Link Budget

Link design result is below. As these tables, RF link is plus margin and it is possible to demonstrate technology of 115.2 kbps (GMSK) transmitter. Furthermore, orbital attitude is designed for 613 km which we will launch.

Table A. 1 Circuit design of FM down link and CW down link

Mode	FM		CW	
Spacecraft				
Antenna Type	Monopole Antenna		Monopole Antenna	
Orbit Altitude	613	H[km]	613	H[km]
Maximum Transmission Distance	1962.0	D[km]	1962.0	D[km]
Elevation Angle	10	θ_{EL}[deg]	10	θ_{EL}[deg]
Spacecraft Transmitter Power Output	0.8	P_{TX}[W]	0.1	P_{TX}[W]
Downlink Frequency	437.6	f[MHz]	437.6	f[MHz]
Spacecraft Total Transmission Line Losses	1.6	L_{FTX}[dB]	1.6	L_{FTX}[dB]
Spacecraft Antenna Gain	2.0	G_{ATX}[dB]	2.0	G_{ATX}[dB]
Spacecraft EIRP	-0.57	P_E[dBW]	-9.6	P_E[dBW]
Downlink Path				
Spacecraft Antenna Pointing Loss	0	L_{APt}[dB]	0	L_{APt}[dB]
S/C-to-Ground Antenna Polarization Loss	0.5	L_P[dB]	0.5	L_P[dB]
Path Loss	151.1	L_d[dB]	151.1	L_d[dB]
Atmospheric Loss	1.1	L_A[dB]	1.1	L_A[dB]
Ionospheric Loss	0.8	LI[dB]	0.8	LI[dB]
Rain Loss	0	L_{RA}[dB]	0	L_{RA}[dB]
Isotropic Signal Level at Ground Station	-154.1	C[dBW]	-163.1	C[dBW]
Ground Station (EbNo Method)				
Ground Station Antenna Pointing Loss	0.2	L_{APr}[dB]	0.2	L_{APr}[dB]
Ground Station Antenna Gain	18	G_{ARX}[dB]	18	G_{ARX}[dB]
Ground Station Total Transmission Line Losses	1.9	L_{FRX}[dB]	1.9	L_{FRX}[dB]
Ground Station Effective Noise Temperature	490	T_A[K]	490	T_A[K]
Ground Station Figure of Merit (G/T)	-10.8	G/T[dB/K]	-10.8	G/T[dB/K]
G.S. Signal-to-Noise Power Density (S/No)	63.5	C/N_0[dB]	54.5	C/N_0[dB]
System Desired Data Rate	1,200	B_{ps}[bps]	100	B_{ps}[bps]
Telemetry System Eb/No for the Downlink	32.7	[dB]	34.5	[dB]
Demodulation Method Selected	FSK		CW	
Forward Error Correction Coding Used	None		None	
System Allowed or Specified Bit-Error-Rate	0.000001	P_b	0.000001	P_b
Demodulator Implementation Loss	1	L_D[dB]	1	L_D[dB]
Telemetry System Required Eb/No	23.2	$(E_b/N_0)_{req}$[dB]	16	$(E_b/N_0)_{req}$[dB]
Eb/No Threshold	24.2	[dB]	17	[dB]
System Link Margin	8.5	M[dB]	17.5	M[dB]
Ground Station Alternative Signal Analysis Method (SNR Computation)				
Ground Station Antenna Pointing Loss	0.20	[dB]	0.20	[dB]
Ground Station Antenna Gain	18.0	[dBi]	18.0	[dBi]
Ground Station Total Transmission Line Losses	1.90	[dB]	1.90	[dB]
Ground Station Effective Noise Temperature	490.0	[K]	490.0	[K]
Ground Station Figure of Merit (G/T)	-10.8	[dB/K]	-10.8	[dB/K]
Signal Power at Ground Station LNA Input	-138.2	[dBW]	-147.2	[dBW]
Ground Station Receiver Bandwidth (B)	10.0	[kHz]	3.0	[kHz]
G.S. Receiver Noise Power (Pn = kTB)	-161.7	[dBW]	-166.9	[dBW]
Signal-to-Noise Power Ratio at G.S. Rcvr	23.5	[dB]	19.7	[dB]
Analog or Digital System Required S/N	23.2	[dB]	16.0	[dB]
System Link Margin	0.3	[dB]	3.7	[dB]

