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www.itu.int/ITU-R/go/WRS-12



Coordination and Analysis of GSO Satellite Networks

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Summary:



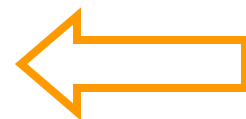
- 1) How to Identify Satellite Networks and other Systems for which Coordination is Required ?
- 2) Several Interference Criteria utilized to evaluate compatibility between GSO satellite networks.
 - ✓ Trigger Arc
 - ✓ DT/T
 - ✓ C/I
- 3) New Coordination Criteria under Study
- 4) Possible methods to be used to facilitate coordination and sharing scenario between GSO.
- 5) How to optimize a filing to be submitted to ITU ?

Appendix 5 indicates technical criteria utilized in every case, including:

- Regulatory provision containing form of coordination
- Sharing scenario associated to the case
- Frequency Band and Region
- Services
- Threshold/condition
- Calculation Method



See Table 5-1, Table 5-2 and Annex 1 to AP5



New !

WRC'12

✓ Criterion of Coordination Arc:

- To identify satellites with frequency overlap operating in the same direction inside the window of ± 7 , ± 8 , ± 12 or ± 16 degrees from nominal orbital longitud, depending on the frequency band, service and Region.
- Applicable to satellite networks in FSS (non plan)
BSS (non plan)
Meteorological-Satellite
associated Space Operations
in specific frequency bands (see AP5)
- Utilized by BR to identify coordination requirements.

Simple but Useful Exercise:

Approach Identifying Satellite Networks with which coordination may be required by using:

SNS-Online or SpaceQuery:

SNS Online Link → http://www.itu.int/sns/query_builder.html

QUERY BUILDER

To build a query with a combination of data items of your choice check "Non-Planned Services" or "Planned Services" from the radio buttons, specify general parameters (the type and name of the satellite, category, notifying administration, longitude range and frequency range) then select data items from the list. Once you have made your selection click "Submit" button.

Non-Planned Services Planned Services/SOF

Frequency Band

Enter query title

General Parameters

Satellite Type: Geo Nongeo Both

Satellite Name:

Notifying Administration:

Network Organization:

Longitude from: to:

Frequency [MHz] from: to:

Notification reason: Coordination Notification API RES49 All

Select Data Items

date of protection

date of publication (IFIC)

date of receipt

earth station name

emission indicator

findings regulatory

class of station,

date of bringing into use,

date of receipt

Display Suppressed Stations: Yes No

Display script: Yes No

GSO Window = 20 E ± 8 degrees

Coordination between GSO/GSO under provision 9.7

Result of Exercise of Coordination Arc Approach



generated query										
satellite name	type	adm	ntwk org	category	longitude	freq_min	freq_max	stn cls	d_inuse	d_rcv
STATSIONAR-27	G	RUS		A	12	3400.00000	3950.00000	EC	01.06.1992	28.08.1987
STATSIONAR-27	G	RUS		C	12	3550.00000	3800.00000	EC	01.06.1992	23.08.2000
						3750.00000	3800.00000	EC	01.06.1992	23.08.2000
						3400.00000	3850.00000	EC	01.06.1992	23.08.2000
						3850.00000	3900.00000	EC	01.06.1992	23.08.2000
						3450.00000	3950.00000	EC	01.06.1992	23.08.2000
						3400.00000	3950.00000	EC	30.07.2001	23.08.2000
AST-12E	G	F		A	12	3400.00000	4200.00000	EC	01.06.2016	25.08.2009
EMARSAT-8W/M	G	UAE		A	12	3400.00000	4200.00000	EC	10.02.2015	18.10.2009
						3400.00000	4200.00000	EK	10.02.2015	18.10.2009
						3400.00000	4200.00000	ER	10.02.2015	18.10.2009
ASAT E012	G	F		A	12	3400.00000	4200.00000	EC	08.07.2017	23.07.2010
AZERSAT C12	G	AZE		A	12	3400.00000	4200.00000	EC	01.01.2016	19.11.2010
AST-2-12E	G	F		A	12	3400.00000	4200.00000	EC	01.01.2018	05.07.2011
AMS-B1-12E	G	ISR		A	12	3400.00000	4200.00000	EC	01.04.2018	16.02.2012
						3400.00000	4200.00000	EK	01.04.2018	16.02.2012
						3400.00000	4200.00000	ER	01.04.2018	16.02.2012
BASAT E012	G	F		A	12	3400.00000	4200.00000	EC	08.08.2018	01.03.2012
EMARSAT-9Y	G	UAE		A	12	3400.00000	4200.00000	EC	30.11.2018	30.11.2011
						3400.00000	4200.00000	EK	30.11.2018	30.11.2011
						3400.00000	4200.00000	ER	30.11.2018	30.11.2011
CHNSAT-12E	G	CHN		A	12	3400.00000	4200.00000	EC	01.01.2019	19.01.2012
AMS-B2-12E	G	ISR		A	12	3400.00000	4200.00000	EC	01.06.2019	17.06.2012
						3400.00000	4200.00000	EK	01.06.2019	17.06.2012
						3400.00000	4200.00000	ER	01.06.2019	17.06.2012
STATSIONAR-27	G	RUS		N	12	3400.00000	3950.00000	EC	23.08.2005	16.08.2005
IRANSAT-12.5E	G	IRN		A	12.5	3400.00000	4200.00000	EC	03.01.2019	03.01.2012
F-SAT-N-E-13E	G	F		C	13	3400.00000	4200.00000	EC	28.05.2016	01.12.2009
						3400.00000	4200.00000	EK	28.05.2016	01.12.2009
						3400.00000	4200.00000	ER	28.05.2016	01.12.2009
F-SAT-N-E-13E	G	F		A	13	3400.00000	4200.00000	EC	28.05.2016	28.05.2009
LUX-G7-4	G	LUX		A	13	3400.00000	4200.00000	EC	18.08.2016	19.08.2009

✓ **Criterion of $\Delta T/T > 6\%$**

- Mask used by BR to establish coordination requirements in any other scenario where CA is not applicable.
- Utilized by Administrations to request BR to include or exclude networks in coordination process under No.9.41
- Described by Appendix 8 to RR.
- It measures the increase of Noise Temperature at Rx due to Interference as a generic method.
- It does not take into account:
 - wanted signal.
 - interfering spectrum shape

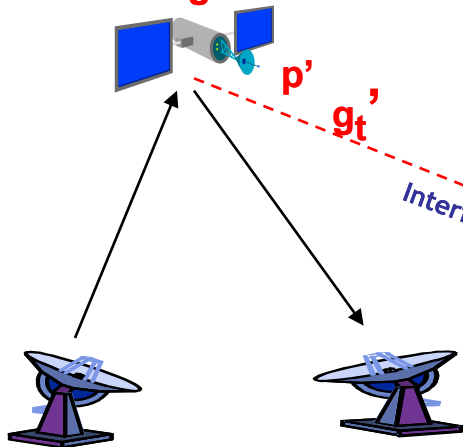
$\Delta T/T > 6\%$ => Potential Harmful Interference

Further detailed analysis is needed to ensure that coordination is really needed (e.g. C/I)

