Date Spring 2021

Lab 11 Link Budget *(yellow highlight / italics = give*

PARAMETER	UPLINK (Commands)	DOWNLINK (Telemetry and Data)	UNITS	Symbol
Speed of Light	*3.0E+08*	*3.0E+08*	*m/s*	*C= λ∗f*
Frequency	*8.4*	*8.0*	*GHz*	*f*
Wavelength	0.036	0.038	m	lambda
Range	*40000*	*40000*	*km*	*R*
Boltzman's Constant	*1.380E-23*	*1.380E-23*	*W/(Hz-K)*	*k*
Data Parameters	*Uplink*	*Downlink*	*Units*	*Symbol*
Bit Error Rate / Probablility of Bit Error	*10-7*	*10-5*	*[-]*	*BER*
Data Coding Scheme	*QPSK*	*QPSK*		
Required Bit Energy to Noise Ratio	11.31	9.59	dB	Eb/No
Data Rate	*9600*	*2,097,152*	*bps (Hz)*	*R*
Required Carrier to Noise Ratio	57.13	75.80	dB-Hz	C/No
Required Design Margin	*6.00*	*3.00*	*dB*	
Minimum C/No	**51.13**	**72.80**	**dB-Hz**	
Noise (applies to receiving elements)	*Uplink*	*Downlink*	*Units*	*Symbol*
Reference Temperature	*290*	*290*	*K*	*To*
Receive Antenna Efficiency	*0.44*	*0.62*	*[-]*	*η*
Receive Antenna Physical Temperature	200	290	K	Tphys
External "scene" Noise Temperature	260	25	K	Text
Antenna Noise Temperature	226.4	125.7	K	Tant
Receiver Cable Loss	*0.90*	*0.90*	*dB*	*Lc*
Receiver Cable Loss	*0.81*	*0.81*	Linear	*Lc*
Receiver Noise Figure (based on receiver)	*3.00*	*1.00*	*dB*	*NF*
Receiver Noise Factor	*1.995*	*1.259*	[-]	F
Receiver Noise Temperature	*288.6*	*75.1*	K	Tr
Receiver System Noise Temperature	627.54	284.86	K	Ts
Receiver System Noise Power	-200.62	-204.05	dBW-Hz	No
Receiver Parameters:	*Uplink*	*Downlink*	*Units*	*Symbol*

Receive Antenna Diameter	*0.18*	*6.8*	*m*	*D*
Receive Antenna Area	0.025	36.317	m^2	A
Receive Antenna Efficiency	*0.44*	*0.62*	*[-]*	*η*
Receive Antenna Effective Area	0.011	22.516	m^2	Ae
Receive Antenna Gain	20.43	53.04	dBi	Gr
Receive Antenna Beamwidth	12.83	0.36	degrees	qr
Receive Antenna Pointing Accuracy	*6.0*	*0.15*	*degrees*	*er*
Receive Antenna Pointing Loss	-2.63	-2.12	dB	Lpr
Receiver Cable Loss (see noise)	*-0.5*	*-0.5*	*dB*	*Lc*
Receiver Figure of Merit	0.04	0.16	dB/K	FOM
Propagation Parameters:	*Uplink*	*Downlink*	*Units*	*Symbol*
Space Loss	-202.97	-202.54	dB	Ls
Atmospheric Attenuation (clear air)	0.0251	0.0251	dB	La
Polarization Loss	*-0.20*	*-0.20*	*dB*	*Lp*
Propagation Losses	*-203.14*	*-202.72*	*dB*	
Transmitter Parameters:	*Uplink*	*Downlink*	*Units*	*Symbol*
Transmit Antenna Diameter	*6.8*	*0.18*	m	D
Transmit Antenna Area	*36.32*	*0.025*	m^2	A
Transmit Antenna Efficiency	*0.62*	*0.44*	[-]	h
Transmit Antenna Effective Area	22.516	0.011	m2	Ae
Transmit Antenna Gain	53.46	20.00	dBi	Gt

Transmit Antenna Beamwidth	0.34	13.47	degrees	qt
Transmit Antenna Pointing Accuracy	*0.15*	*6.0*	degrees	et
Transmit Antenna Pointing Loss	-2.34	-2.38	dB	Lpt
Transmit Line Loss	*-0.5*	*-0.5*	*dB*	*Lt*
Tramsmit Power, Linear	*100*	*5*	W	
Transmit Power	*20.0*	*6.99*	dBW	Pt
Effective Isotropic Radiated Power	72.96	26.49	dBW	EIRP

Link Budget:	*Uplink*	*Downlink*	*Units*	*Symbol*
Effective Isotropic Radiated Power (61)	72.96	26.49	dBW	EIRP
Pointing Losses	-4.97	-4.51	dB	
Propagation Losses (47)	-203.14	-202.72	dB	L
Receive Antenna Gain (36)	20.43	53.04	dB	Gr
Received Power	-114.72	-127.70	dBW	Pr
Receiver System Noise Power (30)	-200.62	-204.05	dBW-Hz	No
Received Carrier to Noise Ratio	85.90	76.35	dB-Hz	C/No
Minimum C/No (17)	51.13	72.80	dB-Hz	C/No
Link Margin	**34.77**	**3.55**	**dB**	

