



Carrier to Interference (C/I ratio) GSO vs GSO Calculation Basics

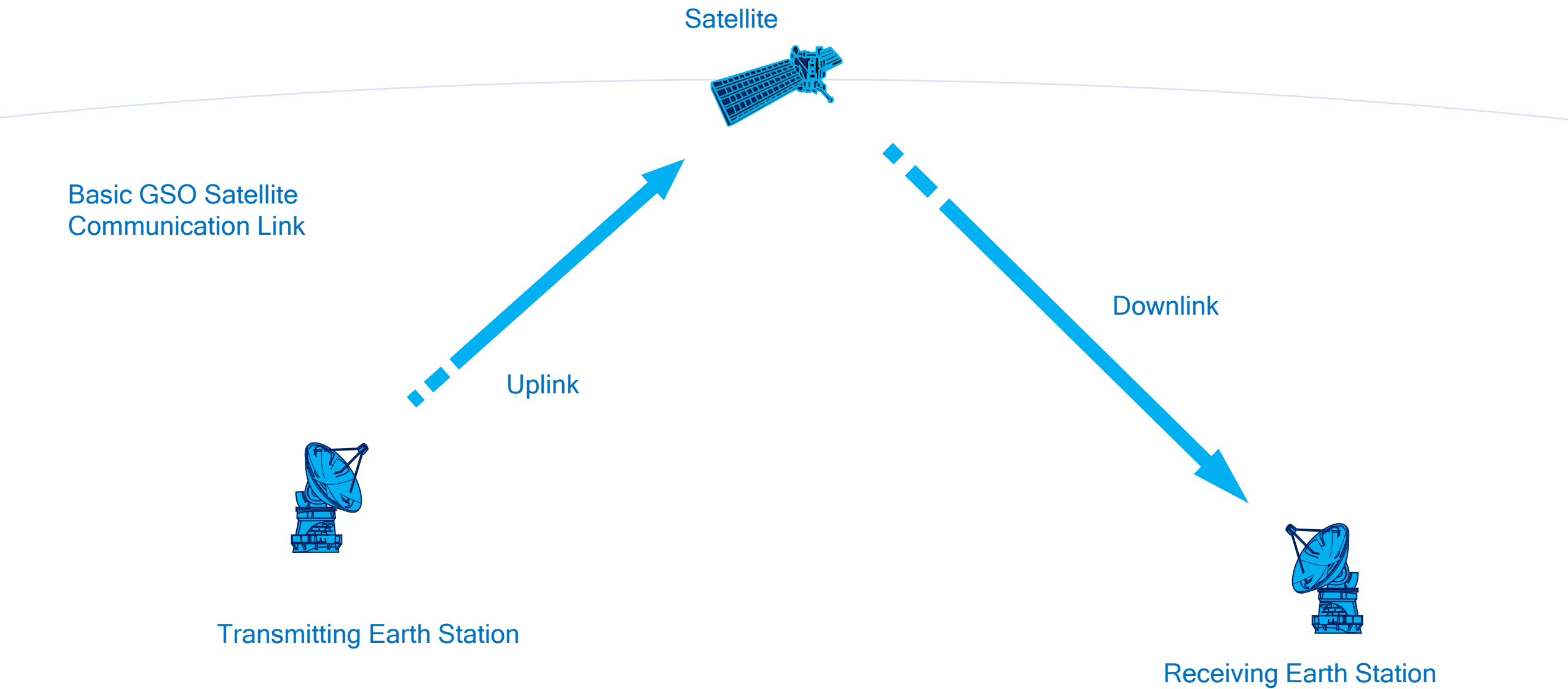
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Space Services Department, Radiocommunication Bureau



