TECHNISCHE UNIVERSITÄT ILMENAU

Fakultät für Informatik und Automatisierung

Design of cooperative communication system based on CubeSat satellites

Masterarbeit

zur Erlangung des akademischen Grades Masteringenieur

vorgelegt von:	Vladimir Fadeev
geboren:	22. July.1993 in Naberezhnye Chelny, Russia
Studiengang:	Elektrotechnik und Informationstechnik
Studienrichtung:	Informationstechnik und Kommunikationstechnik
Anfertigung im Fachgebiet:	Nachrichtentechnik Institut für Informationstechnik Fakultät für Elektrotechnik und Informationstechnik
verantwortlicher Professor:	Prof. Dr.-Ing. Martin Haardt, Prof. Adel Nadeev
Erster wissenschaftlicher Betreuer:	M. Sc. Dipl.-Ing. Marko Hennhöfer
Zweiter wissenschaftlicher Betreuer:	Artur Gaysin
Datum:	14. August 2017

To sum up, main parameters for link budget calculation are maintained in table 2.4.

Additional loses due to scattering in atmosphere can be compute by [9]. Attenuations due to hydrometeors and other additional loses can be evaluated by [11]. Fortunately, for ranges smaller than 10 GHz the losses are smaller than 1 dB.

Tab. 2.1: Transmitter parameters of different ground stations.

System	Stationary station	Mobile station
Transmit power(in Watts)		
IC-910H	5 - 100	-
ISIS Ground Station	5 - 100	
Iridium	-	0.6
Globalstar	3	0.6
Messenger	8 - 12	-
Antenna gains (in dBi)		
IC-910H (connected to Uda-Yagi)	12.8 - 15	-
ISIS Ground Station (connected to dish antenna)	up to 35	-
Iridium	-	0 - 7
Globalstar	up to 17	0 - 7
Messenger	up to 17	-

Fig. 2.1: NanoCom AX100 by GomSpace company.

Tab. 2.2: Equivalent Isotropically Radiated Power for different ranges (total additional losses are 5 dB).

Power (in Watts)	Range (in MHz)	Type of Antenna	Antenna gains (in dBi)	EIRP (in dBm)
Uplink				
5 10 15	144	Uda-Yagi	12.5	49.49 52.5 54.3
5 10 15	2400	Uda-Yagi	18	54.99 58 59.76
5 10 15	2400	Dish antenna	35	71.99 75 76.76
Downlink				
0.5 1 2	433	GomSpace ANT430	1.5	28.5 31.5 34.5
0.5 1 2	2400	GomSpace ANT2000	7.3	34.3 37.3 40.3

Fig. 2.2: NanoCom ANT430 by GomSpace company.

Tab. 2.3: Noise power and Path loss ($d = 750km$).

Range (in MHz)	Bandwidth B (in MHz)	Noise temperature (in K)	Noise power N (in dBm)	Path Loss (in dB)
Uplink				
144	0.5	234	-117.5	-133.1
	1		-114.45	
	2		-111.4	
2400	3	240	-109.57	-157.5
	6		-106.56	
	10		-104.34	
Downlink				
433	0.5	1000	-111.15	-142.7
	1		-108.1	
	2		-105.1	
2400	3	1000	-103.37	-157.5
	6		-100.36	
	10		-98.15	

Fig. 2.3: NanoCom SR2000 by GomSpace company.

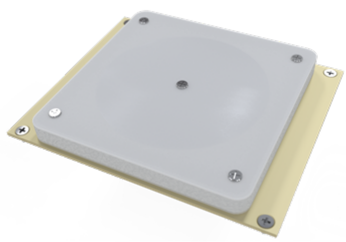

Fig. 2.4: ANT2000 by GomSpace company.

