The International Amateur Radio Union

Since 1925, the Federation of National Amateur Radio Societies
Representing the Interests of Two-Way Amateur Radio Communication

AMATEUR SATELLITE FREQUENCY COORDINATION REQUEST

(Make a separate request for each space station to be operated in the amateur-satellite service.)

Administrative information:

0	**DOCUMENT CONTROL**	
0a	Date submitted	(dd-MMM-yyyy)
0b	Expected launch date	(dd-MMM-yyyy)
0c	Document revision number (start at zero and increment with each revised request)	**Ver.0.1**
1	**SPACECRAFT (published)**	
1a	Name before launch	NEXUS
1b	Proposed name after launch	NEXUS
1c	Country of license	JAPAN
1d	API/A special section number	TBD
2	**LICENSEE OF THE SPACE STATION (published)**	
2a	First (given) name	Yasuyuki
2b	Last (family) name	Miyazaki
2c	Call sign	JQ1YGV
2d	Postal address	7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan
2e	Telephone number (including country code)	+81-47-469-5430
2f	E-mail address (licensee will be our point of contact and receive all correspondence)	miyazaki@forth.aero.cst.nihon-u.ac.jp
2g	Skype or FaceTIme name (if available)	N/A
2h	Licensee's position in any organisation referenced in item 3a.	Professor
2i	List names and e-mail addresses of *additional* people who should receive copies of correspondence.	tamura@forth.aero.cst.nihon-u.ac.jp suzuki@forth.aero.cst.nihon-u.ac.jp
3	**ORGANISATIONS (published) — complete this section for EACH participating organization**	
3a	Name of organisation	Department of Aerospace Engineering, College of Science and Technology, Nihon University The Japan AMSAT Association (JAMSAT) The Japan Amateur Radio League, Inc. (JARL)

3b	Physical address	Department of Aerospace Engineering, College of Science and Technology, Nihon University 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan The Japan AMSAT Association (JAMSAT) 3-30-22 Wada, Suginami, Tokyo 166-8532, Japan The Japan Amateur Radio League, Inc. (JARL) 3-43-1 Minamiothuka, Toshima, Tokyo 170-8073, Japan
3c	Postal address	Department of Aerospace Engineering, College of Science and Technology, Nihon University 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan The Japan AMSAT Association (JAMSAT) 3-30-22 Wada, Suginami, Tokyo 166-8532, Japan The Japan Amateur Radio League, Inc. (JARL) 3-43-1 Minamiothuka, Toshima, Tokyo 170-8073, Japan
3d	Telephone number (including country code)	Department of Aerospace Engineering, College of Science and Technology, Nihon University +81-47-469-5430
3e	E-mail address	miyazaki@forth.aero.cst.nihon-u.ac.jp
3f	Web site URL	Department of Aerospace Engineering, College of Science and Technology, Nihon University http://sat.aero.cst.nihon-u.ac.jp/nexus/ The Japan AMSAT Association (JAMSAT) http://www.jamsat.or.jp/ The Japan Amateur Radio League, Inc. (JARL) http://www.jarl.or.jp/
3g	National Amateur Radio Society (including contact information)	The Japan Amateur Radio League, Inc. (JARL) http://www.jarl.or.jp/
3h	National Amateur Satellite organisation (including contact information)	The Japan AMSAT Association (JAMSAT) http://www.jamsat.or.jp/
3i	Have you involved your National Amateur Satellite organization and/or National Amateur Radio Society? Please, explain.	We are the members of JARL and JAMSAT.

Space station information:

4	**SPACE STATION (published)**	
4a	Mission(s). *Describe in detail what the space station is planned to do. Use as much space as you need.*	The main mission of NEXUS is as follows. ➢ **Demonstration of π/4 shift QPSK transmitter.** NEXUS performs data downlink by π/4 shift QPSK transmitter using the amateur radio band. We will perform the new radiowave format fast communication between satellite and groundstation To evaluate its superiority, against the communication speed(1200~9600bps) which was the mainstream in conventional amateur radio communication. The demodulation performs the evaluation by using both hardware and software proprietary. ➢ **Demonstration of transponder.**

		We perform a space demonstration of transponder made by JAMSAT . We will operate the liner transponder for amateur radio operators. ➢ **Demonstration of FM transceiver.** We perform a space demonstration of FM transceiver which (FSK,AFSK,GMSK) made by JAMSAT. ➢ **Demonstration of a camera system with high versatility and multifunction.** Construction of a camera system with high versatility, focused on newly selected camera modules. We will take some pictures of the earth and use them for amateur radio operators.
4b	Planned duration of each part of the mission.	Critical phase ・Link verification between the satellite and the ground station. The acquisition of House Keeping data by CW beacon. 1 ~ 3 days after launch ・Orbit determination Specific object 3 ~ 7 days after launch ・Check out of satellite function Test operation of satellite system and equipment. a) FM transmitter and receiver(AFSK1200[bps], GMSK9600[bps]). b) Acquisition of sensor data. c) FM transmitter and receiver (FSK(600[bps]~14400[bps]),GMSK(9600[bps]),AFSK(1200 [bps])). d) Confirmation of the power and heat balance. Within 1 months after launch ・Mission phase Mission equipment operation check. a) π/4 shift QPSK transmitter test transmission. b) Open part of the transponder. c) FM transmitter and receiver test operate. d) Photographed by the on board camera. Within 3 months after launch ・Evaluation of the success level a) Performance evaluation of the π/4 shift QPSK transmitter. b) Demonstration of the transponder. c) Demonstration of camera system. Within 1 years after launch
4c	Proposed space station **transmitting** frequency plan. *List for each frequency or frequency band:* ➔ *frequency or frequency band (e.g. 435-438 MHz)* ➔ *requested frequency, if any* ➔ *output power*	**CW/FM integrated transmitter** Frequency: 437.--- [MHz] Output power: 0.1[W](CW), 0.8[W](FM) Emission designator: 500HA1A (CW) 16K0F2D, 16K0F3E, 16K0F3F, 26K0F1D (FM) Modulation method: Morse(CW) AFSK1200bps,GMSK9600bps Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. **Linear transponder** Transmit frequency: 435.--- [MHz] (e.g. 435.480-435.500) Total pass band: 20kHz Output power: 0.5[W] Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. **π/4 shift QPSK transmitter** Transmit frequency: 435.--- [MHz](Using the same frequency as the center frequency of the transponder)

