LINK BUDGET ANALYSIS FOR SATALLITE COMMUNICATION

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LINK BUDGET

- The link budget determines following in satellite link design
1. The antenna size to deploy
2. Power requirements
3. Link availability
4. Bit error rate
5. Overall customer satisfaction with the satellite service.

LINK BUDGET

The link budget must be calculated for an individual transponder, and must be recalculated for each of the individual links.

Link budgets are usually calculated for a worst-case scenario, the one in which the link will have the lowest C/N ratio or lowest tolerable availability.

C–BAND GEO SATELLITE L INK BUDGET IN CLEAR AIR

Table shows a typical link budget for a C band downlink connection using a global beam GEO satellite and a 9m earth station antenna. .

C – band satellite parameters	
Transponder saturated output power	20 W
Antenna gain on axis	20 dB
Transponder bandwidth	36 MHz
Downlink frequency band	3.7 – 4.2 GHz
Signal FM – TV analogue signal	
FM – TV signal bandwidth	30 MHz
Minimum permitted overall C/N in receiver	9.5 dB
Receiving C – band earth station	
Downlink frequency	4 GHz
Antenna gain on axis at 4GHz	49.7 dB
Receiver IF bandwidth	27 MHz
Receiving system noise temperature	75 K
Downlink power budget	
Pt – satellite transponder output power, 20 W	13 dB
Bo – transponder output backoff	-2dB
Gt – satellite antenna gain, on axis	20 dB
Gr – earth station antenna gain	49.7 dB
LP – free space path loss at 4GHz	-196.5 dB
Lant = edge of beam loss for satellite antenna	-3 dB
La = clear air atmospheric	-0.2 dB
Lm = other losses	-0.5dB
Pr = *received power at earth station*	*-119.5 dBW*
Downlink noise power budget in clear air	
k = Boltzmann's constant	-228.6 dBW/K/Hz
TS = system noise temperature, 75 K	18.8 dBK
Bn = noise bandwidth 27 MHz	74.3 dBHz
N = receiver noise power	*-135.5 dBW*
C/N ratio in receiver in clear air	
C/N =Pr – N = -119.5 – (-135.5)	16.0 dB

SATELLITE LINK DESIGN METHODOLOGY

Step 1. Frequency band determination.
Step 2. Satellite communication parameters determination. Make informed guesses for unknown values.
Step 3. Earth station parameter determination; both uplink and downlink.
Step 4. Establish uplink budget and a transponder noise power budget to find (C/N) up in the transponder
Step 5. Determine transponder output power from its gain or output backoff.
Step 6. Establish a downlink power and noise budget for the receiving earth station
Step 7. Calculate (C/N) down and (C/N) uplink for a station at the outermost contour of the satellite footprint.
Step 8. Calculate SNR/BER in the baseband channel.

SATELLITE LINK DESIGN METHODOLOGY

Step 9. Determine the link margin.
Step 10. Do a comparative analysis of the result vis-à-vis the specification requirements.
Step 11. Tweak system parameters to obtain acceptable (C/N) 0 /SNR/BER values.
Step 12. Propagation condition determination.
Step 13. Uplink and downlink unavailability estimation.
Step 14. Redesign system by changing some parameters if the link margins are inadequate.
Step 15. Are gotten parameters reasonable? Is design financially feasible?
Step 16. If YES on both counts in step 15, then satellite link design is successful – Stop.
Step 17. If NO on either (or both) counts in step 15, then satellite link design is unsuccessful – Go to step 1

EXAMPLE

Example 1:
A satellite downlink at 12 GHz operates with a transmit power of 20 W and an antenna gain of 45 dB. Calculate the EIRP in dBW.

Example 2:
A satellite at a distance of 39,000 km from the building radiates a power of 20 W from an antenna with a gain of 22 dB in the direction of a VSAT at the building with an effective aperture area of 10 m^2 .
Calculate:
a. The flux density at the building
b. The power received by the VSAT antenna
c. If the satellite operates at a frequency of 11 GHz and the Earth Station (ES) antenna has a gain of 52.3 dB. Determine the received power.

DOWNLINK AND UPLINK INTERFERENCE RATIOS

Consider two satellites, S_C as the wanted satellite and S_I as the interfering satellite.

The carrier power received at an earth station is given by equation

$$[C] = [EIRP_C] + [G_R] - [F_C] - [L_{ac}]$$

Where Equivalent Isotropic Radiated Power from satellite SC ;
G_R – on-axis receiving antenna gain
F_C – footprint contour of the satellite transmit antenna
L_{ac} - free space loss.

