



Carrier to Interference (C / I ratio) Calculations

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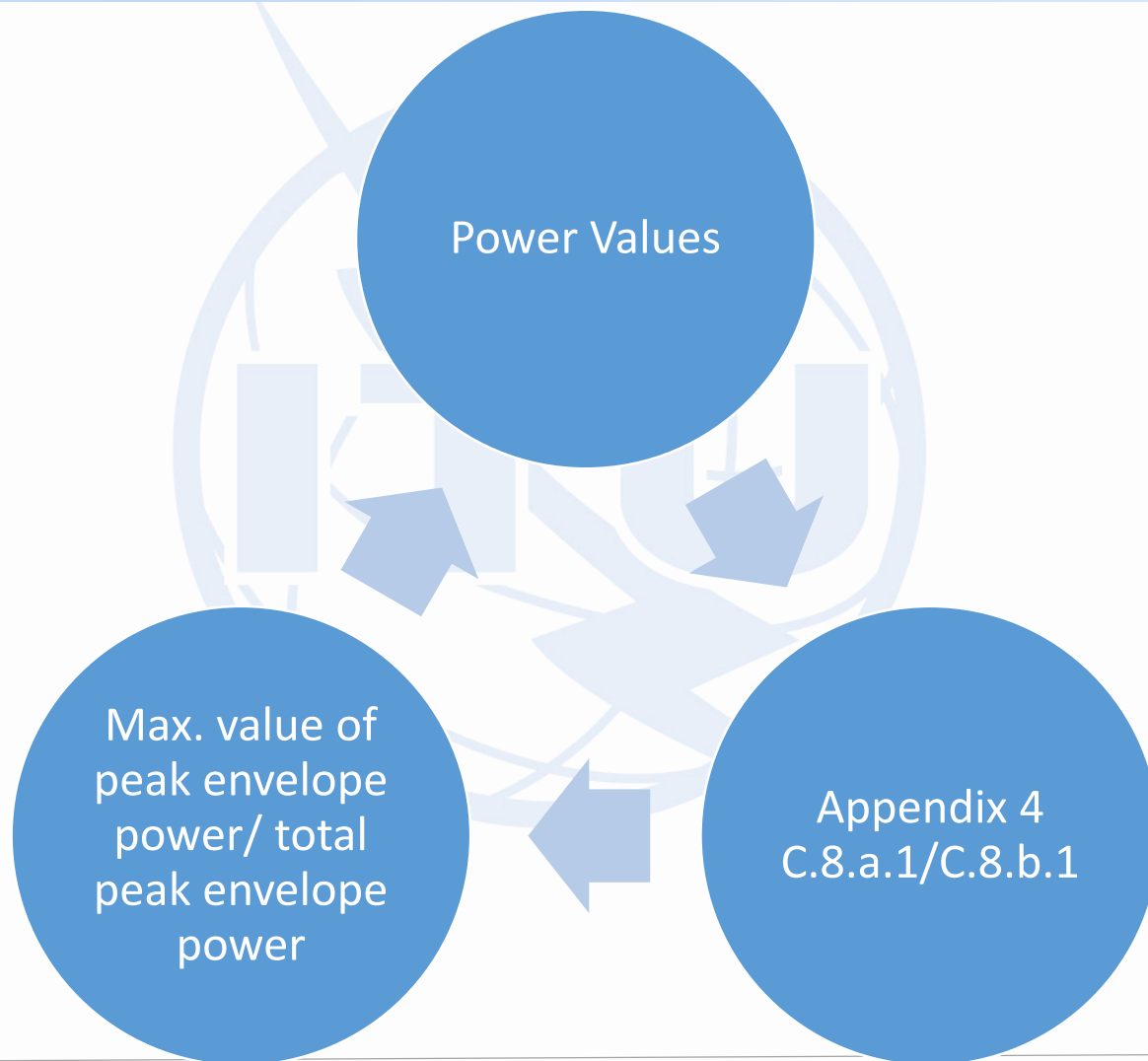
International Telecommunication Union

Section B3, Part B of the Rules of Procedure

- **Outlines the C/I calculation methodology for interference assessment under No.11.32A w.r.t. coordination of networks under No. 9.7 (i.e. GSO vs GSO satellite networks)**

- **The ROP defines**
 - the 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)
 - which criteria to apply for different combinations of carrier types
 - the 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

Min (Calculated, Submitted)*

Submitted

**Existing network
(examined/published)**

**Incoming network
(new/under exam)**

If no C/N objectives are submitted(since this was 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”**
- **To comply with definition, an additional margin will be added to the margins calculated on the basis of the internal system noise temperature (Attachment 2 of ROP)**
- **Wanted Analog TV emissions – 0.46 dB**
- **Other Wanted emissions – 1.87 dB**

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.

C/I methodology

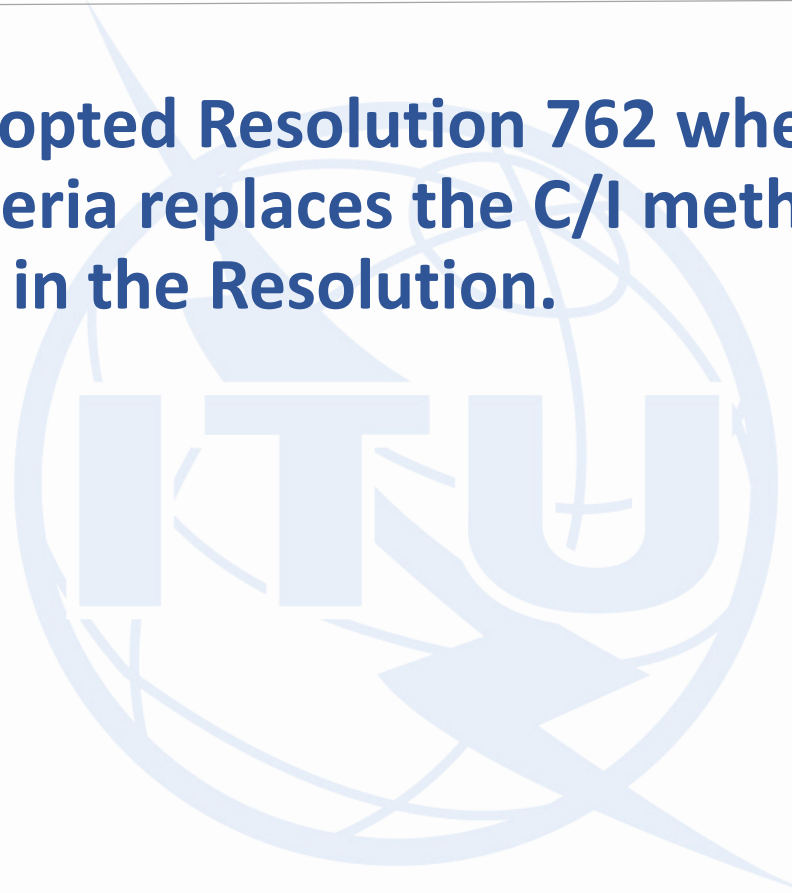
- More complex than delta T/T and more detailed
- Used by Bureau for No.11.32A examination*
- Widely accepted method for assessment of interference especially between geostationary satellite networks
- Widely used by Administrations for coordination of their satellite networks