	➔ *ITU emission designator*[1,2] ➔ *common description of the emission including modulation type AND data rate*[3] ➔ *antenna gain and pattern* ➔ *attitude stabilisation, if used*	Output power: 0.8[W] Emission designator: 30K0G1D Modulation method: π/4 shift QPSK 38400bps Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. **FM transceiver** Transmit frequency: 435.--- [MHz] (e.g. 435.480-435.500) (Same of Linear transponder downlink frequency) Output power: 0.4[W] Emission designator: 09K0F1D,18K5F1D,15K0F1D,09K0F2D Modulation method: FSK600-9600bps(variability),GMSK9600bps,AFSK1200bps Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern.
4d	Proposed space station **receiving** frequency plan. *List for each frequency or frequency band:* ➔ *frequency band* ➔ *requested frequency, if any* ➔ *ITU emission designator* ➔ *common description of the emission including modulation type AND data rate* ➔ *noise temperature* ➔ *associated antenna gain and pattern*	**FM receiver** Frequency: 145.--- [MHz] Emission designator: 20K0F2D Modulation method: AFSK 1200bps Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. Noise temperature: 300[K] **Linear transponder** Reception frequency: 145.--- [MHz]（Using a different frequency from the FM receiver） (e.g. 145.850-145.870MHz) Total pass band: 20kHz Noise temperature: 300[K] Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. **FM transceiver** Frequency: 145.--- [MHz] (Same of transponder uplink frequency) Emission designator: 16K0F1D Modulation method: FSK 1200bps Antenna gain: -2[dB] Antenna pattern: nearly same as mono-pole antenna pattern. Noise temperature: 600[K]
4e	Physical structure. *General description, including dimensions, mass, antennas and antenna placement, whether stabilized or tumbling, etc. Give URL's for drawings.*	Structure material: A7075-T7351 Satellite mass: 1.19kg Dimension: 109.2×105.2×113.5[mm] Antenna: mono-pole antenna Antenna material: elastic phosphorus bronze strip with Teflon coating on the antenna surface Please refer to Appendix 1 for the details of the structure.
4f	Functional Description. *Describe each sections function within the satellite.*	The abbreviations used in the following are as follows. ・SG(Sensor Group Sub System) ・EPS(Electric Power Supply Sub System) ・FMR(Flight Management Receiver Sub System) ・CW(Continuous Wave Sub System) ・C&DH (Command & Data Handling Sub System) ・CAM(Camera Sub System)

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[1] ITU emission designators are explained at: http://life.itu.int/radioclub/rr/ap01.htm. (Thank you, 4U1ITU.) Effect of Doppler shift is NOT included when determining bandwidth.

[2] If using a frequency changing transponder, indicate the transmitting bandwidth. Effect of Doppler shift is NOT included when determining bandwidth.

[3] Common emission description means terms like transponder, NBFM, PSK31, 1200 baud packet (AFSK on FM), etc.

		Transponder: Transponder is a radio repeater with an uplink frequency of 145MHz, and a downlink frequency of 435MHz. The transmission power is 0.5[W]. **π/4 shift QPSK transmitter**: The π/4 shift QPSK transmitter is a transmitter with a communication speed of 38400bps. It will be used for downlink of data in the band of 435MHz. The transmission power is 0.8[W]. **SG**: SG a geomagnetism sensor, gyro sensor, temperature sensor, and a galvanometer is on board of NEXUS. SG has a function of relaying the sensor data to other sub systems. **EPS**: Six Li-ion secondary batteries (3.7V-1880mAh) in parallel are stored in NEXUS. NEXUS has 12 solar cells arranged 2 in series and 6 in parallel. **Communication system**: a total of 4 transceivers; an integrated CW/FM(AFSK1200bps, GMSK9600bps) transmitter, FM receiver, QPSK transmitter, and a transponder are on board. Each of the integrated CW/FM transmitter's transmission powers are; CW:0.1[W], FM(AFSK, GMSK):0.8[W]. The 437MHz band will be used for downlink, and 145MHz band for uplink. Also, for an antenna, a monopole antenna will be used. **FMR**: FMR receives the uplink command from the earth station, it sends a command received in each of the sub-system. **CW**: This system transmits the housekeeping data to the earth station in Morse code. **C&DH**: C&DH transmits the camera data and the sensor data of the downlink, also SSTV, degi-talker sound by using FM transmitter(AFSK1200bps, GMSK9600bps). In addition, C&DH manages a mission equipment π / 4 shift QPSK transmitter, linear transponder and the CAM. **CAM**: This using for shooting of Earth images by a small camera module. Captured image data is stored in a Flash EPROM, and camera sends the data to the ground station through the C&DH.
4g	Power budget. *Describe each power source, power consuming section, power storage, and overall power budget.*	Please refer to Appendix 2 for the details of the power budget.
5	**TELECOMMAND (NOT published)**	
5a	**Telecommand** frequency plan. *List:* ➔ *space station telecommand frequencies,* ➔ *ITU emission designator(s)* ➔ *common description of the emission including modulation type AND data rate* ➔ *link power budget(s)* ➔ *a general description of any cipher system*	**FM receiver** Frequency: 145.--- [MHz] ITU emission designator: 20K0F2D Modulation method: AFSK1200bps Noise temperature: 300[K] Antenna pattern: nearly same as mono-pole antenna pattern Link power budget: 50W(Earth Station) Cipher system: N/A (NEXUS is based on AX.25 protocol.) Please refer to Appendix 3 for the details of the link budget.