#ITUWRS
www.itu.int/go/wrs-20



Link Budget

- Power level
- Gain
- Losses



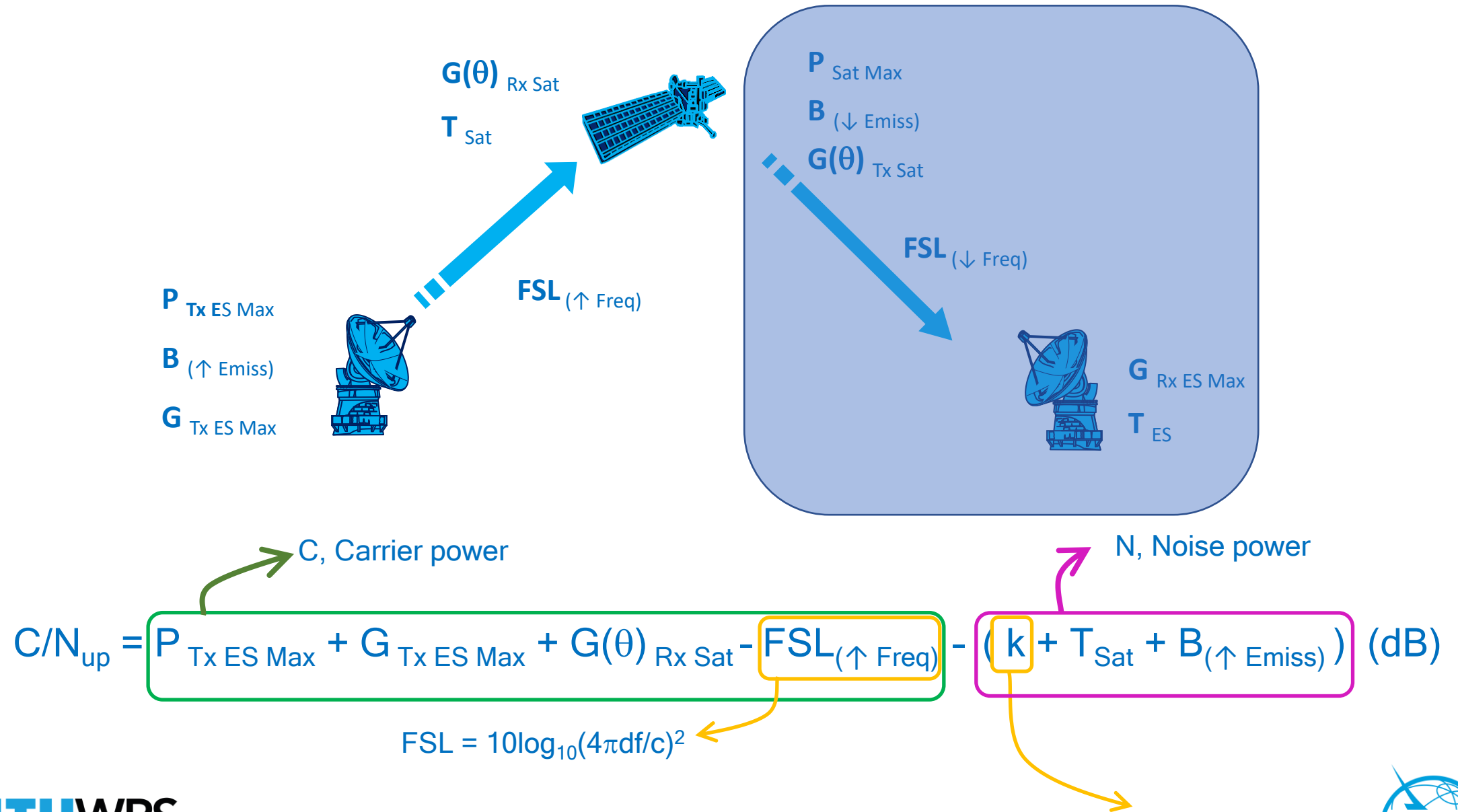
C/N

C/N

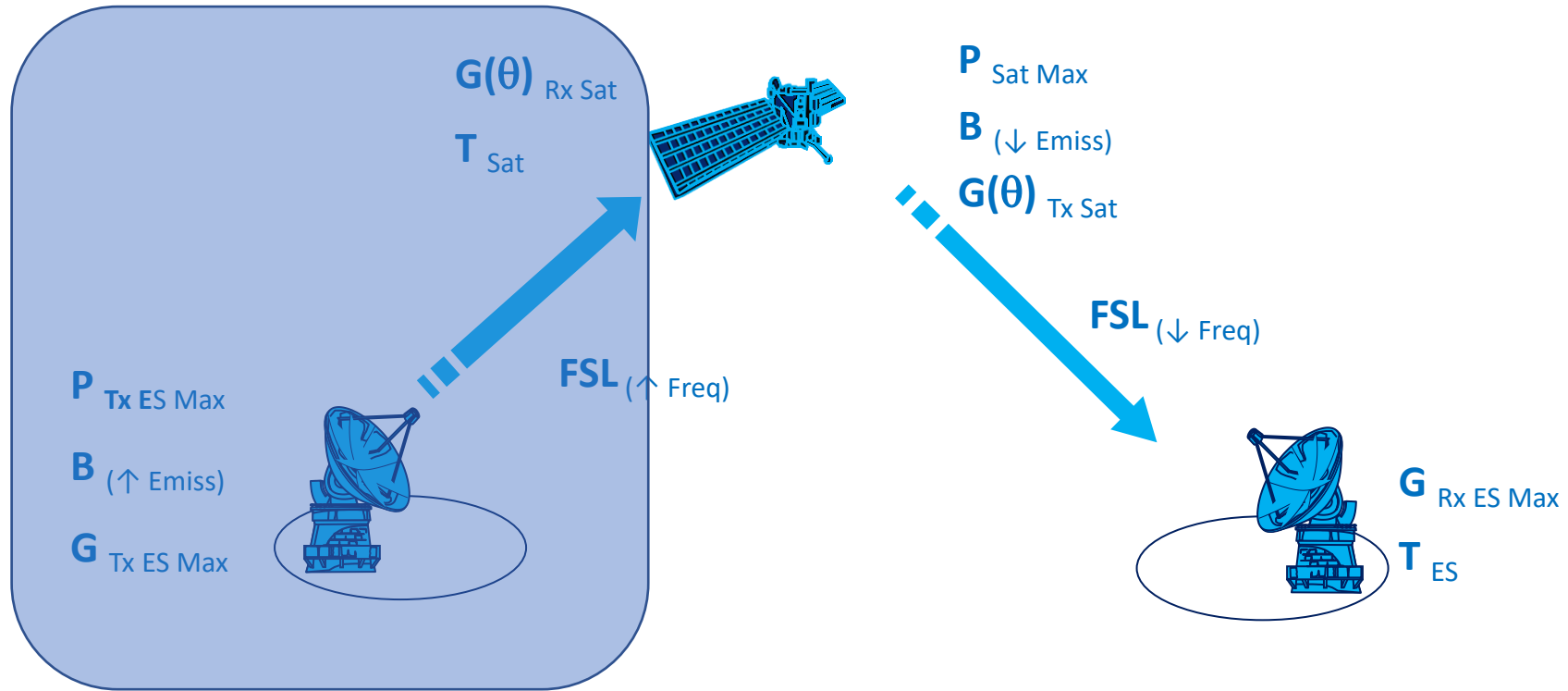
where

- C is the carrier power taking into account gains and losses
- N is the noise power derived by kTB
 - k, Boltzmann constant = -228.6 dBW/K/Hz

Calculate C/N



Calculate C/N



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

↗ C, Carrier power
 ↖ N, Noise power

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

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:

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

where:

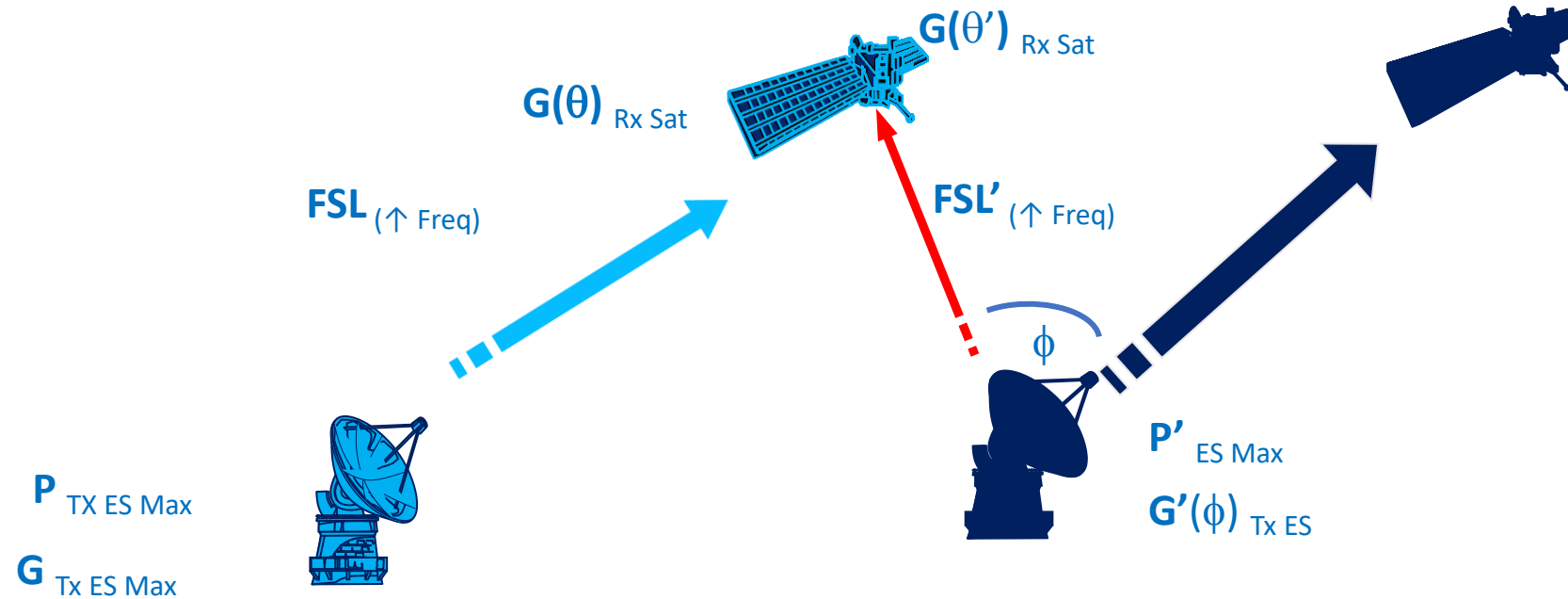
$$\cos \psi = \cos \zeta \times \cos \beta$$

