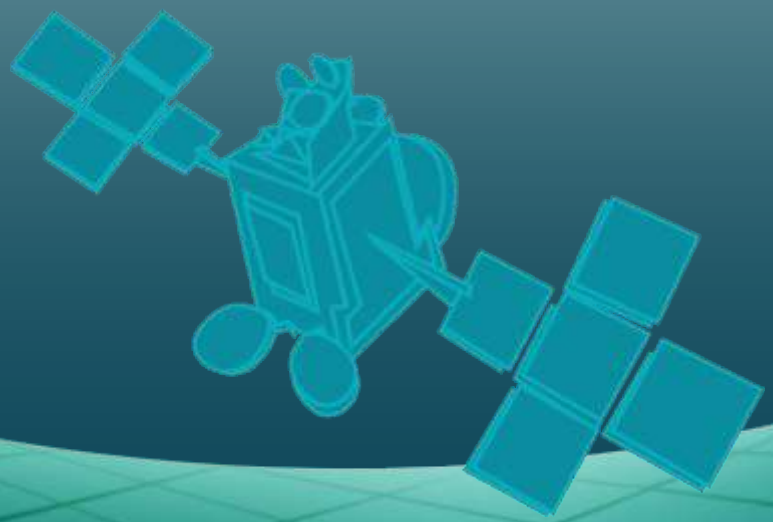
# Link Budget Estimate

## Satcom ABC series (7)



WU Boyang
APMT

# 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

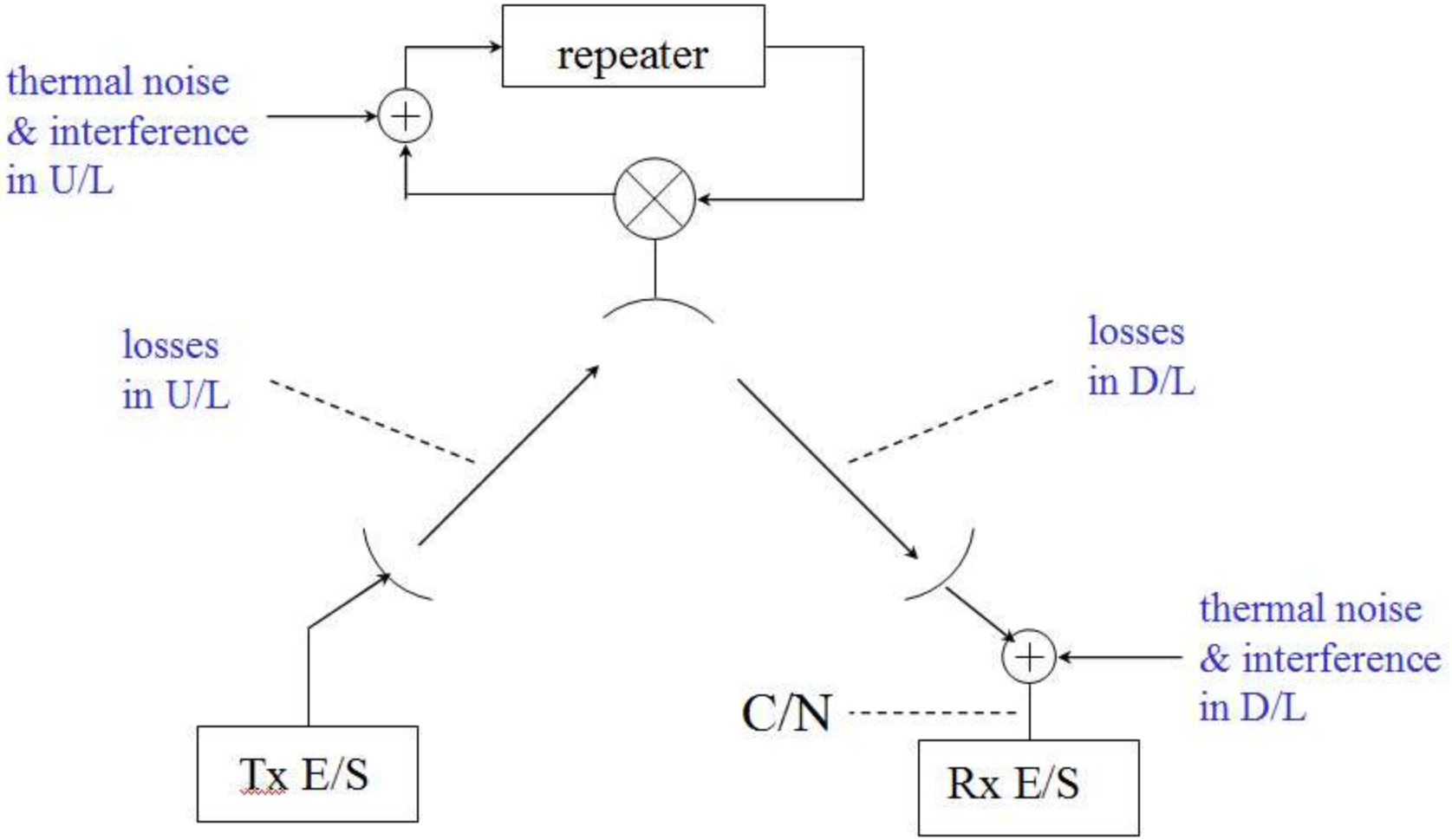
- Satellite, E/S and carrier parameters
- C/N and margin
- Statistics for resource

