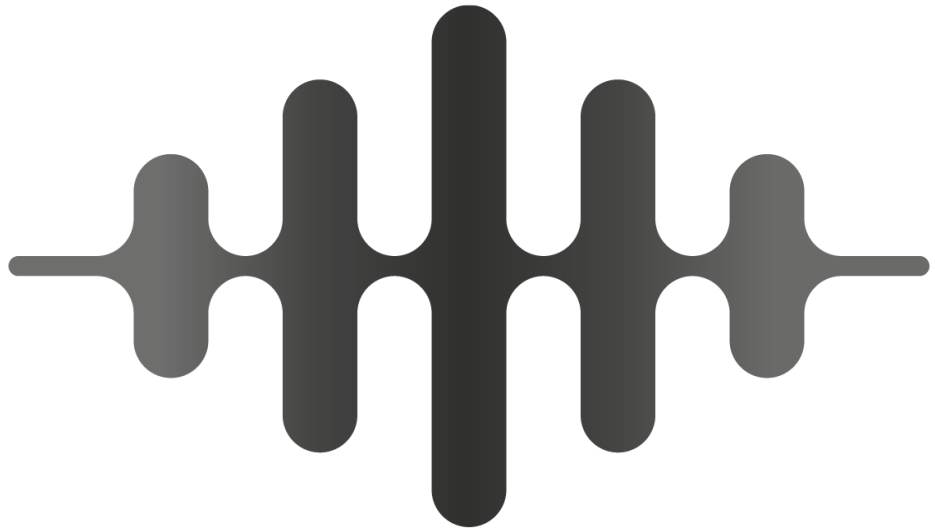


# ITU WRS GENEVA2024

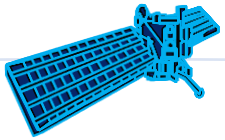
2–6 December 2024
Geneva, Switzerland

# C/I Calculation Basics

**Danny Tham**
Senior Radiocommunication Engineer
Space Services Department
Radiocommunication Bureau, ITU
danny.tham@itu.int