where :

ζ = latitude of earth station

β = difference in longitude btw satellite and earth station

Calculate C/I Up



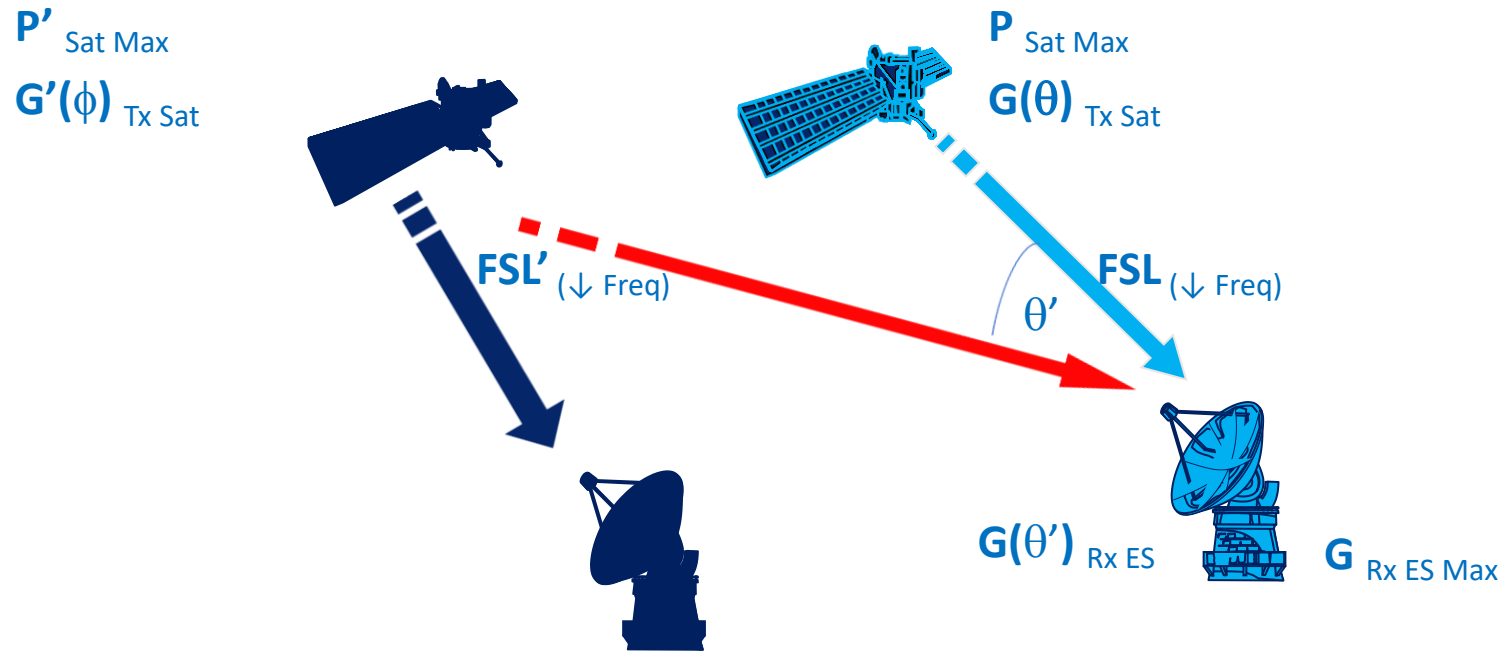
$$C \uparrow = P_{Tx\ ES\ Max} + G_{Tx\ ES\ Max} + G(\theta)_{Rx\ Sat} - FSL_{(\uparrow\ Freq)} \text{ (dBW)}$$

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

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



Calculate C/I Down



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

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

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



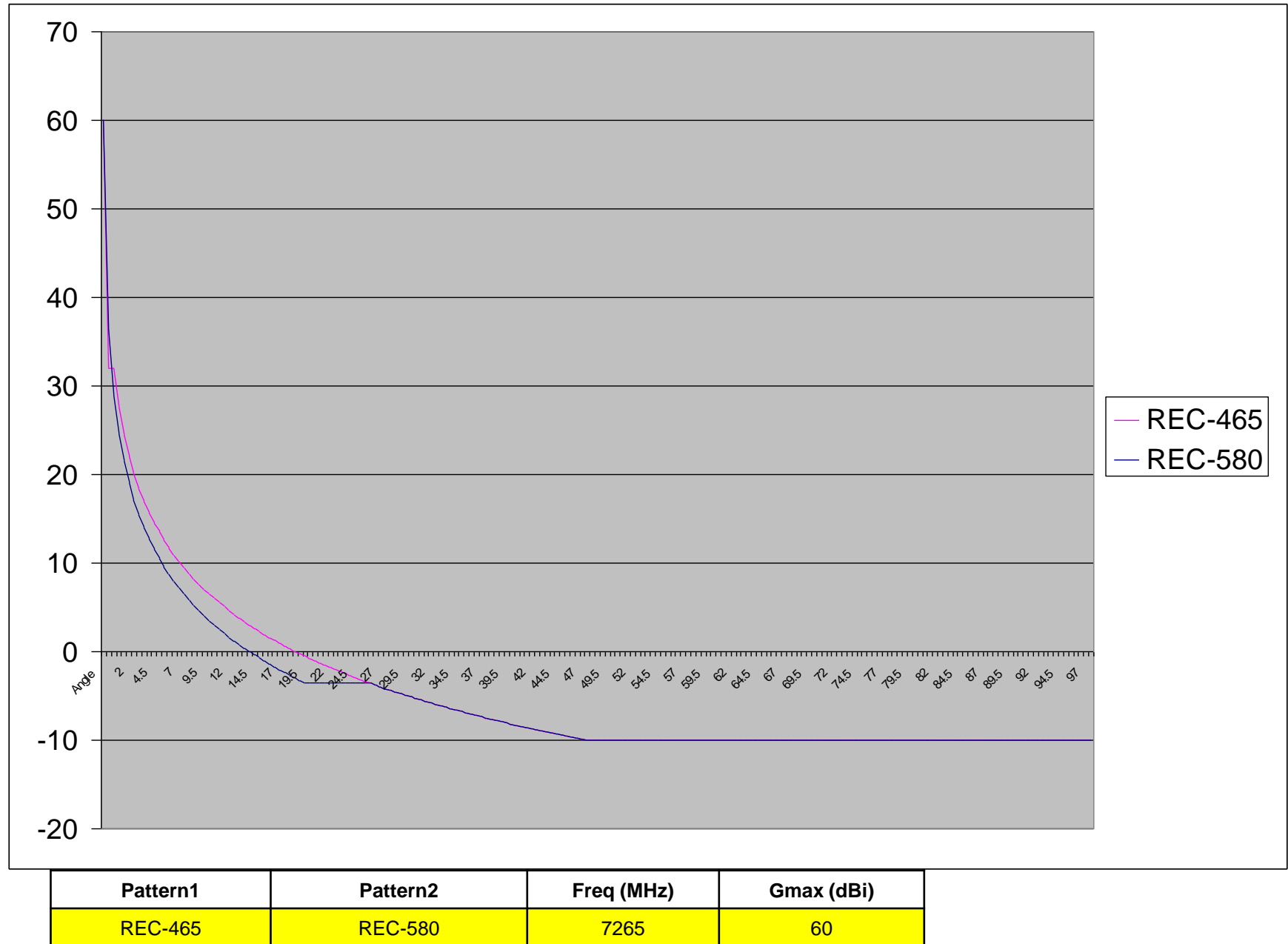
Topocentric Angular Separation Between Two Satellites (Annex I of AP8)