## Link Budget Optimization

## Conclusion

# Satellite Communication Links





# Links and Loss



- Up-link
  - the link from E/S to satellite
- Down-link
  - the link from satellite to E/S

- Free space loss
  - loss between E/S and satellite
  - both in up-link and down-link
  - at long distance transmission
    - ⇨ f, radio frequency
    - ⇨ d, transmission distance
    - ⇨ 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

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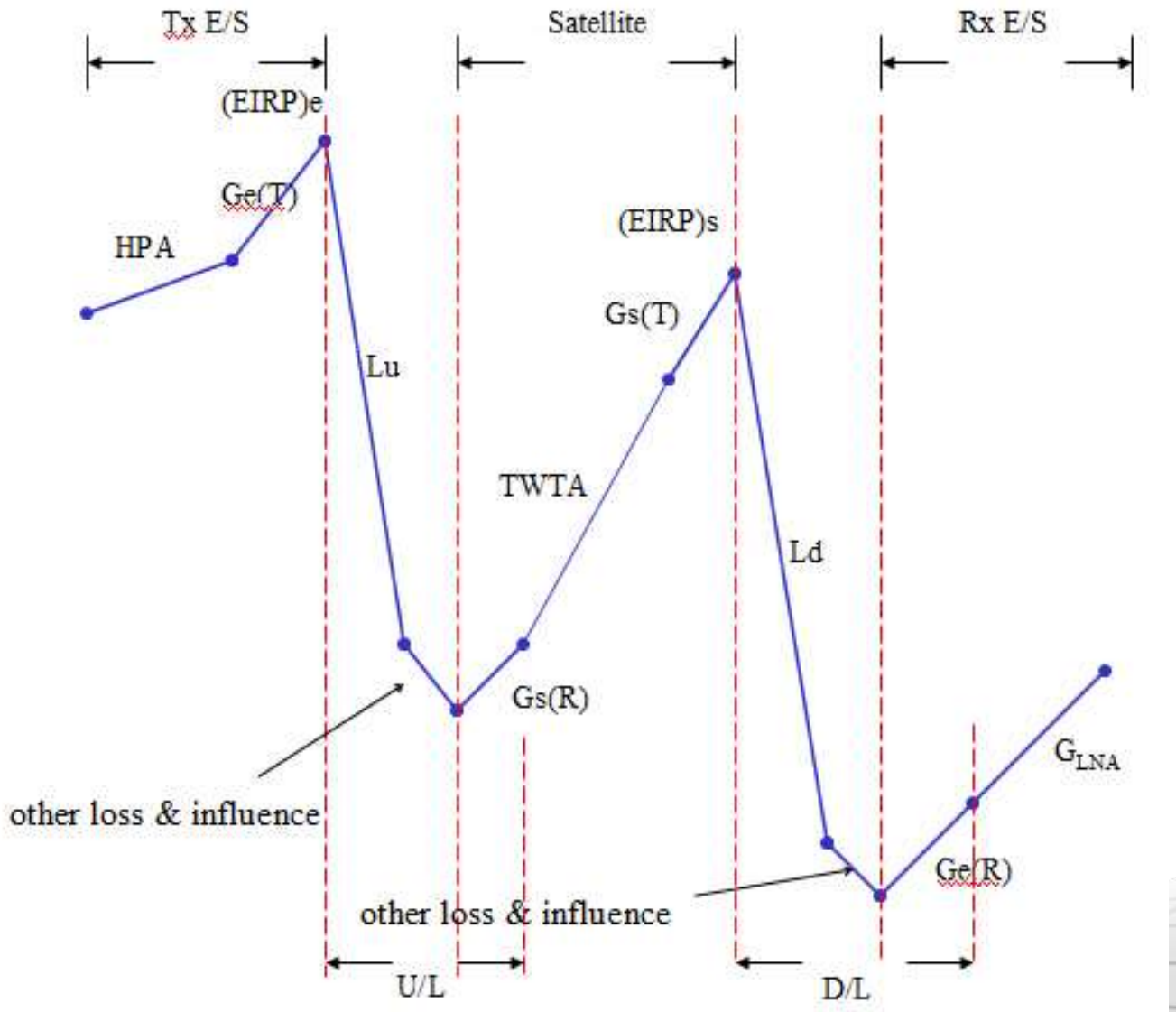