2-6 December 2024, Geneva, Switzerland

Satellite



Basic GSO Satellite
Communication Link

Uplink

Downlink

Transmitting Earth Station

Receiving Earth Station

# Link Budget

- Power level
- Gain
- Losses

**C/N**

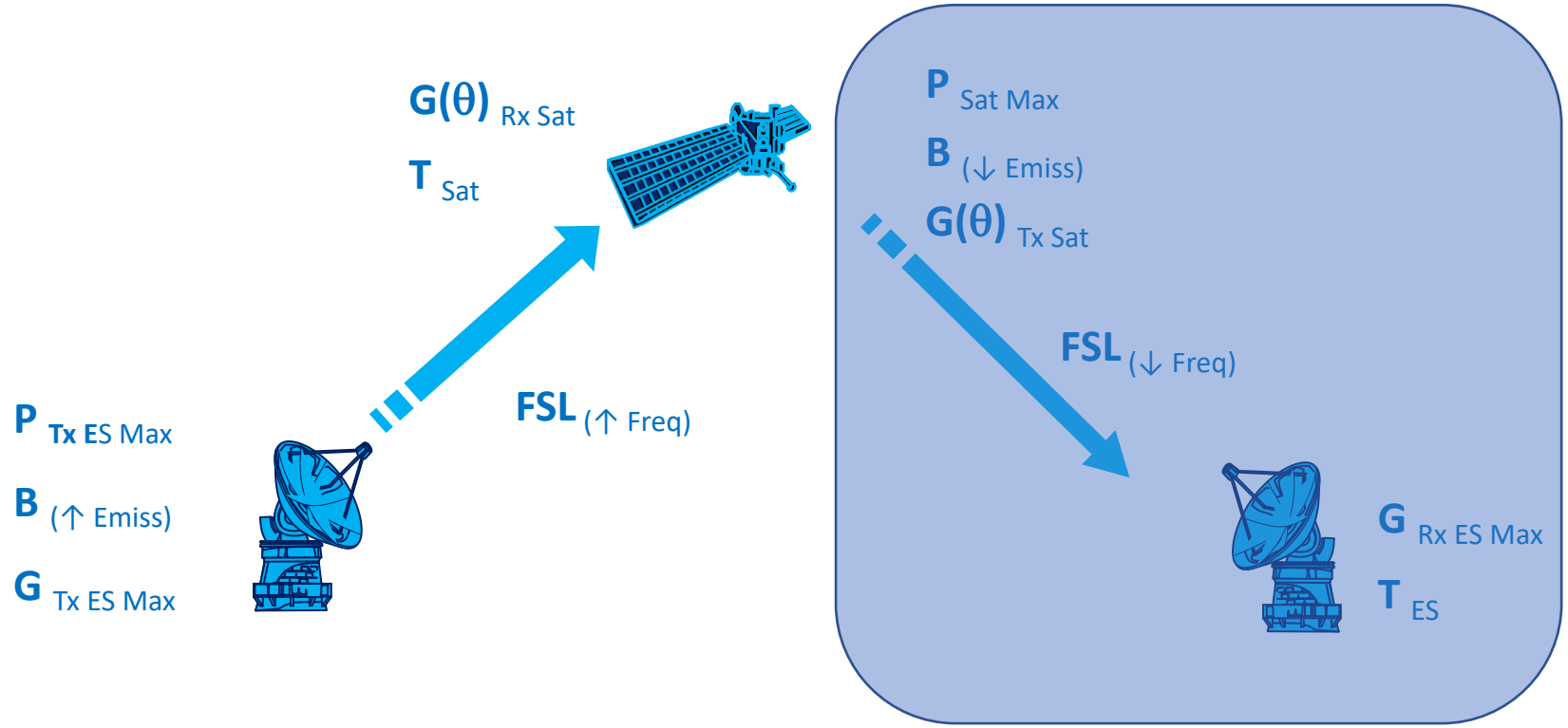
# C/N

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




C, Carrier power

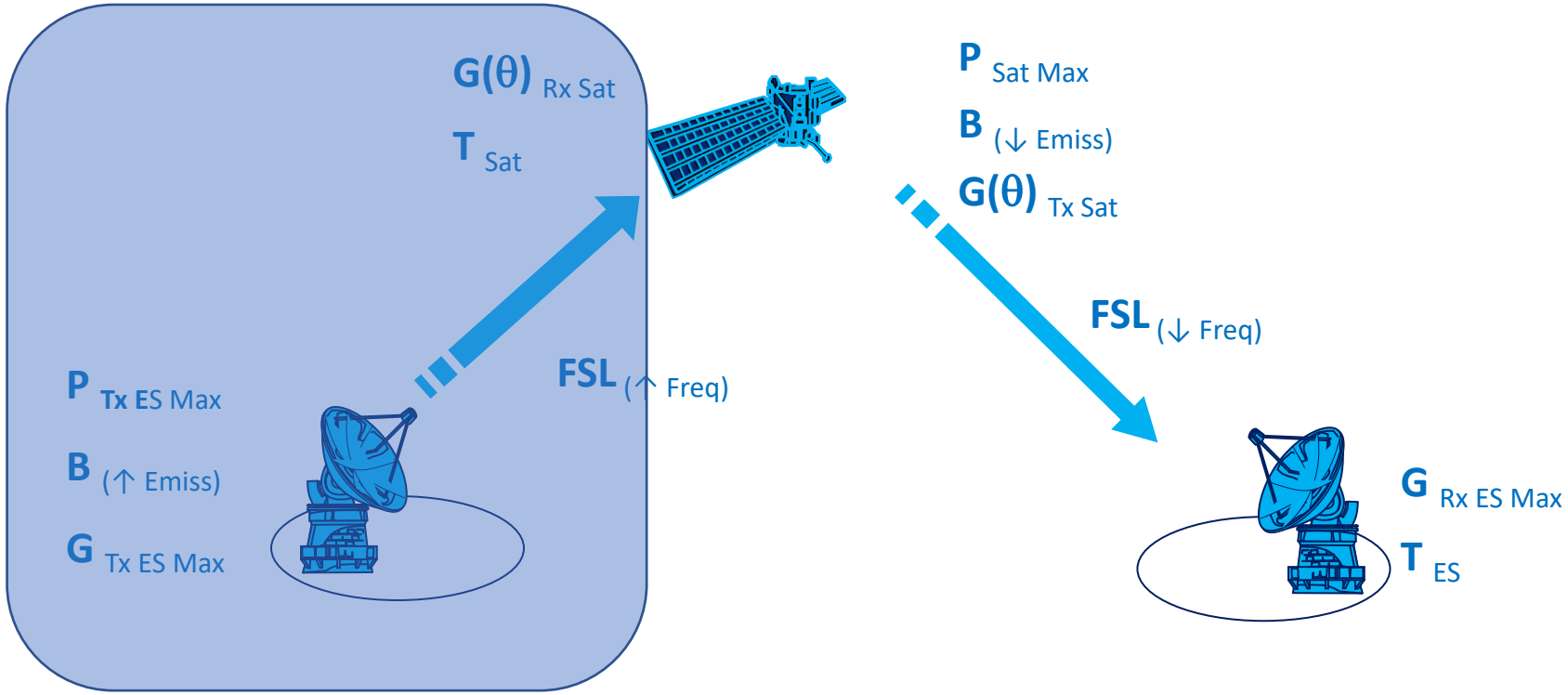
N, Noise power

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

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

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

# Calculate C/N




C, Carrier power

N, Noise power

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

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

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

# Free Space Loss (Annex II of AP8)

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

where :

$f$ : frequency (MHz)

$d$ : distance (km)

where:

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

where:

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

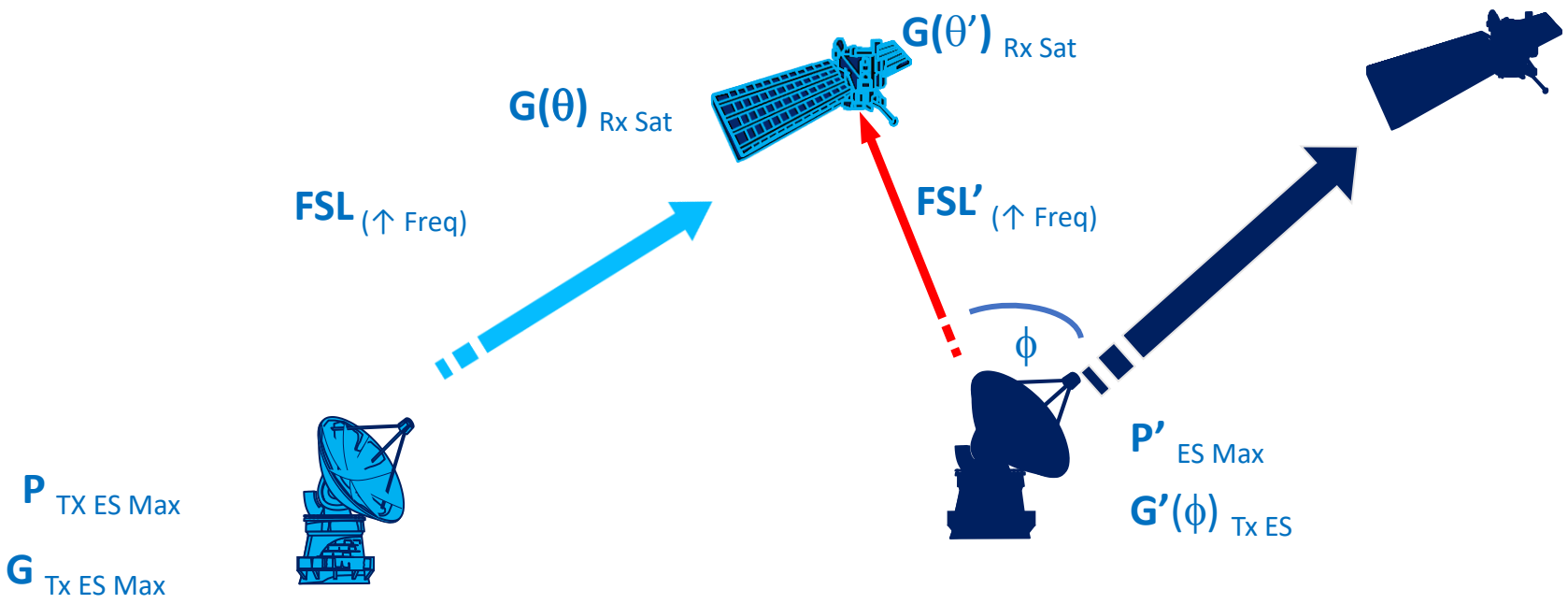
where :

