

DownLink

Link Design Parameters

Modulation Method	GMSK (F1D)		4FSK (F1D)		AFSK (F2D)		OQPSK (G1D)		CW (A1A)		Digitalker on FM (F3E)		SSTV on FM (F3F)	
Orbit Altitude	H[km]	400	H[km]	400	H[km]	400	H[km]	400	H[km]	400	H[km]	400	H[km]	400
Earth radius	R[km]	6378.14	R[km]	6378.14	R[km]	6378.14	R[km]	6378.14	R[km]	6378.14	R[km]	6378.14	R[km]	6378.14
Ground Station Antenna Elevation Angle	θ_{EL} [deg]	5.00	θ_{EL} [deg]	5.00	θ_{EL} [deg]	5.00	θ_{EL} [deg]	5.00	θ_{EL} [deg]	5.00	θ_{EL} [deg]	5.00	θ_{EL} [deg]	10.00
	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.09	θ_{EL} [rad]	0.17
Maximum Path Length	D[km]	1804.52	D[km]	1804.52	D[km]	1804.52	D[km]	1804.52	D[km]	1804.52	D[km]	1804.52	D[km]	1439.84
Propagation speed of radio wave	c[m]	3.0E+08	c[m]	3.0E+08	c[m]	3.0E+08	c[m]	3.0E+08	c[m]	3.0E+08	c[m]	3.0E+08	c[m]	3.0E+08
Boltzmann constant	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23	k[W/Hz·K]	1.38E-23

Space Station

Antenna Type	Monopole Antenna		Monopole Antenna		Monopole Antenna		Monopole Antenna		Monopole Antenna		Monopole Antenna		Monopole Antenna	
Downlink Frequency	f[MHz]	437.5	f[MHz]	437.5	f[MHz]	437.5	f[MHz]	437.5	f[MHz]	437.5	f[MHz]	437.5	f[MHz]	437.5
Transmitter Power Output	P_{TX} [W]	0.4	P_{TX} [W]	0.9	P_{TX} [W]	0.4	P_{TX} [W]	0.9	P_{TX} [W]	0.1	P_{TX} [W]	0.4	P_{TX} [W]	0.4
	P_{TX} [dBW]	-3.9	P_{TX} [dBW]	-0.4	P_{TX} [dBW]	-3.9	P_{TX} [dBW]	-0.4	P_{TX} [dBW]	-10	P_{TX} [dBW]	-3.9	P_{TX} [dBW]	-3.9
Feeder Loss	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2	L_{FTX} [dB]	-2
Transmitting Antenna Gain	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2	G_{ATX} [dBi]	2.2
Transmit EIRP	P_E [dBW]	-3.7	P_E [dBW]	-0.2	P_E [dBW]	-3.7	P_E [dBW]	-0.2	P_E [dBW]	-9.8	P_E [dBW]	-3.7	P_E [dBW]	-3.7
Antenna Pointing Loss	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96	L_{APL} [dB]	-1.96

Link information

Path Loss (Free Space Loss)	L_f [dB]	-150.39	L_f [dB]	-150.39	L_f [dB]	-150.39	L_f [dB]	-150.39	L_f [dB]	-150.39	L_f [dB]	-150.39	L_f [dB]	-148.43
Polarization Coupling Loss	L_p [dB]	-4.76	L_p [dB]	-4.76	L_p [dB]	-4.76	L_p [dB]	-4.76	L_p [dB]	-4.76	L_p [dB]	-4.76	L_p [dB]	-4.76
Atmospheric Loss	L_a [dB]	-2.1	L_a [dB]	-2.1	L_a [dB]	-2.1	L_a [dB]	-2.1	L_a [dB]	-2.1	L_a [dB]	-2.1	L_a [dB]	-2.1
Rain Loss	L_{RA} [dB]	0	L_{RA} [dB]	0	L_{RA} [dB]	0	L_{RA} [dB]	0	L_{RA} [dB]	0	L_{RA} [dB]	0	L_{RA} [dB]	0
Other losses	L_v [dB]	-0.4	L_v [dB]	-0.4	L_v [dB]	-0.4	L_v [dB]	-0.4	L_v [dB]	-0.4	L_v [dB]	-0.4	L_v [dB]	-0.4
Total transmission loss	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-157.65	L_{Σ} [dB]	-155.69
Isotropic Signal Level at Ground Station	P_{RX} [dBW]	-163.31	P_{RX} [dBW]	-159.81	P_{RX} [dBW]	-163.31	P_{RX} [dBW]	-159.81	P_{RX} [dBW]	-169.41	P_{RX} [dBW]	-163.31	P_{RX} [dBW]	-161.35