5b	Positive space station transmitter control. *Explain how telecommand stations will turn off the space station transmitter(s) immediately, even in the presence of user traffic and/or space station computer system failure.* ***NOTE:*** *Transmitter turn off control from the ground is absolutely required. Good engineering practice is to make this capability independent of all other systems.* Be sure to read the paper at: http://www.iaru.org/satellite/ControllingSatellites v27.pdf.	NEXUS turns off the system by the kill command from the following earth station. Department of Aerospace Engineering, College of Science and Technology, Nihon University Amateur Radio Station Call sign: JQ1YGV Location: Latitude 35:43:30.0000 N_DMS Longitude 140:03:25.2000 E_DMS Altitude 50.0[m] Address: 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan
5c	Telecommand stations. *List telecommand stations, including contact details, for sufficient Earth command stations to be established before launch to insure that any harmful interference caused by emissions from a station in the amateur-satellite service can be terminated immediately. See RR 25.11 and RR 22.1*	Department of Aerospace Engineering, College of Science and Technology, Nihon University Amateur Radio Station Call sign: JQ1YGV Location: Latitude 35:43:30.0000 N Longitude 140:03:25.2000 E Altitude 50.0[m] Address: 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan Tel: +81-47-469-5430
5d	Optional: Give the complete space station turn off procedure. *As a service, the IARU Satellite Advisor will keep the space station turn off procedure as a backup for your operation. Only the space station licensee may request the information. If interference occurs and the licensee cannot be located, the licensee grants the Satellite Advisor permission to use the turn off procedure. Please note that the Satellite Advisor will use his best efforts, but cannot guarantee success. The space station licensee is still held responsible for the space station transmitter(s) by the licensing administration.*	N/A
6	**Telemetry (published)**	
6a	Telemetry frequencies *List:* ➔ *all telemetry frequencies or frequency bands,*	Frequency: 437.---[MHz] ITU emission designators: 500HA1A, 16K0F2D,26K0F1D 09K0F1D,18K5F1D,15K0F1D Modulation method: CW, AFSK1200bps, GMSK9600bps, 600~14400bps(variability) Link budgets: 9.37[dB](CW), 3.35[dB](AFSK), 1.10[dB](GMSK) 2.12[dB]~4.33[dB](FSK)

	➔ *ITU emission designators* ➔ *common description of the emission including modulation type AND data rate* ➔ *link budgets*	Please refer to Appendix 3 for the details of the link budget.
6b	Telemetry formats and equations. *Describe telemetry format(s), including telemetry equations.* *NOTE: Final equations must be published as soon as available.*	TBD To the following URL we have published the HP of the NEXUS project. http://sat.aero.cst.nihon-u.ac.jp/nexus/ In the future, in the pages of "Amateur Radio", it will be release the telemetry format.
6c	Is the telemetry transmission format commonly used by radio amateurs? If not, describe how and where it will be published. Be sure to read: RR 25.2A. Text is included in the paper available at: http://www.iaru.org/satellite/sat-freq-coord.html.	To the following URL we have published the HP of the NEXUS project. http://sat.aero.cst.nihon-u.ac.jp/nexus/ In the future, in the pages of "Amateur Radio", it will be release the telemetry format.
7	**Launch plans (published)**	
7a	Launch agency	TBD
7b	Launch location	TBD
7c	Expected launch date	TBD
7d	Planned orbit. *Include planned orbit apogee, perigee, inclination, and period.*	- Orbit: sun-synchronous polar orbit - altitude: 500-600㎞ The details are being adjusted.
7e	List other amateur satellites expected to share the same launch.	なし

Earth station information:

8	**Typical Earth station — transmitting**	
8a	Describe a typical Earth station used to transmit signals to the planned space station.	**Location**: Latitude 35:43:30.0000 N_DMS Longitude 140:03:25.2000 E_DMS Altitude 50.0[m] **Address**: 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan **Ground Station Devices**: * Antenna (Oscar Hunter WHS32N (MASPRO)) * Radio (IC-910D (ICOM)) * TNC (TNC-505 (Tasco)) * Antenna Control Unit(Satellite Tracker RAC805, Direction controller RC5B-3, Elevation controller ERC5A (Creative Design Corp)) **Antenna specification**: 144 MHz Band 1 stack antenna Actual gain 10-12[db] VSWR 1.1-1.5 Approximately rate 20.7-22.5[db] Half value rate 33-35[deg] Sustainable power 50[W]
8b	Link power budget.	Command uplink : 27.31[dB]

	Show complete link budgets for all Earth station transmitting frequencies, except telecommand.	Transponder : 19.35[dB] Please refer to Appendix 3 for the link budget of the details.
9	**Typical Earth station — receiving**	
9a	Describe a typical Earth station to receive signals from the planned satellite.	**Location**: Latitude 35:43:30.0000 N_DMS Longitude 140:03:25.2000 E_DMS Altitude 50.0[m] **Address**: 7-24-1 Narashinodai, Funabashi, Chiba 274-8501, Japan **Ground Station Devices**: * Antenna (Oscar Hunter WHS32N (MASPRO)) * Radio (IC-910D (ICOM)) * TNC (TNC-555 (Tasco)) * Antenna Control Unit(Satellite Tracker RAC805, Direction controller RC5B-3, Elevation controller ERC5A (Creative Design Corp)) **Antenna specification**: 430 MHz Band 2 stack antenna Actual gain 12.5-13.4[db] VSWR 1.1-1.5 Approximately rate 16.5-18.3[db]Half value rate 27-29[deg]
9b	Link power budget. *Show complete link budgets for all Earth station receiving frequencies.*	① 437.---[MHz] CW transmission: 9.37[dB] FM transmisson(AFSK1200[bps]): 3.35[dB] FM transmisson(GMSK9600[bps]): 1.10[dB] ② 435.---[MHz] Transponder 2.75[dB] π/4 shift QPSK 4.25[dB] Please refer to Appendix 3 for the link budget of the details.

Additional information:

Do not attach large files. Indicate the URL where the information is available.

