POLITECNICO MILANO 1863

Reverse Engineering of Juno Mission
Homework 3

Course of Space System Engineering & Operations
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Group 5

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Contents

Notation

TMTC	Telemetry and Telecommand
HGA	High Gain Antenna
MGA	Medium Gain Antenna
LGA	Low Gain Antenna
TLGA	Toroidal Low Gain Antenna
ALGA	Aft Low Gain Antenna
FLGA	Forward Low Gain Antenna
SYM	Symbol description[1]

1 TMTC architecture

2 Rationale of TMTC system

3 Reverse sizing of TMTC system

The reverse sizing of the TMTC system is based on the link budget equation that represents a power balance between the transmitted signal and the receiver noise. The same equation can be applied on both uplink and downlink. It is valid for all the architectures, both that transmit data or tones

$$\frac{P_{rx}}{N_0} = \frac{P_{tx} G_{tx} G_{rx} L_{tot}}{k T_{eq}} > \left(\frac{P_{rx}}{N_0}\right)_{min} \tag{1}$$

For antennas that broadcast data, an additional equation is used to constrain the sizing.

$$\frac{E_b}{N_0} = \frac{P_{tx} G_{tx} G_{rx} L_{tot}}{k T_{eq} R} > \left(\frac{E_b}{N_0}\right)_{min} \tag{2}$$

L_{tot} considers the following losses:

$$L_{tot} = L_c \cdot L_s \cdot L_{p,tx} \cdot L_{p,rx} \cdot L_a \cdot L_c \tag{3}$$

For each communication link, different minimum required ratios are defined. In particular, $\frac{E_b}{N_0}$ must also satisfy the Shannon theorem by ensuring a value higher than −1.59 dB.

3.1 HGA links sizing

The HGA as described in (sec) is used for the downlink of telemetry and scientific data during the science orbits around Jupiter. It has been sized in the following scenario:

- the maximum distance from Earth $r_{JE} = 6.5$ AU;
- the minimum datarate $R = 18$ kbps has to be ensured regarding the distance.

From the literature, some other parameters where recovered:

	X-Down	**X-Up**	**Ka-Down**	**Ka-Up**
f **[GHz]**	8.4	7.1	34.4	32.1
R **[kbps]**	18	2	–	–
d_{HGA} **[m]**	2.5			
d_g **[m]**	34			
P_{tx} **[W]**	25	$1.8 \cdot 10^4$	2.5	$1.8 \cdot 10^4$
η_{HGA} **[deg]**	0.25			
η_g **[deg]**	$4 \cdot 10^{-3}$		$2 \cdot 10^{-3}$	
L_c **[dB]**	−2	–	−2	–
L_a **[dB]**	−0.2		−1.09	
L_c **[dB]**	−0.25		−0.5	
T_s **[K]**	21	401.25	21	770.63
$(P/N_0)_{min}$ **[dB-Hz]**	43.64	49.13	26.50	42.57
$(E_b/N_0)_{min}$ **[dB]**	−0.1	9.6	–	–

Table 1: Overall mission budget and simulation

The link budget equation can be expressed in a dB form, each term is then calculated as follows:

$$G = 10 \cdot \log_{10}\left(\frac{\pi d \mu}{\lambda}\right)$$

$$L_s = 20 \cdot log_{10}\left(\frac{\lambda}{4\pi d_{JE}}\right)$$

$$EIRP_{dw} = P_{tx} + G_{HGA} + L_{cb} + L_{cv}$$

$$P_{rx,dw} = EIRP_{dw} + G_g + L_s + L_a + L_p$$

$$\frac{P}{N_0} = P_{rx} - N_0$$

$$\theta_{bw} = 65.3 \cdot \frac{\lambda}{d}$$

$$L_p = -12 \cdot \left(\frac{\eta}{\theta_{bw}}\right)$$

$$EIRP_{up} = P_{tx} + G_g$$

$$P_{rx,up} = EIRP_{up} + G_{HGA} + L_a + L_s + L_p + L_{cv}$$

$$\frac{E_b}{N_0} = \frac{P}{N_0} - 10\log_{10}$$

Bibliography

[1] Richard Grammier. *Overview of the Juno Mission to Jupiter*. Site: `https://www.jpl.nasa.gov/missions/juno`. 2006.