Ground Station

Antenna Type	Cross Yagi Antenna		Cross Yagi Antenna		Cross Yagi Antenna		Cross Yagi Antenna		Cross Yagi Antenna		Cross Yagi Antenna		Cross Yagi Antenna	
Antenna Pointing Loss	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75	L_{APL} [dB]	-0.75
Antenna Gain	G_{ARX} [dB]	19	G_{ARX} [dB]	19	G_{ARX} [dB]	19	G_{ARX} [dB]	19	G_{ARX} [dB]	19	G_{ARX} [dB]	19	G_{ARX} [dB]	19
Feeder Loss	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1	L_{FRX} [dB]	-1
	$L[-]$	1.26	$L[-]$	1.26	$L[-]$	1.26	$L[-]$	1.26	$L[-]$	1.26	$L[-]$	1.26	$L[-]$	1.26
Antenna Noise Temperature	T_A [K]	238.30	T_A [K]	238.30	T_A [K]	238.30	T_A [K]	238.30	T_A [K]	238.30	T_A [K]	238.30	T_A [K]	238.30
Feeder Noise temperature	T_F [K]	80.27	T_F [K]	80.27	T_F [K]	80.27	T_F [K]	80.27	T_F [K]	80.27	T_F [K]	80.27	T_F [K]	80.27
Receiver noise temperature	T_E [K]	14.61	T_E [K]	14.61	T_E [K]	14.61	T_E [K]	14.61	T_E [K]	14.61	T_E [K]	14.61	T_E [K]	14.61
Receiver Noise Figure	$nf[-]$	1.05	$nf[-]$	1.05	$nf[-]$	1.05	$nf[-]$	1.05	$nf[-]$	1.05	$nf[-]$	1.05	$nf[-]$	1.05
	NF[dB]	0.20	NF[dB]	0.20	NF[dB]	0.20	NF[dB]	0.20	NF[dB]	0.20	NF[dB]	0.20	NF[dB]	0.20
Ground temperature	T_G [K]	310	T_G [K]	310	T_G [K]	310	T_G [K]	310	T_G [K]	310	T_G [K]	310.00	T_G [K]	310.00
Receiving System noise temperature	T_S [K]	333.18	T_S [K]	333.18	T_S [K]	333.18	T_S [K]	333.18	T_S [K]	333.18	T_S [K]	333.18	T_S [K]	333.18
Bandwidth	B[kHz]	15	B[kHz]	40	B[kHz]	15	B[kHz]	40	B[kHz]	0.5	B[kHz]	15	B[kHz]	15
Noise power	N[W]	6.90E-17	N[W]	1.84E-16	N[W]	6.90E-17	N[W]	1.84E-16	N[W]	2.30E-18	N[W]	6.90E-17	N[W]	6.90E-17
	N[dBW]	-161.61	N[dBW]	-157.35	N[dBW]	-161.61	N[dBW]	-157.35	N[dBW]	-176.38	N[dBW]	-161.61	N[dBW]	-161.61
Noise power density	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37	N_0 [dBW/Hz]	-203.37
Receiving Antenna Gain	G[dB]	18	G[dB]	18	G[dB]	18	G[dB]	18	G[dB]	18	G[dB]	18	G[dB]	18
Figure of Merit (G/T)	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2	G/T[dB/K]	-7.2
Demodulator Implementation Loss	L_D [dB]	-1	L_D [dB]	-1	L_D [dB]	-1	L_D [dB]	-1	L_D [dB]	-1	L_D [dB]	-1	L_D [dB]	-1
System Desired Data Rate	B_{DS} [bps]	9,600	B_{DS} [bps]	24,000	B_{DS} [bps]	1,200.0	B_{DS} [bps]	24,000	B_{DS} [bps]	26.7	B_{DS} [bps]	1,200	B_{DS} [bps]	1,200
	B_{DS} [dBHz]	39.82	B_{DS} [dBHz]	43.80	B_{DS} [dBHz]	30.79	B_{DS} [dBHz]	43.80	B_{DS} [dBHz]	14.27	B_{DS} [dBHz]	30.79	B_{DS} [dBHz]	30.79
System Allowed or Specified Bit-Error-Rate	P_b	1.E-05	P_b	1.E-05	P_b	1.E-05	P_b	1.E-05	P_b	1.E-05	P_b	1.E-05	P_b	1.E-05
Signal-to-Noise Power Density (C/No)	C/No[dB·Hz]	17.49	C/No[dB·Hz]	17.01	C/No[dB·Hz]	26.52	C/No[dB·Hz]	17.01	C/No[dB·Hz]	17.01	C/No[dB·Hz]	17.01	C/No[dB·Hz]	17.01
Telemetry System Required Eb/No	$(E_b/N_0)_{req}$ [dB·Hz]	9.6	$(E_b/N_0)_{req}$ [dB·Hz]	10.7	$(E_b/N_0)_{req}$ [dB·Hz]	23.2	$(E_b/N_0)_{req}$ [dB·Hz]	23.2	$(E_b/N_0)_{req}$ [dB·Hz]	9.6	$(E_b/N_0)_{req}$ [dB·Hz]	9.6	$(E_b/N_0)_{req}$ [dB·Hz]	9.6
Signal Power at Ground Station LNA Input:														
G.S. Receiver Noise Power (Pn = kTB)														
Signal-to-Noise Power Ratio at G.S. Rcvr:														
Analog System Required S/N:														
System Link Margin	M[dB]	6.89	M[dB]	5.31	M[dB]	2.32	M[dB]	6.41	M[dB]	12.23	M[dB]	1.56	M[dB]	0.52