10	Please, supply any additional information that may assist the Satellite Advisor to coordinate your request(s). NEXUS project web site http://sat.aero.cst.nihon-u.ac.jp/nexus/

Certification:

11*	[ ] The licensee of the planned space station has reviewed all relevant laws, rules, and regulations, and certifies that this request complies with all requirements as understood by IARU to the best of his/her knowledge. *We confirm we meet the requirements of RR 1.56 and RR 1.57 in that the proposed satellite will operate without pecuniary interest. Please list any commercial interests. If none, please state none.*
	[ ] The licensee of the planned space station has reviewed all relevant laws, rules, and regulations and disagrees with IARU interpretations of Treaty requirements. The IARU Satellite Advisor is asked to consider the following interpretation. Explanation follows.

* Please tick ONE appropriate box.

Signature:

12	(REQUIRED!)	
	宮崎康行	15 December, 2016
	Signature of space station licensee.	Date submitted for coordination.

Appendix

Appendix 1 Structure.. A.1

Appendix 2 Power budget A.3

Appendix 3 Link budget A.5

Appendix 4 Communication diagram... A.13

Appendix 1 Structure

Show a satellite appearance image to FigA.1. In addition, equipment layout of internal satellite is shown in FigA.2

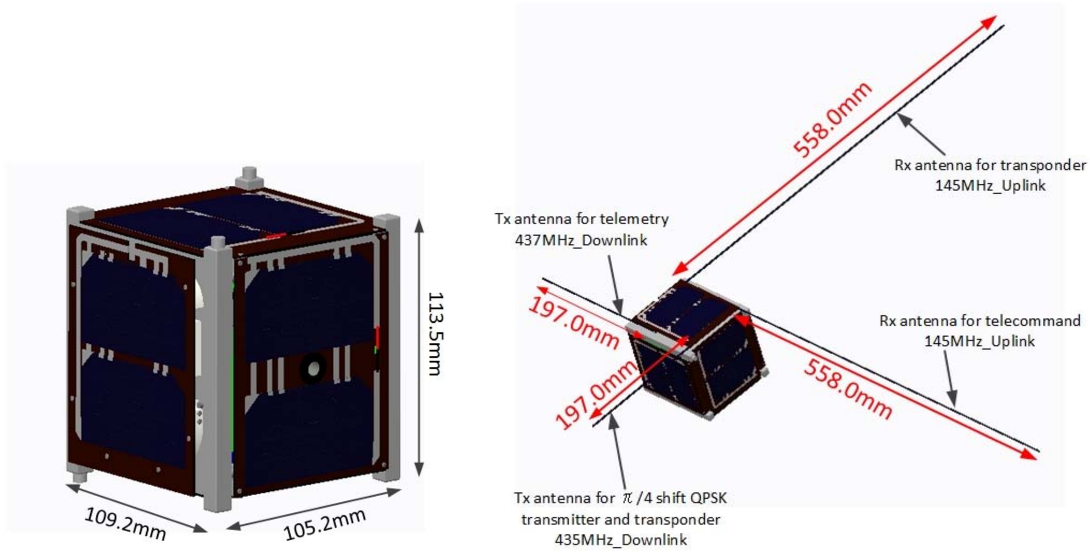


Fig.A 1 Satellite overview

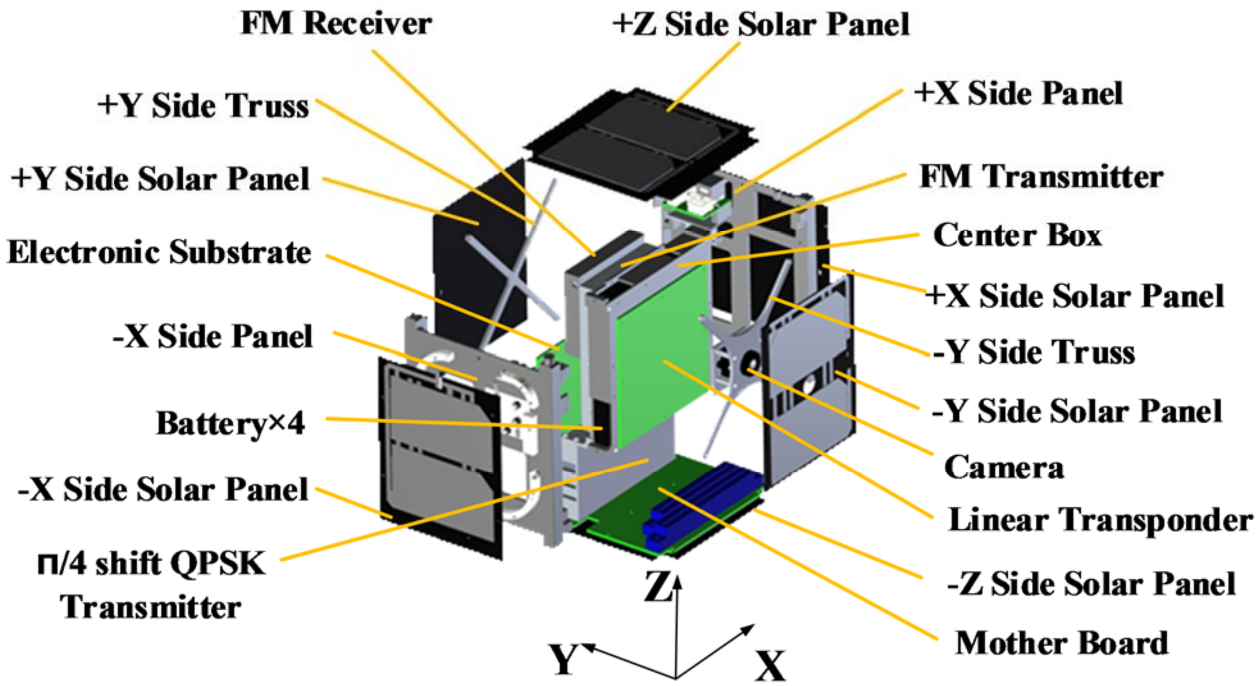


Fig.A 2 equipment layout of internal satellite

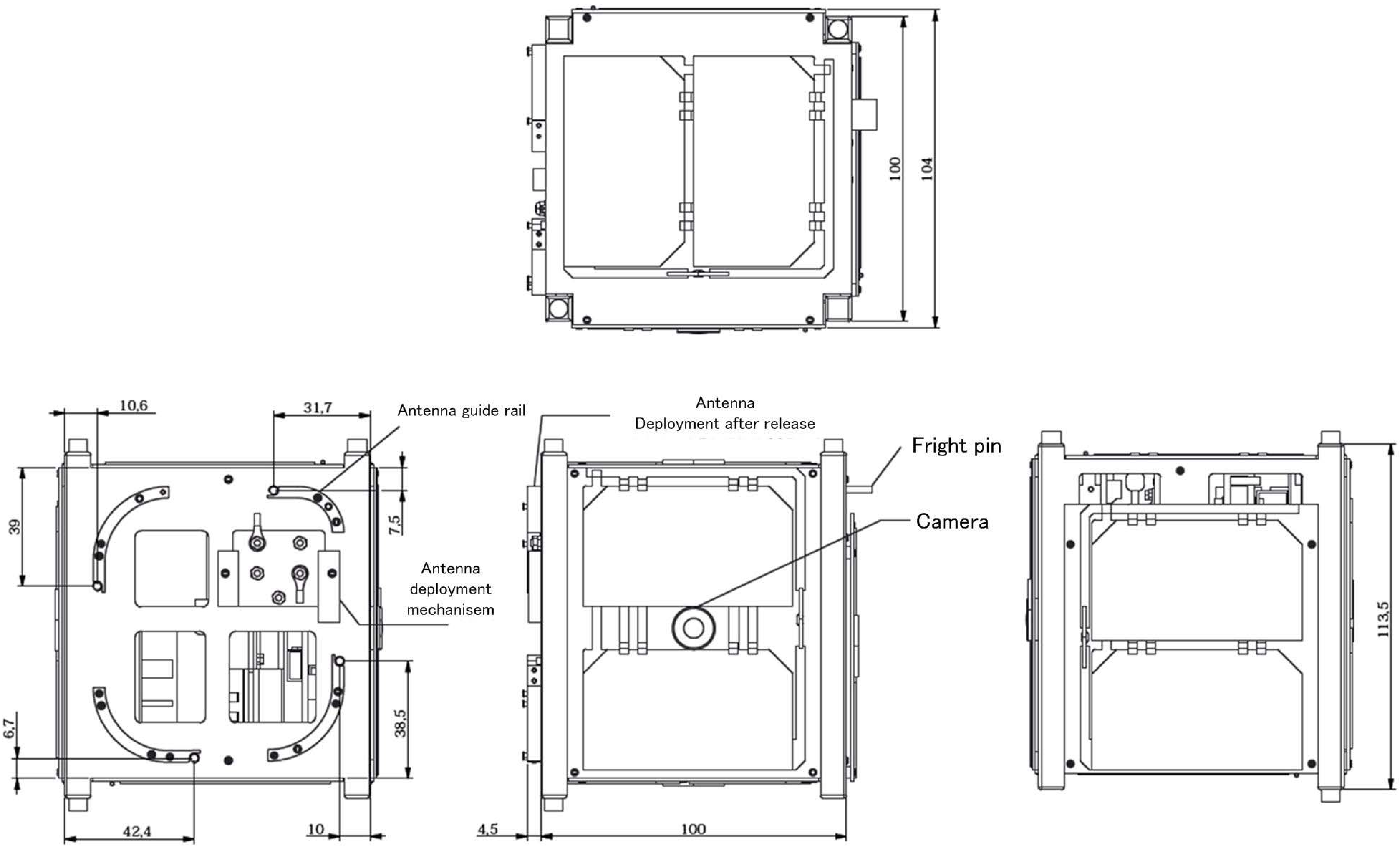


Fig.A.1　Drawing of satellite (launch configuration)

Appendix 2　Power budget

1. Power source

In the NEXUS, each two solar cell is attached to all surface. Daylight is available to charge a lithium-ion battery and the operation of each components. The specifications of Solar cells and the lithium ion battery are as shown in TableA.1 and TableA.2.

Table A.1　Solar cell

Category	Specification
Type	Triple junction (InGaP/InGaAs/Ge)
Mount type	Body mount
Number of cells	12cells (2 cells on each sides)
Arrangement	2 in series and 6 in parallel
Dimension (1 cell)	40.15mm x 80.15mm (cell area: 30.18cm^2)
Maximum efficiency	More than 27.5%