DOWNLOWNLINK AND UPLINK INTERFERENCE RATIOS

The interfering carrier power received at an earth station is given by equation

$$[I]=[EIRP_I]+[G_R(\theta)]-[F_I]-[L_{ac}]+[P_D]$$

Where Equivalent Isotropic Radiated Power from satellite SC ;

$G_R(\theta)$ – off -axis receiving antenna gain

F_I – footprint contour of the satellite transmit antenna

L_{ac} - free space loss.

P_D – Polarize discrimination

$$[C]-[I]=[EIRP_C]-[EIRP_I]+[G_R]-[G_R(\theta)]+[P_D]$$

$$\Rightarrow$$

$$[C/I]_D=\Delta[EIRP]+[G_R]-[G_R(\theta)]+[P_D]$$

DOWNLINK AND UPLINK INTERFERENCE RATIOS

For the Earth-Space path (Uplink), the C/I ratio will be given by equation

$$[C/I]_U = \Delta[Power] + [G_S] - [G_S(\theta)] + [P_U]$$

Where Equivalent Isotropic Radiated Power from satellite SC ;
Δ[Power] – Difference in dB between wanted and interference transmit power
G_s – Satellite receive antenna gain for wanted earth station
G S (θ) - Satellite receive antenna gain for interfering earth station
P_u – Uplink polarization discrimination

Total interference ratio of the satellite link

$$[I/C]_{UD} = [I/C]_U + [I/C]_D$$

EXAMPLE

Example 3:
The desired carrier [EIRP] from a satellite is 36 dBW, and the on-axis ground station receiving antenna gain is 43 dB, while the off-axis gain is 25 dB towards an interfering satellite. The interfering satellite radiates an [EIRP] of 31dBW. The polarization discrimination is assumed to be 4 dB. Find the downlink Carrier to Interference ratio.

Example 4:
Given that $[C/I]_U = 26$ dB and $[C/I]_D = 24$ dB, determine the overall Carrier-to-Interference ratio of the given link $[C/I]_{UD}$

EXAMPLE

Example 5:

Suppose we have a 4 GHz receiver with the following gains and noise temperatures:

G_{rf} = 23 dB, T_{in} = 25 K, T_m = 500 K, T_{if} =1000 K and T_{rf} = 50 K.

a) Calculate the system noise temperature assuming that the mixer has a gain G_m = 0 dB.

b) Determine the system noise temperature when the mixer has a 10 dB loss.

Example 4:

Given that $[C/I]_U$ = 26 dB and $[C/I]_D$ = 24 dB, determine the overall Carrier-to-Interference ratio of the given link $[C/I]_{UD}$

ANTENNA SCAN ANGLE AND COSINE ROLL-OFF

To determine the gain of an ESA terminal, its scan angle is required. The scan angle is one of two angles that define the direction of the satellite beam (known as the bores-sight vector) relative to the antenna in a spherical coordinate system

Theta (θ) is the scan angle. This is the angle between the boresight vector and the broadside vector (the axis that is perpendicular to the plane of the antenna). If the plane of the antenna panel is horizontal, the broadside vector is vertical