*GSO vs GSO satellite networks



WRC-15 – Resolution 762

- **WRC-15 adopted Resolution 762 where power flux-density criteria replaces the C/I method for cases as mentioned in the Resolution.**





WRC-15 – Resolution 762

- 5 725-5 850 MHz (Region 1), 5 850-6 725 MHz and 7 025-7 075 MHz (Earth-to-space) having a nominal orbital separation in the geostationary-satellite orbit of more than 7° , FSS vs FSS networks

pfd limit

$-204.0 \text{ dB(W/(m}^2 \cdot \text{Hz))}$



WRC-15 – Resolution 762

- 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) and 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) having a nominal orbital separation in the geostationary-satellite orbit of more than 6°:

pfd limit

$5.8^\circ < \theta \leq 20.9^\circ$	$-187.2 + 25\log(\theta/5)$	$\text{dB(W}/(\text{m}^2 \cdot \text{Hz}))$
$20.9^\circ < \theta$	-171.67	$\text{dB(W}/(\text{m}^2 \cdot \text{Hz}))$

WRC-15 – Resolution 762

- 13.75-14.5 GHz (Earth-to-space) having a nominal orbital separation in the geostationary-satellite orbit of more than 6° , FSS vs FSS

pfd limit

$-208 \text{ dB}(\text{W}/(\text{m}^2 \cdot \text{Hz}))^*$,

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

Examine Probability of Harmful Interference



➤ Margin

Negative Margin

Potential for
Harmful Interference

Positive or Zero
Margin

No Harmful Interference

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**

Finding C/I Required

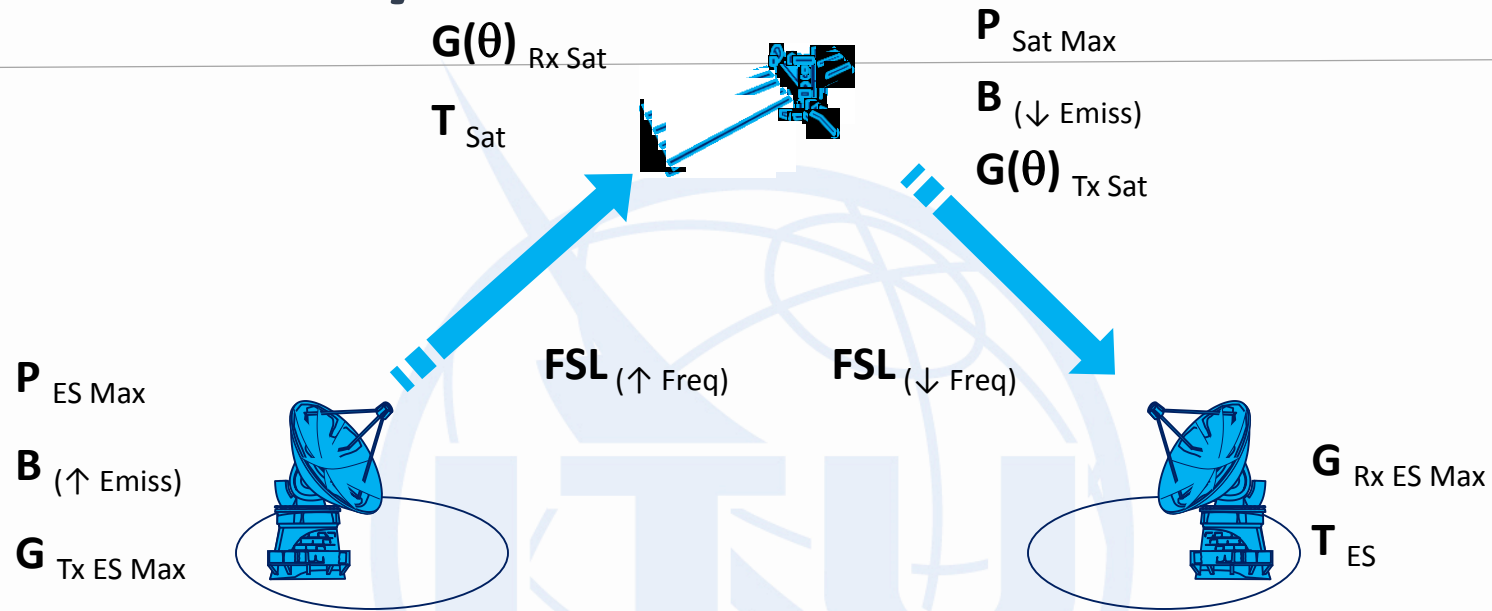


$$\text{Margin} = \text{C/I} - \text{C/I}_{\text{required}} \quad (\text{dB})$$

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

P_{Max}

Necessary Bandwidth of Emission

B

Maximum Earth Station Antenna Gain

$G_{ES Max}$

Free Space Loss (assigned frequency)

FSL

Off-axis Satellite Antenna Gain

$G(\theta)_{Sat}$

Receiver System Noise Temperature

T

Service Area

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
 E BR3a/BR3b Provision reference C BR2 Adm. serial no. C1UR R