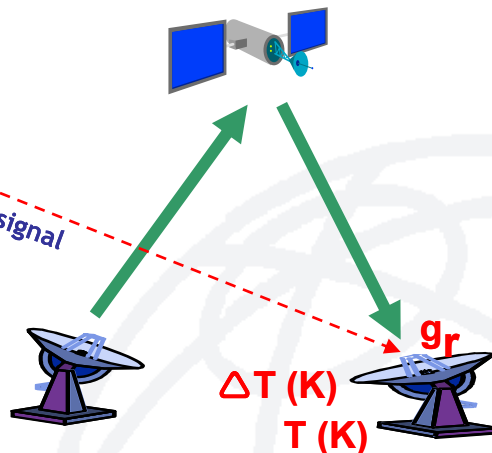
$\Delta T/T \leq 6\%$ => No Harmful Interference

$\Delta T/T$: Introduction to General Method

Interfering sat. network



Wanted sat. network



AP8 describes the method including definitions

$$\Delta T / T = (p' g_t' g_r) / KLT$$

Interfering power density level

Transmission gain γ :

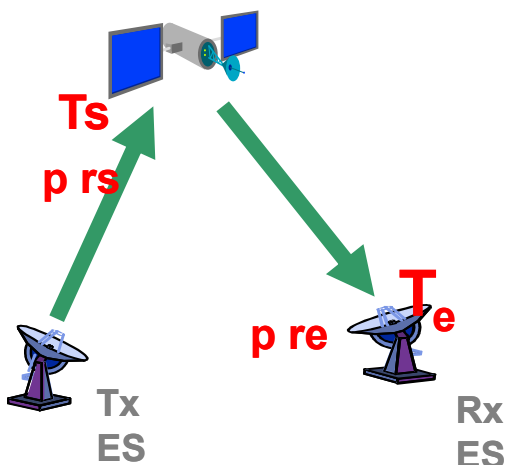
- ✓ Valid for Simple Freq. Changing Transponders (Bent Pipe) only.
- ✓ Not applicable when satellite has on-board signal processing (digital regenerating transponders, change of modulation, etc). This case requires separate treatment of up and downlinks.

$$\gamma = p_{re} / p_{rs}$$

Power received at the earth stn.
Power received at the satellite

Equivalent Satellite Link Noise Temperature:

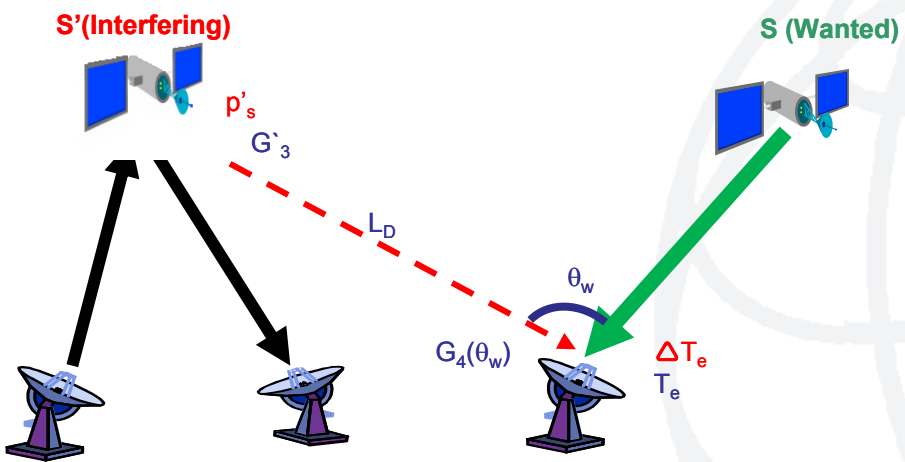
$$T = T_e + \gamma T_s \text{ (K)}$$



$\Delta T/T$ Case I : Freq. Overlap Co-Directional

Separate treatment of Up and Downlink
(Wanted Satellite has on-board signal processing)

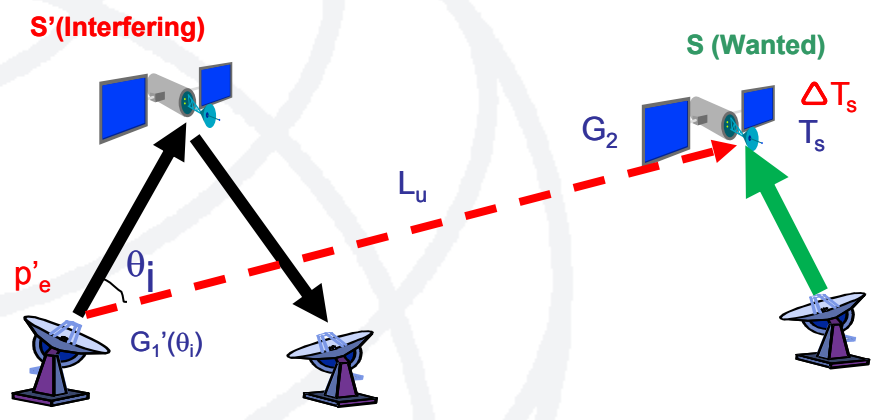
Freq.Overlap in Downlink only



$$\Delta T/T = \Delta T_E / T_E$$

$$\Delta T/T = 10\log(p'_s) + G'_3 - L_D + G_4(\theta_w) - K - T_E \quad (\text{dB})$$

Freq.Overlap in Uplink only

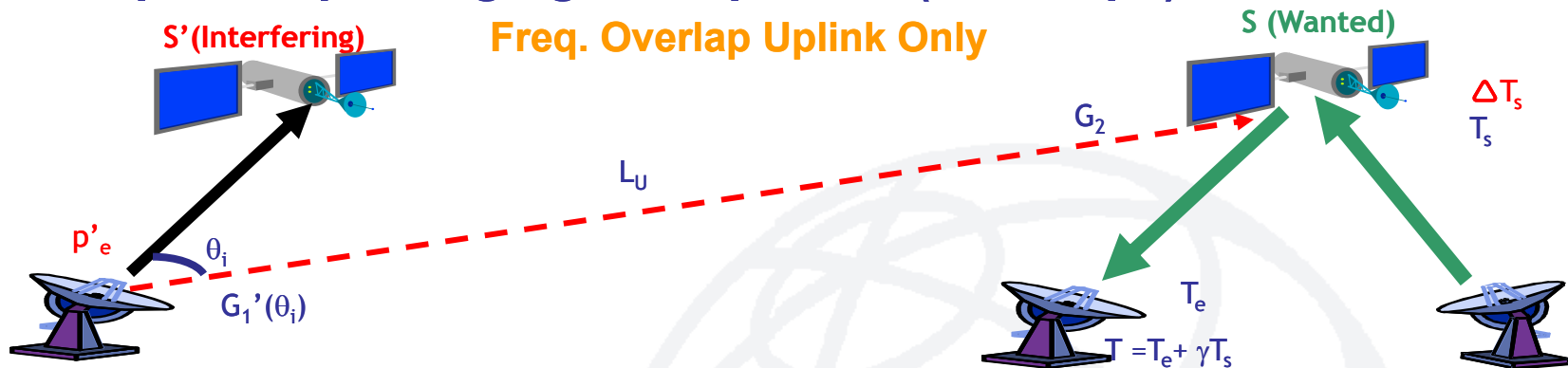


$$\Delta T/T = \Delta T_s / T_s$$

$$\Delta T/T = 10\log(p'_e) + G'_1(\theta_i) - L_U + G_2 - K - T_S \quad (\text{dB})$$