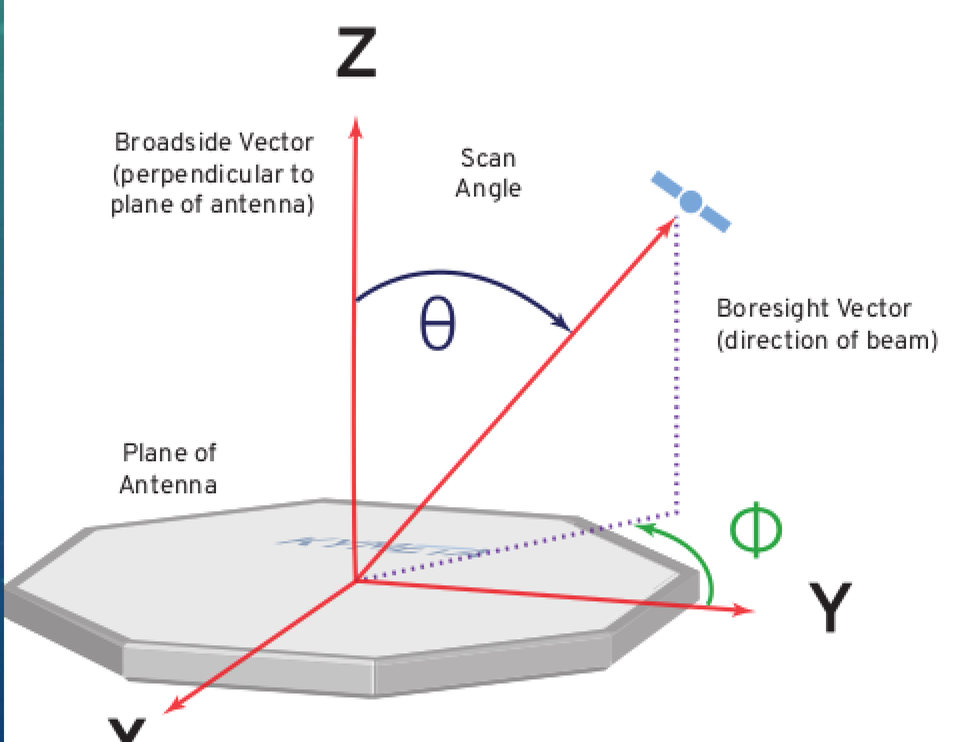

FIGURE 5. ESA BEAM POINTING COORDINATES

ANTENNA SCAN ANGLE AND COSINE ROLL-OFF

Peak Gain (dBi) = Peak gain of the antenna when the broadside And boresight vectors are aligned (θ = 0), so that there is no loss of gain caused by a reduction in the effective area of the antenna as seen by the satellite.
This is typically specified by the antenna manufacturer.
Cosine roll-off = An antenna coefficient for the reduction in gain caused by scan angle (θ). Also called scan roll-off.
This is also provided by the manufacturer.

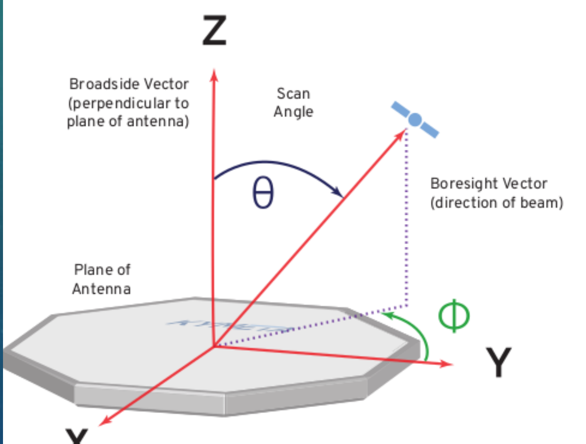

FIGURE 5. ESA BEAM POINTING COORDINATES

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ANTENNA SCAN ANGLE AND COSINE ROLL-OFF

$$G(dBi) = Peak\ Gain\ (dBi) - cosine\ roll\text{-}off \times 10 \times log\ (\cos\theta)$$

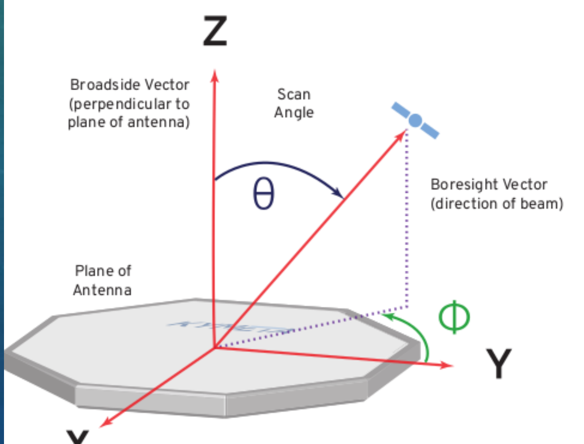

FIGURE 5. ESA BEAM POINTING COORDINATES

EXAMPLE

Example 6:

A Kymeta u7 Ku-band terminal in mobility mode in Seattle using G-18 with a scan angle of 55 degrees.

Satellite EIRP = 46.6 dBW, Transponder BW = 36 MHz, Theta = 55 degrees, Polarization: horizontal, Cosine roll-off = 1.2, Peak receive gain = 33.0 dB, d=38200km, Atmospheric loss = 0.35 dB

1. Calculate the gain at theta of the receiving antenna.
2. Calculate (G/T) of the terminal
3. Calculate the free space path loss.
4. Calculate SNR