# Link Budget

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- Communication link design
  - to get E/S parameters
    - ⇨ from desired transponder and carrier parameters
  - to get carrier parameters
    - ⇨ from desired transponder and E/S parameters
  - to adjust carrier power and $Eb/N_0$ margin
    - ⇨ from desired E/S and carrier parameters

- Link parameter adjustment
  - for transponder resource
    - ⇨ to match BW and power percentages
  - for link design
    - ⇨ 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
    - ⇨ 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

Introduction

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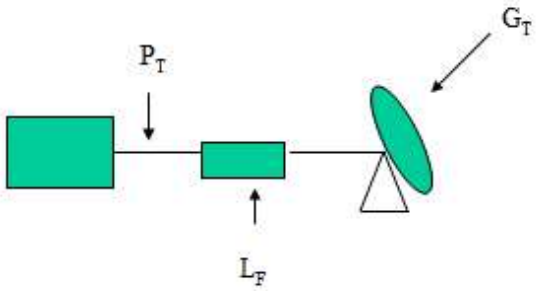
# EIRP



- EIRP

$$(EIRP)_e = \frac{P_T G_T}{L_F}$$

  - ⇨ $P_T$, output power
  - ⇨ $G_T$, antenna gain
  - ⇨ $L_F$, feed loss




  - ➢ EIRP in dB

    [EIRP] = 10 lg $P_T$ + 10 lg $G_T$ - 10 lg $L_F$

- $EIRP_e$
  - ➢ EIRP of the E/S
- $EIRP_S$
  - ➢ EIRP of the Satellite

# G/T



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

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

    - f, radio frequency
    - D, antenna diameter
    - c, light speed
    - $\eta$, antenna efficiency
  - T, equivalent thermal noise of receive system

- G/T in dB

$$[G/T] = 10 \lg G - 10 \lg T$$

# SFD



- 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)

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

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

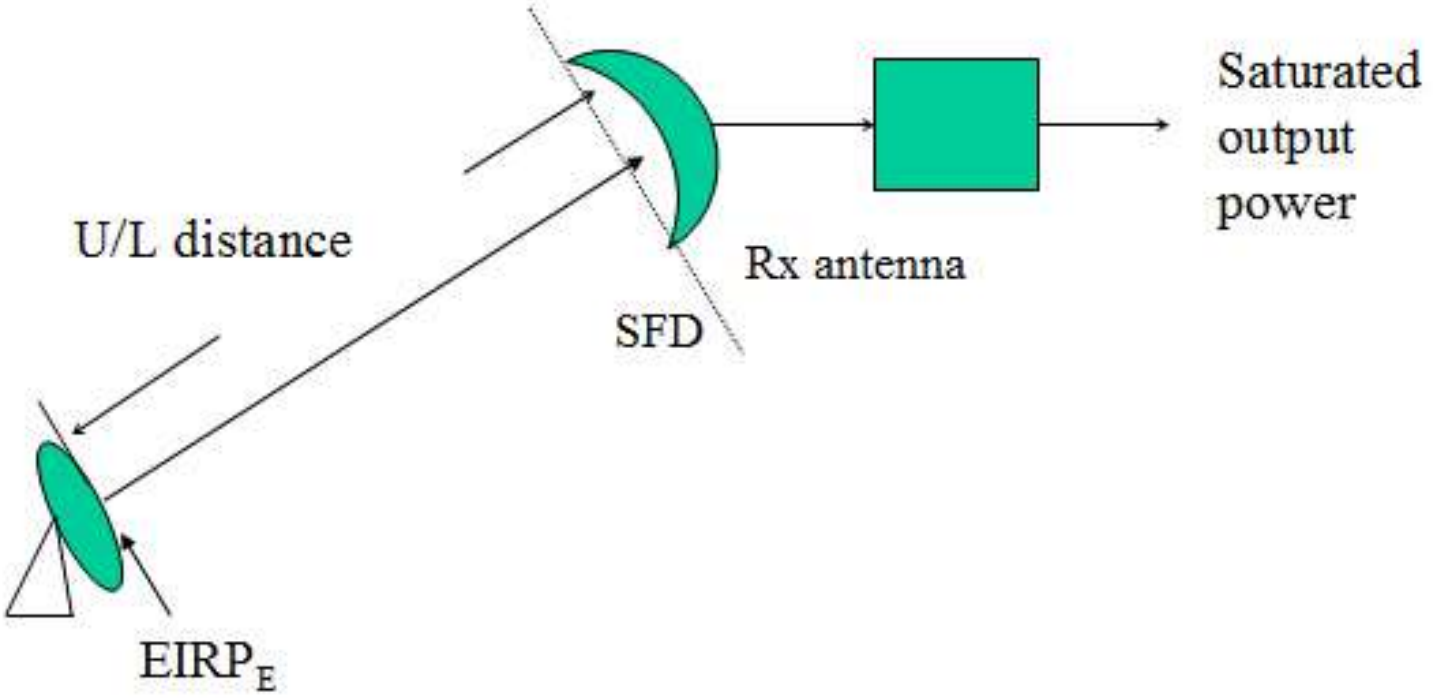
$$SFD = \frac{EIRP_e}{4\pi d_u^{\ 2}} \qquad (W/m^2)$$