$\zeta$ = latitude of earth station

$\beta$ = difference in longitude btw satellite and earth station


C/I

# Calculate C/I Up



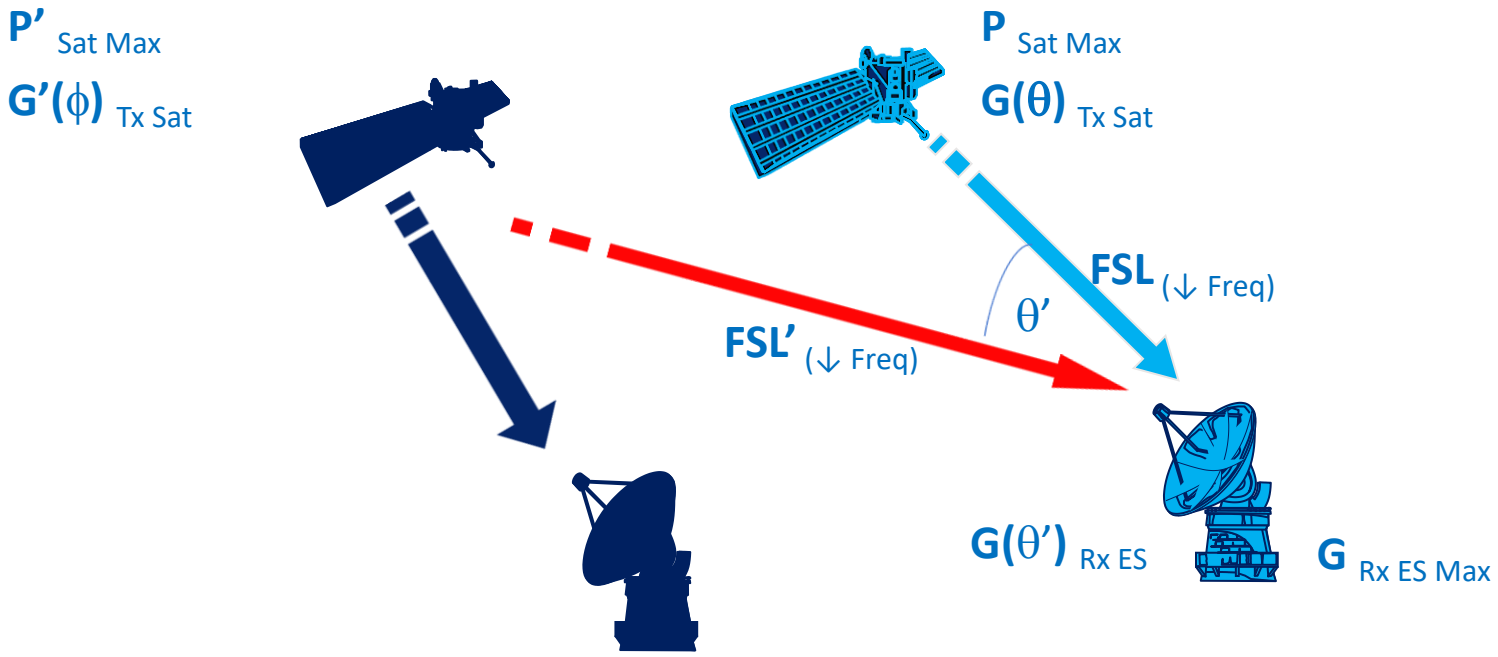

$$C\uparrow = P_{\text{Tx ES Max}} + G_{\text{Tx ES Max}} + G(\theta)_{\text{Rx Sat}} - FSL_{(\uparrow \text{Freq})} \ (\text{dBW})$$