Beam Level

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 B3f Ant. gain vs orbit long. diag.
 B3e B3e2 B3e3 Coef. A B3e4 Coef. B

Group Level

BR7a/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
 C1f C1f1a3 Service area diagram

Sub-Group or Frequency Assignment Level

C2a Assigned frequency

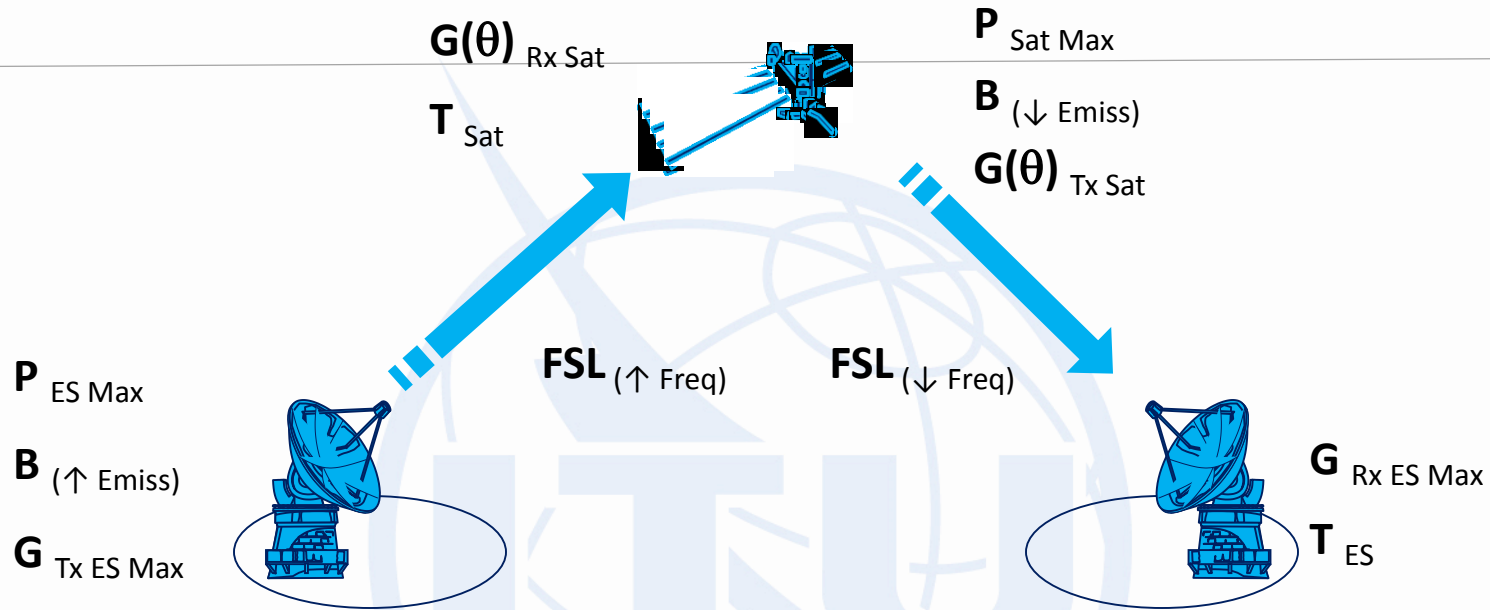
5945	MHz	6065	MHz	6185	MHz	6305	MHz	6445	MHz	6565	MHz	6685	MHz	
5985	MHz	6105	MHz	6225	MHz	6345	MHz	6485	MHz	6605	MHz			
6025	MHz	6145	MHz	6265	MHz	6385	MHz	6525	MHz	6645	MHz			

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



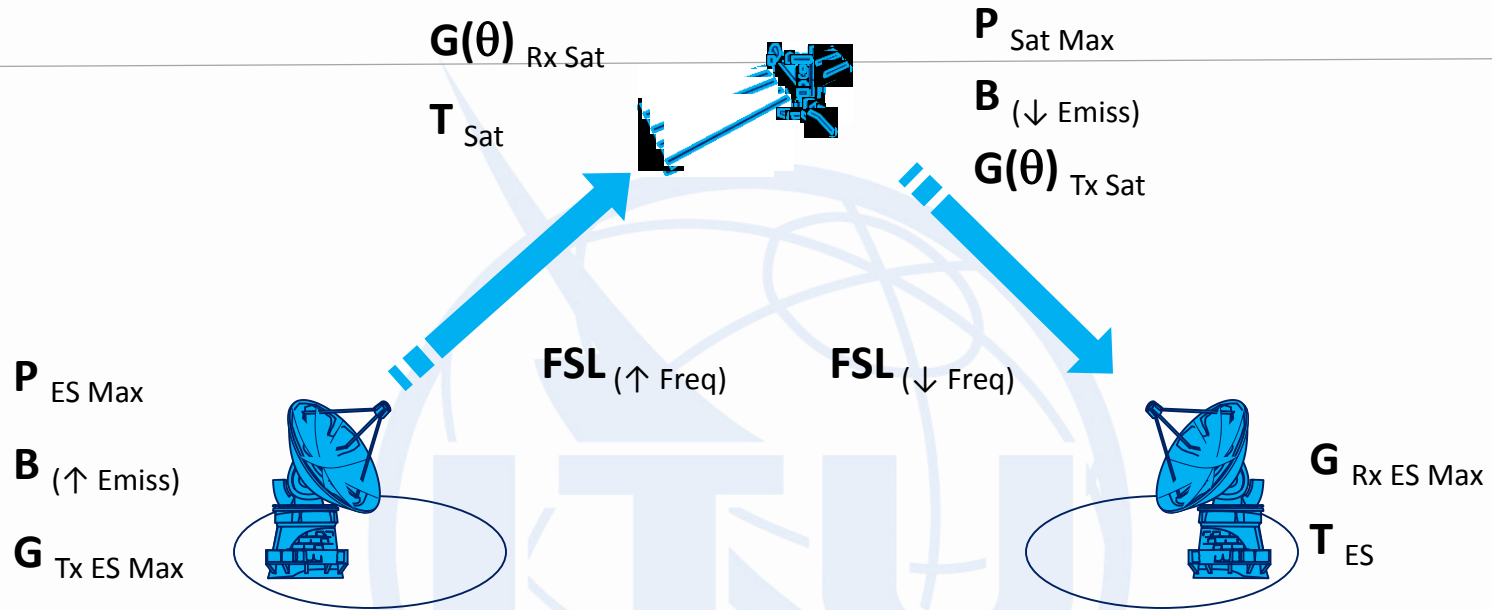
- Maximum Peak Power
- Necessary Bandwidth of Emission
- Maximum Earth Station Antenna Gain
- Free Space Loss (assigned frequency)
- Off-axis Satellite Antenna Gain
- Receiver System Noise Temperature
- Service Area