# SFD (cont.)



- SFD
  - saturated flux density for 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 Setting



- FGM
  - Fixed gain mode
  - SFD vs. G/T for LaoSat-1
    - ⇨ SFD = - (70 to 93 + G/T)
    - ⇨ SFD = -71 to -94 dBW/$m^2$ for C-band
    - ⇨ SFD = -82 to -105 dBW/$m^2$ for Ku-band
  - Gain step setting relative to proper SFD
    - ⇨ for SFD at around -90 dBW/$m^2$
    - ⇨ 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



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

- $T_e$
  - Equivalent thermal noise

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

    - ⇨ $P_N$, 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
  - both in U/L and D/L

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

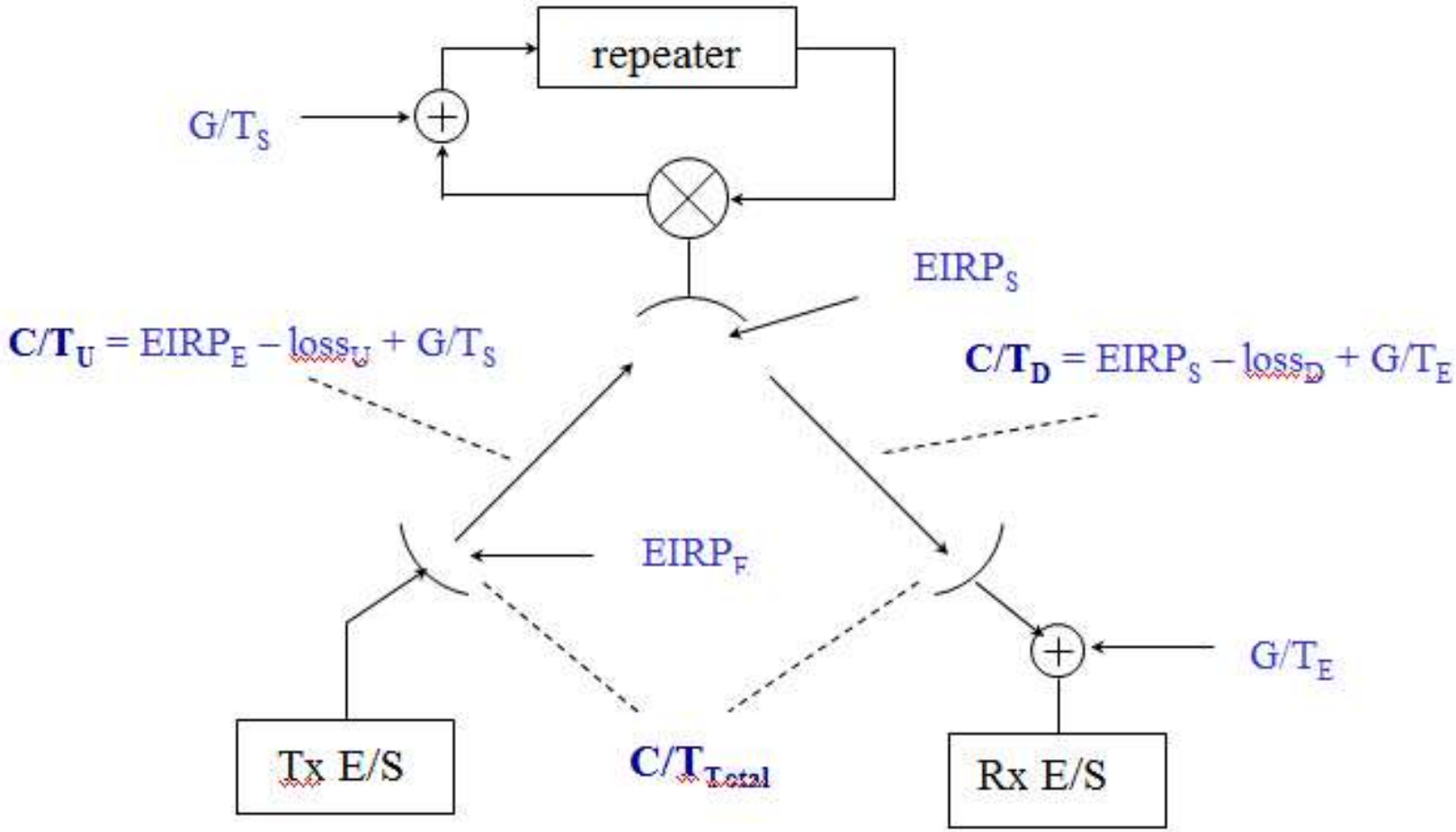
    ⇨ k, BOSSMAN constant

    ⇨ $BW_N$, 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)