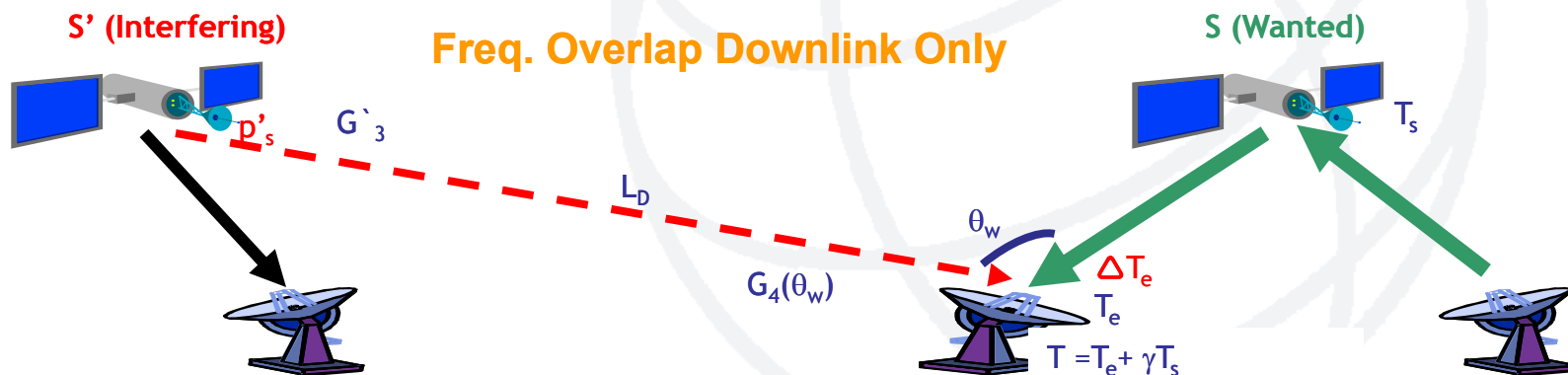
$\Delta T/T$ Case I : Freq. Overlap Co-Directional

Simple Freq.Changing Transponder (Bent Pipe)



$$\Delta T/T = \gamma \Delta T_s / T$$

$$\Delta T/T = 10 \log \gamma + 10 \log(p'_e) + G'_1(\theta_i) - L_U + G_2 - K - T \text{ (dB)}$$



$$\Delta T/T = \Delta T_e / T$$

$$\Delta T/T = 10 \log(p'_s) + G'_3 - L_D + G_4(\theta_w) - K - T \text{ (dB)}$$

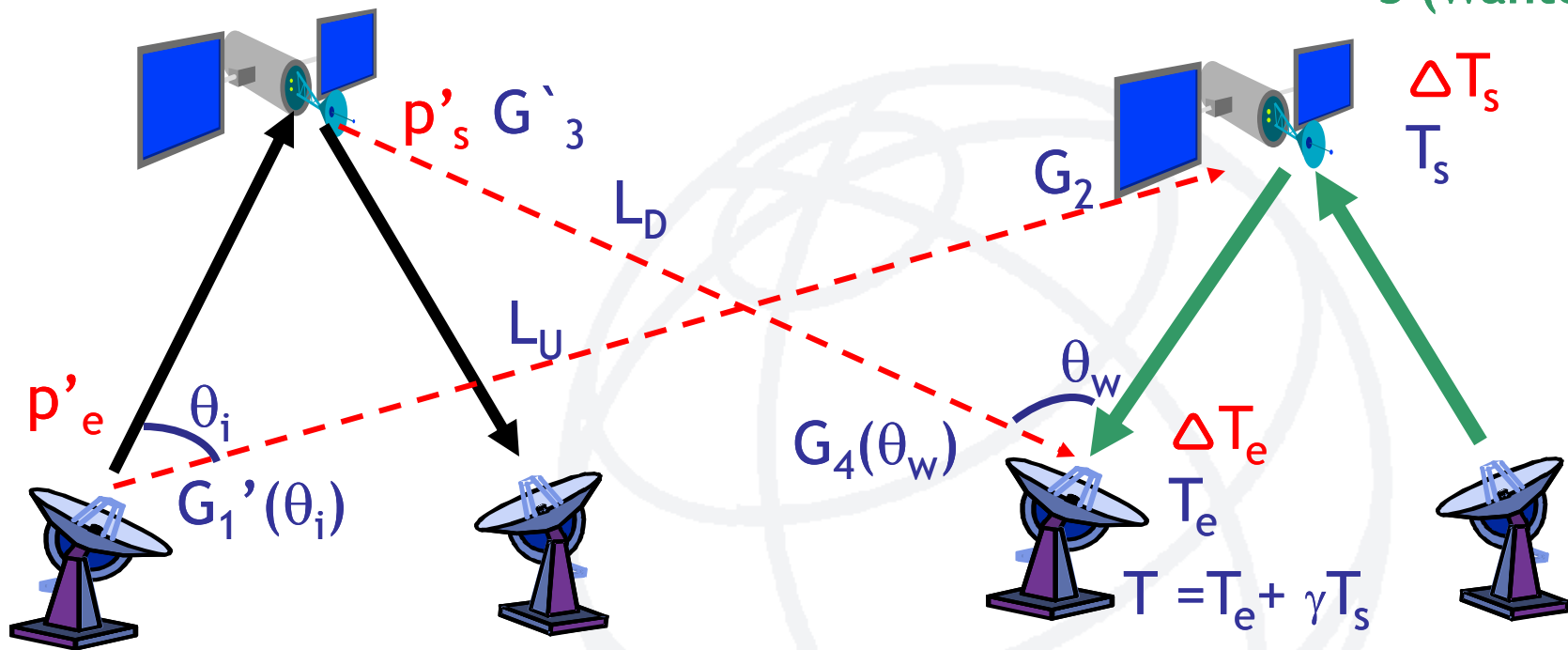
$\Delta T/T$ Case I : Freq. Overlap Co-Directional

Simple Freq.Changing Transponder (Bent Pipe)

S' (Interfering)

Freq.Overlap in both links

S (Wanted)



$$\Delta T/T = (\Delta T_e + \gamma \Delta T_s) / T$$

$$\Delta T/T = (p'_s g'_3 g_4(\theta_w)) / (k I_D T) + \gamma (p'_e g'_1(\theta_i) g_2) / (k I_U T)$$

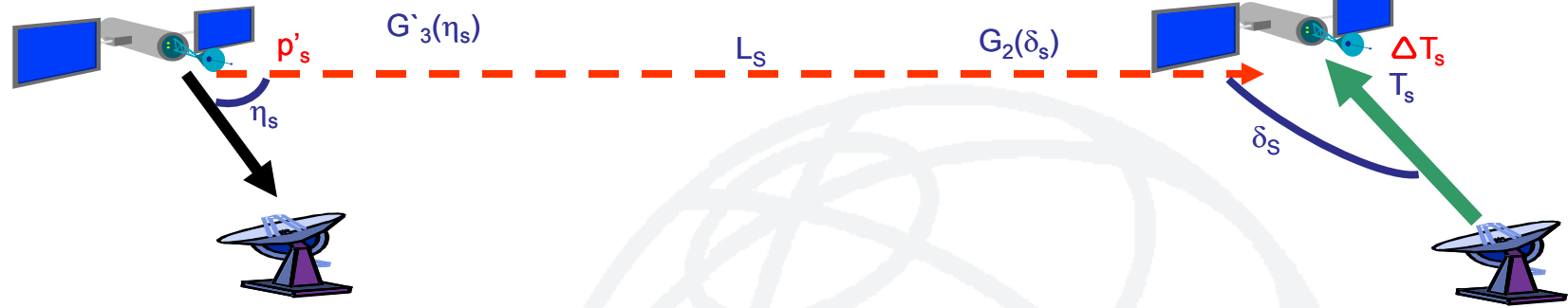
$\Delta T/T$ Case II: Freq.Overlap in Opposite Direction of Tx. (Inter-Satellite)