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

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

Appendix
4

Finding C/I Required Calculate C/N

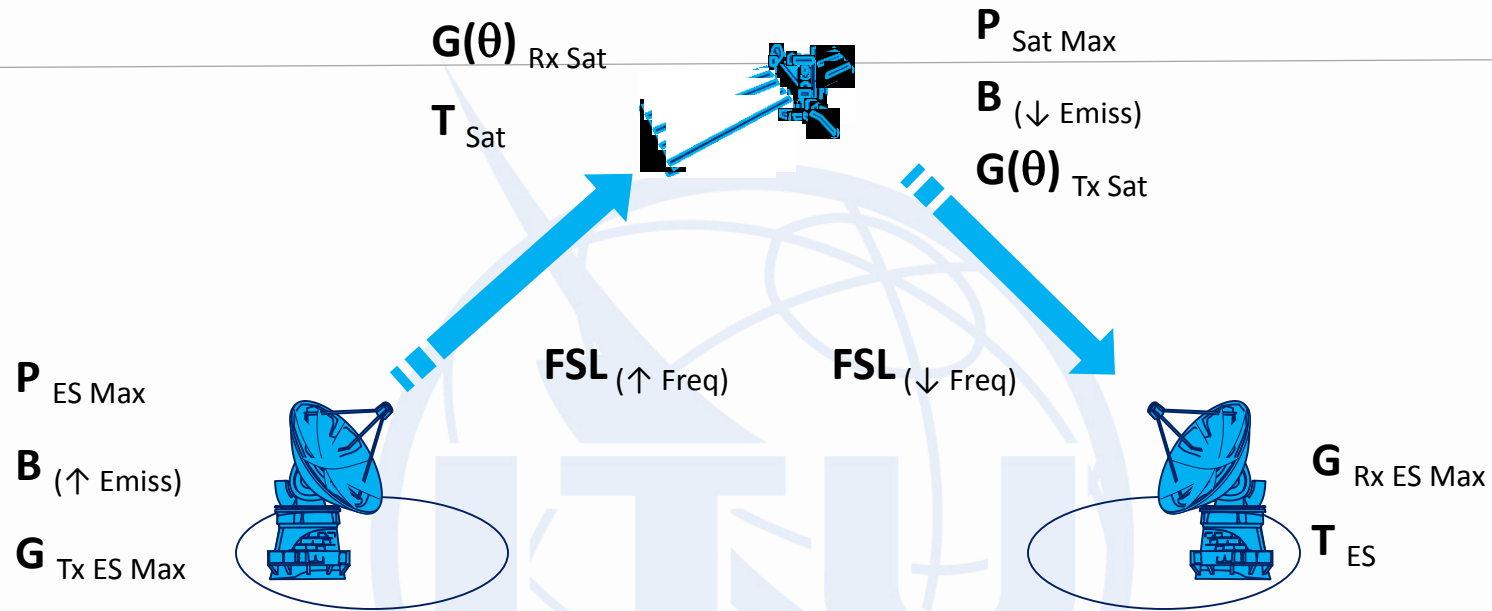


$$C/N = P_{Max} + G_{ES Max} + G(\theta)_{Sat} - FSL_{(Freq)} - (k + T + B_{(Emiss)}) \quad (dB)$$

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

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

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

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



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



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



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

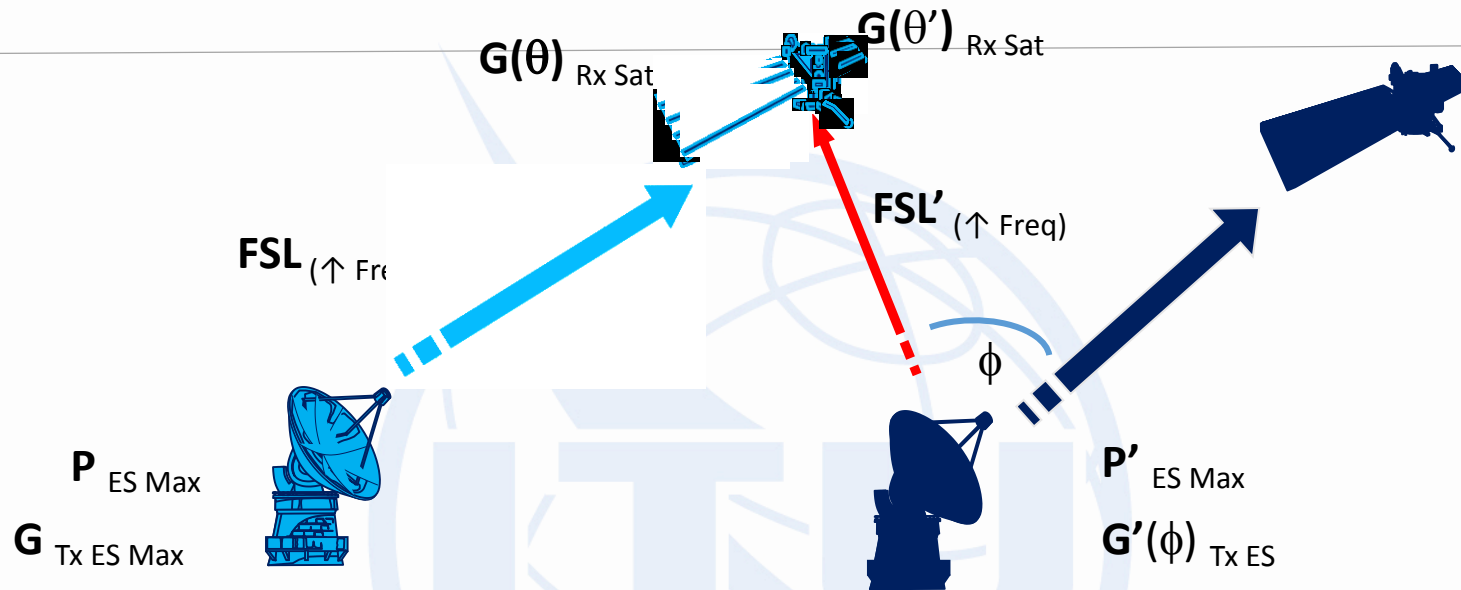
C/I: Carrier to Interference (dB)