Averaged efficiency of power supply from the cells to the components	90%
Avaraged daytime/round	3897 sec/round
Averaged energy generation/ round	6386 mWh/round

Table A.2　Battery

Category	Specification
Type	Li-ion
Nominal voltage	3.7V
Nominal capacity (each battery)	1880mAh
Number of batteries	4
Arrangement	4 single-cells in parallel
Total capacity	7520mAh
Averaged efficiency of power supply from the cells to the battery	90%

2. Daylight and eclipse

Estimate of daylight time and eclipse time are as shown in TableA.3.

Table A.3　estimate of daylight and eclipse

Category	Data
Daylight	3897 [sec]
Eclipse	1980 [sec]

3. Power consumption

In the electrical power analysis, We assume the eclipse time for the mode to be used primarily during normal operation. The discharge rate and depth of discharge of the battery was calculated by the operation of the battery only. As a result we confirmed that is within a tolerance. In order to determining the maximum amount of power that can be charged during one daylight, showing the value of power analysis of CW operation (during Daylight) a phase of normal operation. Power consumption at each operation phase is shown in TableA.4, and operation time and discharge current and discharge capacity at each phase are shown in Table A.5.

Table A.4 . Power consumption at each operation phase

State	Operation mode	Consumption current [mA]	Consumption Power [mW]	Operation time[s]	Current consumption [mAh]	Power consumption [mWh]
daylight	CW operation（daylight）	219	1008	3897	221	1092
eclipse	CW operation（eclipse）	273	1008	1980	112	555
eclipse	FM downlink of 1200bps	1203	4451	1980	495	2448
eclipse	FM downlink of 9600bps	1205	4459	1980	495	2452
eclipse	QPSK downlink	1086	4019	1980	862	2210
eclipse	Digi-talker and SSTV operation	1182	4375	1980	482	2406
eclipse	CW and transponder operation	1136	4202	1980	564	2311
eclipse	CW and take a picture	1188	4397	1980	465	1970
eclipse	Sensing and antenna deployment	2432	8997	1980	175	919
eclipse	Real time image downlink	1861	6887	600	296	1148

As a result , consumption per one battery when the battery 4 Parallel (1 series) are shown in the Table A.5.

