

Link Budget Estimate Satcom ABC series (7)



Introduction

Transponder Specifications C/N and C/(N+I) Calculation

C/T and C/N Interference and rain fade

Earth Station and Carrier Parameters

Target for Link Design

Antenna size Carrier parameter BW and power

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Link margin Carrier monitoring and management

Sample of Link Budget

- Satellite, E/S and carrier parameters
- C/N and margin Statistics for resource
- Link Budget Optimization

Conclusion

Satellite Communication Links^{CHINA APMT}



Links and Loss

Up-link

➤ the link from E/S to satellite

Down-link

➤ the link from satellite to E/S

Free space loss

- Ioss between E/S and satellite
- ➢ both in up-link and down-link
- ➤ at long distance transmission
 ⇒ f, radio frequency
 - \Rightarrow 1, 12010 frequency \Rightarrow d. transmission distort
 - ⇒d, transmission distance
 - \Rightarrow c, light speed
- free space loss in dB

[L]= 92.45 + 20 lg d + 20 lg f

 $L = \left(\frac{4\pi f d}{c}\right)^2$

Carrier Level in Satellite Links CHINA APMT



Link Budget

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Communication link design

- ➤ to get E/S parameters
 - ⇒ from desired transponder and carrier parameters
- ➤ to get carrier parameters

 \Rightarrow from desired transponder and E/S parameters

➤ to adjust carrier power and Eb/N₀ margin
⇒ from desired E/S and carrier parameters

Link parameter adjustment

➢ for transponder resource

 \Rightarrow to match BW and power percentages

➤ for link design

 \Rightarrow to match E/S and carrier parameters

for earth station

⇒ to match antenna size and HPA power

Link Budget (cont.)

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- Link margin verifying
 - estimated carrier C/N
 - link margin
 - ➤ availability

 \Rightarrow under the interference and rain fade condition

- Carrier link optimization
 - optimization for link margin
 - adjusting SFD for raising total C/N
 - power adjustment for star network

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Conclusion

EIRP

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PT

LF

 G_T

 $[EIRP] = 10 \text{ Ig } P_T + 10 \text{ Ig } G_T - 10 \text{ Ig } L_F$

✤ EIRP_e

➢ EIRP of the E/S

✤ EIRP_s

EIRP of the Satellite

G/T

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- Figure of merit for receive system
- The ratio of antenna receive gain to thermal noise
 - ➤ G, antenna receive gain

$$G = \eta \left(\frac{\pi f D}{c}\right)^2$$

 \Rightarrow f, radio frequency

⇒ D, antenna diameter

 \Rightarrow c, light speed

 $\Rightarrow \eta, \, \text{antenna efficiency}$

T, equivalent thermal noise of receive system

✤ G/T in dB [G/T] = 10 lg G - 10 lg T

✤ FD

- Power flux density
- The power at the unit area from a omni-directional radiation power (P_T) which pass through a transmission distance (d)

$$FD = \frac{P_T}{4\pi d^2} \qquad (W/m^2)$$

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✤ SFD

- saturated power flux density of the satellite transponder
- the FD that happen to drive the transponder output power at the saturated point

$$SFD = \frac{EIRP_e}{4\pi d_u^2} \qquad (W/m^2)$$



Gain Mode and Gain step SettingHINA APMT

FGM

- Fixed gain mode
- SFD vs. G/T for LaoSat-1
 - $\Rightarrow SFD = (70 \text{ to } 93 + G/T)$
 - \Rightarrow SFD = -71 to -94 dBW/m² for C-band
 - \Rightarrow SFD = -82 to -105 dBW/m² for Ku-band
- Gain step setting relative to proper SFD
 - \Rightarrow for SFD at around -90 dBW/m²
 - ⇒ gain step set at 4dB for C-band
 - ⇒ gain step set at 15dB for Ku-band

✤ ALC

- Auto level control mode
- Only for single carrier usage in Ku-band

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C/N and C/T

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✤ C/N

- ratio of carrier power (C) noise power (N)
- showing transmission performance of the communication link

$rightarrow T_e$

Equivalent thermal noise

$$T_e = \frac{P_N}{kB}$$

 $\Rightarrow P_N$, noise power

⇒k, BOSSMAN constant

⇒B, bandwidth

✤ C/T

ratio of carrier power (C) thermal noise (T)

 $N = kB T_e$ $C/N = C/(kB T_e) = C/T / kB$

Formulas for C/N and C/T

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✤ C/T in dB

```
➢ U/L and D/L
[C/T]_U = [EIRP_E] - [loss_U] - [G/T_S]
[C/T]_D = [EIRP_S] - [loss_D] - [G/T_E]
```

✤ C/N in dB

 \succ both in U/L and D/L

 $[C/N] = [C/T] - [k] - [BW_N] = [C/T] + 228.6 - [BW_N]$

⇒ k, BOSSMAN constant

 \Rightarrow BW_N, carrier noise bandwidth

Total C/T and C/N

➤ to get U/L and D/L C/T (or C/N)

➤ and then the total C/T (or C/N)

CHINA APMT C/T_U, C/T_D and C/T_{Total} repeater G/T_S EIRP_S $C/T_{U} = EIRP_{E} - loss_{U} + G/T_{S}$ $C/T_D = EIRP_S - loss_D + G/T_E$ EIRPF G/T_E C/T_{Total} Tx E/S Rx E/S

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Interference

Adjacent satellite interference (ASI)

- ➤ up-link interference
 - ⇒ up-link power from interfering E/S to interfered satellite
- down-link interference
 down-link power from
 interfering satellite to
 interfered E/S
- ➢ figure for ASI
 - ⇒ A, interfered system
 ⇒ B, interfering system
 ⇒ β, orbital space
 between interfered and interfering satellites



Interference (cont.)