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

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 Separat 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

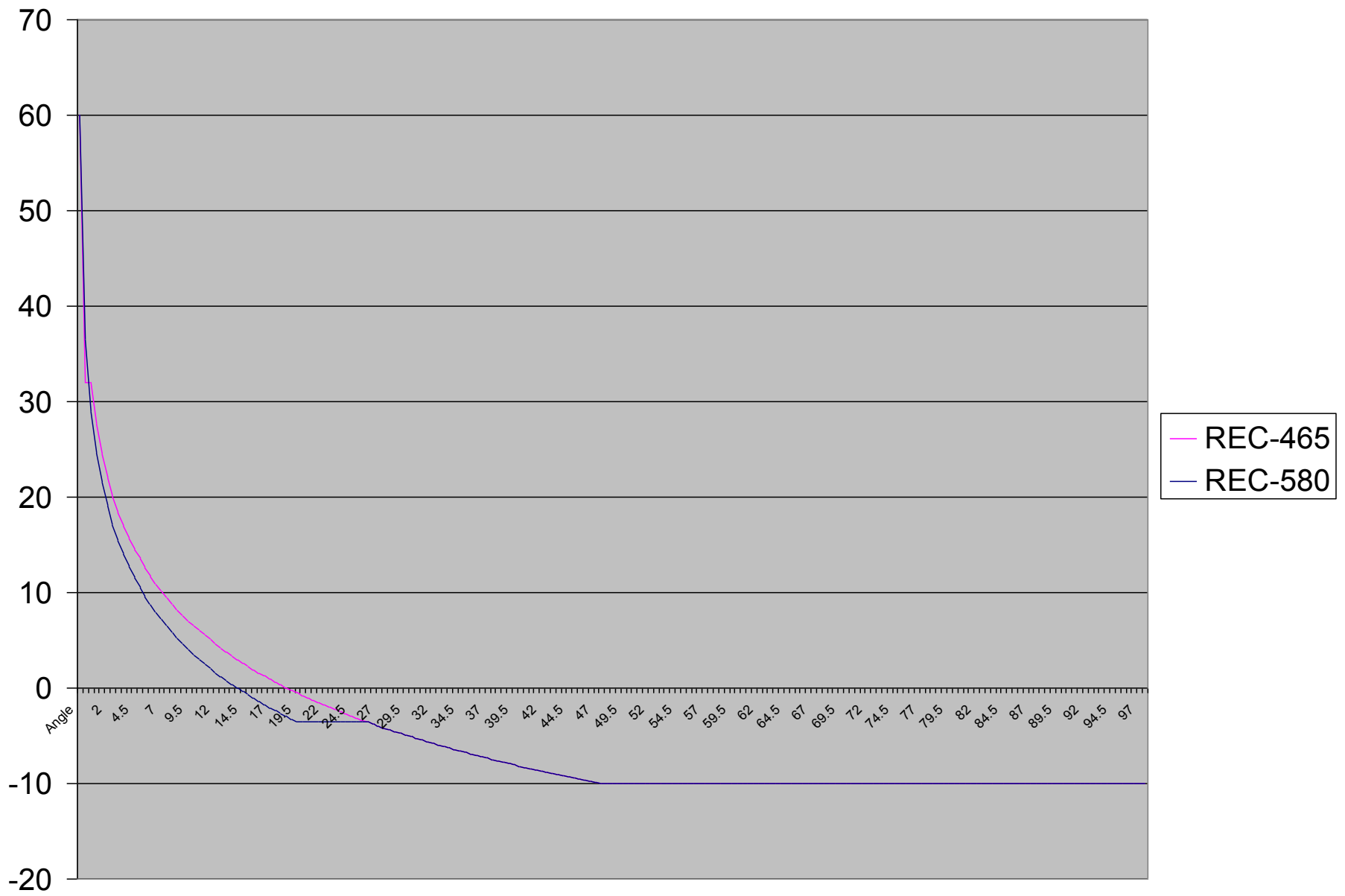
ITU-R S.465-6

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



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