# $C/T_U$, $C/T_D$ and $C/T_{Total}$





# Formulas for Total C/T and C/N



- C/T
  - C, carrier power
  - T, equivalent noise temperature

$$\frac{1}{C/T} = \frac{1}{(C/T)u} + \frac{1}{(C/T)d}$$

- C/N
  - N, noise power

$$\frac{1}{C/N} = \frac{1}{(C/N)u} + \frac{1}{(C/N)d}$$

- $C/N_0$
  - $N_0$,, noise power spectrum density

$$\frac{1}{C/N_0} = \frac{1}{(C/N_0)u} + \frac{1}{(C/N_0)d}$$

- The relationship between T, N & $N_0$

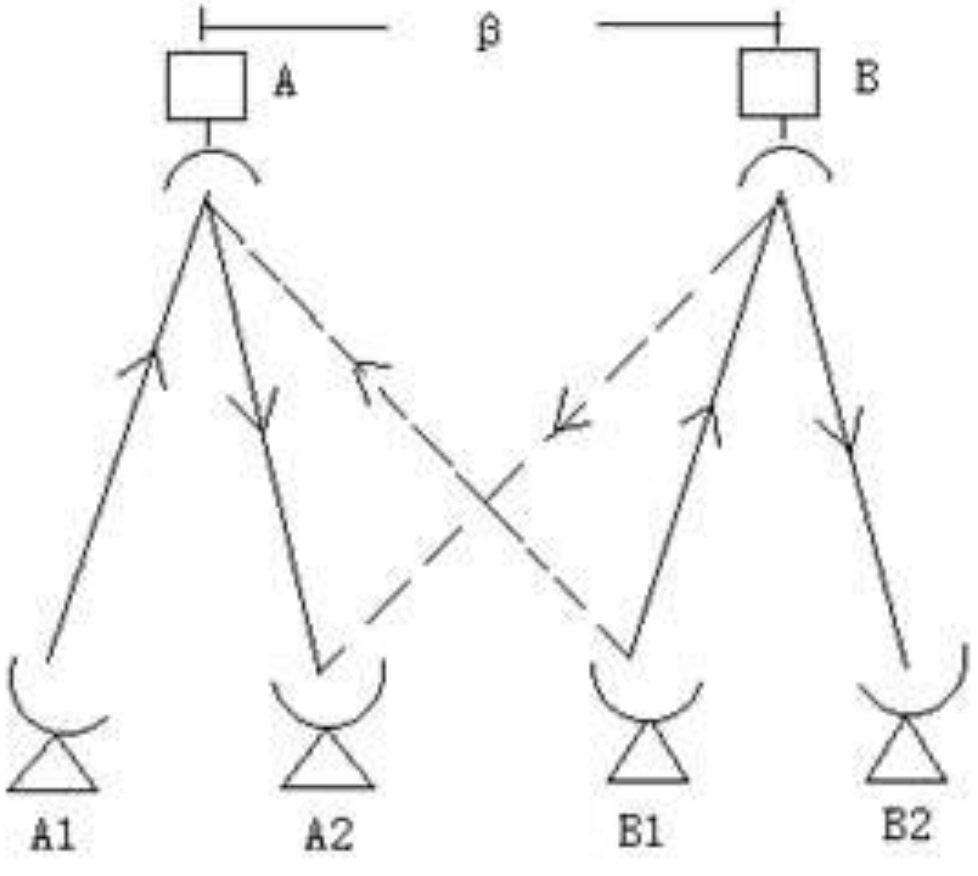
$N = N_0\, BW_N = kT\, BW_N$

$[C/N] = [C/N_0] - [BW_N] = [C/T] + 228.6 - [BW_N]$

# Interference

CHINA APMT

- 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.)

CHINA APMT

- Inter-modulation interference (IMI)
  - up-link interference
    - ⇨ 3rd 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

# C/(N+I)



- C/(N+I)
  - C/N including interference
- C/(N+I) in dB

  $[C/(N+I)]_U = [C/N]_U - [ASI_U] - [IMI_U]$

  $[C/(N+I)]_D = [C/N]_D - [ASI_D] - [IMI_D]$

  $[C/(N+I)]_{Total} = [C/N]_{Total} - [XPI] - [ACI]$
- C/(N+I) estimate
  - impossible to get accurate result
  - data validity
    - ⇨ 3.0 + 2.3 = 5.3
    - ⇨ 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

CHINA APMT

- Attenuation
  - normally in Ku above band
    - ⇨ 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 El, 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

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# Earth Station Parameters

CHINA APMT

- 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

CHINA APMT

- 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 $Eb/N_0$ depending on coding rate and decoding type
    - ⇨ according to MODEM manual