Inter-modulation interference (IMI)

- > up-link interference
 - Srd order inter-modulation product caused by HPA at multi-carrier operation
- down-link interference

⇒ 3IM product caused by satellite transponder at multi-carrier operation

- Cross-pol interference (XPI)
 - interference caused by insufficient cross-pol discrimination (XPD)
- ✤ Adjacent carrier interference (ACI)
 - interference caused by less guard band between adjacent carriers



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✤ C/(N+I)

C/N including interference

✤ C/(N+I) in dB

$$\begin{split} & [C/(N+I)]_{U} = [C/N]_{U} - [ASI_{U}] - [IMI_{U}] \\ & [C/(N+I)]_{D} = [C/N]_{D} - [ASI_{D}] - [IMI_{D}] \\ & [C/(N+I)]_{Total} = [C/N]_{Total} - [XPI] - [ACI] \end{split}$$

✤ C/(N+I) estimate

- impossible to get accurate result
- data validity

 \Rightarrow 3.0 + 2.3 = 5.3

 \Rightarrow 3 + 2.3 = (2.5 to 3.4) + 2.3 = (4.8 to 5.7) = 5

➤ estimate

⇒ 1dB for C-band and 2dB for Ku-band

⇒ case by case for small antennas with narrow orbital space, and improper conditions

Rain Attenuation

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Attenuation

➢ normally in Ku above band

 \Rightarrow fading carrier level

⇒ raising noise floor

➤ time availability

⇒ 99%, 99.5%, 99.9%, 99.95%, even 99.99% available in a year
⇒ depending on rain zone, rain height, antenna EI, freq. & pol., etc.

Compensation

- ➢ UPC and ALC at U/L
- allowance at D/L

Estimate

- ➤ (6 and) 5 dB at (U/L and) D/L for rain fade
- 1 to 2 dB at total for thermal noise



Earth Station Parameters

- ✤ Antenna gain
 - ➤ antenna size
 - ➤ frequency
 - efficiency
 - ⇔60%, 65%, or 70%
- ✤ HPA power
 - plentiful margin
- **☆** G/T
 - System T ⇒ 85k for C-band ⇒ 120k for Ku-band

Carrier Parameters

- Modulation type
 > BPSK, QPSK, 8PSK and 8QAM
- Coding rate
 - ➢ FEC at 1/2, 2/3, 3/4, 5/6, or 7/8, etc.
 - ➢ R-S at (204, 188)
 - required Eb/N₀ depending on coding rate and decoding type according to MODEM manual

Transmission Index

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✤ P_b
➢ bit error rate

✤ Eb/N₀

- ➢ Eb, signal energy per bit
- $> N_0$, noise spectral density

★ Eb/N₀ vs. C/N
$$\frac{E_b}{N_0} = \left(\frac{C}{N}\right) \frac{B}{R_b}$$

$$\Rightarrow B, \text{ noise bandwidth}$$

$$\Rightarrow R_b, \text{ information rate}$$

Carrier Parameters (cont.)

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Bandwidth

- Information rate
- ➤ coding rate

⇒ higher than information rate after encoded

 \Rightarrow dividing by 1, 2, 3, or 4 for BP, QP, 8P, or 16P

➤ noise BW

 \Rightarrow 1.2 times of coding rate

➤ occupied BW

 \Rightarrow 1.4 (or 1.3⁺) times of coding rate

➤ allocated BW

 \Rightarrow equal and wider than OBW with guard band

Gain Transfer Curve



Power Assignment

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O.5 to 1 dB output back-off (OBO) for full BW carrier to avoid AM/PM distortion

✤ 3dB OBO for transponder in multi-carrier utilization

carrier back-off as the ratio of allocated BW to XPD BW

 \Rightarrow OBO_{1/2BW} = 3 + 3 (dB)

 \Rightarrow OBO_{1/4BW} = 3 + 6 (dB)

⇒ OBO_{1/10BW} = 3 + 10 (dB)

➢ balancing power percentage with the bandwidth percentage
 ⇒ for multi-carrier system assigned by a single consumer
 ⇒ less back-off for the carrier from large antennas to small ones
 ⇒ more back-off for the carrier from small antennas to large ones
 ➢ higher payment for higher power assignment

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Link Design

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E/S parameters

- ➤ to get antenna size and HPA power
- From desired transponder and carrier parameters
- Carrier parameters
 - get modulation type and coding rate
 - From desired transponder and earth station parameters

Carrier power

- > to be balanced with carrier bandwidth
- > or to be adjusted as more power or less power
- From desired transponder, E/S and carrier parameters

Link Margin

✤ Clear sky

- ➤ to get carrier C/N
 - ⇒ from desired transponder, earth station and carrier parameters
- ➤ to get C/(N+I)
 - ⇒ from C/N and interference which mainly relative to Rx antenna size and orbital gap

- ➤ to get link margin
 - \Rightarrow at least 1dB for C-band
 - \Rightarrow 2dB or above for Ku-band

Link Margin (cont.)