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	

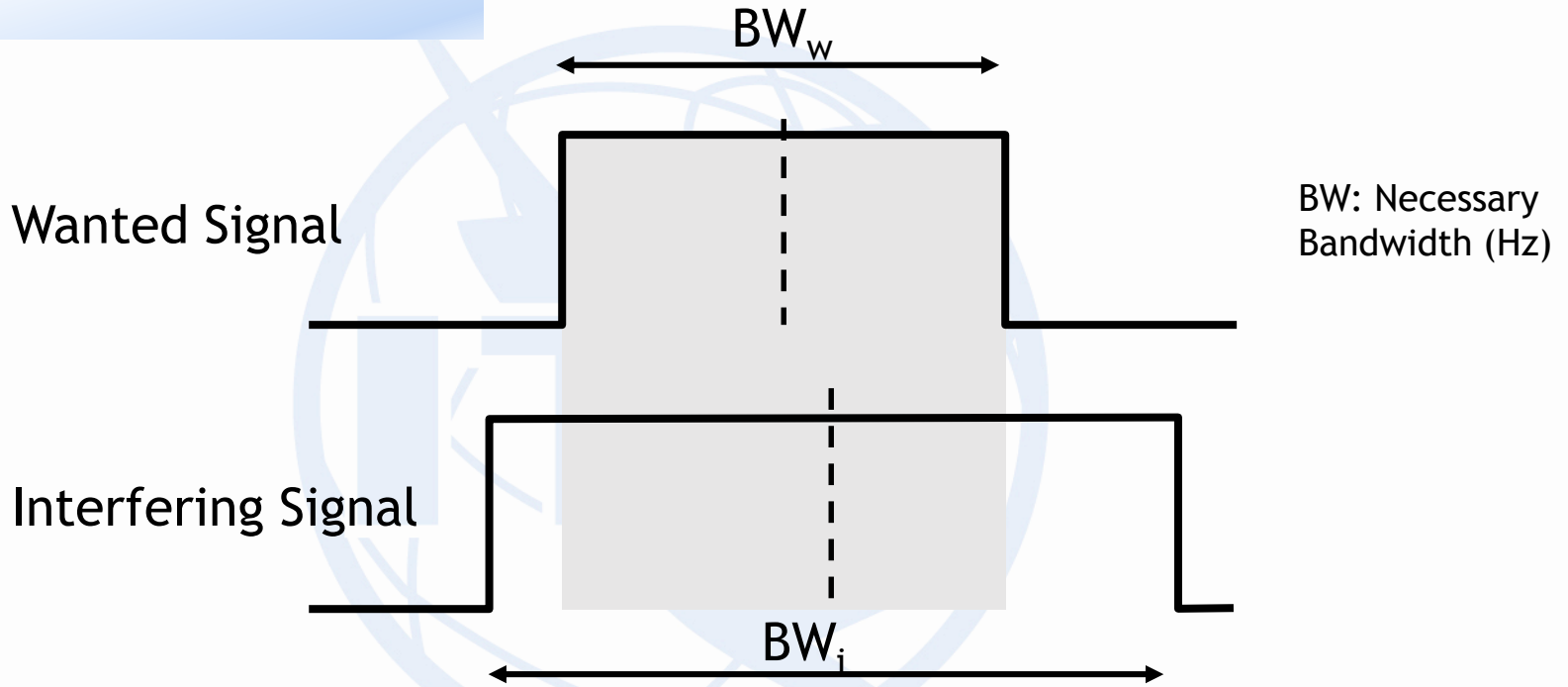
Source: Table 1 in Section B3 of Rules of Procedures, ITU-R S.741-2

Finding C/I

Get Adjustment Factor



Method 1:



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

$$= 10 \log_{10} (BW_w / BW_i)$$

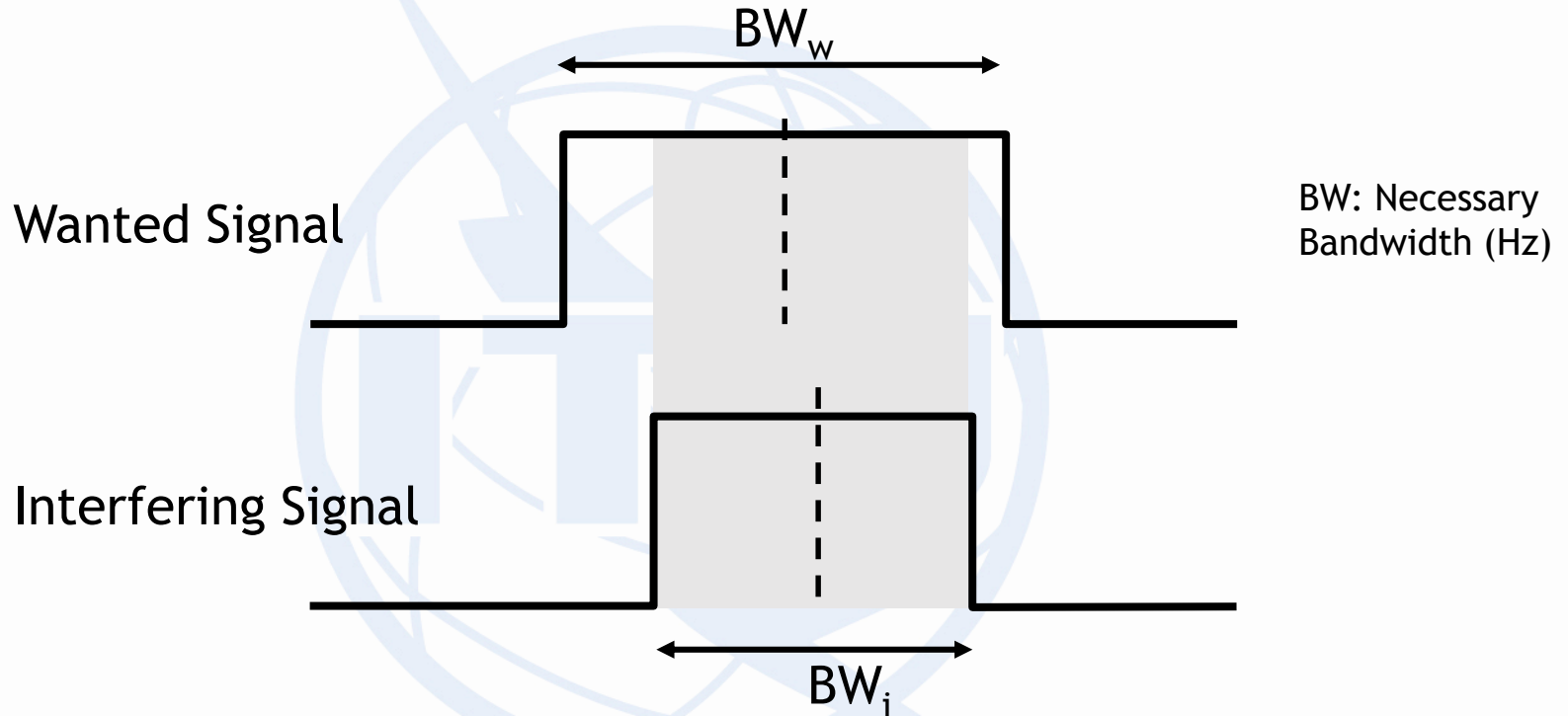
< 0 = Improvement!