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

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

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

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

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

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)	C/N + 12.2 (dB)	
	else if $BW_w > BW_{eqi}$ then 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)	

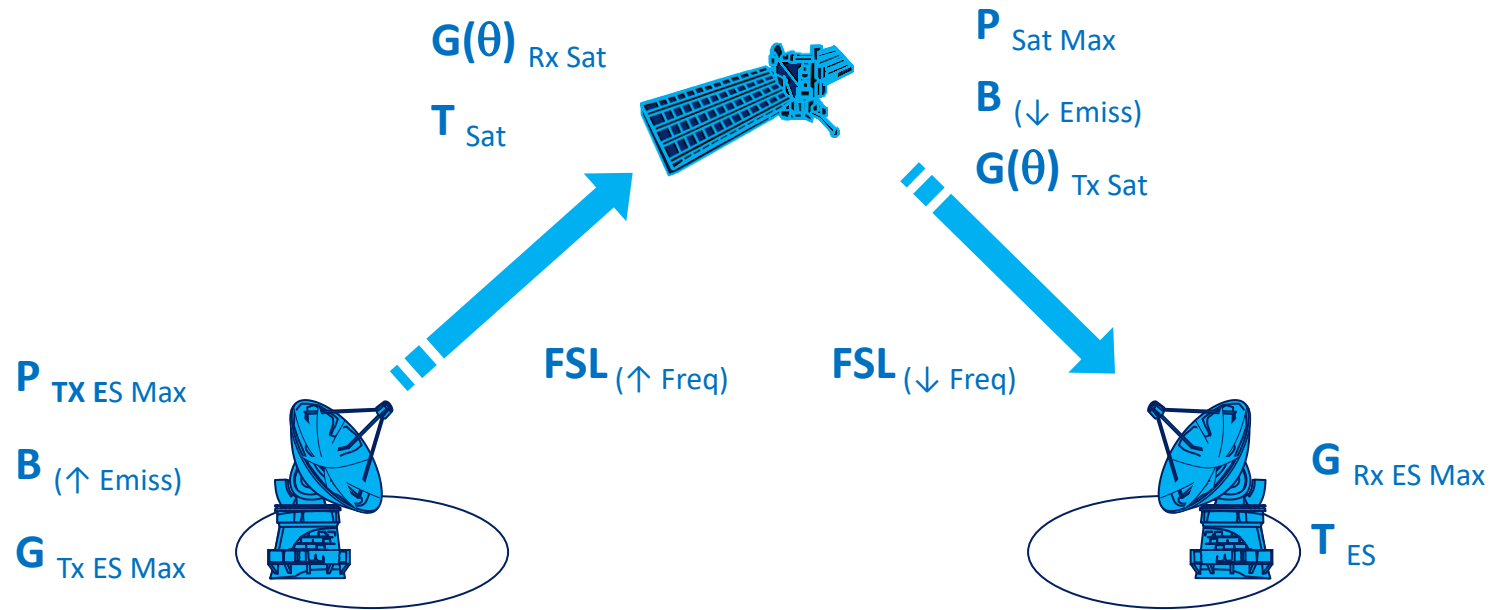
Source: Table 2 in Section B3 of Rules of Procedures, ITU-R S.741-2

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



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

Where to get these information?