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Rain fade condition

- ➤ rain attenuation
 - ⇒ relative to availability
- > U/L power
 - ⇒ compensated by UPC and/or ALC
- ≻ D/L EIRP
 - \Rightarrow reserved margin
- ➤ thermal noise
 - ⇒ about 6k for 0.1dB attenuation
 - ⇒1 to 2 dB?
- adaptive coding and modulation
- link margin
 - ⇒ about 5dB for Ku-band?

Carriers monitoring and managemethe APMT

One transponder per sheet

- > only for satellite operator
- ➤ carriers listed one by one
- sequenced by center frequency
- Rx antenna 2 at SCC
 - carriers' C/N monitored at SCC
 - For comparing occupied and allocated power of the carriers

⇒ allocated power, specified by satellite operator

⇒ occupied power, actually launched by user

- Bandwidth and power resource statistics
 - balancing total BW and power resource for a group of carriers of one user

statistical data of occupied resource for whole transponder

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Link Budget - Sample p.1 Satellite and carrier parameters

	1. 0.	E E	H			
1		Out-Route1	In-Route1	DVB-S2	TOTAL	NOTE
2						
3	卫星轨位 (deg E)	128.5	128.5	128.5	128.5	
4	转发器和载波设置					
5	转发器衰减档 (dB)	-16	-16	-16	-16	调低SFD灵敏度以增大上行功率,从而提高上行C/T并获较高的系统C/T
5	输出回退 (dB)	12.9	25.3	3.6	3.0	
3	输入回退 (dB)	15.9	28.3	6.6	6.0	
3	上行频率 (MHz)	12833.6	12835.9	12844.5	12850	
0	下行频率 (MHz)	10773.6	10775.9	10784.5	10790	
1	转发器参数					
2	转发器 SFD (dBw/m ²)	-89.0	-89.0	-89.0	-105.0	Total所列参数为SFD的最灵敏值;调低SFD灵敏度后,需要提高上行功率
3	接收系统G/T (dB/k)	12.0	12.0	12.0	12.0	
4	下行饱和EIRP (dBw)	57.0	57.0	57.0	57.0	
5	载波参数	1 1000040		0.00000	Constanting of the second s	
6	调制方式	8PSK	8PSK	QPSK		左侧二列为饱和功率及线性功率条件下的DVB-S2,右侧二列采用503所选
7	信息速率 (kbps)	6000	2000	44000		择的载波编码参数,中间三列为对503参数作修改后另添一个DVB-S2载
8	FEC编码率	0.875	0.875	0.67		波; 宽带和窄带载波分别采用LDPC和Turbo编解码
9	R-S编码率	1	1	1		
0	符号速率 (kbps)	2286	762	33000		
1	噪声带宽 (kHz)	2743	914	39600		1
2	占用带宽 (kHz)	3200	1067	46200		
:3	分配带宽 (kHz)	3200	1100	47000	54000	
:4	系统要求的E _b /N _o (dB)	9.0	10.0	3.0		左5列为经验值,右2列为503提供参数
E						

Transponder and carrier setting HINA APMT

- ✤ Gain step setting
 - compared with the most sensitive SFD
- Output back-off
 - carrier power balanced with bandwidth
 - adjustable on demand and contract
- Input back-off
 - same difference between OBO and IBO
 for both single carrier and whole transponder
 in linier condition
- Center frequency
 - \succ U/L and D/L

Transponder specification

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Getting the data

- Relative to earth station location
 - \Rightarrow from city table
 - \Rightarrow or from contour map

SFD

adjusted by gain step setting rightarrow from the most sensitive one

✤ G/T

✤ EIRP

Carrier parameters

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✤ ModCod

- modulation type
- ➤ coding rate
- Data rate
 - ➤ information rate
 - ⇒ without or with overhead
 - ➤ symbol rate

 \Rightarrow depend on information rate, modulation type and coding rate

Carrier parameters (cont.)

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Bandwidth

- noise bandwidth
 - \Rightarrow 1.2 times of symbol rate
- occupied bandwidth
 - \Rightarrow 1.4 times of symbol rate
 - \Rightarrow considering MODEM operation manual
- allocated bandwidth
 - ⇒ considered with occupied bandwidth and guard band