Table A.5

State	Operation mode	Consumption current [mA]	Consumption power [mW]	Operation time[s]	Current consumption [mAh]	C	DOD [%]
Daylight	CW operation（daylight）	244	1121	245	1213	-	-
eclipse	CW operation（eclipse）	303	1121	125	540	0.0403	1.66
eclipse	FM downlink of 1200bps	1337	4946	550	2720	0.178	7.31
eclipse	FM downlink of 9600bps	1339	4954	551	2725	0.178	7.32
eclipse	QPSK downlink	1207	4466	958	2456	0.178	4.88
eclipse	Digi-talker and SSTV	1314	4861	536	2673	0.175	7.13
eclipse	CW and transponder operation	1262	4669	626	2568	0.168	8.33
eclipse	CW and take a picture	1320	4885	517	2189	0.176	6.9
eclipse	Sensing and antenna deployment	2702	9996	194	1021	0.359	2.579
eclipse	Real time image downlink	2068	7652	328	1275	0.275	4.366

The maximum amount of power that can be charged in once Daylight is 4546 [mWh].This is power generation of the solar cell in once daylight, and the amount of CW operation of normal operation phase. This result exceeds the target value, so we determined that can be operated in 4 Parallel.

Appendix 3　Link budget

It shows the link budget result of the transmitter below. From these tables, the link budget has been established. π / 4 shift QPSK transmitter and linear transponder technology demonstration is also possible. This link budget is supposed to altitude 530km.

Table A. 6 Link budget of FM downlink

Downlink 1200bps/AFSK		
Modulation Method	AFSK	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087266463
Visible Limit Angle	θ[rad]	0.305699756
	θ[deg]	17.51530582
Maximun Transmission Distance	D[km]	2077.956733
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.8
	P_{TX}[dBW]	-0.96910013
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-4.96910013
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.5642873
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.5642873

Ground station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	18.5
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-143.0333875
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	16
Noise Power	N[W]	1.32E-16
	N[dB]	-158.7784968
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	16.5
Receive G/T	G/T[dB/K]	-11.2815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	1200
	B_{ps}[dBHz]	30.79181246
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	15.75
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	3.25

Downlink 9600bps/GMSK		
Modulation Method	GMSK	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087266463
Visible Limit Angle	θ[rad]	0.305699756
	θ[deg]	17.51530582
Maximun Transmission Distance	D[km]	2077.956733
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.8
	P_{TX}[dBW]	-0.96910013
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-4.96910013
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.5642873
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.5642873

Ground station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	18.5
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-143.0333875
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	26
Noise Power	N[W]	2.15E-16
	N[dB]	-156.6699632
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	16.5
Receive G/T	G/T[dB/K]	-11.2815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	9600
	B_{ps}[dBHz]	39.82271233
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	13.63657569
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	1.14

Table A. 7 Link budget of CW downlink and FM uplink

Downlink CW		
Modulation Method	CW	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087266463
Visible Limit Angle	θ[rad]	0.305699756
	θ[deg]	17.51530582
Maximun Transmission Distance	D[km]	2077.956733
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.1
	P_{TX}[dBW]	-10
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-14
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.5642873
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.5642873

Ground station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	18.5
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-152.0642873
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	0.5
Noise Power	N[W]	4.14E-18
	N[dB]	-1.74E+02
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	16.5
Receive G/T	G/T[dB/K]	-11.2815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	25
	B_{ps}[dBHz]	13.97940009
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	2.18E+01
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	23.24

Uplink 1200bps		
Modulation Method	AFSK	
Satellite Antenna	Cross Yagi Anntena 2 stack	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087266463
Visible Limit Angle	θ[rad]	0.305699756
	θ[deg]	17.51530582
Maximun Transmission Distance	D[km]	2077.956733
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Ground Station		
Transmission Frequency	f[MHz]	145
Transmitter Power	P_{TX}[W]	50
	P_{TX}[dBW]	16.98970004
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	13
Effective Isotropically Radiated Power	P_E[dBW]	27.98970004
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-142.0218622
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-145.0218622

Satellite		
Ground Station Antenna	Mono-Pole Antenna	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	0
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-119.0321622
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	16
Noise Power	N[W]	1.32E-16
	N[dB]	-1.59E+02
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	-2
Receive G/T	G/T[dB/K]	-29.7815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	1200
	B_{ps}[dBHz]	30.79181246
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	3.97E+01
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	27.25

Table A. 8 Link budget of transponder

Transponder_Uplink		
Modulation Method		
Satellite Antenna	Cross Yagi Anntena 2 stack	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	15
	θ_{EL}[rad]	0.261799388
Visible Limit Angle	θ[rad]	0.198974269
	θ[deg]	11.40038587
Maximun Transmission Distance	D[km]	1407.52077
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Ground Station		
Transmission Frequency	f[MHz]	145
Transmitter Power	P_{TX}[W]	10
	P_{TX}[dBW]	10
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	13
Effective Isotropically Radiated Power	P_E[dBW]	21
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-138.6382285
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-141.6382285

Satellite		
Ground Station Antenna	Mono-Pole Antenna	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	0
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-122.6382285
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	20
Noise Power	N[W]	1.66E-16
	N[dB]	-157.8093967
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	-2
Receive G/T	G/T[dB/K]	-29.7815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	1200
	B_{ps}[dBHz]	-
Bit Error Rate	P_b	-
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	3.52E+01
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	22.67

Transponder_Downlink		
Modulation Method		
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	15
	θ_{EL}[rad]	0.261799388
Visible Limit Angle	θ[rad]	0.198974269
	θ[deg]	11.40038587
Maximun Transmission Distance	D[km]	1407.52077
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	12
	P_{TX}[dBW]	10.79181246
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	6.79181246
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-148.1806536
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-151.1806536

