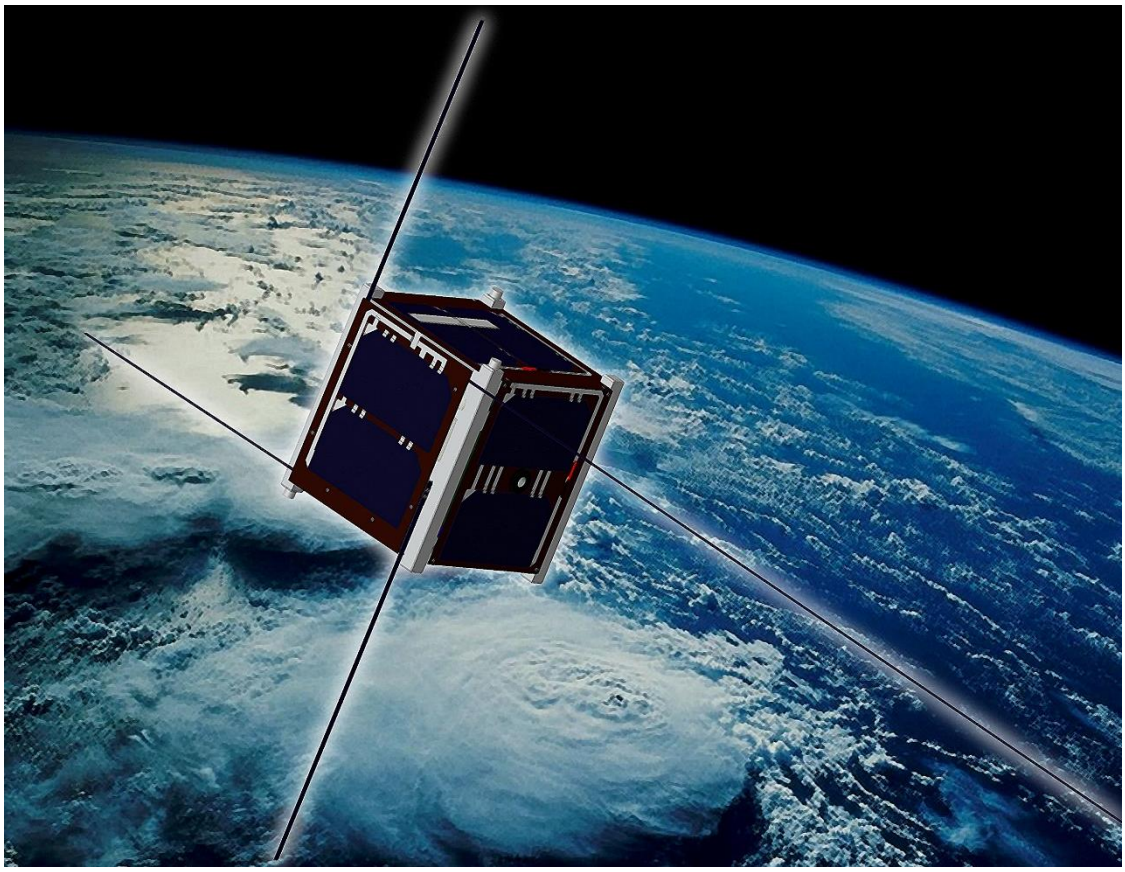
NEXUS Project Team



Amateur Communication Technology Demonstration Satellite NEXUS

「FM Downlink Format」

Doc.No.TBD Ver1.0	Date：2018/12/09

Revision History

ver	Date	Revision	Autor	Approval
1.0	2018/12/09	1st	T.Nakamura	

1. Outline of the downlink format

Here, we outline the downlink format of FM. For specific contents of downlink data, refer to Chapter 2 "Data contents". The outline of the downlink format is as follows.

Table 1 Outline of the FM downlink format

Contents	Details
Center frequency	437.075[MHz]
modulation method	AFSK1200bps (NRZI) GMSK9600bps (NRZI, 17Bit LFSR)
Protocol	AX.25
INFO data size	12~256 [bytes]
data content	HK data, image data, Field intensity(FI) data

The modulation method is AFSK 1200 bps / GMSK 9600 bps, and it can be decoded by TNC which is commonly used for amateur radio.

2. Data contents

Here, we will describe the specific contents of data transmitted by FM. The contents of concrete downlink data are as follows.