✤ Required Eb/N₀

- depended on modulation type and coding rate
- based on MODEM operation manual

Link Budget - Sample p.2 Earth station parameters

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Image: Constraint of the system of		A	U	E	ar:	1	J	
2	1		Out-Route1	In-Route1	DVB-S2	TOTAL	NOTE	
5 上方弦参数 13 13 13 14 7 天気口径(m) 13 13 13 13 9 地球式新压地 万象 万象 5% 5% 10 纬度(deg) 102.6 102.6 102.6 102.6 11 到口屋距离(km) 36821 36821 36821 2 天気角角(deg) 52.6 52.6 52.6 3 天気方位角(deg) 124.9 124.9 124.9 4 天気空(%) 65 65 65 5 天気着着(dB) 63.0 42.3 63.0 6 旧学时的波波力像(bw) 26.8 7.8 7.8 7 市会时的波波力像(bw) -4.7 3.0 4.6 6 市会时的波波力像(bw) -4.7 3.0 4.6 7 市会地域上の山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山山	2							
7 天気口谷(m) 13 1.2 13 8 地球抗所在地 万愈 万愈 万愈 9 经度(deg F) 102.6 102.6 102.6 11 912星北高(km) 36921 36921 2 天线肉倚(deg) 52.6 52.6 2 天线肉倚(deg) 124.9 124.9 2 天线肉倚(deg) 124.9 124.9 2 天线肉倚(deg) 65.0 65.0 5 天线道谷(BN) 65.0 65.0 5 天线道谷(BN) 64.0 30.0 16 HPA最大輸出功享(dBW) -4.7 3.0 4.6 17 師宮时的演演功享(dBW) -4.7 3.0 4.6 18 moethon事余量(dB) 32.0 8.8 12.0 18 moethon事余量(dB) 32.0 4.6 12.0 18 #Sethonmas(dB) 32.0 4.6 12.0 14 地球抗術在地 万愈 万象 12.6 12.6 12 修復(deg N) 1.	6	上行站参数						
9 地球站所在地 万余 万余 万余 9 28度 (deg F) 102.6 102.6 102.6 9 98 (deg N) 19.8 19.8 18.8 10 91 (ge N) 19.8 19.8 18.8 11 91 (ge N) 52.6 52.6 52.6 12 天线方仓角 (deg) 124.9 124.9 124.9 14 天线安倉 (%) 65. 65. 15 天线常췁 (dB) 63.0 42.3 63.0 16 HPAA 大給出力享 (dBW) 28.8 76.8 75.8 17 晴空时的游享力章 (dBW) 28.8 76.8 75.8 18 宇空时的游享力章 (dBW) 28.8 76.8 75.8 19 万余 38.9 76.8 75.8 10 天台電力力算力(dBW) 28.8 75.8 75.8 10 天台電 (M) 1.2 1.6 75.8 10 天台湾 (Ge (m) 1.2 1.8 75.8 12 安台湾 (Ge N) 19.8	:7	天线口径 (m)	13	1.2	13			Γ
9 9	:8	地球站所在地	万象	万象	万象			
9 纬度 (deg N) 19.8 19.8 19.8 1 212星距离 (km) 36921 36921 2 天线内位 (deg) 52.6 52.6 52.6 3 天线文位 (deg) 124.9 124.9 124.9 4 天线效率 (%) 65. 65. 65. 5 天线 化 (dB) 12.0 28.8 12.0 6 HPA 具大輸出力率 (dBw) 28.8 12.0 28.8 功助功率为750%与10% 7 晴空时的顶系力率 (dBw) -4.7 3.0 4.6 8 晴空时的顶系力率 (dBw) -4.7 3.0 4.6 9 下方站 参数 12.0 28.8 12.0 28.8 12.0 9 大行 ふ (dB) 32.0 78 48 149 149 10 大気 小 (m) 1.2 13 0.45 142.6 142.6 11 地球 小 (m) 1.2 13 0.45 142.6 142.6 12 冬生焼 (deg N) 19.8 19.8 <	9	经度 (deg E)	102.6	102.6	102.6			Γ
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3 天気方位角 (deg) 124.9 124.9 124.9 4 天気效率 (%) 65 65 65 65 65 5 天気物量 (dB) 66.0 42.3 63.0 42.3 63.0 42.3 6 HPA最大输出功率 (dBW) 28.8 12.0 28.8 功放功率为750%与10% 7 諸空时的功率余俚 (dB) -4.7 3.0 4.6 22.7 60.0 75.0 75.0 9 下行 計卷致 -4.7 3.0 4.6 22.7 60.0 75.0 75.0 75.0 9 下行 計卷数 -4.7 3.0 4.6 22.7 60.0 75.0 75.0 9 天行 計卷数 -4.7 3.0 4.6 22.7 60.0 75.0 75.0 10 天気 打各 -4.7 1.2 1.2 0.45 -4.5 75.0 75.0 11 地球所在他 万象 万象 78.0 9.8 19.8 -4.6 -4.6 12 天気均角 (deg) 12.4 9.8 19.8 -4.6 -4.6 -4.6 -4.6 <t< td=""><td>12</td><td>天线仰角 (deg)</td><td>52.6</td><td>52.6</td><td>52.6</td><td></td><td></td><td></td></t<>	12	天线仰角 (deg)	52.6	52.6	52.6			
4 天我常益(4B) 65 65 65 5 天我常益(4B) 63.0 42.3 63.0 功劢功率为750Ψ与10Ψ 6 HPAb大输出功率(4Bw) 28.8 功劢功率为750Ψ与10Ψ 7 瑞空时的演激功率(4BW) 28.8 功劢功率为750Ψ与10Ψ 8 管时的功率余里(4B) 32.0 8.8 D 9 所有益参数 -4.7 3.0 4.6 - 9 下有益参数 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 万有益参数 1.2 13 0.45 - 10 大抗介在(10) 1.2.6 102.6 102.6 102.6 - 12 经度(deg I) 19.8 19.8 19.8 - - 13 纬見(deg) 19.8 19.8 - - - 14 到卫星距离(MD) 36921 36921 - - - 15 天线加拿(M) 18.8 19.8 - - - 15 天线加拿(MB)	13	天线方位角 (deg)	124.9	124.9	124.9			