SECTION SPECIALE / SPECIAL SECTION / SECCION ESPECIAL										CR/C/45																																																																							
A1a Sat. Network		MEASAT-91.5R		A1f1 Notifying adm.		MLA		A1f2 Inter. sat. org.		BR1 Date of receipt		11.02.1999		BR20/BR21 IFIC no./part		2464/																																																																	
BR6/BR6b Id. no.		99520006		BR3a/BR3b Provision reference		RR1060		C		BR2 Adm. serial no.				C1UR		R																																																																	
<div>Beam Level</div> <div>Group Level</div> <div>Sub-Group or Frequency Assignment Level</div>																																																																																	
A4a1				A4a2 Long. tolerance		0.1°		A4a3 Inclination excursion		0.1°																																																																							
A4a3 Visibility arc		11 E - 171 E		A4a4 Service arc		11 E - 171 E		A4a5 Reason for arc diff.																																																																									
B1a/B1b Beam designation		C1UR		B2 Emi-Rop		R		B3a1/B3b1/B3b2a Max. ant. gain		30		B3d Pointing accuracy		0.05																																																																			
B3a2/B3b2 Ant. gain cont. diag.				B3f Ant. gain vs orbit long. diag.		2																																																																											
B3e1				B3e2 Ref. pat.				B3e3 Coef. A				B3e4 Coef. B																																																																					
BR7a/BR7b Group id.		99880283		BR14 Special Section		CR/C/45																																																																											
C4a Class of station		BC		C3a Assigned freq. band		36000		C5a Noise temperature		500																																																																							
C4b Nature of service		CP		C6a Polarization type		L		C6b Polarization angle		90		C8d/C8g Max. pwr																																																																					
C11a1 Service area no.		1		C11a2 Service area				C11a3 Service area diagram		1																																																																							
A5/A6				A5/A6				A5/A6				A5/A6				A5/A6																																																																	
A2a Date of bringing into use		10.08.2003		A2b Period of valid.		50		A3a Op. agency		15		A3b Adm. resp.		A		BR16 Value of type C8b		BR17 Reason for C8c/C8e absent																																																															
<table border="1"> <thead> <tr> <th colspan="10">C2a Assigned frequency</th> </tr> </thead> <tbody> <tr> <td>5945</td><td>MHz</td><td>6065</td><td>MHz</td><td>6185</td><td>MHz</td><td>6305</td><td>MHz</td><td>6445</td><td>MHz</td><td>6565</td><td>MHz</td><td>6685</td><td>MHz</td><td></td><td></td><td></td><td></td> </tr> <tr> <td>5985</td><td>MHz</td><td>6105</td><td>MHz</td><td>6225</td><td>MHz</td><td>6345</td><td>MHz</td><td>6485</td><td>MHz</td><td>6605</td><td>MHz</td><td></td><td></td><td></td><td></td><td></td><td></td> </tr> <tr> <td>6025</td><td>MHz</td><td>6145</td><td>MHz</td><td>6265</td><td>MHz</td><td>6385</td><td>MHz</td><td>6525</td><td>MHz</td><td>6645</td><td>MHz</td><td></td><td></td><td></td><td></td><td></td><td></td> </tr> </tbody> </table>																		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						
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A13 Ref. to Special Sections		1 AR11/A 393		C7a Design. of emission		1 38K4G7E--		C8a1/C8b1 Max. peak pwr		9.1		C8a2/C8b2 Max. pwr dens.		-35.6		C8c1 Min. peak pwr		5.1		C8c2 Min. pwr dens.		-39.6		C8e C/N ratio		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(P1)																																																																			
Findings		2D Date		11.02.1999		13A Conformity with RR		A-----		13B1 Provision				13B2 Remarks				13B3 Date of Review																																																															
13C Remarks																																																																																	

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

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

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

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

C/I: Carrier to Interference (dB)

$$C/I = C/I_b - I_a$$

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

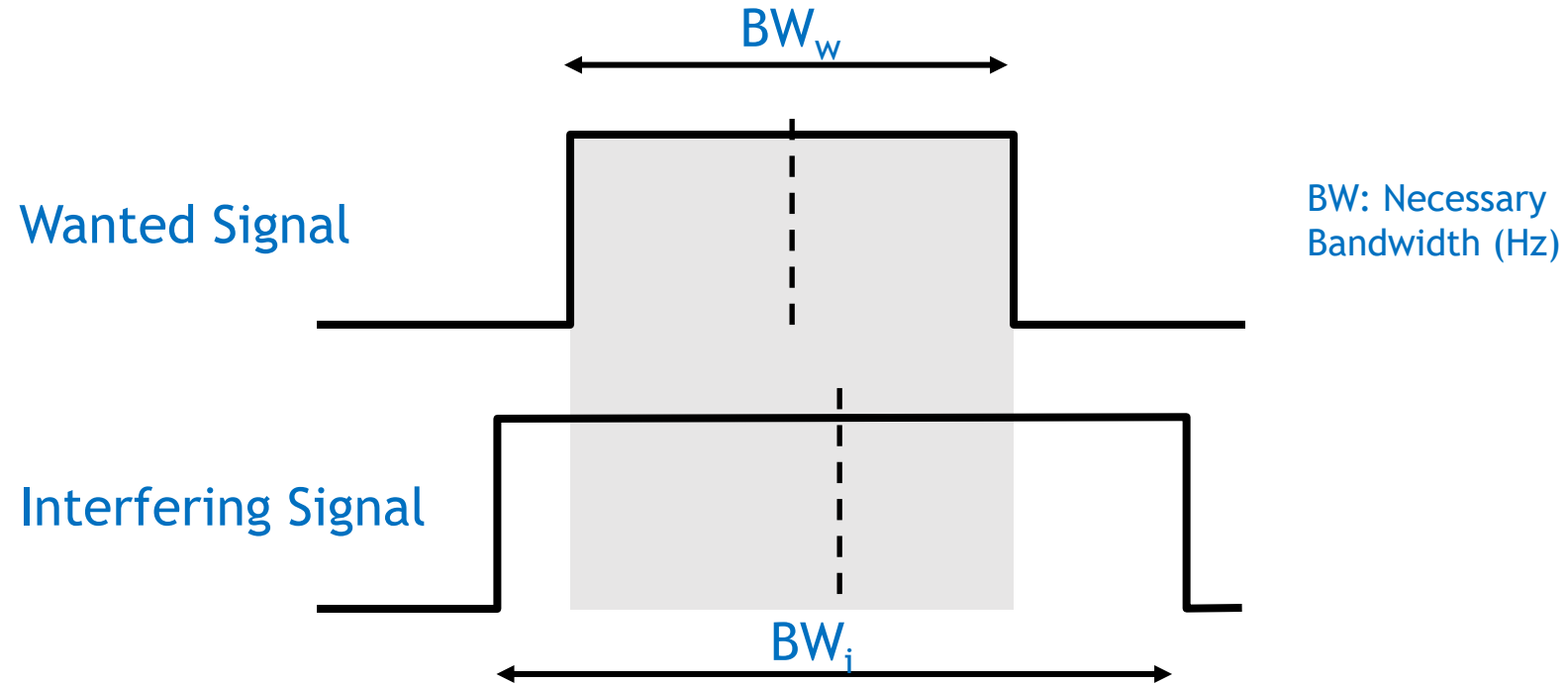
Wanted Interfering	Digital	Analogue (Other than TV/FM)	Other	TV/FM
Digital	METHOD 1: Wanted Bandwidth (BW) to Interfering BW Overlapping Ratio Adjustment			
TV/FM	METHOD 2: Wanted BW to Interfering Equivalent BW Overlapping Ratio Adjustment			METHOD 1: Co-freq.
Analogue (Other than TV/FM)				METHOD 3: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