Finding C/I

Get Adjustment Factor



Method 1:



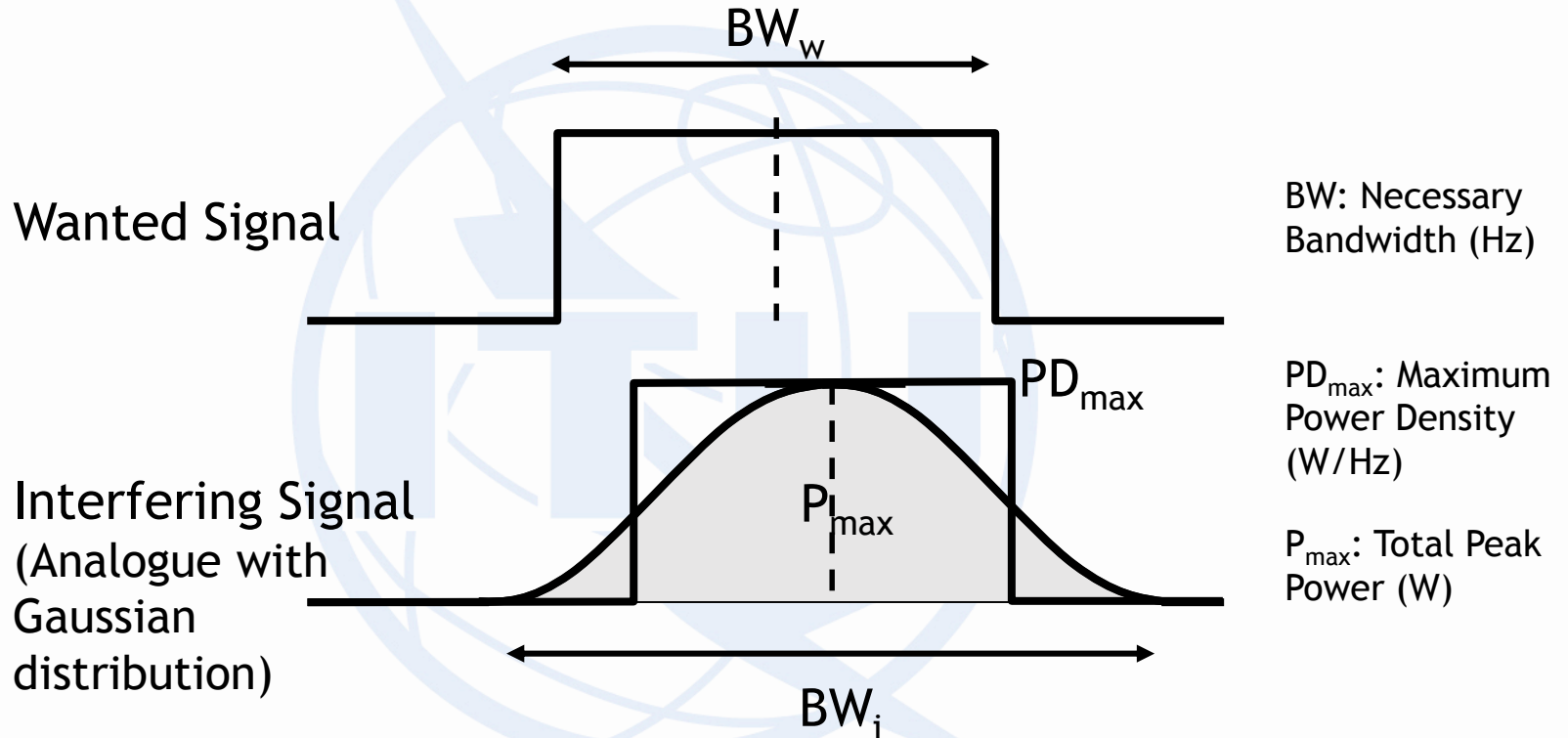
$$\begin{aligned} I_a &= 10\log_{10} (BW_{\text{overlap}} / BW_i) \\ &= 10\log_{10} (BW_i / BW_i) \\ &= 0 = \text{No Improvement!} \end{aligned}$$

Finding C/I

Get Adjustment Factor



Method 2:



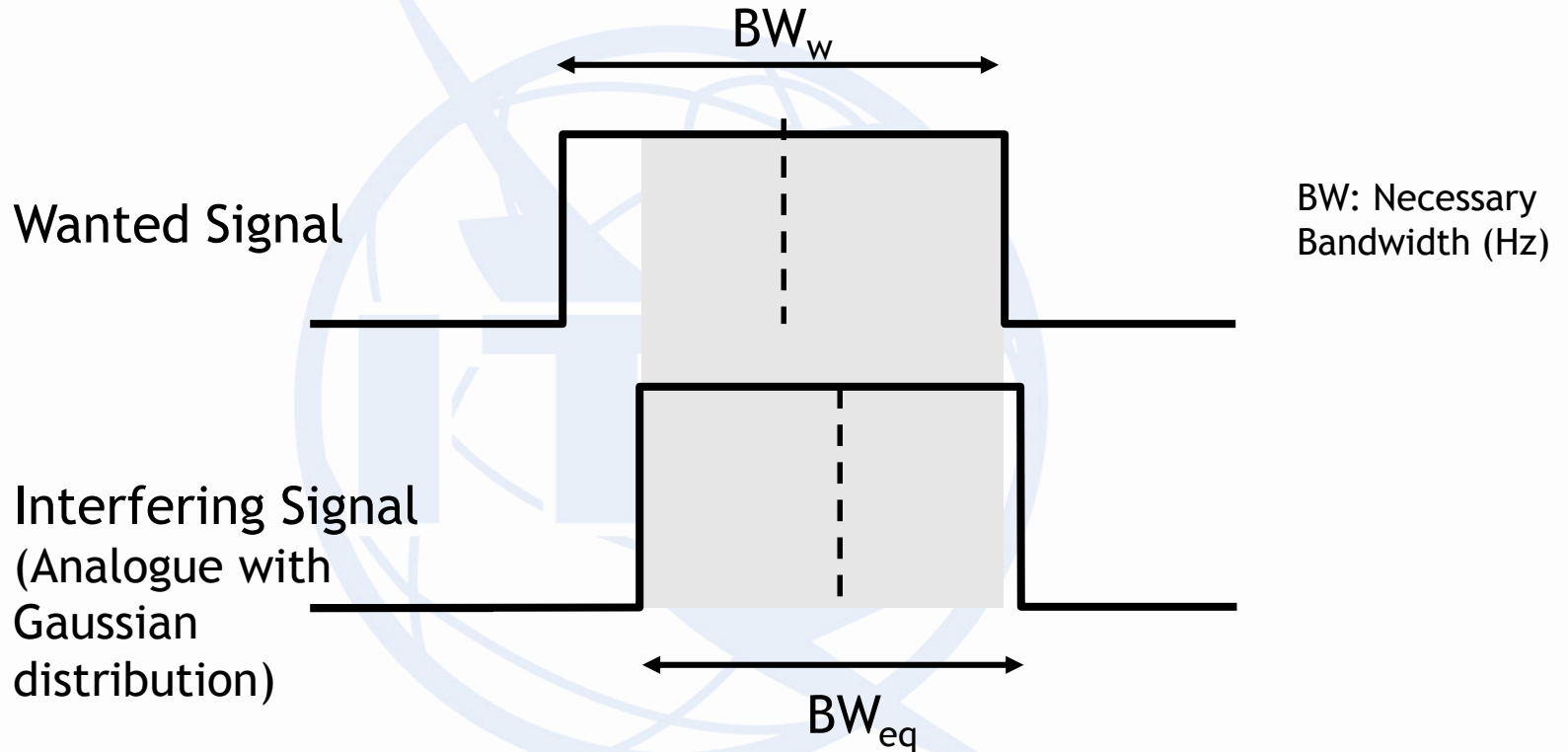
$$BW_{eq} = P_{max} / PD_{max}$$

Finding C/I

Get Adjustment Factor



Method 2:



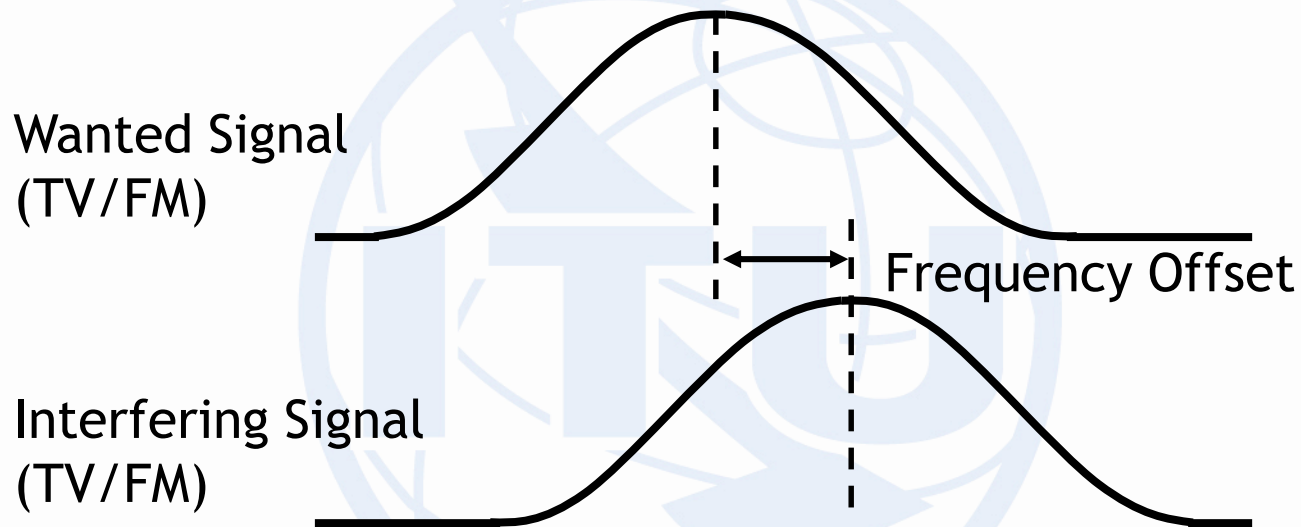
$$I_a = 10\log_{10} (BW_{\text{overlap}} / BW_{\text{eq}})$$

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

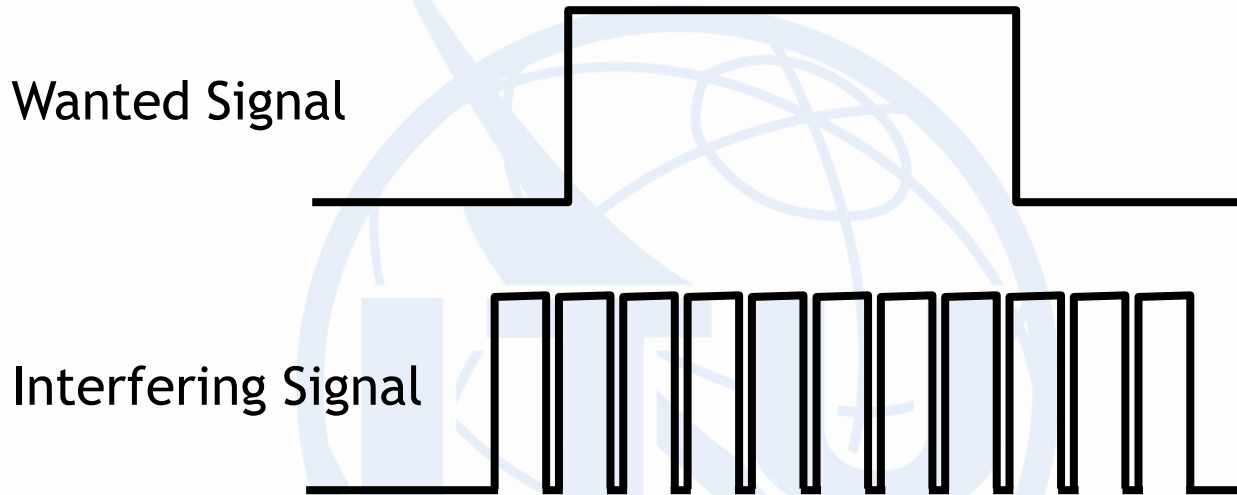
Finding C/I



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

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



- 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)

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