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	18.5
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.584893192
Received Signal Power	C[dBW]	-127.8888411
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.010299957
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	20
Noise Power	N[W]	1.66E-16
	N[dB]	-1.58E+02
Noise Power density	N_0[dB]	-2.01E+02
Receiving Gain	G[dB]	16.5
Receive G/T	G/T[dB/K]	-11.2815125

Demodulation Loss	L_D[dB]	2
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	2
Bit Rate	B_{ps}[bps]	-
	B_{ps}[dBHz]	-
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	2.99E+01
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.5
Margin	M[dB]	17.42

Table A. 9　Link budget of π/4 shift QPSK downlink

QPSK Transmitter(QPSK/38400bps)		
Modulation Method	π/4 shift QPSK(G1D)	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	15
	θ_{EL}[rad]	0.262
Visible Limit Angle	θ[rad]	0.199
	θ[deg]	11.400
Maximun Transmission Distance	D[km]	1407.521
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.4
	P_{TX}[dBW]	-3.98
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-7.98
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-148.18
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-151.18

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	20
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dBW]	-141.16
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.01
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	20
Noise Power	N[W]	1.66E-16
	N[dBW]	-1.58E+02
Noise Power density	N_0[dBW]	-2.01E+02
Receiving Gain	G[dB]	18
Receive G/T	G/T[dB/K]	-9.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	19,200
	B_{ps}[dBHz]	42.83
Bit Error Rate	P_b	1.0E-06
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	16.65
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.50
Margin	M[dB]	4.15

Table A. 10 FM downlink (GMSK and AFSK)

FM Data Transmitter Downlink(GMSK/9600bps)		
Modulation Method	GMSK(F1D)	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087
Visible Limit Angle	θ[rad]	0.306
	θ[deg]	17.515
Maximun Transmission Distance	D[km]	2077.957
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.4
	P_{TX}[dBW]	-3.979
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-7.98
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.56
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.56

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	20
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dBW]	-144.54
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.01
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	15
Noise Power	N[W]	1.24E-16
	N[dBW]	-1.59E+02
Noise Power density	N_0[dBW]	-2.01E+02
Receiving Gain	G[dB]	18
Receive G/T	G/T[dB/K]	-9.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	9600
	B_{ps}[dBHz]	39.82
Bit Error Rate	P_b	1.E-06
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	14.52
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.50
Margin	M[dB]	2.02

FM Data Transmitter Downlink(AFSK/1200bps)		
Modulation Method	AFSK	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087
Visible Limit Angle	θ[rad]	0.306
	θ[deg]	17.515
Maximun Transmission Distance	D[km]	2077.957
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.4
	P_{TX}[dBW]	-3.98
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-7.98
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.56
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.56

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	20
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dBW]	-144.54
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.01
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	9
Noise Power	N[W]	7.45E-17
	N[dBW]	-1.61E+02
Noise Power density	N_0[dBW]	-2.01E+02
Receiving Gain	G[dB]	18
Receive G/T	G/T[dB/K]	-9.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	1200
	B_{ps}[dBHz]	30.79
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	16.73
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	12.50
Margin	M[dB]	4.23

Table A. 11 FM downlink (FSK 600bps~9600bps)

FM Data Transmitter Downlink(FSK/9600bps)		
Modulation Method	FSK(F1D)	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	15
	θ_{EL}[rad]	0.262
Visible Limit Angle	θ[rad]	0.199
	θ[deg]	11.400
Maximun Transmission Distance	D[km]	1407.521
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.4
	P_{TX}[dBW]	-3.98
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-7.98
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-148.18
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-151.18

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	20
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dBW]	-141.16
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.01
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	18.5
Noise Power	N[W]	1.53E-16
	N[dBW]	-1.58E+02
Noise Power density	N_0[dBW]	-2.01E+02
Receiving Gain	G[dB]	18
Receive G/T	G/T[dB/K]	-9.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	9600
	B_{ps}[dBHz]	39.82
Bit Error Rate	P_b	1.E-05
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	16.99
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	11.9
Request C/N_0	$(C/N_0)_{req}$[dB]	13.90
Margin	M[dB]	3.09

FM Data Transmitter Downlink(FSK/600bps)		
Modulation Method	FSK(F1D)	
Satellite Antenna	Mono-Pole Antenna	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087
Visible Limit Angle	θ[rad]	0.306
	θ[deg]	17.515
Maximun Transmission Distance	D[km]	2077.957
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Satellite		
Transmission Frequency	f[MHz]	435
Transmitter Power	P_{TX}[W]	0.4
	P_{TX}[dBW]	-3.98
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	-2
Effective Isotropically Radiated Power	P_E[dBW]	-7.98
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

Characteristic Transmission		
Free Space Loss	L_d[dB]	-151.56
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-154.56

Ground Station		
Ground Station Antenna	Cross Yagi Anntena 2 stack	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	20
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dBW]	-144.54
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	2
	NF[dB]	3.01
Ground Station System Noise Temperature	T_S[K]	600
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	9
Noise Power	N[W]	7.45E-17
	N[dBW]	-1.61E+02
Noise Power density	N_0[dBW]	-2.01E+02
Receiving Gain	G[dB]	18
Receive G/T	G/T[dB/K]	-9.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	600
	B_{ps}[dBHz]	27.78
Bit Error Rate	P_b	1.E-05
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	16.73
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	11.9
Request C/N_0	$(C/N_0)_{req}$[dB]	13.90
Margin	M[dB]	2.83

Table A. 12 FM Uplink(FSK)

FM Data Transmitter Uplink 1000bps		
Modulation Method	FSK(F1D)	
Satellite Antenna	Cross Yagi Anntena 2 stack	
Orbit Altitude	H[km]	500
Earth Radius	R[km]	6378.142
E.levation Angle	θ_{EL}[deg]	5
	θ_{EL}[rad]	0.087
Visible Limit Angle	θ[rad]	0.306
	θ[deg]	17.515
Maximun Transmission Distance	D[km]	2077.957
Maximun Transmission Speed	c[m]	3.0E+08
Boltzmann Constant	k[W/Hz·K]	1.38E-23