UpLink

Link Design Parameters

Modulation Method	AFSK(F2D)	
Orbit Altitude	H[km]	400
Earth radius	R[km]	6378.14
Ground Station Antenna Elevation Angle	θ_{EL} [deg]	5.00
	θ_{EL} [rad]	0.09
Maximum Path Length	D[km]	1804.52
Propagation speed of radio wave	c[m]	3.0E+08
Boltzmann constant	k[W/Hz·K]	1.38E-23

GMSK(F1D)	
H[km]	400
R[km]	6378.14
θ_{EL} [deg]	5.00
θ_{EL} [rad]	0.09
D[km]	1804.52
c[m]	3.0E+08
k[W/Hz·K]	1.38E-23

Ground Station

Antenna Type	Cross Yagi Antenna	
Uplink Frequency	f[MHz]	437.5
Transmitter Power Output	P_{TX} [W]	50
	P_{TX} [dBW]	17
Feeder Loss	L_{FTX} [dB]	-1
Transmitting Antenna Gain	G_{ATX} [dB]	19
Transmit EIRP	P_E [dBW]	35.00
Antenna Pointing Loss	L_{APt} [dB]	-0.75

Cross Yagi Antenna	
f[MHz]	437.5
P_{TX} [W]	50
P_{TX} [dBW]	17
L_{FTX} [dB]	-1
G_{ATX} [dB]	19
P_E [dBW]	35.00
L_{APt} [dB]	-0.75

Link information

Path Loss (Free Space Loss)	L_d [dB]	-150.39
Polarization Coupling Loss	L_p [dB]	-4.76
Atmospheric Loss	L_A [dB]	-2.1
Rain Loss	L_{RA} [dB]	0
Other losses	L_V [dB]	-0.4
Total transmission loss	L_{pr} [dB]	-157.65
Isotropic Signal Level at Space Station	P_{rx} [dBW]	-123.40

L_d [dB]	-150.39
L_p [dB]	-4.76
L_A [dB]	-2.1
L_{RA} [dB]	0
L_V [dB]	-0.4
L_{pr} [dB]	-157.65
L_{pr} [dB]	-123.40

Space Station

Antenna Type	Monopole Antenna	
Antenna Pointing Loss	L_{APr} [dB]	-1.96
Antenna Gain	G_{ARX} [dB]	2.2
Feeder Loss	L_{FRX} [dB]	-2
	L[-]	1.58
Antenna Noise Temperature	T_A [K]	189.287203
Feeder Noise temperature	T_F [K]	175.47
Receiver noise temperature	T_E [K]	123.76
Receiver Noise Figure	nf[-]	1.41
	NF[dB]	1.50
Spacecraft temperature	T_G [K]	300
Receiving System noise temperature	T_S [K]	488.52
Bandwidth	B[kHz]	15
Noise power	N[W]	1.01E-16
	N[dBW]	-159.95
Noise power density	N_0 [dBW]	-201.71
Receiving Antenna Gain	G[dB]	0.2
Figure of Merit (G/T)	G/T[dB/K]	-26.7
Demodulator Implementation Loss	L_D [dB]	-1
System Desired Data Rate	B_{ps} [bps]	1,200
	B_{ps} [dBHz]	30.79
System Allowed or Specified Bit-Error-Rate	P_b	1.E-05
Signal-to-Noise Power Density (C/No)	C/ N_0 [dB]	45.76
Telemetry System Required Eb/No	$(E_b/N_0)_{req}$ [dB]	23.2
Signal Power at Space Station LNA Input:		
G.S. Receiver Noise Power ($P_n = kTB$)		
Signal-to-Noise Power Ratio at G.S. Rcvr:		
Analog System Required S/N:		
System Link Margin	M[dB]	21.56

Monopole Antenna	
L_{APr} [dB]	-1.96
G_{ARX} [dB]	2.2
L_{FRX} [dB]	-2
L[-]	1.58
T_A [K]	189.287203
T_F [K]	175.47
T_E [K]	123.76
nf[-]	1.41
NF[dB]	1.50
T_G [K]	300
T_S [K]	488.52
B[kHz]	15
N[W]	1.01E-16
N[dBW]	-159.95
N_0 [dBW]	-201.71
G[dB]	0.2
G/T[dB/K]	-26.7
L_D [dB]	-1
B_{ps} [bps]	9,600
B_{ps} [dBHz]	39.82
P_b	1.E-05
C/ N_0 [dB]	36.73
$(E_b/N_0)_{req}$ [dB]	9.6
M[dB]	26.13