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

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

Source: ITU-R S.740

# Calculate C/I Down




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

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

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

Source: ITU-R S.740

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

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

Where

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

$\theta g$ 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

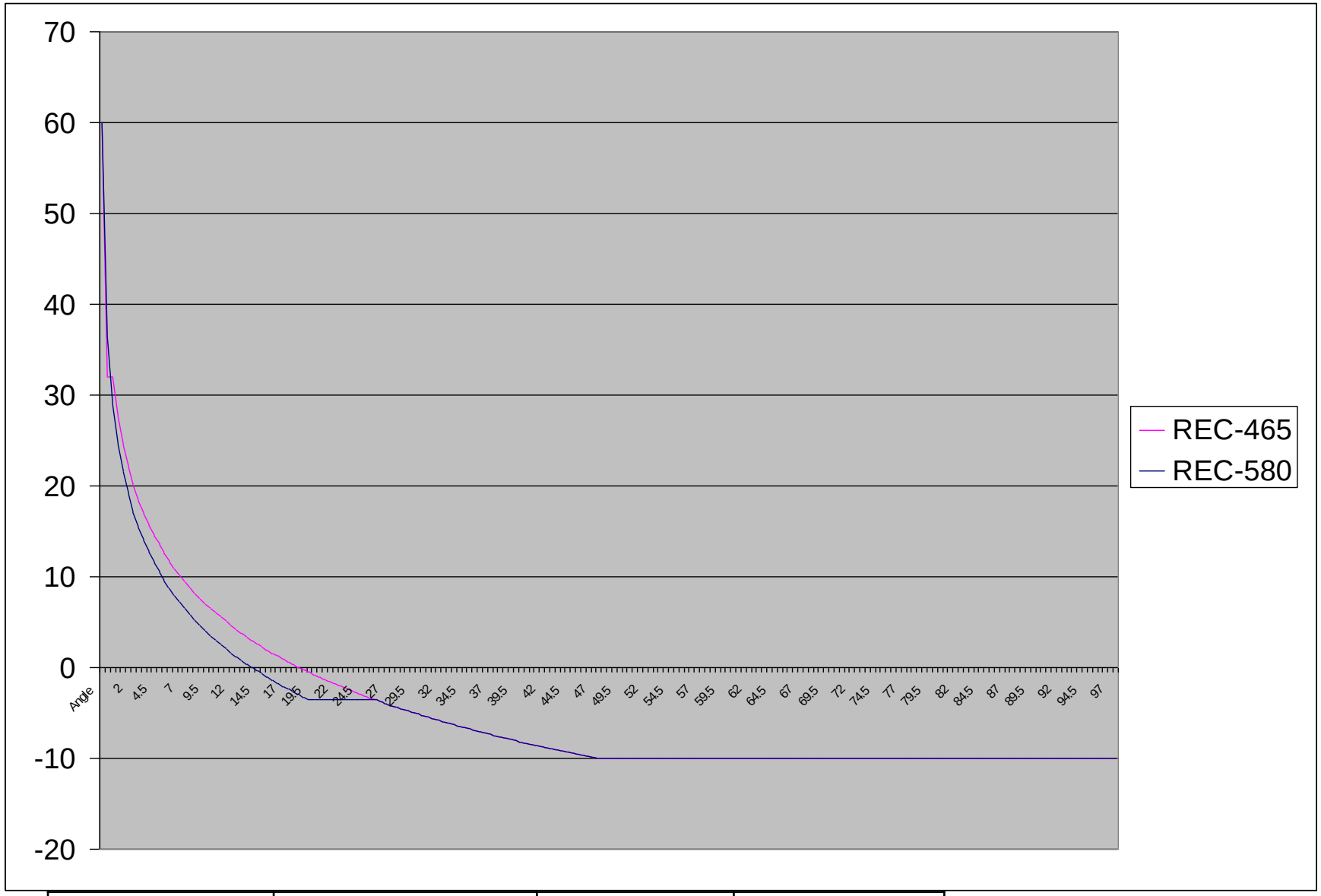
ITU-R S.465-6

ITU-R BO.1900

ITU-R M.694-1

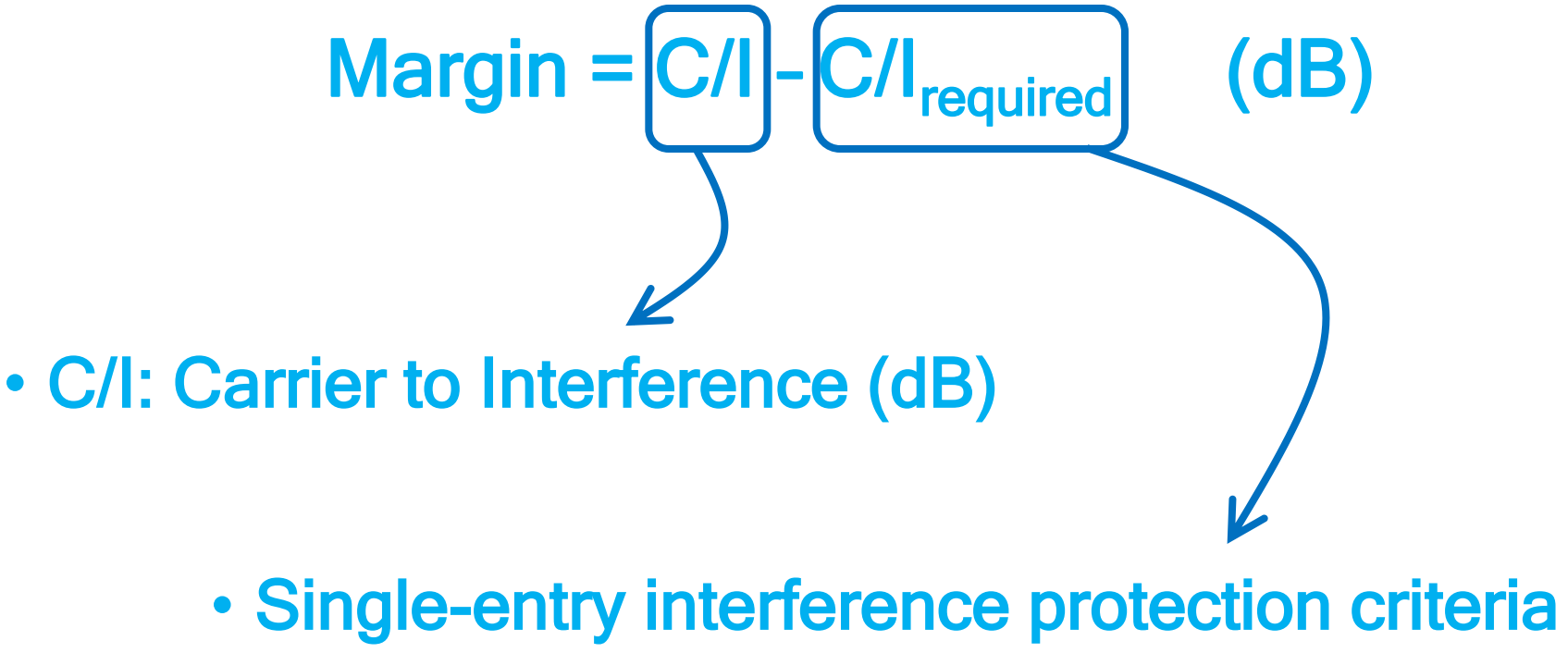
ITU-R BO.1213-1

ITU-R BO.1295




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

# Calculating Margin



# Margin

| No harmful interference | Potential for harmful interference |
| --- | --- |

# Finding C/I Required

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

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 $BW_w$ <= $BW_{eqi}$ then C/N + 5.5 + 3.5*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*log ($BW_w$) (dB) | C/N + 12.2 (dB) | |
| **Other** | 11.4 + 2*log ($BW_w$) (dB) | C/N + 14 (dB) | |

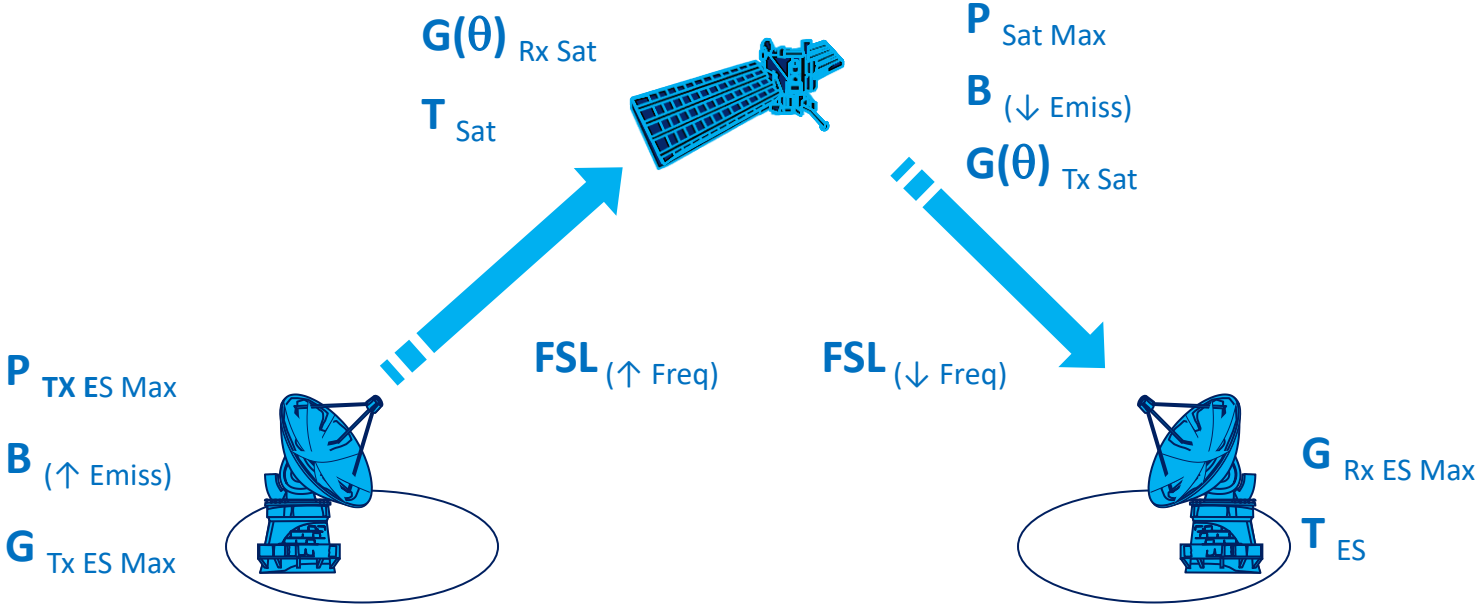
Source: Table 2 in Section B3 of Rules of Procedures, ITU-R S.741-2