5 天銀増益(dBi) 63.0 42.3 63.0 6 HPA最大输出功率(dBw) 28.8 12.0 28.8 功放功率为750V与10V 7 瑞空时的溃坂亦 (dBw) -4.7 3.0 4.6 功放功率为750V与10V 8 瑞空时的赤余里(dB) 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 万行站参数 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 10 大线口径(m) 1.2 13 0.45 11 地球訪所在地 万象 万象 万象 2 終度(deg I) 102.6 102.6 102.6 102.6 102.6 3 纬度(deg N) 19.8 19.8 19.8 3 纬度(deg) 52.6 52.6 52.6 5 天线均角(deg) 124.9 124.9 6 天线增益(dBi) 40.8 52.2 7 天线改會上 20.0 20.0 20.0 8 天线增益(dBi) 40.8 51.5 52.4 <td>4</td> <td>天线效率 (%)</td> <td>65</td> <td>65</td> <td>65</td> <td></td> <td></td> <td></td>	4	天线效率 (%)	65	65	65			
16 HPA最大输出功率(dBw) 28.8 功放功率为750Ψ与10Ψ 7 商空时的诱策功率(dBw) -4.7 3.0 4.6 8 節空时的功率余里(dB) 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 万拾参数 6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 10 天行站参数 7.8 7.8 8.6 11 地球站所在地 万象 7.8 7.8 12 经度(deg E) 102.6 102.6 102.6 13 纬度(deg N) 19.8 19.8 19.8 14 到卫星距离(km) 36921 36921 36921 15 天线仰角(deg) 52.6 52.6 52.6 16 天线小角(deg) 124.9 124.9 124.9 17 天线效率(%) 65 65 65 18 天线小着(dBl) 20.0 20.0 503取值为30.3dB/k与16.2dB/k 19 新校端奏道(dBl) 61.5 12.2 503取值为30.3dB/k与16.2dB/k 14 加拾菜一台(dBl) 61.5 12.2 503取值为30.3dB/k与16.2dB/k 15 天线電着(dBl) 61.5 61.5 51	15	天线增益 (dBi)	63.0	42.3	63.0			
7 第空时的溃疡功率(dBw) -4.7 3.0 4.6 8 第空时的功率余里(dB) 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 万式参数 1.2 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 万式参数 1.2 13 0.45 10 天线口径 (m) 1.2 13 0.45 12 地球抗所在地 万象 万象 102.6 102.6 12 经度 (deg P) 102.6 102.6 102.6 102.6 19 9.8 19.8 19.8 19.8 19.8 14 列足距离 (km) 36921 36921 36921 15 天线角 (deg) 124.9 124.9 17 天线效率 (%) 65 65 18 天线操電 (dB) 40.8 61.5 32.2 19 系統噪声過優 (dBk) 20.0 20.0 503取值为30.3dB/k与16.2dB/k 13 13	6	HPA最大输出功率 (dBw)	28.8	12.0	28.8		功放功率为750W与10W	
8 第空时的功率余量(dB) 32.0 8.6 22.7 假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB 9 下行站参数 </td <td>17</td> <td>晴空时的溃源功率 (dBw)</td> <td>-4.7</td> <td>3.0</td> <td>4.6</td> <td></td> <td></td> <td></td>	17	晴空时的溃源功率 (dBw)	-4.7	3.0	4.6			
9 下行站参数 1 <th1< th=""> 1 1 1<td>18</td><td>晴空时的功率余里 (dB)</td><td>32.0</td><td>8.6</td><td>22.7</td><td></td><td>假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB</td><td></td></th1<>	18	晴空时的功率余里 (dB)	32.0	8.6	22.7		假设大站波导损耗为1.5dB,小站电缆损耗为0.5dB	
0 天线口径(m) 1.2 13 0.45 1 地球站所在地 万象 万象 万象 12 经度(deg E) 102.6 102.6 102.6 13 纬度(deg N) 19.8 19.8 19.8 14 到卫星距离(km) 36921 36921 36921 15 天线仰角(deg) 52.6 52.6 52.6 16 天线方位角(deg) 124.9 124.9 124.9 17 天线效率(%) 65 65 65 18 天线增益(dBi) 40.8 61.5 32.2 19 系统噪声温度(dBk) 20.0 20.0 20.0 14 测控站参数 13 12.2 503取值为30.3dB/k与16.2dB/k 15 天线增益(dBi) 61.5 61.5 16 天线增益(dBi) 13 13 17 天线增益(dBi) 61.5 61.5 18 天线增益(dBi) 61.5 13 19 系统噪声温度(dBk) 20.0 20.0 10 天线增益(dBi) 61.5 61.5 11 系统噪声温度(dBk) 20.0 <t< td=""><td>19</td><td><u>下行站参数</u></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	19	<u>下行站参数</u>						
1 地球站所在地 万象 万象 万象 12 经度 (deg E) 102.6 102.6 102.6 13 纬度 (deg N) 19.8 19.8 19.8 14 到卫星距离 (km) 36921 36921 36921 15 天线仰角 (deg) 52.6 52.6 52.6 16 天线方位角 (deg) 124.9 124.9 124.9 17 天线效率 (%) 65 65 65 18 天线增益 (dBi) 40.8 61.5 32.2 19 系统噪声温度 (dBk) 20.0 20.0 20.0 10 接收系统G/T (dB/k) 20.8 41.5 12.2 13 13 13 503取值为30.3dB/k与16.2dB/k 14 测控站参数 13 13 13 15 氏1.5 61.5 61.5 11 系统噪声温度 (dBk) 20.0 20.0 20.0	10	天线口径 (m)	1.2	13	0.45			
