data, find basic calculated C/I_b
- From Table 1 in Section B3 of Rules of Procedure, find Interference Adjustment Factor I_a
- $\text{C/I} = \text{C/I}_b - I_a$

Calculating Margin



$$\text{Margin} = C/I - C/I_{\text{required}} \quad (\text{dB})$$

- **Positive or Zero Margin:**
No harmful interference
- **Negative Margin:**
Potential for harmful interference