$BW_w$: Necessary bandwidth of wanted carrier (MHz)

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

C/N: Carrier to Noise ratio (dB)

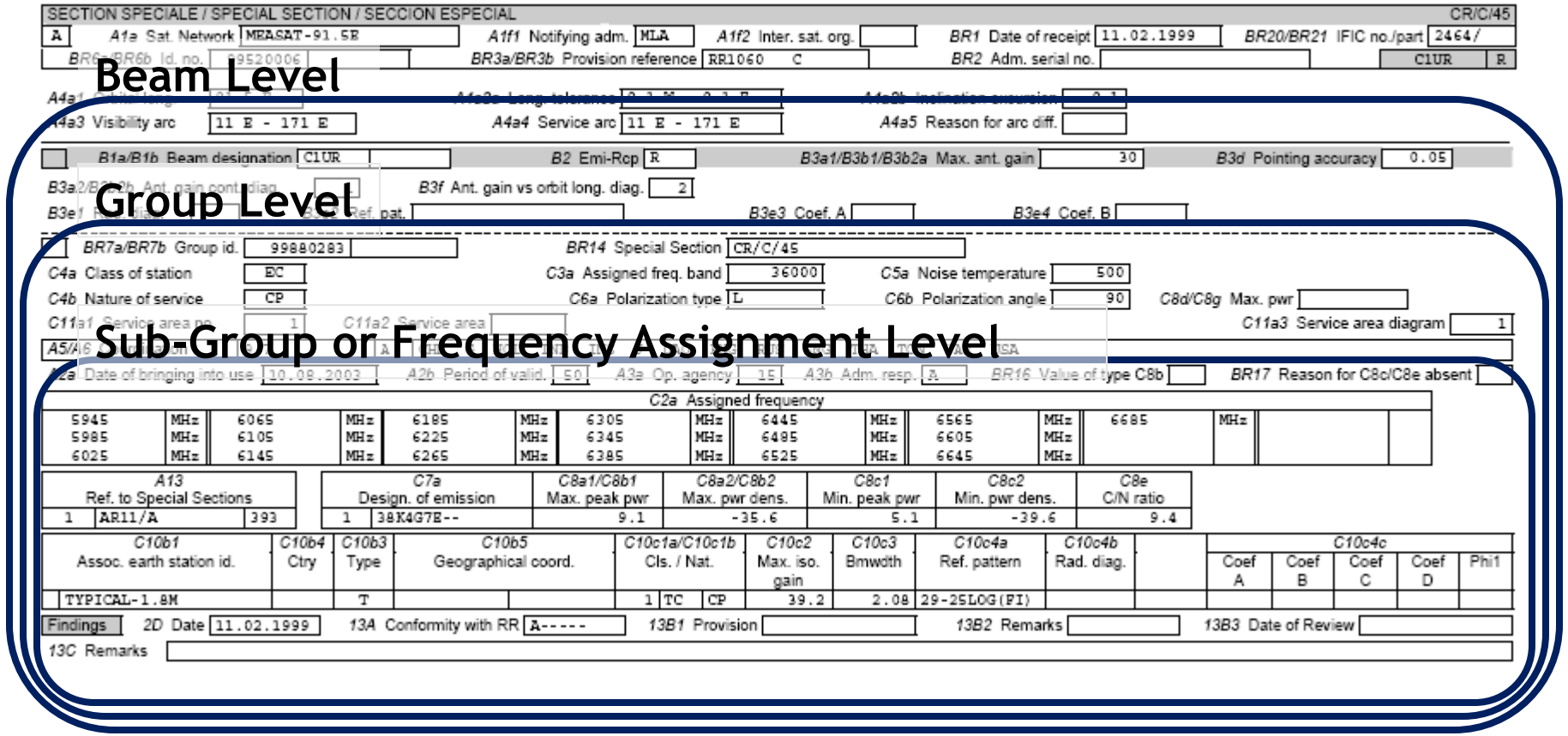
# Finding C/I Required




| | | |
|---|---|---|
| Maximum Peak Power | $P_{Max}$ | C8a1/C8b1 |
| Necessary Bandwidth of Emission | B | C7a |
| Maximum Earth Station Antenna Gain | $G_{ES\ Max}$ | C10d3 |
| Free Space Loss (assigned frequency) | FSL | C2a1 |
| Off-axis Satellite Antenna Gain | $G(\theta)_{Sat}$ | B3a + B3b |
| Receiver System Noise Temperature | T | C5a/C10d6 |
| Service Area | | C11a |

Appendix 4

# Where to get these information?



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

Source: Item C.7 Annex 2 of Appendix 4, Section II of Appendix 1

# Finding C/I Required

| Interfering / Wanted | TV/FM or Other | Digital | Analogue (Other than TV/FM) |
|---|---|---|---|
| **TV/FM** | C/N + 14 (dB) | | |
| **Digital** | If $BW_w$ <= $BW_{eqi}$ then C/N + 5.5 + 3.5*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*log ($BW_w$) (dB) | C/N + 12.2 (dB) | |
| **Other** | 11.4 + 2*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)

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

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

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

C/I: Carrier to Interference (dB)

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

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

# Finding C/I

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

C/I: Carrier to Interference (dB)