12 经度 (deg E) 102.6 102.6 102.6 13 纬度 (deg N) 19.8 19.8 19.8 14 到卫星距离 (km) 36921 36921 36921 15 天线仰角 (deg) 52.6 52.6 52.6 16 天线方位角 (deg) 124.9 124.9 124.9 17 天线效率 (%) 65 65 65 18 天线増益 (dBi) 40.8 61.5 32.2 19 系统噪声温度 (dBk) 20.0 20.0 20.0 10 接收系统G/T (dB/k) 20.8 41.5 12.2 17 天线增益 (dBi) 13 13 503取值为30.3dB/k与16.2dB/k 10 天线增益 (dBi) 61.5 61.5 61.5 10 天线增益 (dBi) 61.5 61.5 61.5 10 天线增益 (dBi) 61.5 61.5 61.5 10 天线増益 (dBi) 61.5 61.5 61.5 11 系统噪声温度 (dBk) 20.0 20.0 20.0	1	地球站所在地	万象	万象	万象			
13 纬度 (deg N) 19.8 19.8 19.8 14 到卫星距离 (km) 36921 36921 36921 15 天线仰角 (deg) 52.6 52.6 52.6 16 天线方位角 (deg) 124.9 124.9 124.9 17 天线增益 (dBi) 65 65 65 18 天线增益 (dBi) 40.8 61.5 32.2 19 系统噪声温度 (dBk) 20.0 20.0 20.0 10 接收系统G/T (dB/k) 20.8 41.5 12.2 12 天线增益 (dBi) 13 13 503取值为30.3dB/k与16.2dB/k 12 天线增益 (dBi) 61.5 61.5 61.5 13 13 13 13 13 10 天线增益 (dBi) 61.5 61.5 61.5 11 系统噪声温度 (dBk) 20.0 20.0 20.0 20.0	12	经度 (deg E)	102.6	102.6	102.6			
14 到卫星距离 (km) 36921 36921 36921 36921 15 天线仰角 (deg) 52.6 52.6 52.6 16 天线方位角 (deg) 124.9 124.9 124.9 17 天线增益 (dBi) 65 65 65 18 天线增益 (dBi) 40.8 61.5 32.2 19 系统噪声温度 (dBk) 20.0 20.0 20.0 10 接收系统GT (dB/k) 20.8 41.5 12.2 11 测控站参数 61.5 61.5 503取值为30.3dB/k与16.2dB/k 12 天线归径 (m) 13 13 13 10 天线增益 (dBi) 61.5 61.5 61.5 11 系统噪声温度 (dBk) 20.0 20.0 20.0	13	纬度 (deg N)	19.8	19.8	19.8			
S F34仰角(deg) 52.6 52.6 52.6 52.6 6 天3方位角(deg) 124.9 124.9 124.9 7 天3效率(%) 65 65 65 18 天3增益(dBi) 40.8 61.5 32.2 19 系统噪声温度(dBk) 20.0 20.0 20.0 10 接收系统GT(dB/k) 20.8 41.5 12.2 12 测控站参数 20.8 41.5 12.2 13 14 12.2 503取值为30.3dB/k与16.2dB/k 14 测控站参数 13 13 14 16 天线增益(dBi) 61.5 61.5 61.5 11 系统噪声温度(dBk) 20.0 20.0 20.0	4	到卫星距离 (km)	36921	36921	36921			
16 天线方位角(deg) 124.9 124.9 124.9 7 天线效率(%) 65 65 65 8 天线增益(dBi) 40.8 61.5 32.2 9 系统噪声温度(dBk) 20.0 20.0 20.0 10 接收系统GT (dB/k) 20.8 41.5 12.2 12 测控站参数 65 61.5 503取值为30.3dB/k与16.2dB/k 12 天线口径 (m) 13 13 13 13 561.5 61.5 61.5 14 系统噪声温度 (dBk) 20.0 20.0 20.0	15	天线仰角 (deg)	52.6	52.6	52.6			
7 天线效率 (%) 65 65 65 8 天线增益 (dBi) 40.8 61.5 32.2 9 系统噪声温度 (dBk) 20.0 20.0 20.0 0 接收系统G/T (dB/k) 20.8 41.5 12.2 1 测控站参数 40.5 12.2 503取值为30.3dB/k与16.2dB/k 2 天线口径 (m) 13 13 13 10 天线增益 (dBi) 61.5 61.5 61.5 11 系统噪声温度 (dBk) 20.0 20.0 20.0	16	天线方位角 (deg)	124.9	124.9	124.9			
8 天线增益(dBi) 40.8 61.5 32.2 9 系统噪声温度(dBk) 20.0 20.0 20.0 0 接收系统G/T (dB/k) 20.8 41.5 12.2 503取值为30.3dB/k与16.2dB/k 1 测控站参数	17	天线效率 (%)	65	65	65			
9 系统噪声温度(dBk) 20.0 20.0 20.0 0 接收系统GT(dB/k) 20.8 41.5 12.2 503取值为30.3dB/k与16.2dB/k 1 测控站参数 - - - - 2 天线口径(m) 13 13 - 10 天线增益(dBi) 61.5 61.5 61.5 11 系统噪声温度(dBk) 20.0 20.0 20.0	18	天线増益 (dBi)	40.8	61.5	32.2			
1 20.8 41.5 12.2 503取值为30.3dB/k与16.2dB/k 1 测控站参数	19	系统噪声温度 (dBk)	20.0	20.0	20.0			
測控站参数 I III III III III III III III IIII IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	0	接收系统G/T (dB/k)	20.8	41.5	12.2		503取值为30.3dB/k与16.2dB/k	
2 天线口径 (m) 13 13 13 0 天线增益 (dBi) 61.5 61.5 61.5 1 系统噪声温度 (dBk) 20.0 20.0 20.0	1	测控站参数						
0 天线增益 (dBi) 61.5 61.5 1 系统噪声温度 (dBk) 20.0 20.0	2	天线口径 (m)	13	13	13			
1 系统噪声温度 (dBk) 20.0 20.0 20.0	0	天线增益 (dBi)	61.5	61.5	61.5			
	1	系统噪声温度 (dBk)	20.0	20.0	20.0			
2 接收系统G/T (dB/k) 41.5 41.5	12	接收系统G/T (dB/k)	41.5	41.5	41.5			L