# Transmission Index

CHINA APMT

- $P_b$
  - bit error rate
- $Eb/N_0$
  - Eb, signal energy per bit
  - $N_0$, noise spectral density
- $Eb/N_0$ vs. C/N

$$\frac{E_b}{N_0} = \left(\frac{C}{N}\right)\frac{B}{R_b}$$

  - ⇨ B, noise bandwidth
  - ⇨ $R_b$, information rate

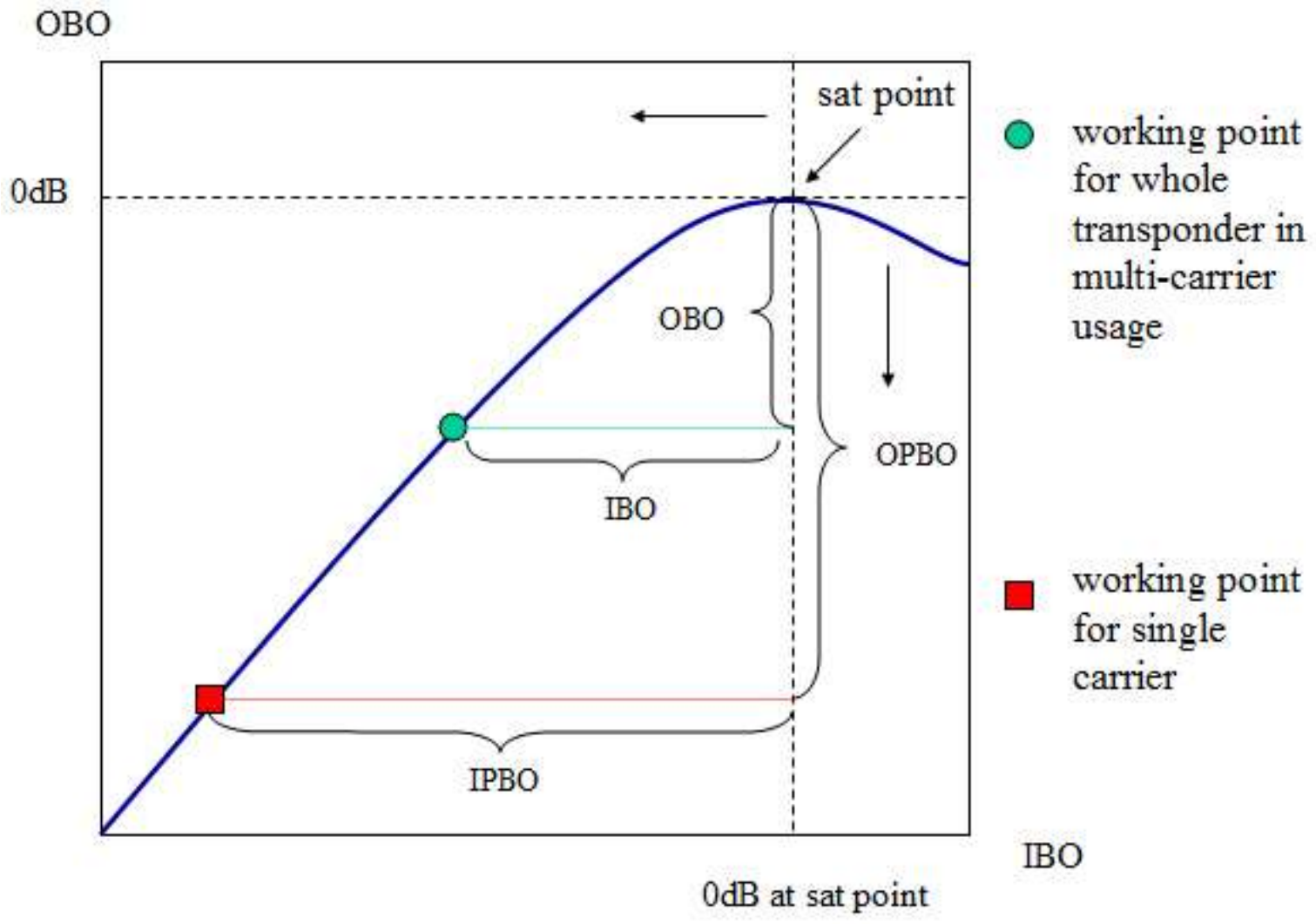
# Carrier Parameters (cont.)