Downlink (interfering) overlaps Uplink(wanted)

S'(Interfering)

Separate treatment of up & down links

S (Wanted)



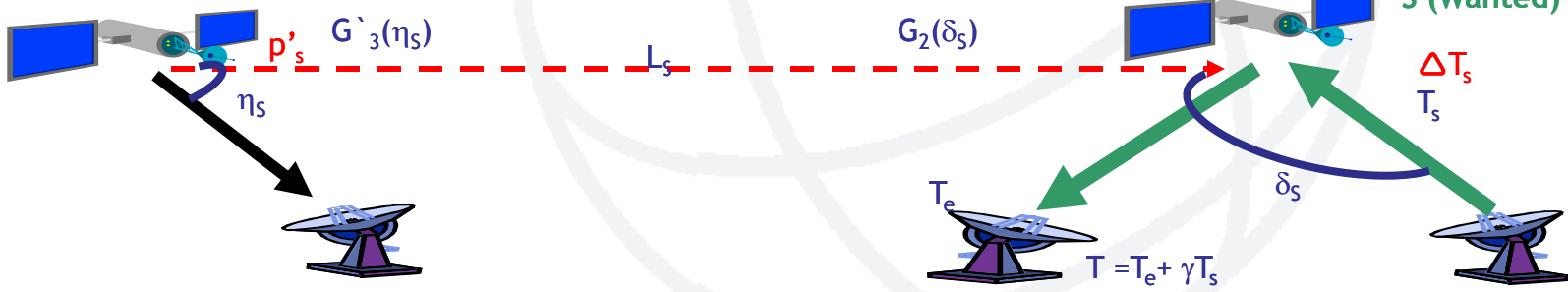
$$\Delta T/T = \Delta T_s/T_s$$

$$\Delta T/T = 10\log(p'_s) + G_3(\eta_s) - L_s + G_2(\delta_s) - K - T_s \quad (\text{dB})$$

Wanted Satellite has Simple Freq. Changing TXP (bent-pipe)

S'(Interfering)

S (Wanted)



$$\Delta T/T = \gamma \Delta T_s/T$$

$$\Delta T/T = 10\log \gamma + 10\log(p'_s) + G_3(\eta_s) - L_s + G_2(\delta_s) - K - T(\text{dB})$$

✓ C/I Criterion

- Utilized by BR to perform detailed examination of probability of harmful interference when so requested by Administrations under No.11.32A of RR.
- Based on methodology and protection criteria defined by REC ITU-R S.741-2 and associated Rule of Procedure from RRB, or by common agreement between Adms.
- It takes into account:
 - Wanted signal
(level and type of carrier-modulation)
 - Interfering signal
(level and spectrum shape)
 - Overlapped BandWidth
- More accurate to perform inter-networks sharing analysis, based on quality and availability objectives.
- Used by operators in coordination meetings.

Concept of C/I:

$$C/I = C/N + K$$

Protection ratio

(generally, between 12.2 - 14 dB, depending on the type of carriers)

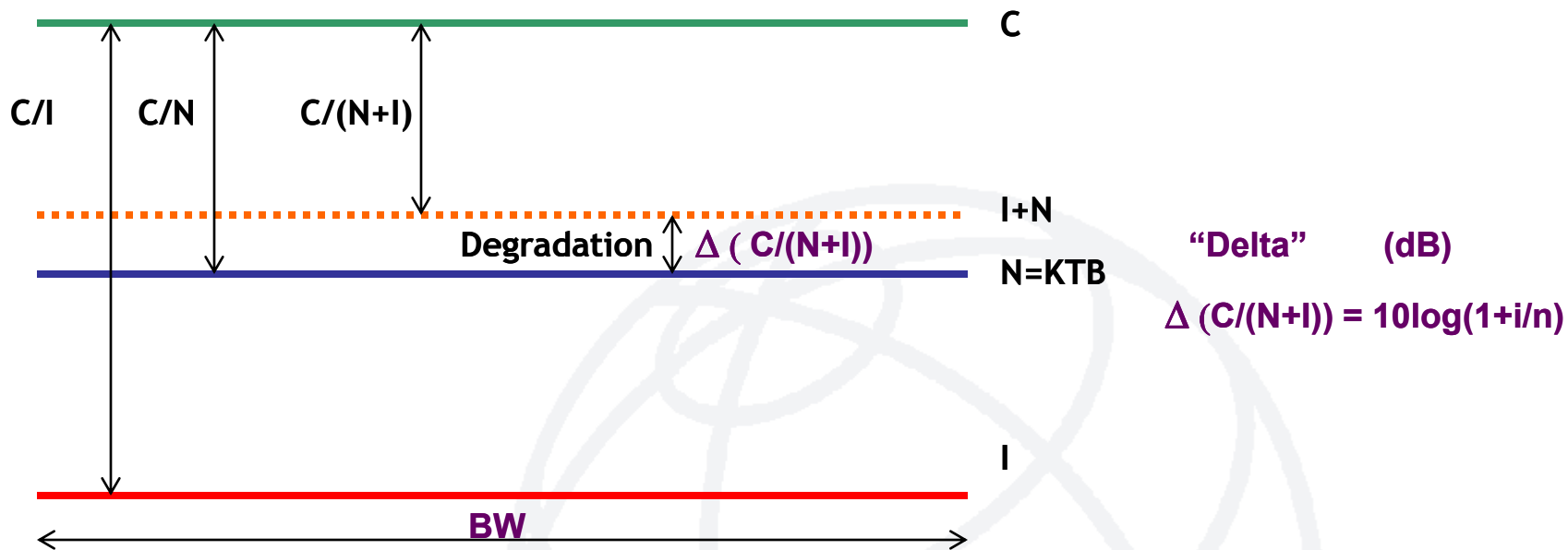
Result of your Link Budget

(considering objectives like S/N or BER, availability, etc)

Protection required to ensure compatibility between networks

****C/I examination will be presented in detail in a separate document****

Interference: Criteria and typical values



- $I/N = -12 \text{ dB} \rightarrow \text{Degradation} \cong 0.26 \text{ dB} \rightarrow \Delta T/T = 6\%$
- $I/N = -10 \text{ dB} \rightarrow 0.4 \text{ dB}$
- $I/N = -6 \text{ dB} \rightarrow 1 \text{ dB}$

- Worst case given by

$$I_{\text{Total}} = 10.\log [10^{(I_1 / 10)} + 10^{(I_2 / 10)} + \dots + 10^{(I_n / 10)}]$$

where $I_{\text{Total}}, I_1, I_2 \dots I_n$ are in dBW.