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

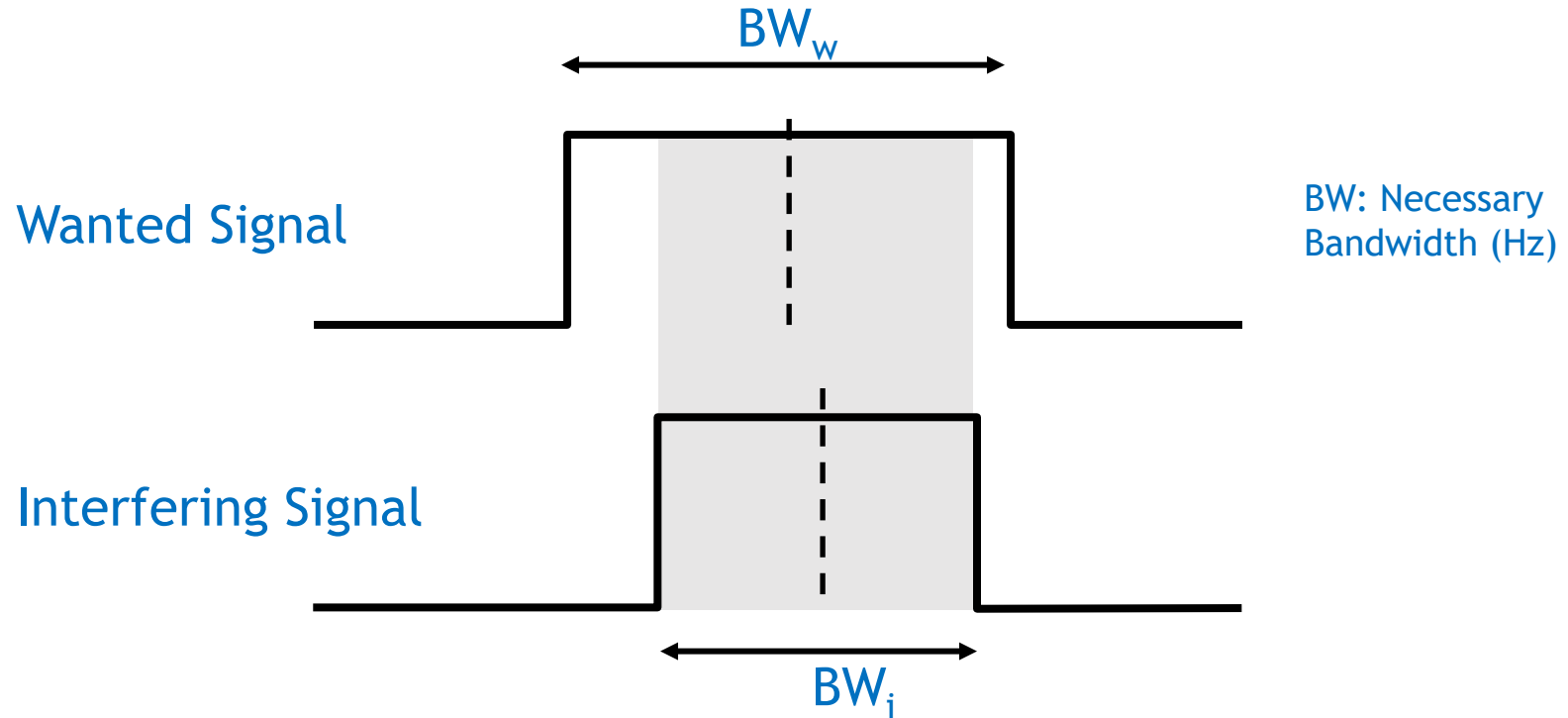
$$= 10\log_{10} (BW_w / BW_i)$$

< 0 = Improvement!

Finding C/I

Get Adjustment Factor

Method 1:



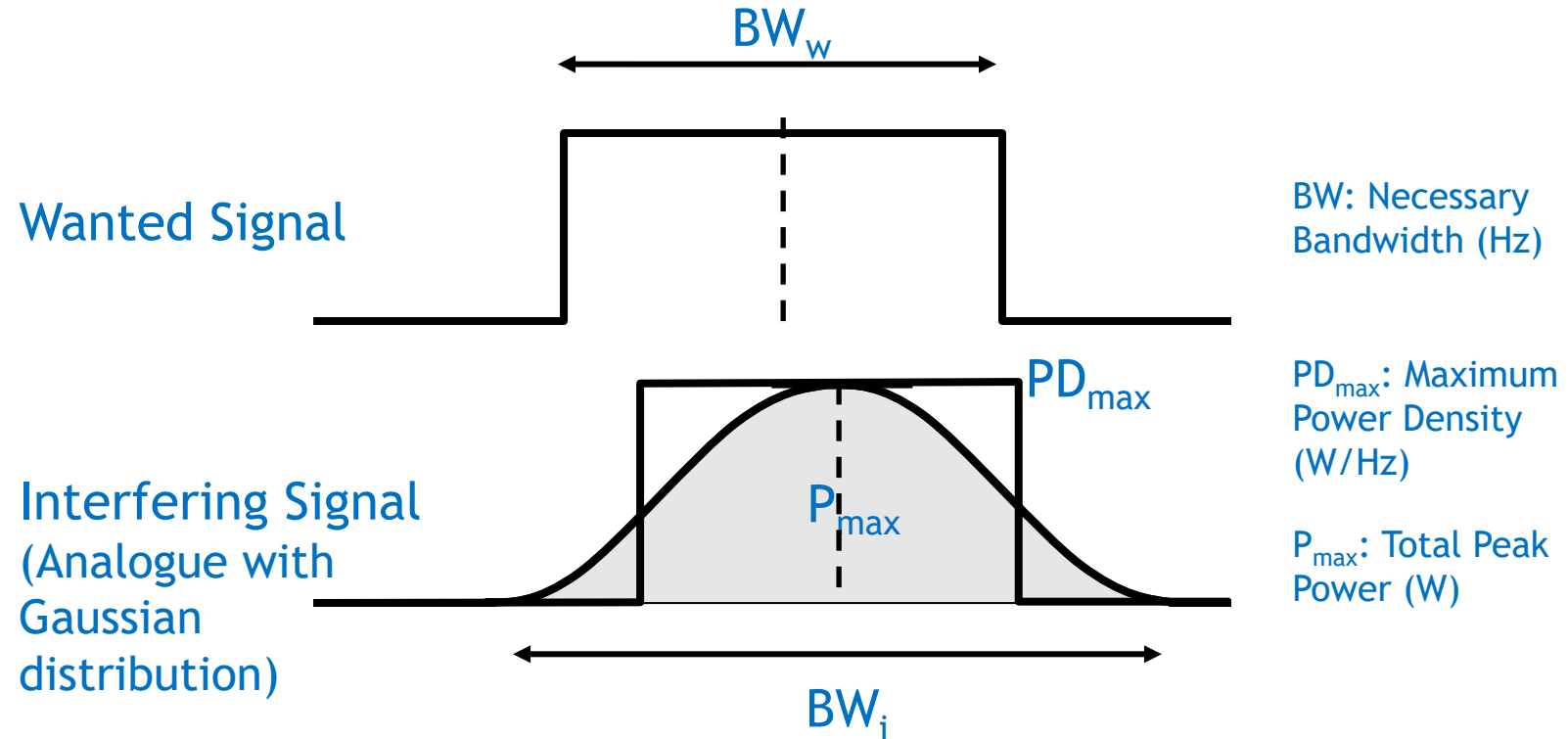
$$I_a = 10\log_{10} (BW_{\text{overlap}} / BW_i)$$

