5 Communications

5.1 Link Budget

Consider a satellite in a geostationary orbit with the following information given:

- $f = 12GHz$
- $R = 40.000km$
- $P_t = 10W$
- $\Theta_{3dB} = 2°$
- $\eta_t = 0.55$
- $L_{l,dB} = 0dB$
- $L_{c,dB} = 0dB$
- $L_{t,dB} = 0dB$
- $D_r = 4m$
- $\eta_r = 0.6$
- $T_{sys} = 140K$

1. Calculate the maximal Power Flux Density (PFD) recieved at the earth surface.
2. Calculate the recieved energy at the ground station.
3. Calculate if a symbol rate of 100 Msym per second can be achieved with a given link margin of 20 dB.

1.

We start with the emited EIRP of the satellite. The EIRP in dB is defined as:

$$EIRP_{dB} = P_{t,dB} - L_{l,dB} + G_{t,dB}$$

Due to the zero line loss this can be simplified to

$$EIRP_{dB} = P_{t,dB} + G_{t,dB}$$

With P_t given this leads to an power flux density of

$$\Phi_{max,dB} = P_{t,dB} + G_{t,dB} - 10\log 4\pi - 20\log R$$

Written in the linear form the equation would be

$$\Phi_{max} = \frac{P_t \cdot G_t}{4\pi \cdot R^2}$$

To obtain the PFD we have to calculate the gain of the transmitting antenna. We know that the θ_{3dB} angle is defined as:

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$$\theta_{3dB} = 70° \frac{\lambda}{D_t}$$

The wavelength can be found with the basic equation of :

$$c = f \cdot \lambda$$

with c as the velocity of electromagnetic waves in the vacuum (a.k.a velocity of light) $(3 \cdot 10^8 m/s)$. So the wavelength is

$$\lambda = \frac{c}{f} = 0,025m$$

The antenna diameter of the transmitting antenna can be found through:

$$D_t = \frac{70° \cdot \lambda}{\theta_{3dB}} = 0.875m$$

Using the known gain equation we can find the antenna gain

$$G_{t,dB} = 10 \log \left(\eta_t \cdot \left(\frac{D_t \cdot \pi}{\lambda} \right)^2 \right) = 38.3dBi$$

$$\Phi_{max,dB} = 10 + 38.3 - 11 - 152 = -114.7dBW/m^2$$

2.

We want to compute the exact power C that is recieved at the ground station. Therefore we use the EIRP and add the losses that occur during the transmission between the satellite and the ground station. Additionally we use the antenna diameter to determine how much of the transmitted energy can be recieved.

$$C_{dB} = EIRP_{dB} + L_{s,dB} + G_{r,dB}$$

The space loss equation from the formulary yields:

$$L_{s,dB} = 10 \cdot \log \left(\frac{4\pi \cdot R}{\lambda} \right)^2 = 205.2dB$$

The gain can be calculated using the same equation as for the transmitting antenna:

$$G_{r,dB} = 51.8dBi$$

This leads to:

$$C_{dB} = 10 + 38.3 - 205.2 + 51.8 = -105.7dB$$

$$C = 31 \cdot 10^{-12} W$$

3.

The basic idea of the link budget equation is to sum up all gains and losses and derive the final margin. If the margin is above a defined threshold (here 20 dB) the link can be judged as 'safe'. One way to find out if the margin is large enough, is to compute the margin with the minimal data

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rate (100 Msym per second). To do this we will need the complete link equation (all values are in dB, so all dB indices are omitted):

$$\frac{E_b}{N_0} = P_t - L_l + G_t - L_s - L_t + G_r - L_c - k_B - T_{sys} - R$$

k_B is the Boltzman constant and has the value -228.5 dB. The dB-value of the system noise temperature can be determined by

$$T_{sys,dB} = 10 \cdot \log(T_{sys}) = 21.5db$$

A data rate of 100 Msym per second can be converted into dB

$$R = 10 \cdot \log(100 \cdot 10^6) = 80db$$

Adding up all values we can find

$$\frac{E_b}{N_0} = 21.1dB$$

So the margin is above the threshold of 20 dB and the link should be capable to transmit the given data rate of 100 Msym per second.

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