- In terms of C/I:

$$C/i_{\text{Total}} = \frac{1}{\frac{1}{C/i_{\text{Adj. Sat.}}} + \frac{1}{C/i_{\text{Terrest}}} + \frac{1}{C/i_{\text{Other}}}}$$

Under Study:

- Resolution 756 (WRC-12), WRC-12 resolved to invite ITU-R:
 - 1 to carry out studies to examine the **effectiveness and appropriateness** of the current criterion ($\Delta T/T > 6\%$) used in the application of **No. 9.41** and **consider any other possible alternatives** (including the alternatives outlined in Annexes 1 and 2 to this Resolution, such as **pfd masks or C/I**, as appropriate), for the bands referred to in *recognizing e*);
 - 2 to study whether **additional reductions in the coordination arcs** in RR Appendix 5 (Rev.WRC-12) are appropriate for the **6/4 GHz** and **14/10/11/12 GHz** frequency bands, and whether it is appropriate to reduce the coordination arc in the **30/20 GHz** band.
- **Director of BR will include the results in his Report to WRC-15.**

Ongoing studies are considering:



- which frequency bands would be subject to the new coordination criterion?
- new threshold would be based on single-entry or multiple sources of interference?
- to apply different criteria for each combination of interfering and interfered-with carrier type?
(noting that Recommendation ITU-R S.741 may not take into account some modulation-coding schemes currently in use, as well as the difficulties of identifying them using the current RR Appendix 4 parameters)
- the possibility of defining a reasonable range of technical parameters (e.g. uplink G/T, downlink noise temperature, antenna sizes)
- identifying provisions and situations where the new criteria should be applied

Contributions to studies are based on:



- **homogenous networks**
- **separation of two and three degrees**
- **possible levels of permissible interference and**
- **associated loss of energy margin and capacity**

**See Annex 13 to the report of the
Working Party 4A Chairman**

Methods to facilitate coordination and sharing scenario between GSO



- ❑ **Frequency Separation**
 - Band Segmentation
 - Channeling Plan

- ❑ **Polarization**

- ❑ **Improvement of antenna system spatial discrimination**
 - Design of Antenna gain contours, roll-off and service areas associated to satellite beams
 - Modifying antenna diameters in the ground segment
 - Improvement to Earth Station Radiation Pattern

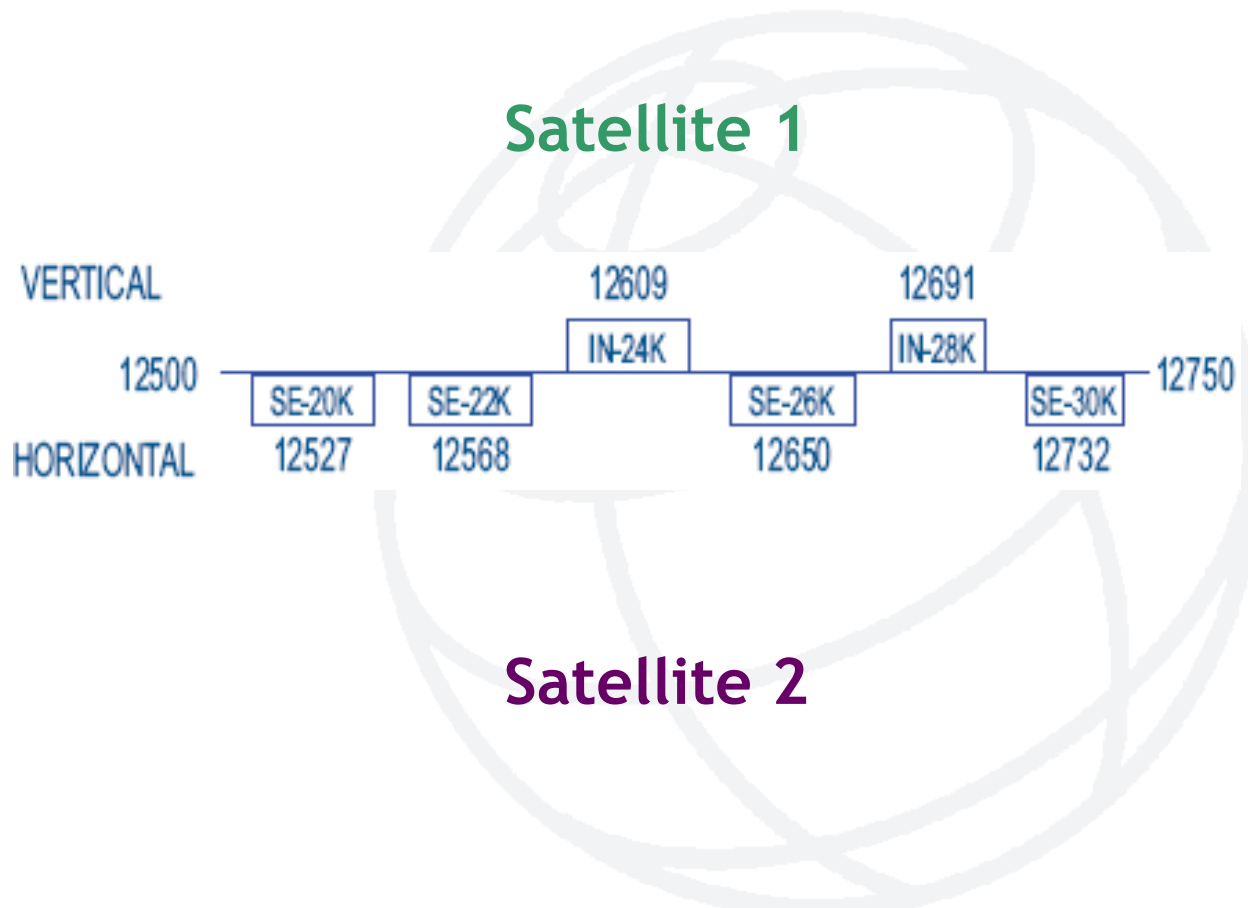
- ❑ **To Adjust orbital separation between adjacent satellites.**

- ❑ **To Reorganize distribution of different types of carrier.**

- ❑ **Use of advanced modulation/FEC technologies (eg. DVB-S2), signal coding and processing techniques (spread spectrum or CDMA, etc).**

- ❑ **Re-engineering of the link budget, including modulation-FEC, power density levels, adjusting Quality and Availability Objectives in order to tolerate higher levels of interference.**