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

$$= 0 = \text{No Improvement!}$$

Get Adjustment Factor

Method 2:

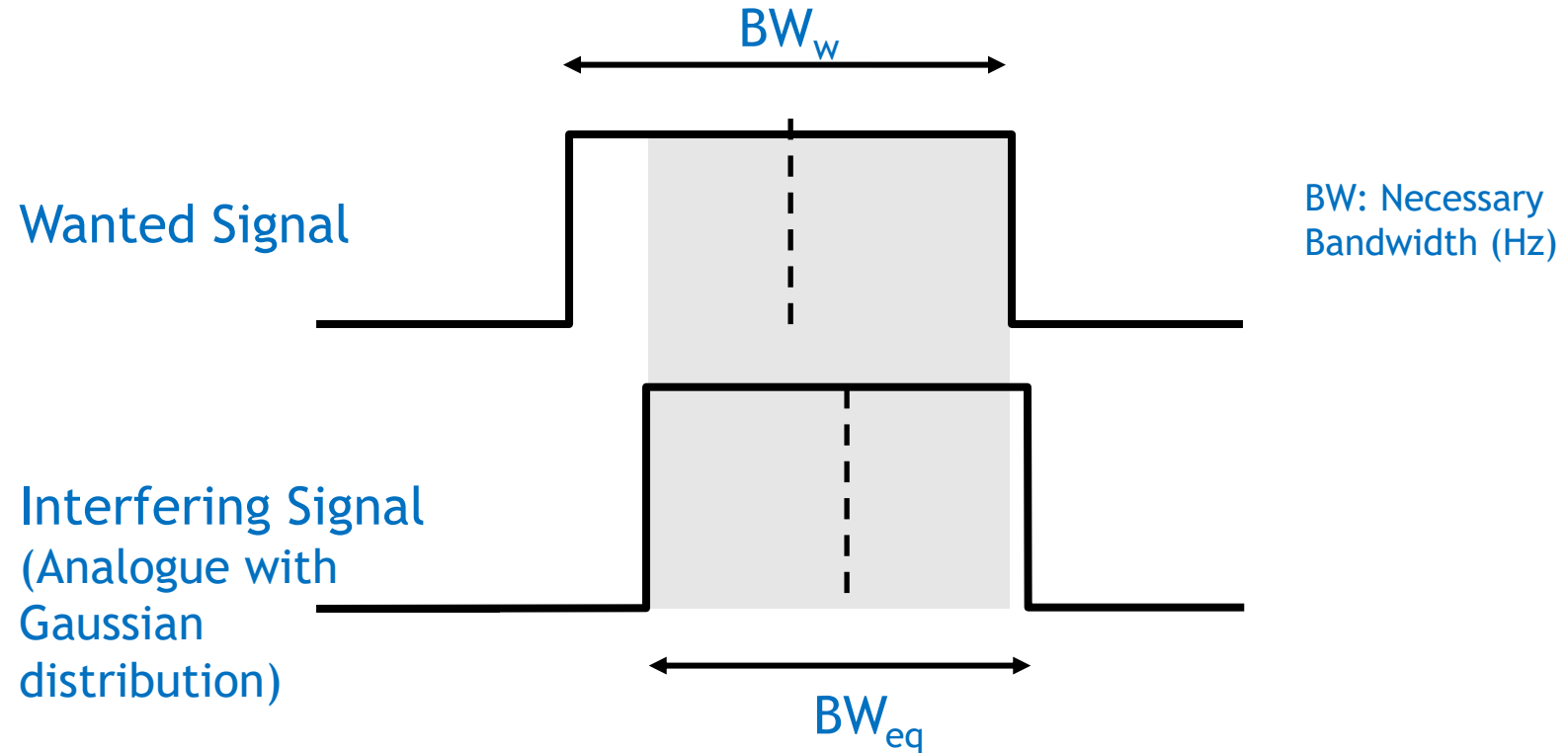


$$BW_{eq} = P_{max} / PD_{max}$$

Finding C/I

Get Adjustment Factor

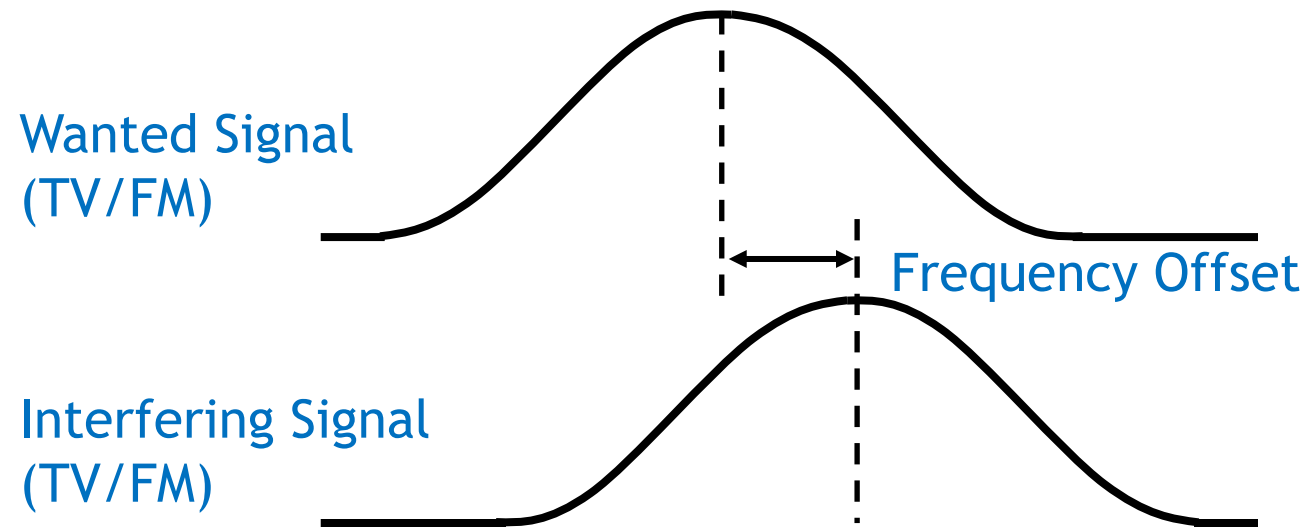
Method 2:



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

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

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

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
- $C/I = C/I_b - I_a$

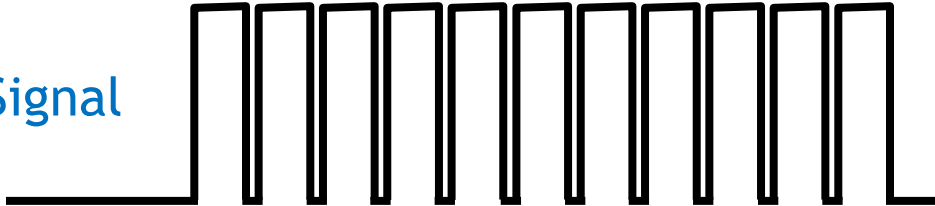
Finding C/I

Multiple interfering narrowband carriers

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)

Calculating Margin

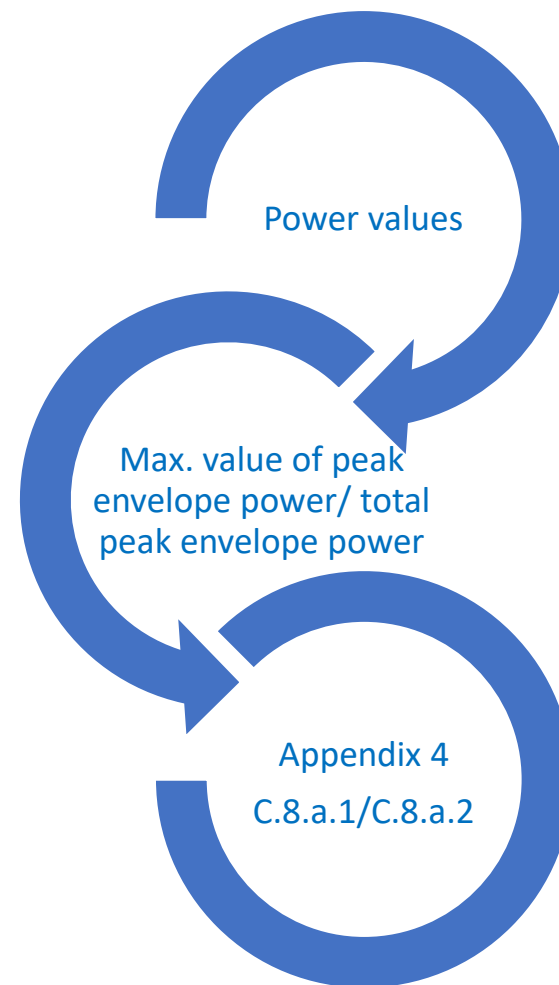
$$\text{Margin} = C/I - C/I_{\text{required}} \quad (\text{dB})$$

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

Section B3, Part B of the Rules of Procedure

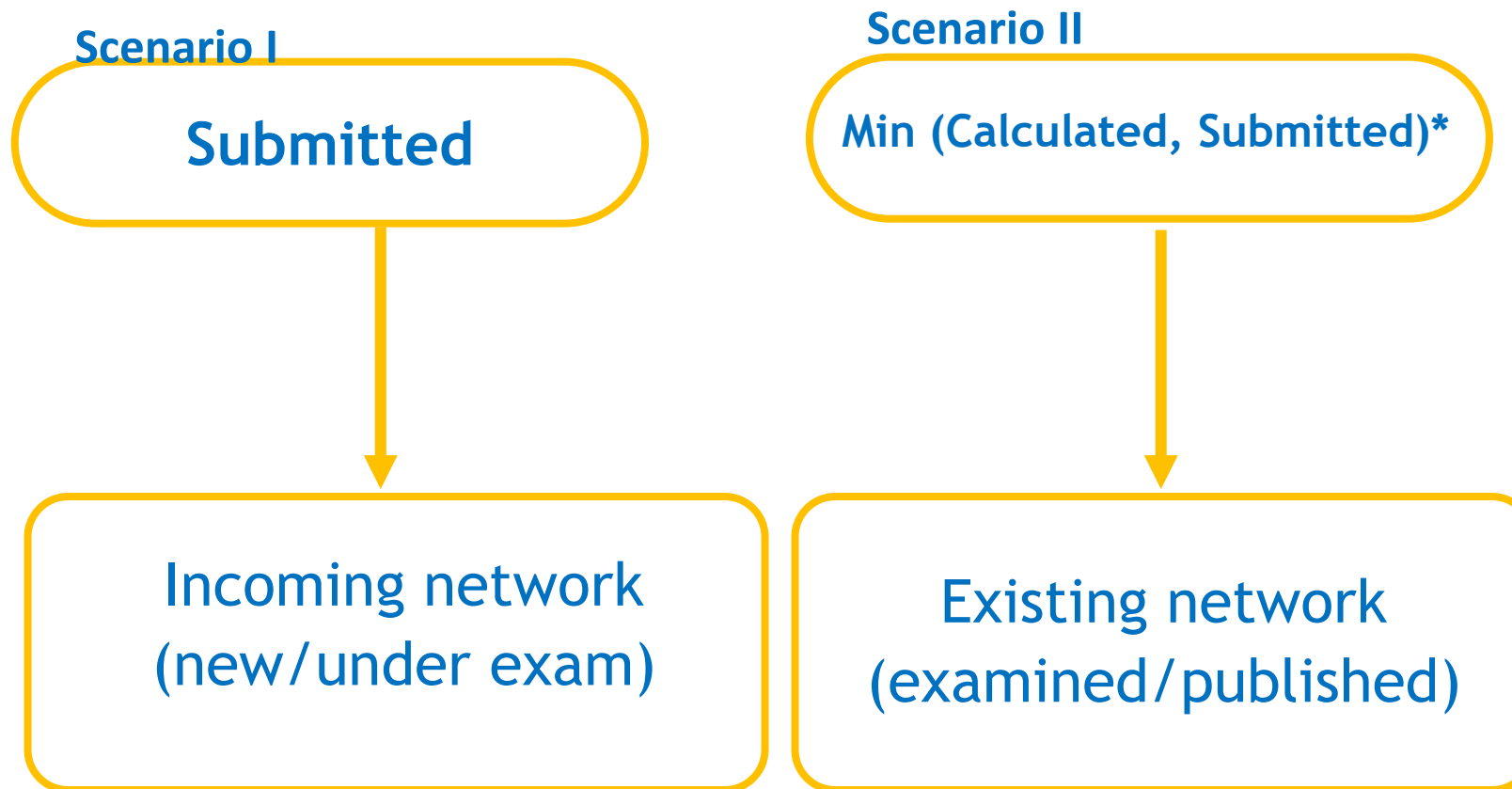
- The ROP defines
 - power values to use
 - how the different type of carriers are categorized according to the class of emission (item C.7 a Annex 2 in Appendix 4)
 - criteria to apply for different combinations of carrier types
 - interference adjustment factor to consider for different combinations 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



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:

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

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

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

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

Thank you!

ITU – Radiocommunication Bureau

Questions to danny.tham@itu.int