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

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

Finding C/I

# Get Adjustment Factor

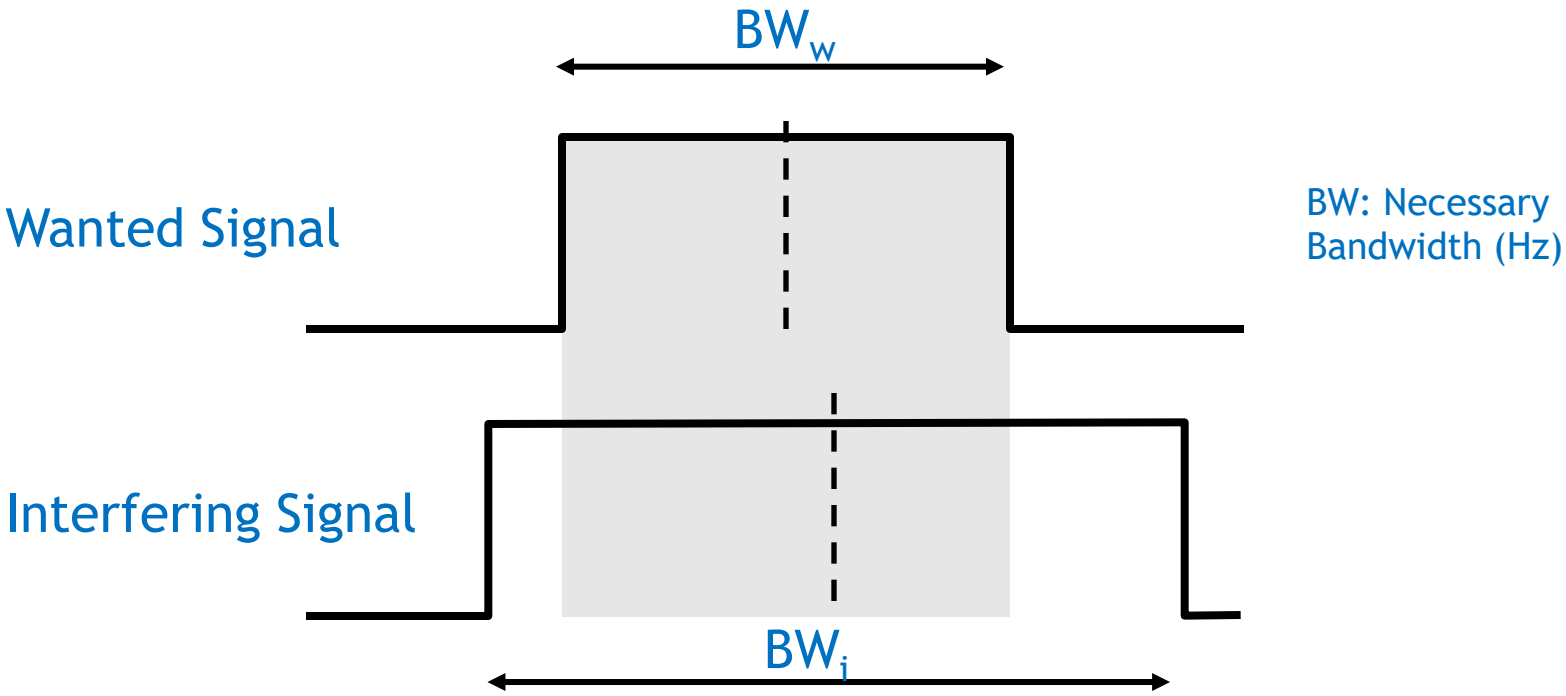
<table>
<tr><th>Wanted / Interfering</th><th>Digital</th><th>Analogue (Other than TV/FM)</th><th>Other</th><th>TV/FM</th></tr>
<tr><td>Digital</td><td colspan="4">METHOD 1: Wanted Bandwidth (BW) to Interfering BW Overlapping Ratio Adjustment</td></tr>
<tr><td>TV/FM</td><td colspan="3" rowspan="3">METHOD 2:<br>Wanted BW to Interfering Equivalent BW Overlapping Ratio Adjustment</td><td>METHOD 1: Co-freq.</td></tr>
<tr><td>Analogue (Other than TV/FM)</td><td>METHOD 3: Non co-freq. (Relative Protection Ratio)</td></tr>
<tr><td>Other</td><td rowspan="2">METHOD 2</td></tr>
</table>

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

Finding C/I

# Get Adjustment Factor

## Method 1:




BW: Necessary Bandwidth (Hz)

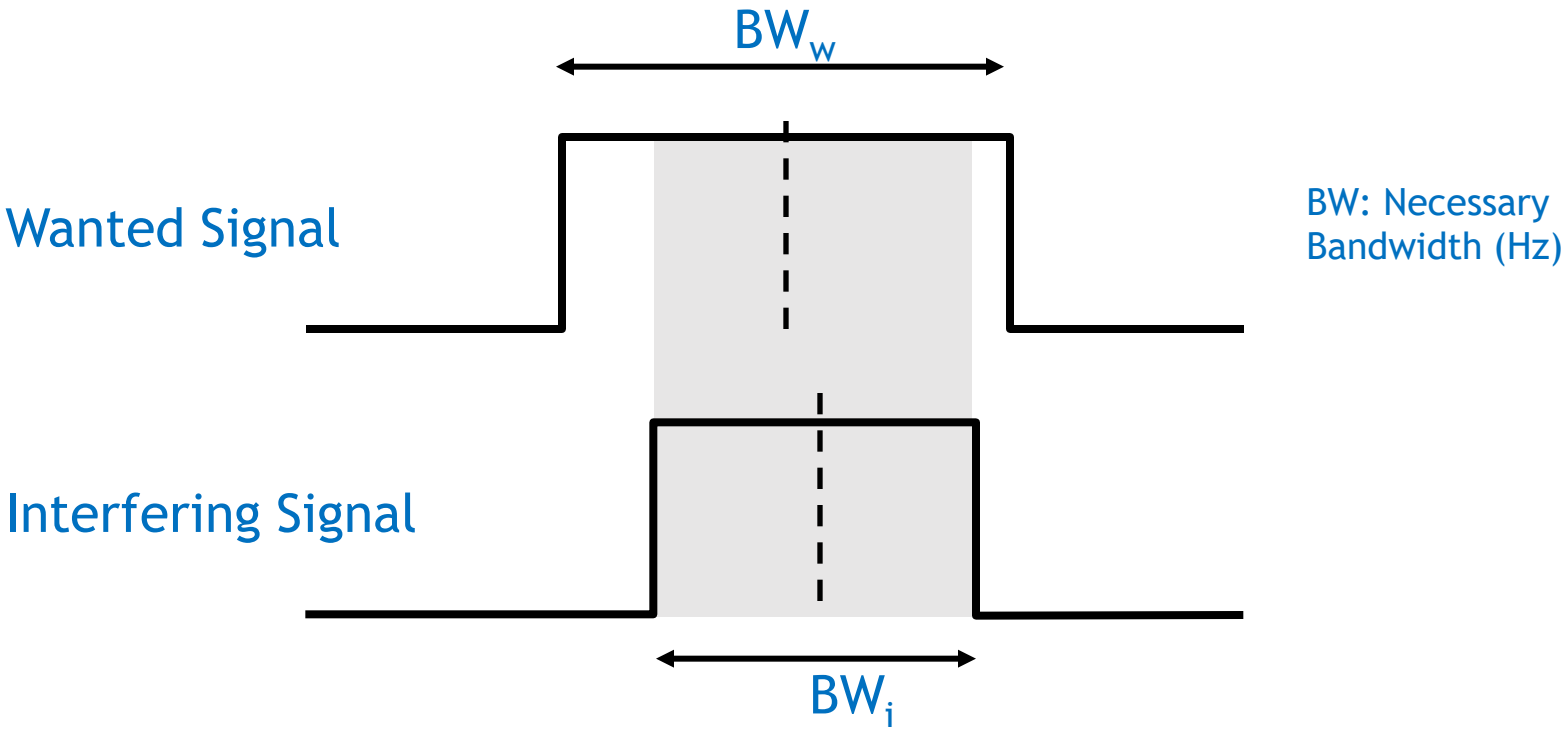
$$I_a = 10\log_{10}(BW_{overlap} / BW_i)$$