CHINA APMT

- Bandwidth
  - Information rate
  - coding rate
    - ⇨ higher than information rate after encoded
    - ⇨ dividing by 1, 2, 3, or 4 for BP, QP, 8P, or 16P
  - noise BW
    - ⇨ 1.2 times of coding rate
  - occupied BW
    - ⇨ 1.4 (or $1.3^{+}$) times of coding rate
  - allocated BW
    - ⇨ equal and wider than OBW with guard band

# Gain Transfer Curve

CHINA APMT



# Power Assignment

CHINA APMT

- 0.5 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
    - $OBO_{1/2BW}$ = 3 + 3 (dB)
    - $OBO_{1/4BW}$ = 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

CHINA APMT

- 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

CHINA APMT

- 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
    - ⇨ at least 1dB for C-band
    - ⇨ 2dB or above for Ku-band

# Link Margin (cont.)

CHINA APMT

- Rain fade condition
  - rain attenuation
    - ⇨ relative to availability
  - U/L power
    - ⇨ compensated by UPC and/or ALC
  - D/L EIRP
    - ⇨ 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 management

- 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

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| | Out-Route1 | In-Route1 | DVB-S2 | TOTAL | NOTE |
|---|---|---|---|---|---|
| 卫星轨位 (deg E) | 128.5 | 128.5 | 128.5 | 128.5 | |
| **转发器和载波设置** | | | | | |
| 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 |
| 输出回退 (dB) | 12.9 | 25.3 | 3.6 | 3.0 | |
| 输入回退 (dB) | 15.9 | 28.3 | 6.6 | 6.0 | |
| 上行频率 (MHz) | 12833.6 | 12835.9 | 12844.5 | 12850 | |
| 下行频率 (MHz) | 10773.6 | 10775.9 | 10784.5 | 10790 | |
| **转发器参数** | | | | | |
| 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 |
| 接收系统G/T (dB/k) | 12.0 | 12.0 | 12.0 | 12.0 | |
| 下行饱和EIRP (dBw) | 57.0 | 57.0 | 57.0 | 57.0 | |
| **载波参数** | | | | | |
| 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载波；宽带和窄带载波分别采用LDPC和Turbo编解码 |
| 信息速率 (kbps) | 6000 | 2000 | 44000 | | |
| FEC编码率 | 0.875 | 0.875 | 0.67 | | |
| R-S编码率 | 1 | 1 | 1 | | |
| 符号速率 (kbps) | 2286 | 762 | 33000 | | |
| 噪声带宽 (kHz) | 2743 | 914 | 39600 | | |
| 占用带宽 (kHz) | 3200 | 1067 | 46200 | | |
| 分配带宽 (kHz) | 3200 | 1100 | 47000 | 54000 | |
| 系统要求的$E_b/N_0$ (dB) | 9.0 | 10.0 | 3.0 | | 左5列为经验值，右2列为503提供参数 |

# Transponder and carrier setting

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- 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
  - U/L and D/L

# Transponder specification

CHINA APMT

- Getting the data
  - Relative to earth station location
    - ⇨ from city table
    - ⇨ or from contour map
- SFD
  - adjusted by gain step setting
    - ⇨ from the most sensitive one
- G/T
- EIRP

# Carrier parameters

CHINA APMT

- ModCod
  - modulation type
  - coding rate
- Data rate
  - information rate
    - ⇨ without or with overhead
  - symbol rate
    - ⇨ depend on information rate, modulation type and coding rate

# Carrier parameters (cont.)

CHINA APMT

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

- Required $Eb/N_0$
  - depended on modulation type and coding rate
  - based on MODEM operation manual

# Link Budget - Sample p.2

## Earth station parameters

CHINA APMT

| | A | D | E | F | I | J |
|---|---|---|---|---|---|---|
| 1 | | Out-Route1 | In-Route1 | DVB-S2 | TOTAL | NOTE |
| 2 | | | | | | |
| 16 | 上行站参数 | | | | | |
| 17 | 天线口径 (m) | 13 | 1.2 | 13 | | |
| 18 | 地球站所在地 | 万象 | 万象 | 万象 | | |
| 19 | 经度 (deg E) | 102.6 | 102.6 | 102.6 | | |
| 20 | 纬度 (deg N) | 19.8 | 19.8 | 19.8 | | |
| 21 | 到卫星距离 (km) | 36921 | 36921 | 36921 | | |
| 22 | 天线仰角 (deg) | 52.6 | 52.6 | 52.6 | | |
| 23 | 天线方位角 (deg) | 124.9 | 124.9 | 124.9 | | |
| 24 | 天线效率 (%) | 65 | 65 | 65 | | |
| 25 | 天线增益 (dBi) | 63.0 | 42.3 | 63.0 | | |
| 26 | HPA最大输出功率 (dBw) | 28.8 | 12.0 | 28.8 | | 功放功率为750W与10W |
| 27 | 晴空时的馈源功率 (dBw) | -4.7 | 3.0 | 4.6 | | |
| 28 | 晴空时的功率余量 (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 |
| 29 | 下行站参数 | | | | | |
| 30 | 天线口径 (m) | 1.2 | 13 | 0.45 | | |
| 31 | 地球站所在地 | 万象 | 万象 | 万象 | | |
| 32 | 经度 (deg E) | 102.6 | 102.6 | 102.6 | | |
| 33 | 纬度 (deg N) | 19.8 | 19.8 | 19.8 | | |
| 34 | 到卫星距离 (km) | 36921 | 36921 | 36921 | | |
| 35 | 天线仰角 (deg) | 52.6 | 52.6 | 52.6 | | |
| 36 | 天线方位角 (deg) | 124.9 | 124.9 | 124.9 | | |
| 37 | 天线效率 (%) | 65 | 65 | 65 | | |
| 38 | 天线增益 (dBi) | 40.8 | 61.5 | 32.2 | | |
| 39 | 系统噪声温度 (dBk) | 20.0 | 20.0 | 20.0 | | |
| 50 | 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 |
| 51 | 测控站参数 | | | | | |
| 52 | 天线口径 (m) | 13 | 13 | 13 | | |
| 60 | 天线增益 (dBi) | 61.5 | 61.5 | 61.5 | | |
| 61 | 系统噪声温度 (dBk) | 20.0 | 20.0 | 20.0 | | |
| 62 | 接收系统G/T (dB/k) | 41.5 | 41.5 | 41.5 | | |