Table A. 2 Circuit design of GMSK down link

Mode	GMSK（115bps）	
Spacecraft		
Antenna Type	Monopole Antenna	
Orbit Altitude	613	H[km]
Maximum Transmission Distance	1962.0	D[km]
Elevation Angle	10	θ_{EL}[deg]
Spacecraft Transmitter Power Output	0.8	P_{TX}[W]
Downlink Frequency	437.6	f[MHz]
Spacecraft Total Transmission Line Losses	1.6	L_{FTX}[dB]
Spacecraft Antenna Gain	2.0	G_{ATX}[dB]
Spacecraft EIRP	-0.57	P_E[dBW]
Downlink Path		
Spacecraft Antenna Pointing Loss	4.7	L_{APt}[dB]
S/C-to-Ground Antenna Polarization Loss	0.5	L_P[dB]
Path Loss	151.1	L_d[dB]
Atmospheric Loss	1.1	L_A[dB]
Ionospheric Loss	0.8	LI[dB]
Rain Loss	0	L_{RA}[dB]
Isotropic Signal Level at Ground Station	-158.8	C[dBW]
Ground Station (EbNo Method)		
Ground Station Antenna Pointing Loss	0.2	L_{APr}[dB]
Ground Station Antenna Gain	18	G_{ARX}[dB]
Ground Station Total Transmission Line Losses	1.9	L_{FRX}[dB]
Ground Station Effective Noise Temperature	490	T_A[K]
Ground Station Figure of Merit (G/T)	-10.8	G/T[dB/K]
G.S. Signal-to-Noise Power Density (S/No)	58.8	C/N_0[dB]
System Desired Data Rate	115,200	B_{ps}[bps]
Telemetry System Eb/No for the Downlink	8.2	[dB]
Demodulation Method Selected	GMSK	
Forward Error Correction Coding Used	LDPC	
System Allowed or Specified Bit-Error-Rate	0.000001	P_b
Demodulator Implementation Loss	1	L_D[dB]
Telemetry System Required Eb/No	5.5	$(E_b/N_0)_{req}$[dB]
Eb/No Threshold	6.5	[dB]
System Link Margin	1.7	M[dB]
Ground Station Alternative Signal Analysis Method (SNR Computation)		
Ground Station Antenna Pointing Loss	0.20	[dB]
Ground Station Antenna Gain	18.0	[dBi]
Ground Station Total Transmission Line Losses	1.90	[dB]
Ground Station Effective Noise Temperature	490.0	[K]
Ground Station Figure of Merit (G/T)	-10.8	[dB/K]
Signal Power at Ground Station LNA Input	-142.9	[dBW]
Ground Station Receiver Bandwidth (B)	150.0	[kHz]
G.S. Receiver Noise Power (Pn = kTB)	-149.9	[dBW]
Signal-to-Noise Power Ratio at G.S. Rcvr	7.1	[dB]
Analog or Digital System Required S/N	5.5	[dB]
System Link Margin	1.6	[dB]

Table A. 3 Circuit design of FM up link

Mode	FM	
Ground Station		
Antenna Type	Cross Yagi Antenna 2 stack	
Ground Station Latitude	34.292655	[deg]
Ground Station Longitude	134.063769	[deg]
Elevation Angle	10	θ_{EL}[deg]
Ground Station Transmitter Power Output	50	P_{TX}[W]
Uplink Frequency	437.6	f[MHz]
Ground Station, Total Transmission Line Losses	3.6	L_{FTX}[dB]
Antenna Gain	16.0	G_{ATX}[dB]
Ground Station EIRP	29.4	P_E[dBW]
Uplink Path		
Ground Station Antenna Pointing Loss	0.1	L_{APt}[dB]
Gnd-to-S/C Antenna Polarization Losses	0.5	L_P[dB]
Path Loss	151.12	L_d[dB]
Atmospheric Loss	1.1	L_A[dB]
Ionospheric Loss	0.7	L_I[dB]
Rain Loss	0	L_{RA}[dB]
Isotropic Signal Level at Ground Station	-124.1	C[dBW]
Spacecraft Station (EbNo Method)		
Spacecraft Antenna Pointing Loss	4.7	L_{APr}[dB]
Spacecraft Antenna Gain	2	G_{ARX}[dB]
Spacecraft Total Transmission Line Losses	2	L_{FRX}[dB]
Spacecraft Effective Noise Temperature	220	T_A[K]
Spacecraft Figure of Merit (G/T)	-23.4	G/T[dB/K]
S/C Signal-to-Noise Power Density (S/No)	76.3	C/N_0[dB]
System Desired Data Rate	1,200	B_{ps}[bps]
Command System Eb/No	45.6	[dB]
Demodulation Method Selected	FSK	
Forward Error Correction Coding Used	None	
System Allowed or Specified Bit-Error-Rate	0.000001	P_b
Demodulator Implementation Loss	1	L_D[dB]
Telemetry System Required Eb/No	10.5	$(E_b/N_0)_{req}$[dB]
Eb/No Threshold	11.5	[dB]
System Link Margin	34.1	M[dB]
Spacecraft Alternative Signal Analysis Method (SNR Computation)		
Spacecraft Antenna Pointing Loss	4.70	[dB]
Spacecraft Antenna Gain	2.0	[dBi]
Spacecraft Total Transmission Line Losses	2.00	[dB]
Spacecraft Effective Noise Temperature	220.0	[K]
Spacecraft Figure of Merit (G/T)	-23.4	[dB/K]
Signal Power at Spacecraft LNA Input	-128.8	[dBW]
Spacecraft Receiver Bandwidth	10.0	[kHz]
Spacecraft Receiver Noise Power (Pn = kTB)	-165.2	[dBW]
Signal-to-Noise Power Ratio at G.S. Rcvr	36.3	[dB]
Analog or Digital System Required S/N	10.5	[dB]
System Link Margin	25.8	[dB]