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

$$< 0 = \text{Improvement!}$$

# Get Adjustment Factor

## Method 1:



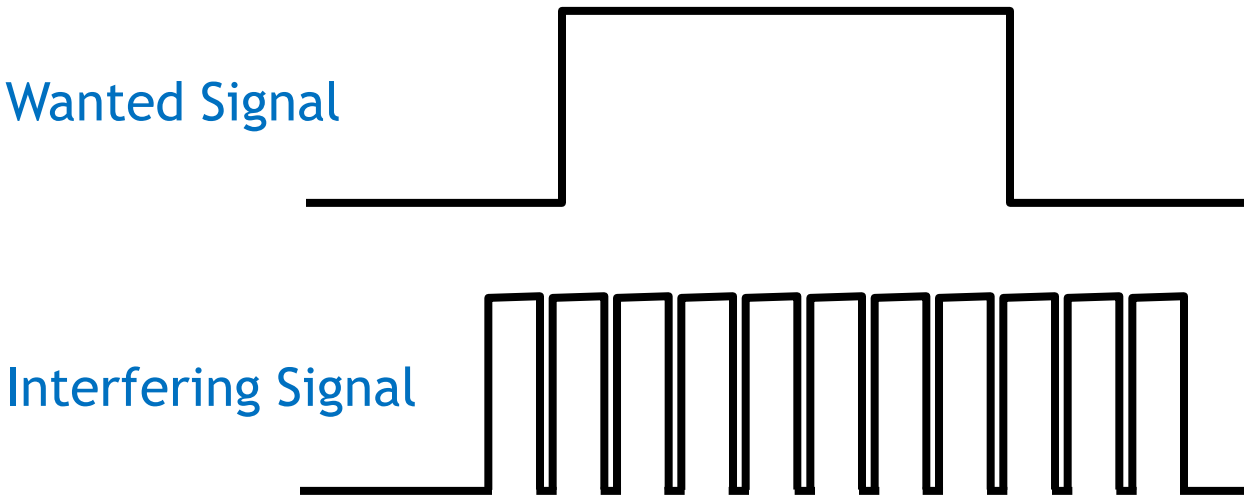

BW: Necessary Bandwidth (Hz)

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

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

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

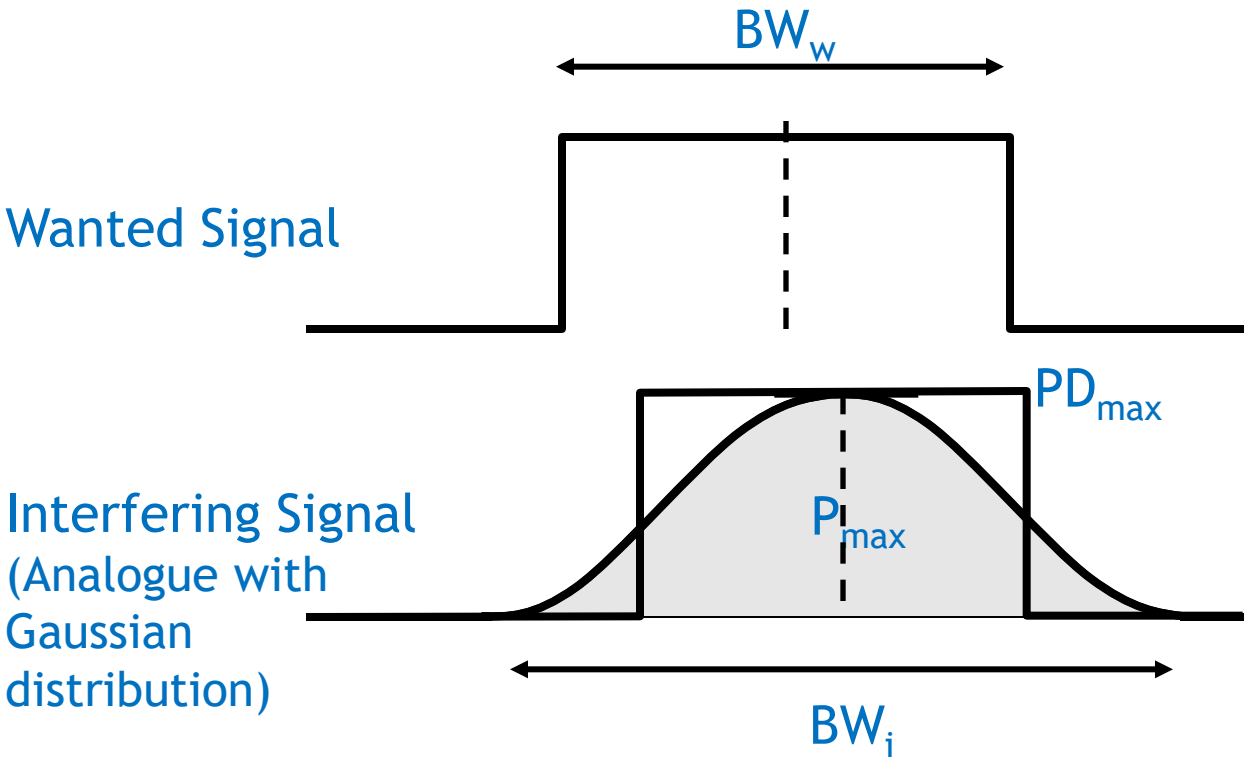
# Multiple interfering narrowband carriers




- 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)

# Get Adjustment Factor

## Method 2:




BW: Necessary Bandwidth (Hz)