# Antenna and Pointing parameter

CHINA APMT

- Antenna parameter
  - antenna size
  - efficient
  - antenna gain
    - ⇨relative to antenna size, efficient and Tx or Rx frequency
- E/S location
  - longitude 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

CHINA APMT

- 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
    - ⇨ considering feed loss
- Multi-carrier usage
  - considering linear back-off
- UPC for rain attenuation
  - considering UPC range

# G/T



- 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

$$T_S = T_a + (L_F - 1)\, T_1 + L_F\, T_e \text{ (dBk)}$$

  - ⇨ $T_a$, antenna noise temperature
  - ⇨ $T_e$, LNA noise temperature
  - ⇨ $L_F$, feed loss, about 0.2dB?
  - ⇨ $T_1$, environment temperature at waveguide or cable

# Link Budget - Sample p.3

## C/N and margin

CHINA APMT

| | Out-Route1 | In-Route1 | DVB-S2 | TOTAL | NOTE |
|---|---|---|---|---|---|
| 上行C/T | | | | | |
| 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 | | |
| 1 $m^2$标准天线增益 (dBi/$m^2$) | 43.6 | 43.6 | 43.6 | | |
| 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 |
| 下行C/T | | | | | |
| 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 | | |
| 晴空时的下行C/T (dBw/k) | -139.9 | -132.1 | -138.9 | | |
| 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 | | |
| 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 | | |
| 晴空时的系统余里 (dB) | 8.3 | 4.6 | 8.0 | | |
| 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 | | |
| 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 | | |
| 晴空时的下行C/T (dBw/k) | -119.2 | -131.6 | -109.9 | | |
| 测控站系统总载噪比 | | | | | |
| 晴空时的系统总C/T (dBw/k) | -136.6 | -149.0 | -127.3 | | |
| 晴空时的系统总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 |
| 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 |
| | | | | | 饱和载波C/(N+I)的实测值比估算值高约?dB |

# Up-link C/T

CHINA APMT

- Carrier PFD
  - calculated by transponder SFD - carrier OBO
- Losses
  - free space loss
  - antenna pointing error and others
- EIRPe
  - calculated by PFD, losses, and $1m^2$ 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
    - ⇨ 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)

CHINA APMT

- $C/T_{Total}$
  - 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.)



- Estimated $C/(N+I)_{Total}$
  - 1dB 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 $Eb/N_0$
  - in clear sky and in rain condition

# Link Budget - Sample p.4

## Statistics for transponder resources

CHINA APMT

| | Out-Route1 | In-Route1 | DVB-S2 | TOTAL | NOTE |
|---|---|---|---|---|---|
| 系统资源统计 | | | | | |
| 载波数 | 1 | 3 | 1 | 9 | |
| 晴空时的系统余量 (dB) | 8.3 | 4.6 | 8.0 | | |
| 降雨时的系统余量 (dB) | 3.4 | 3.4 | 2.2 | | |
| 输出回退 (dB) | 12.9 | 20.5 | 3.6 | 3.0 | |
| 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 |
| 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 |
| 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 |

# 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

# 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/T

CHINA 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 $C/T_U >> C/T_D$, $C/T_{Total}$ -> $C/T_D$
    - ⇨ vice versa

- Raising $C/T_U$ and getting higher $C/T_{Total}$
  - EIRPs is fixed
    - ⇨ so $C/T_D$ is limited
  - EIRPe could be increased
    - ⇨ by selecting less sensitive SFD
    - ⇨ higher EIRPe and then higher $C/T_U$
  - $C/T_{Total}$ could be raised
    - ⇨ 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 Network

CHINA 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
    - ⇨ for all carriers in star network
  - to let $C/N_{O/R}$ close to $C/N_{I/R}$

- 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**

# 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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