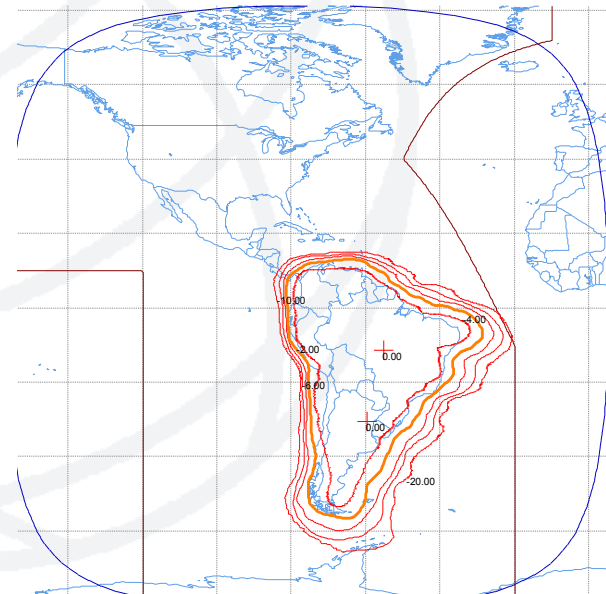
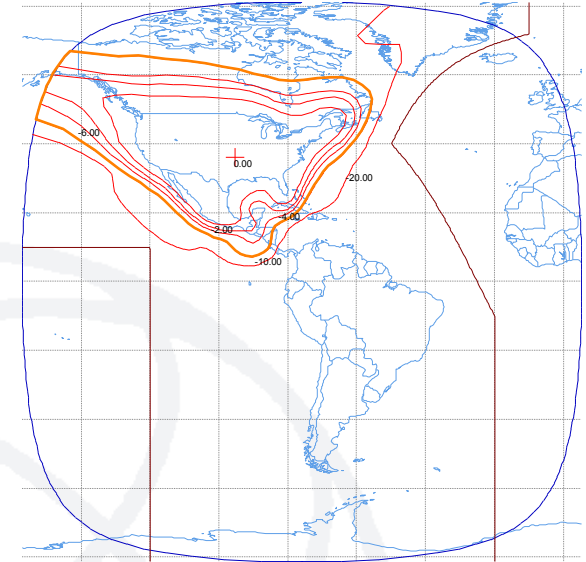
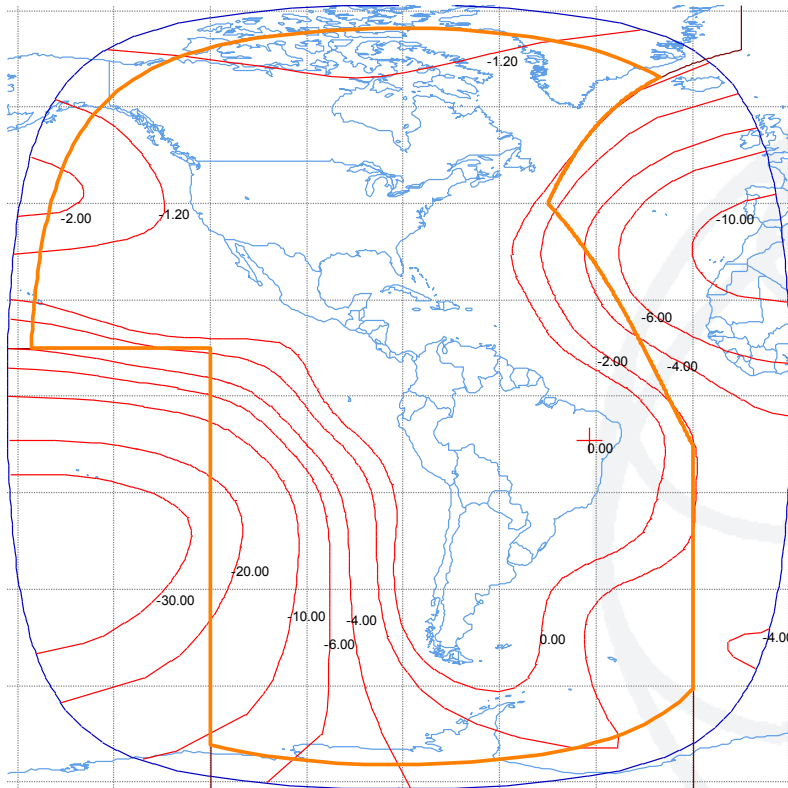
Frequencies - Polarizations



Satellite 1

Satellite 2

Space Segment - Spatial Discrimination



Modifying Orbital Separation:

Exercise:

Assuming $D/\lambda = 100$; ES Antenna Patterns REC 465-5 / REC 580-6

Interference Reduction:

$$I_f - I_i = 25 \cdot \log (\varphi_i / \varphi_f)$$

where

φ_f : minimum final separation between satellites

φ_i : minimum initial separation between satellites

Scenario 1

$$\Theta_{1n} - \Theta_{2n} = 2^\circ$$

$$\Delta_{\Theta 1} = \Delta_{\Theta 2} = \pm 0.1^\circ$$

→ Nominal Orbital Separation

→ E-W Station Keeping

Interference Reduction with respect to Scenario 1

Scenario 2

$$\Theta_{1n} - \Theta_{2n} = 3^\circ$$

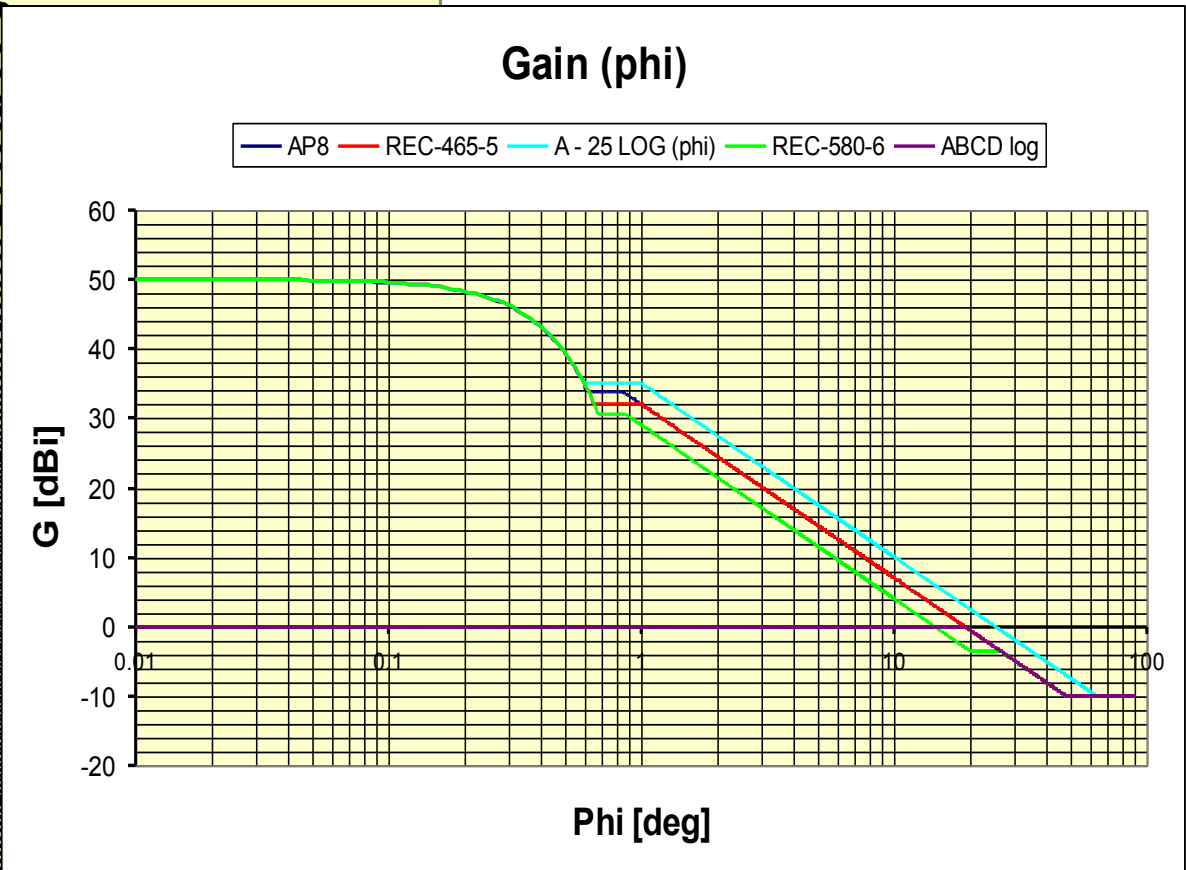
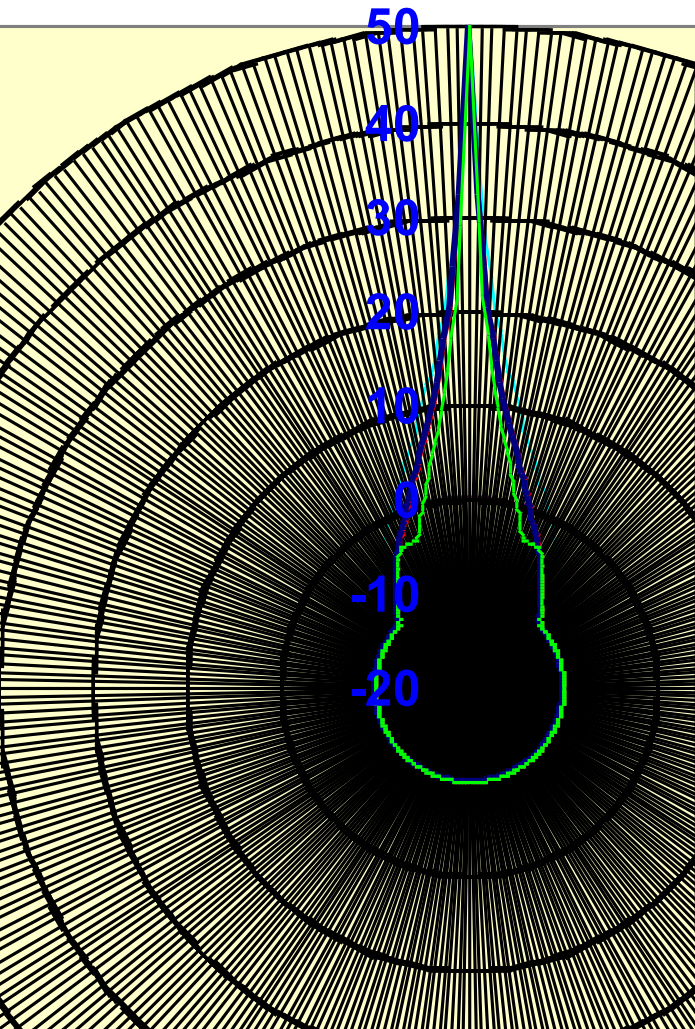
$$\Delta_{\Theta 1} = \Delta_{\Theta 2} = \pm 0.1^\circ$$