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Antenna and Pointing parameterHINA APMT

- Antenna parameter
 - ➤ antenna size
 - ➤ efficient
 - antenna gain

⇒ relative to antenna size, efficient and Tx or Rx frequency

- E/S location
 - Iongitude and latitude
- Elevation and azimuth
 - calculated by satellite orbit, E/S longitude and latitude
- Transmission distance
 - calculated by satellite orbit, E/S longitude and latitude



✤ HPA power

- ➢ in up-link station
- maximum power
 - ⇒ higher than power in clear sky + multi-carrier back-off + UPC range

- ➢ feed power in clear sky
 - ⇒ calculated as EIRPe Tx antenna gain
- margin in clear sky
 - \Rightarrow considering feed loss
- Multi-carrier usage
 - considering linear back-off
- UPC for rain attenuation
 - considering UPC range



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For both down-link and SCC station

☆ G/T

getting it from equipment supplier

System noise temperature

➢ 85k for C-band and 120k for Ku-band?

Formula for system T

 $T_{s} = T_{a} + (L_{F} - 1) T_{1} + L_{F} T_{e} (dBk)$

 \Rightarrow T_a, antenna noise temperature

- ⇒ T_e, LNA noise temperature
- \Rightarrow L_F, feed loss, about 0.2dB?
- \Rightarrow T₁, environment temperature at waveguide or cable

Link Budget - Sample p.3 C/N and margin

_	Α.	U	L			Li constance
1		Out-Route1	In-Route1	DVB-S2	TOTAL	NOTE
	<u>上行C/T</u>					
	晴空时的上行EIRP (dBw)	58.3	45.2	67.5		
	自由空间损耗 (dB)	206.0	206.0	206.0		
	天线跟踪误差 (dB)	0.8	0.2	0.8		
Č.	1 m ² 标准天线增益 (dBi/m ²)	43.6	43.6	43.6		
Ê	到达卫星的载波PFD (dBw/m ²)	-104.9	-117.3	-95.6		
	晴空时的上行C/T (dBw/k)	-136.5	-148.9	-127.2		假设上行降雨衰耗为6dB,并可被UPC及自适应调制编码技术所补偿
	<u>下行C/T</u>					
	载波下行EIRP (dBw)	44.1	31.7	53.4		
	自由空间损耗 (dB)	204.4	204.4	204.5		
	天线跟踪误差 (dB)	0.3	0.8	0.1		
1111	睛空时的下行C/T (dBw/k)	-139.9	-132.1	-138.9		
i.	降雨时的下行C/T (dBw/k)	-144.9	-137.1	-143.9		假设下行降雨衰耗为5dB
	系统总载噪比					
	晴空时的系统总C/T (dBw/k)	-141.5	-149.0	-139.2		
	波兹曼常数 (dBw/k-Hz)	-228.6	-228.6	-228.6		
	噪声带宽 (dB-Hz)	64.4	59.6	76.0		
	晴空时的系统总C/N (dB)	22.7	20.0	13.4		
i.	晴空时的系统总C/(N+I) (dB)	20.7	18.0	11.4		
	降雨时的系统总C/(N+I) (dB)	15.8	16.8	5.6		假设降雨时噪声底抬高1dB
	系统要求的C/N (dB)	12.4	13.4	3.5		
E.	晴空时的系统余里 (dB)	8.3	4.6	8.0		
Ē	降雨时的系统余里 (dB)	3.4	3.4	2.2		
	测控站下行C/T					
	载波下行EIRP (dBw)	44.1	31.7	53.4		
5	自由空间损耗 (dB)	204.4	204.4	204.5		
	天线跟踪误差 (dB)	0.3	0.3	0.3		
1	睛空时的下行C/T (dBw/k)	-119.2	-131.6	-109.9		
	测控站系统总载噪比					
	睛空时的系统总C/T (dBw/k)	-136.6	-149.0	-127.3		
2	睛空时的系统总C/N (dB)	27.6	20.0	25.3		因频段特殊,几无邻星干扰(若有则小口径接收天线的C/N将更差),假
3	晴空时的系统总C/(N+I) (dB)	26.6	19.0	24.3		设晴空条件下各项干扰将C/N拉下2dB
6						饱和载波C/(N+I)的实测值比估算值高约?dB