Tab. 2.4: Expected Signal-to-Noise ratios

Range (in MHz)	Bandwidth (in MHz)	Uplink		Downlink	
		Power (in Watts)	SNR (in dB)	Power (in Watts)	SNR (in dB)
144 / 433 antenna gains: 12.5 dBi (ground) 1.5 dBi (CubeSat)	0.5	5	30.3	0.5	6.97
		10	33.3	1	9.98
		15	35.1	2	13
	1	5	27.3	0.5	3.96
		10	30.3	1	6.97
		15	32.1	2	9.98
	2	5	24.3	0.5	0.95
		10	27.3	1	3.96
		15	29.1	2	6.97
2400 antenna gains: 18 dBi (ground) 7.3 dBi (CubeSat)	3	5	9.3	0.5	-6.88
		10	12.3	1	-3.87
		15	14.1	2	-0.86
	6	5	6.3	0.5	-9.89
		10	9.3	1	-6.88
		15	11.1	2	-3.87
	10	5	4.1	0.5	-12.1
		10	7.1	1	-9.1
		15	8.9	2	-6.09
2400 antenna gains: 35 dBi (ground) 7.3 dBi (CubeSat)	3	5	26.3	0.5	10.1
		10	29.3	1	13.1
		15	31.3	2	16.1
	6	5	23.3	0.5	7.1
		10	26.3	1	10.1
		15	28.3	2	13.1
	10	5	21.1	0.5	4.88
		10	24.1	1	7.8
		15	25.9	2	10.9

SYMBOLS AND NOTATIONS

$$
\begin{aligned}
a,\ b,\ c \quad & \text{Scalars} \\
\boldsymbol{a},\ \boldsymbol{b},\ \boldsymbol{c} \quad & \text{Column vectors} \\
\boldsymbol{A},\ \boldsymbol{B},\ \boldsymbol{C} \quad & \text{Matrices} \\
a^* \quad & \text{Complex conjugate of } a \\
\boldsymbol{A}^T \quad & \text{Transpose of matrix } \boldsymbol{A} \\
\boldsymbol{A}^H \quad & \text{Hermitian transpose of matrix } \boldsymbol{A} \\
\mathrm{Re}\{a\} \quad & \text{Real part of } a \\
\mathrm{Im}\{a\} \quad & \text{Imaginary part of } a \\
\mathbb{E}\{\boldsymbol{a}\} \quad & \text{Expected value of the random vector } \boldsymbol{a} \\
\|\boldsymbol{A}\|_F \quad & \text{The Frobenius norm of the matrix } \boldsymbol{A}
\end{aligned}
\tag{6.1}
$$

ACRONYMS

AWGN	**A**dditive **W**hite **G**aussian **N**oise **C**hannel
BER	**B**it **E**rror **R**ate
C2V	**C**heck to **V**ariable nodes transmission
CSI	**C**hannel **S**tate **I**nformation
FSK	**F**requency **S**hift **K**eying
GMSK	**G**aussian **M**inimum **S**hift **K**eying
ISI	**I**nter **S**ymbol **I**nterference
LEO	**L**ow **E**arth **O**rbit
LoS	**L**ine of **S**ight
MIMO	**M**ultiple **I**nput **M**ultiple **O**utput
MISO	**M**ultiple **I**nput **S**ingle **O**utput
MSK	**M**inimum **S**hift **K**eying
NF	**N**oise **F**igure
OQPSK	**O**ffset **Q**adrature **P**hase **S**hift **K**eying
PDF	**P**robability **D**ensity **F**unction
PSK	**P**hase **S**hift **K**eying
OAM	**Q**adrature **A**mplitude **M**odulation
QPSK	**Q**adrature **P**hase **S**hift **K**eying
RS	**R**eed-**S**olomon codes
SIMO	**S**ingle **I**nput **M**ultiple **O**utput

SISO **S**ingle **I**nput **S**ingle **O**utput

SNR **S**ignal to **N**oise **R**atio

UHF **U**ltra **H**igh **F**requency

V2C **V**ariable to **C**heck nodes transmission

VHF **V**ery **H**igh **F**requency

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