$$I_f - I_i = 25 \cdot \log (1.8 / 2.8) = -4.8 \text{ dB}$$



Warning: From Regulatory point of view, it may be an Impact of New Coordination Requirements in some cases due to increase of interference to other satellites

Antenna Radiation Patterns Comparison Sidelobes



Changing the Earth Station Antenna Diameter:

Ga max [dBi]=	43.2
Gb max [dBi]=	56

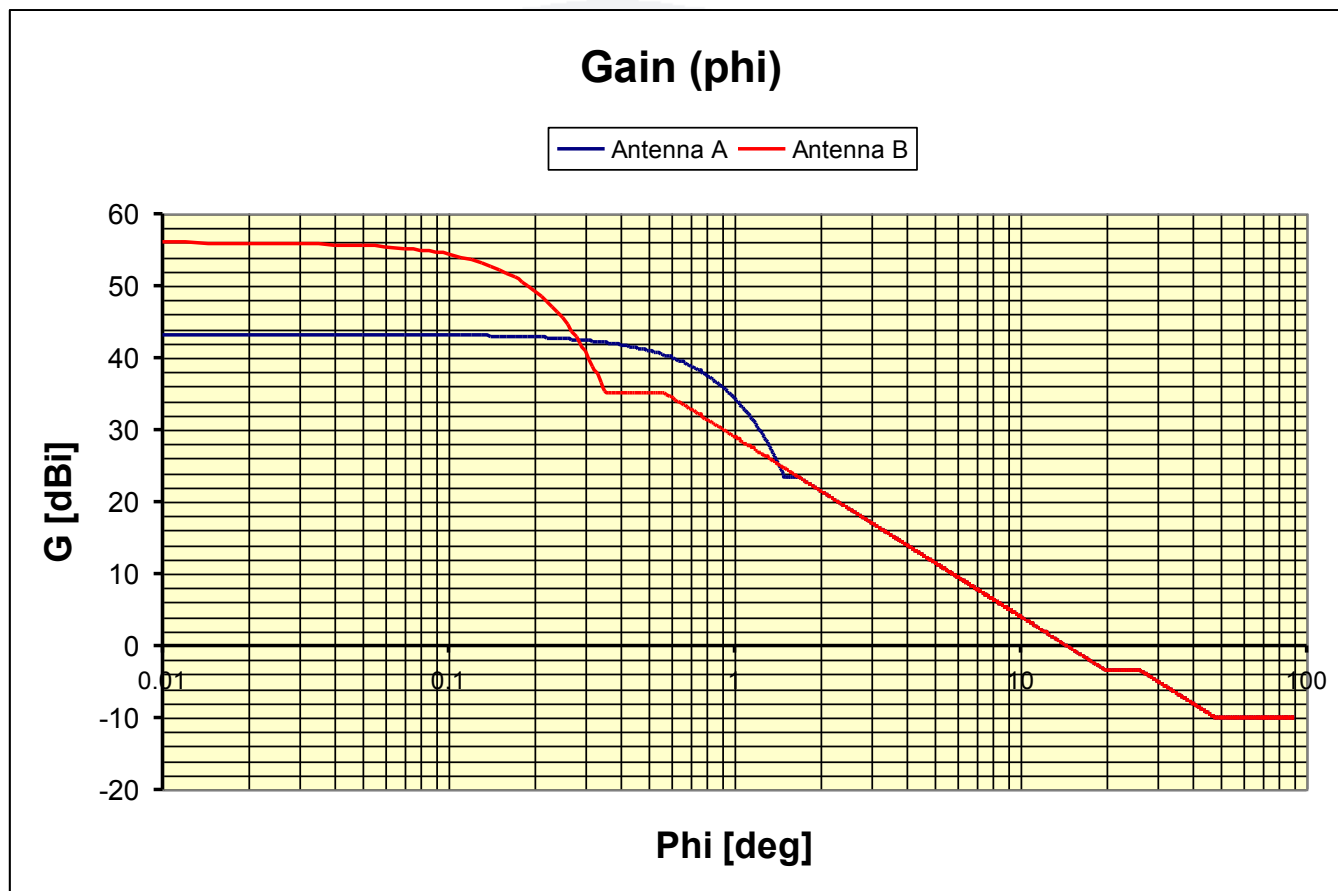
Mainlobe and Near-Sidelobes REC-580-6 Antenna Pattern

Antenna A

G1 =	23.34
Phi m =	1.50
D/L =	59.40
Phi r =	1.68
Phi b=	47.86
Beamwidth=	1.17

Antenna B

G1 =	35.21
Phi m =	0.35
D/L =	259.28
Phi r =	0.56
Phi b=	47.86
Beamwidth=	0.27



REFERENCES - COMMENTS:

Antenna A= Typical 1.2M

Antenna B= Typical 13M

Reorganizing distribution of different types of carrier

- ✓ To identify different types of carriers such as:
 - TT&C
 - Analog TV/FM
 - Digital Data
- ✓ To consider their characteristics of diversity in terms of BW, Max. Power and spectral density distribution.
- ✓ To group them in the frequency domain taking into account the distribution of similar carriers used by neighboring satellites.
- ✓ Off-axis eirp masks associated to type of carriers and frequency bands, as well as operational restrictions or relaxations, may be agreed during the coordination process.