Ground Station		
Transmission Frequency	f[MHz]	145
Transmitter Power	P_{TX}[W]	50
	P_{TX}[dBW]	16.99
Transmitter Feeding Power Loss	L_{FTX}[dB]	-2
Transmission Antenna Gain	G_{ATX}[dB]	13
Effective Isotropically Radiated Power	P_E[dBW]	27.99
Transmission Antenna Pointing Loss	L_{APt}[dB]	0

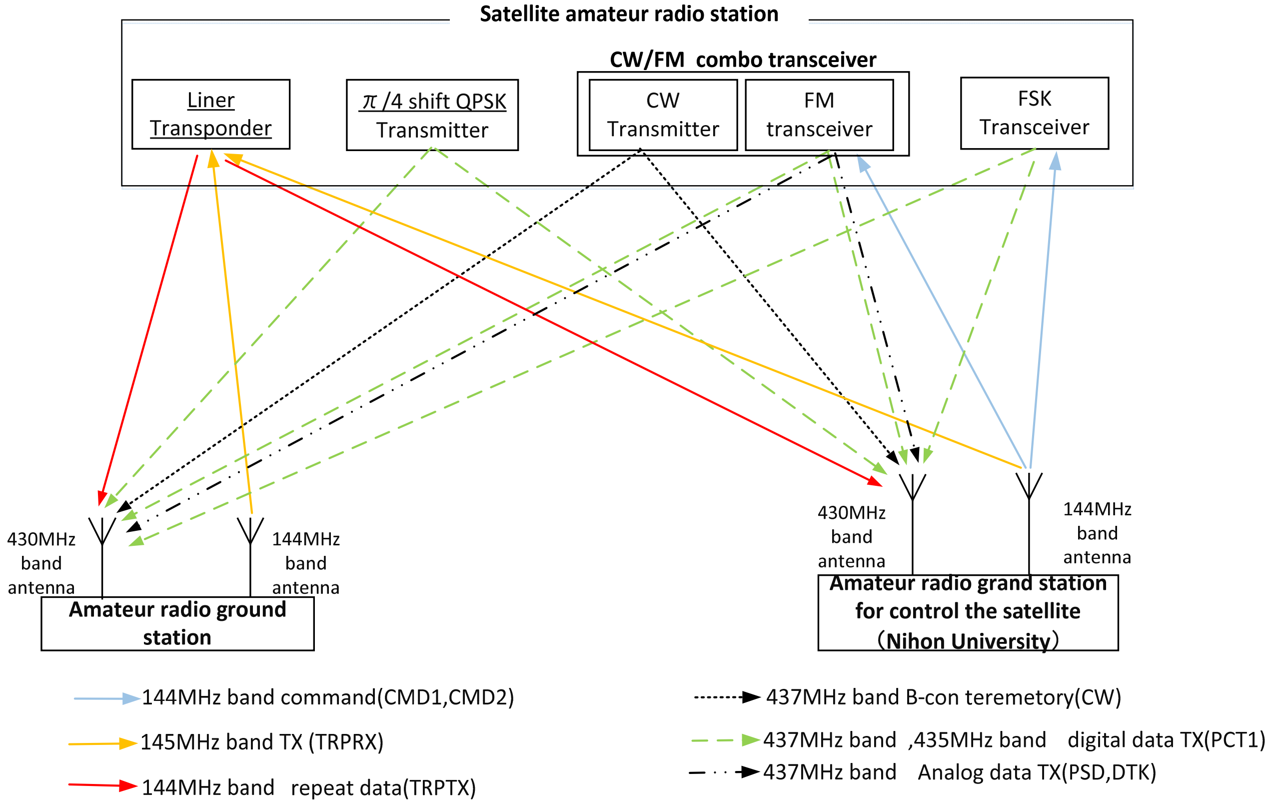
Characteristic Transmission		
Free Space Loss	L_d[dB]	-142.02
Polarized Wave Loss	L_P[dB]	-3
Atmospheric Absorption Loss	L_A[dB]	0
Rain Loss	L_{RA}[dB]	0
Various Loss	L_V[dB]	0
Total Transmission Loss	L_{pr}[dB]	-145.02

Satellite		
Ground Station Antenna	Mono-Pole Antenna	
ReceivedAntenna Pointing Loss	L_{APr}[dB]	0
Received Antenna Gain	G_{ARX}[dB]	0
Received Feeding Power Loss	L_{FRX}[dB]	-2
	L[-]	1.58
Received Signal Power	C[dB]	-119.03
Antenna Noise Temperature	T_A[K]	300
Feeding Power Line Noise Temperature	T_F[K]	300
Receiver Noise Temperature	T_E[K]	300
Ground Station Temperature	T_0[K]	300
Noise Factor	nf[-]	5
	NF[dB]	6.99
Ground Station System Noise Temperature	T_S[K]	1500
Ground Temperature	T_G[K]	300
Average Temperature	T_m[K]	286
Sky Noise Temperature Increase	T_{SKY}[K]	0
Maximun Signal Pass Bandwidth	B[kHz]	5
Noise Power	N[W]	1.04E-16
	N[dB]	-1.60E+02
Noise Power density	N_0[dB]	-1.97E+02
Receiving Gain	G[dB]	-2
Receive G/T	G/T[dB/K]	-33.8

Demodulation Loss	L_D[dB]	1
Internal Ground Station Transmission Loss	L_G[dB]	0
Ground Station Processing Loss	L_0[dB]	1
Bit Rate	B_{ps}[bps]	1000
	B_{ps}[dBHz]	30.00
Bit Error Rate	P_b	0.000001
Receive C/N_0 (Received Power/Noise Power)	C/N_0[dB]	40.82
Request E_b/N_0	$(E_b/N_0)_{req}$[dB]	10.5
Request C/N_0	$(C/N_0)_{req}$[dB]	11.86
Margin	M[dB]	28.96

Appendix 4　　Communication diagram

This satellite is communicated by some amateur radio station. The communication diagram is shown in



FigA.2 communication dyagram