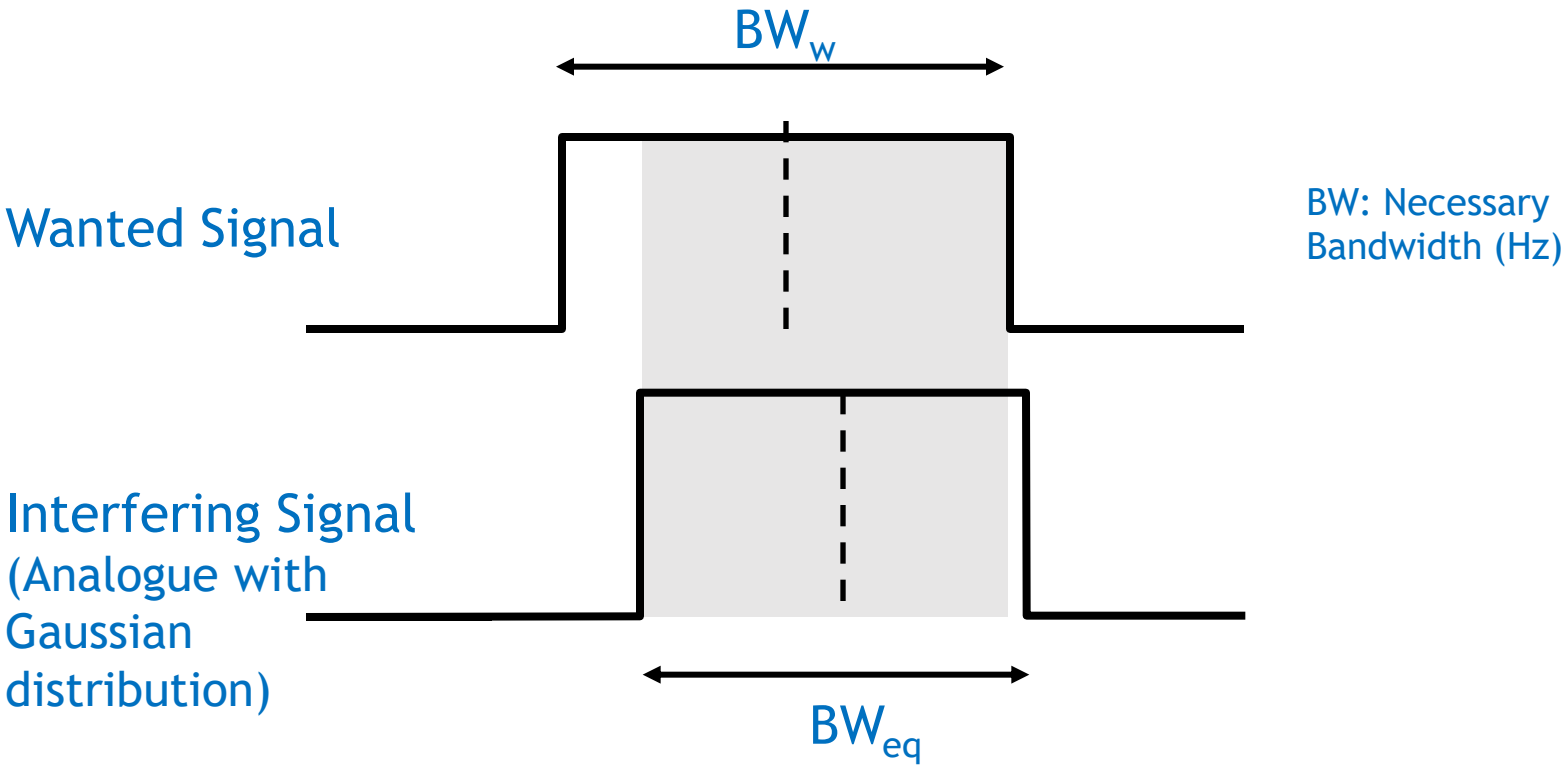
$PD_{max}$: Maximum Power Density (W/Hz)

$P_{max}$: Total Peak Power (W)

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

# Get Adjustment Factor

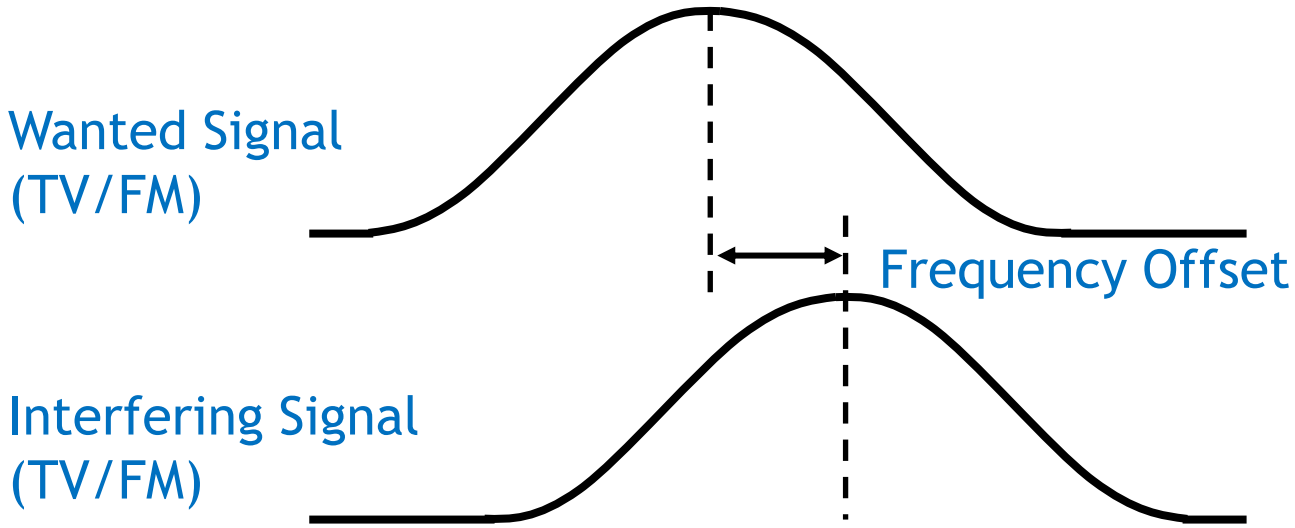
## Method 2:




BW: Necessary Bandwidth (Hz)

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

# Method 3: Get Adjustment Factor




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

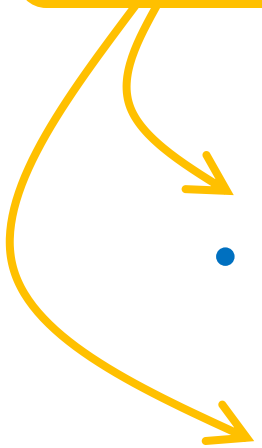
$$\text{Margin} = C/I - C/I_{required} \quad \text{(dB)}$$

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

# Calculating Margin

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



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

# 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

# Thank you!

ITU – Radiocommunication Bureau

Questions to brmail@itu.int or danny.tham@itu.int