- ❑ Administrations are free to choose the way to organize a filing
- ❑ Coordination Request: {
 - needs certain flexibility of parameters
 - may be a General Approach
- ❑ Notification: {
 - specific
 - accurate parameters
 - realistic

Filing is Group Structured



BR6a/BR6b Id. no. 103500259 BR3a/BR3b Provision reference 11.2 N BR2 Adm. serial no. KR1 R

BR62 Expiry date for bringing into use BR63 Confirmed date of bringing into use BR64 Date of receipt of 1st Res49

BR14 Special Section

C4a Class of station EC EK ED C3a Assigned freq. band 36000 C5a Noise temperature 600

C4b Nature of service CO CP CV C6a Polarization type V C6b Polarization angle

C11a1 Service area no. 1 C11a2 Service area C11a3 Service area diagram 2

A13 Co-ordination agreements .7 O AUS USA/IT

C2a1 Assigned frequency					
14.02	GHz	14.1	GHz	14.18	GHz
14.06	GHz	14.14	GHz	14.22	GHz
14.26	GHz	14.34	GHz		
14.3	GHz	14.38	GHz		

A13 Ref. to Special Sections	C7a Design. of emission	C7a1/C7a1 Max. peak pwr	C7a2/C7a2 Max. pwr dens.	C7c1 Min. peak pwr	C7c2 Attach.	C7c3 Min. pwr dens.	C7c4 Attach.	C7e1 C/N ratio	C8e2 Attach.
AR11/A /1147	1 14K0G7W--	-19.4	-60	-32.2		-72.8		6.8	
AR11/C /3147	2 15M0G7W--	22	-49.2	5.3		-65.9		1.3	
	3 36M0G7W--	18.4	-57.1	1.7		-73.8		5.1	
	4 5K00G1X--	-11.8	-47.5	-32.2		-68		8.5	
	6 5M00G1X--	12.7	-51.2	-7.7		-71.7		4.8	
	7 7M89G7W--	15.1	-53.2	-1.6		-69.9		0.9	

C10b1 Assoc. earth station id.	C10b2 Type	C10c1 Geographical coord.	C10c2 Ctry	C10d1/C10d2 Cls. / Nat.	C10d3 Max. iso. gain	C10d4 Bmwidth	C10d7 Ant. diameter	C8g1 Max. aggr. pwr.	C8g2 Aggr. bandwidth	C8g3 Transp. bandwidth = Aggr. bandwidth
STD D	T			1 TC 2 TK 3 TD	52	0.39				
STD E	T			1 TC 2 TK 3 TD	47.6	0.72				
STD F	T			1 TC 2 TK	45.1	1.41				
STD G	T			1 TC 2 TK	41.2	1.41				

C10d5a Co-polar antenna pattern							
C10b1 Assoc. earth station id.	Co-polar ref. pattern	Coef. A	Coef. B	Coef. C	Coef. D	Phi1	Co-polar rad. diag.
STD F	REC-580						
STD D	REC-580						
STD E	REC-580						
STD G	REC-580						

13C Remarks

Diversity of: Beam/Service Areas



Frequencies



Emissions



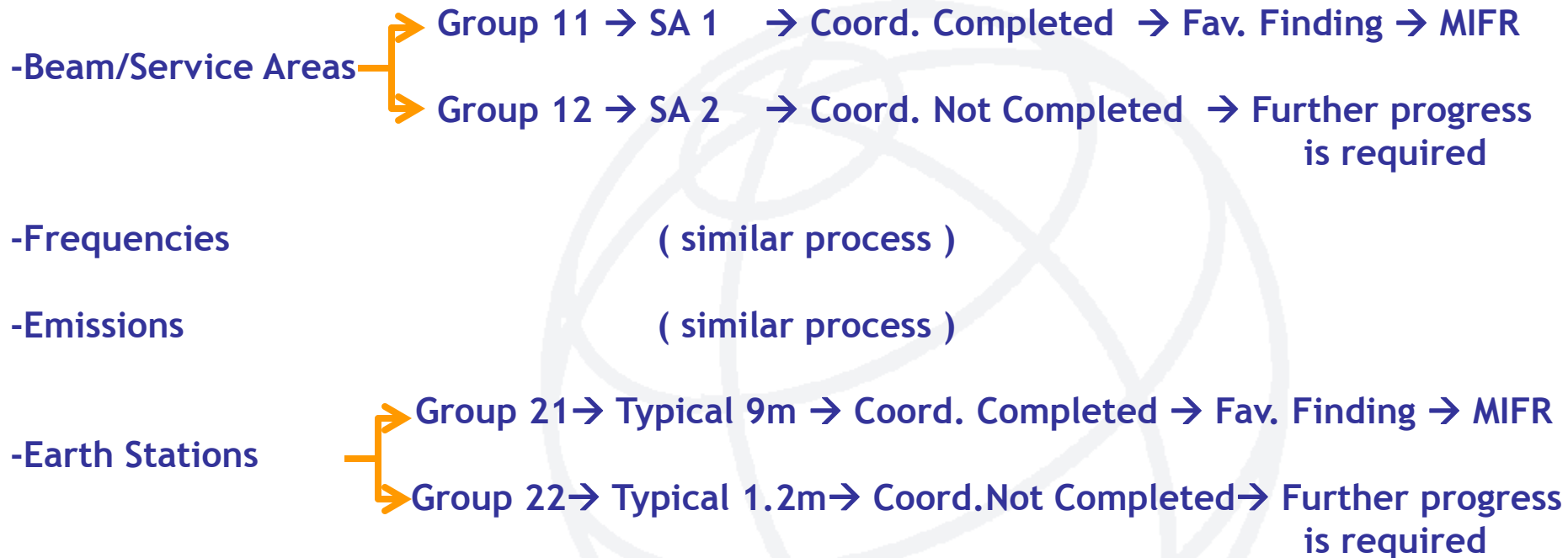
Earth Stations



Reorganize Filing considering diversity of frequency assignments and respective progress in coordination



For example: To split groups of frequency assignments by



Remarks: locating worst cases in separated groups will ensure recording of successfully coordinated frequency assignments.

Some Useful Recommendations:

- ITU-R S.741-2 Carrier-to-interference calculations between networks in the FSS.
- ITU-R S.740 Technical coordination methods for fixed-satellite networks
Rules of Procedure of Radio Regulations Board associated to C/I analysis under 11.32A
- ITU-R SM.1132 General principles and methods for sharing between
radiocommunication services or between radio stations
- ITU-R S.738 Procedure for determining if coordination is required between
geostationary-satellite networks sharing the same frequency bands
- UIT-R S.580-6 Radiation diagrams for use as design objectives for antennas of earth
stations operating with geostationary satellites
- UIT-R S.465-5 Reference radiation pattern of earth station antennas in the fixed-
satellite service for use in coordination and interference assessment in
the frequency range from 2 to 31 GHz
- UIT-R S.1855 Alternative reference radiation pattern for earth station antennas
used with satellites in the geostationary-satellite orbit for use in
coordination and/or interference assessment in the frequency range
from 2 to 31GHz
- UIT-R SF.766 Methods for determining the effects of interference on the
performance and the availability of terrestrial radio-relay systems and
systems in the fixed-satellite service
- Appendix 8 to Radio Regulations (Volume 2 of RR)
Handbook on Satellite Communications - ITU, Wiley

Questions?

Thank You !