The given data in the link budget suggest that you are designing a geostationary satellite, communicating in the X-band. The (command) has a low data rate, when compared to the downnlinked data/telemetry to Earth. The more critical uplink comma choices and list your equations. Use additional sheets to elaboarte on your design choices.

n data / requirements; blue cells - to be completed)

Reference
constant
Input: system choice, X-band mil.com.sat.
Linked to row 1 C and row 2 f, $\lambda = C/f$
Input: Geostationary Satellite
constant
Reference
Input: design requirement
Input: chosen modulation (SMAD Tab.13-10)
Supplemental notes page 8 , matlab qinv fucntion used, lines 37 - 40 in provided code
Input: based on mission / objective
Supplemental notes page 8, RDM = line 16, $\frac{C}{N_o} = \frac{\mathrm{E_b}}{\mathrm{N_o}} + 10\log(\mathrm{R}) + \mathrm{RDM}$
Input: design rule (Hoffmann chap. 9.4.4)
Reference
SMAD Eqn13-24
Input: typical value
Uplink: Receiver on the S/C looks at Earth which is 260K | Downlink: Receiver looks at Space which is 25K
Lecture Slides: Slide 38, rows 21, 22, 23 $T_{ant} = (\eta * T_{ext} + (1-\eta) * T_{phys}$
SMAD Table 13-10
Related to row 25, RL_linear = 10^(RL_dB/10)
SMAD Table 13-10
Related to row 27: F = 10^(NF/10)
Lecture Slides: Slide 41, rows 20, 26, 28 $T_r = T_o * (F-1)$
Lecture slides: slide 39 + 40 , related to rows 24,26 ,29 $T_{cable} = T_{Physical} * \left(1 - L_{C(linear)}\right), T_{sys(RX)} = L_{c(linear)} * T_{cable} + T_r$
Lecture Slides: slide 35, related to row 30, 14, 8 $N = K_b * T_s * R$
Reference

Input: given geometry from spacecraft

Assuming simple circular aperature, linked to row 34, $A = \frac{\pi * D^2}{4}$

Linked to row 21

Lecture Slides: slide 14, linked to row 35 , 36, $A_e = \eta * A$

Lecutre Slides: slide 14, linked to rows 37, 36, 6 $G_r = \frac{4 * \pi * A_e}{\lambda^2}$

Lecutre Slides: slide 16, linked to rows 37, 36 , $qr = \sqrt{\frac{\eta * 41253}{G_r}}$

Input: pointing error e for chosen system

lecture slides: slide 30, linked to rows 39,40, $L_{pr} = -12 * \left(\frac{er}{qr}\right)^2$

Input: typical value

Lecture Slides: slide 46, linked to rows 30, 38, $FOM = \frac{G_r}{Ts}$

Reference

Lecture slides: slide 24, related to row 6, row 7, $L_s = \left(\frac{\lambda}{4 * pi * R}\right)^2$

Lecture slides: slide 27 Absorbition loss v Frequency Graph approximation

Input: typical value

Related to rows 46,47,48 $L = L_s + L_a + L_p$

Reference

reciprocity Tx is Rx and Rx is Tx: Linked to row 33 but swapped

reciprocity Tx is Rx and Rx is Tx: Linked to row 34 but swapped

reciprocity Tx is Rx and Rx is Tx: Linked to row 21 but swapped

Related to rows 52, 53, 54, $A_e = h * A$

Related to rows 56, 6, $G_t = \frac{4 * pi * A_e}{\lambda^2}$

Related to rows 56, 54, $qt = \sqrt{\frac{h * 41253}{G_t}}$

Reciprocity, linked to row 40 but swapped.

lecture slides: slide 30, linked to rows 57,58, $L_{pr} = -12 * \left(\frac{et}{qt}\right)^2$

Input: based on chosen cable/geometry
Input: chosen transmitter

Conversion from linear to dB, linked to row 61, $P_{t(ldB)} = 10 * log10\left(P_{t(linear)}\right)$

Lecture slides: slide 20, linked to rows 56,60,62 $EIRP = P_t * L_t * G_t$

Reference
linked to row 61
Sum of pointing loss for reciever and transmitter, linked to rows 41 and 59
linked to row 47
linked to row 36
pr = sum(rows 66->69)
linked to row 30
pr/no row70-row71
linked to row 17
row72-row73

e satellite features a small, high gain antenna, and communicates to/from a large, medium-gain gain antenna on Earth. Uplink to the satellite ands require a lower bit error rate than the large quantity downlink data. The satellite uses QPSK data coding. Carefully reference your design