Up-link C/T

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Carrier PFD

calculated by transponder SFD - carrier OBO

Losses

- ➤ free space loss
- > antenna pointing error and others

✤ EIRPe

> calculated by PFD, losses, and 1m² standard antenna gain

✤ C/T_U

- ➢ equal to EIRPe losses + G/Ts
- considering rain fade if no UPC and/or ALC in rain for Ku-band

Down-link C/T

CHINA APMT

✤ EIRPs

calculated by transponder EIRP - carrier OBO

Losses

- ➢ free space loss
- > antenna pointing error and others
- ✤ C/T_D
 - ➢ equal to EIRPs losses + G/Te

 \Rightarrow in clear sky

equal to EIRPs - rain fade - losses + G/Te

⇒ in rain for Ku-band

Total C/T, C/N and C/(N+I)

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♦ C/T_{Total}
> calculated by the formula below $\frac{1}{C/T} = \frac{1}{(C/T)u} + \frac{1}{(C/T)d}$ > in clear sky and in rain condition

✤ C/N_{Total}

> converted by the formula below $[C/N] = [C/T] + 228.6 - [BW_N]$

- ✤ C/(N+I)_{Total}
 - ➤ considering C/ASI, C/XPI for both C/T_U and C/T_D
 - ➤ considering C/IMI, C/ACI for C/T_{Total}
 - not used in this sample of link budget sheet

Total C/T, C/N and C/(N+I) (cont.)^{CHINA APMT}

Estimated C/(N+I)_{Total}

- IdB worse than C/N_{Total} for C-band
- > 2dB worse than C/N_{Total} for Ku-band in clear sky
- ➢ 3dB worse than C/N_{Total} for Ku-band at about 5dB rain fade
- reconsidering ASI at very small antenna with narrow orbital gap

Link margin

- calculated by C/(N+I)_{Total} required Eb/N₀
- \succ in clear sky and in rain condition

Link Budget - Sample p.4 Statistics for transponder resources

	527		-			×
		Out-Route1	In-Route1	DVB-S2	TOTAL	NOTE
2		-				
17	系统资源统计					
)8	载波数	1	3	1	9	
99	晴空时的系统余里 (dB)	8.3	4.6	8.0		
0	降雨时的系统余里 (dB)	3.4	3.4	2.2		
1	输出回退 (dB)	12.9	20.5	3.6	3.0	
2	分配带宽 (kHz)	3200	3300	47000	53500	右二列采用503所取载波编码参数,系统余量过高,八个载波共占用76%的
3	占用的EIRP资源(%)	10.3	1.8	87.0	99	转发器资源,资源利用率太低;中间三列对503参数作修改后,八个载波
4	占用的带宽资源 (%)	5.9	6.1	87.0	99	只占用49%的转发器资源,得以另添一个DVB-S2载波
E						

Statistical Data

CHINA APMT

Carrier numbers

➢ for a group of same carriers

Link margin

➢ in clear sky and in rain condition

Occupied power resource

- OBO of the carrier
- EIRP percentage of the carrier

Occupied bandwidth resource

- BW of the carrier
- BW percentage of the carrier

Introduction **Transponder Specifications** C/N and C/(N+I) Calculation C/T and C/N Interference and rain fade Earth Station and Carrier Parameters **Target for Link Design** Antenna size Carrier parameter BW and power Link margin **Carrier monitoring and management** Sample of Link Budget Satellite, E/S and carrier parameters C/N and margin Statistics for resource Link Budget Optimization Conclusion Page 52

Optimization for link margin

CHINA APMT

- Insufficient margin
 - larger Rx antenna
 - less efficient coding rate and/or modulation type

Excessive margin

- ➤ smaller Rx antenna
- more efficient coding rate and/or modulation type

Adjusting SFD for raising total C/TINA APMT

- ♣ Relationship between C/T_U, C/T_D and C/T_{Total}
 if C/T_U = C/T_D, C/T_{Total} = C/T_U (or C/T_D) 3dB
 if C/T_U >> C/T_D, C/T_{Total} -> C/T_D
 ivice versa
- ✤ Raising C/T_U and getting higher C/T_{Total}
 - EIRPs is fixed
 - \Rightarrow so C/T_D is limited
 - EIRPe could be increased
 - ⇒ by selecting less sensitive SFD
 - \Rightarrow higher EIRPe and then higher C/T_U
 - \succ C/T_{Total} could be raised
 - \Rightarrow when if C/T_U close to or less than C/T_D,
 - ⇒ by selecting less sensitive SFD, and increasing EIRPe

Power Adjustment for Star NetworkNA APMT

Star network

out-route carrier

⇒ from hub (large Tx antenna) to remote (small Rx antenna)
 ⇒ lower C/N

in-route carriers

⇒ from remote (small Tx antenna) to hub (large Rx antenna)
 ⇒ higher C/N

Power adjustment

- decrease OBO of out-route carrier
- ➢ increase OBO of in-route carriers
- balancing power percentage and bandwidth percentage
 Is for all carriers in star network
- \succ to let C/N_{O/R} close to C/N_{I/R}

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Engineering Tool

- Different to scientific analysis
- To get a proper link margin for satellite carriers
 - ➢ no insufficient
 - not too excessive
- Impossible and no necessary to get accurate result
 - > 1dB daily variation on C-band carrier power level
 - > 2dB daily variation on Ku-band carrier power level



Thanks!

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