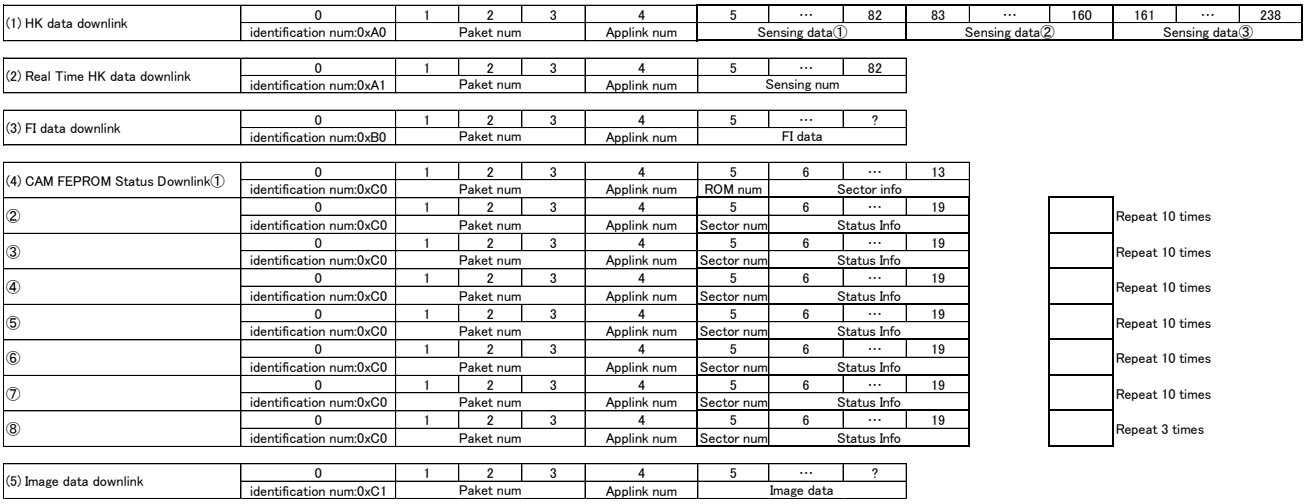


Figure 1 Downlink data contents

For all packets, three pieces of information, an identification number, a packet number, and an uplink number are added with 5 bytes. A description of each downlink data will be given below.

2.1. HK data downlink

Read and transmit the HK data saved in C&DH. The identification number is 0xA0. The data content of one packet is as follows.

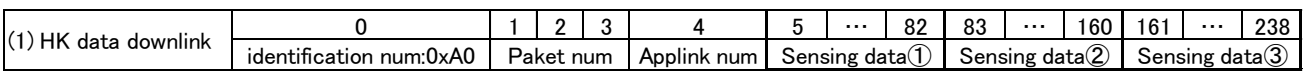


Figure 2 HK data downlink contents (1packet)

HK data consists of 78 bytes, and one packet can downlink three HK data of 78 bytes. The number of HK data wrapped in one packet is variable on the uplink, and the default is one. The breakdown of HK data is as follows.

Table 2 Breakdown of HK data

Contents	Data type	Data amount
Satellite time	int	4 bytes
Switch information	int	1 byte
Reset information	int	5 bytes
Battery Voltage	long	2 bytes
Battery Current	long	2 bytes
Current data	long	12 bytes
Battery temperature 1	long	2 bytes
Battery temperature 2	long	2 bytes
5V regulator temperature 1	long	2 bytes
5V regulator temperature 2	long	2 bytes
3.5V regulator temperature	long	2 bytes
Power amplifier temperature in transponder	long	2 bytes
QPSK transmitter temperature	long	2 bytes
FSK transmitter temperature	long	2 bytes
+x Solar panel temperature	long	2 bytes
+y Solar panel temperature	long	2 bytes
+z Solar panel temperature	long	2 bytes
-x Solar panel temperature	long	2 bytes
-y Solar panel temperature	long	2 bytes
-z Solar panel temperature	long	2 bytes
Bus transmitter temperature	long	2 bytes
Bus receiver temperature	long	2 bytes
Gyro sensor temperature (x,y,z)	long	6 bytes
Gyro data(x,y,z)	long	6 bytes
Magnet data(x,y,z,ref)	long	8 bytes
SUM		78 bytes

Since HK data is transmitted in hexadecimal notation, it is necessary to convert to physical quantity, respectively. The conversion formulas are shown in the next section.

2.1.1. Satellite time

Satellite time count binary every 0.5 sec. So, conversion formula is shown in follow.

$$\text{Time} = 0.5 \times \text{satellite(dec)} \quad (1)$$

2.1.2. Switch information

Switch information doesn't need to convert. The meaning of this data is shown as follow.

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit(LSB)
Forced execution	Heater	3.5V regulator	CDH	CAM	QPSK	FSK	TPR

< caution >

Forced execution: Operate regardless of power condition.
Heater : Heater that warm up battery.
CDH : Command Data Handling system.
CAM : Camera system.
QPSK : QPSK transmitter.
FSK : FSK transmitter.
TPR : Transponder

If each bit shows 1, it means switch ON, and it shows 0, means switch Off.

2.1.3. Reset information

This data also doesn't need to convert. Each 1-byte count reset times. The meaning of each bytes are shown as blow.

reset info[0]	reset info[1]	reset info[2]	reset info[3]	reset info[4]
FMR	CDH	CW	EPS	SG

2.1.4. Battery Voltage

Battery voltage can be converted as follow.

$$\text{Bus Voltage [V]} = 5 \times \text{data} \div 4096 \tag{2}$$

2.1.5. Battery Current

Battery current can be converted as follow.

$$\begin{aligned} \text{Vdata} &= 5 \times \text{data} \div 4096 \\ \text{Bus Current [mA]} &= \text{Vdata} \div 0.0005 \end{aligned} \tag{3}$$

2.1.6. Current data

Current data can be converted as follow.

$$\begin{aligned} \text{Vdata} &= 5 \times \text{data} \div 4096 \\ \text{Current data[mA]} &= \text{Vdata} \div 0.01 \end{aligned} \tag{4}$$

2.1.7. 温度データ

Temperature data can be converted as follow. Temperature data is signed data.

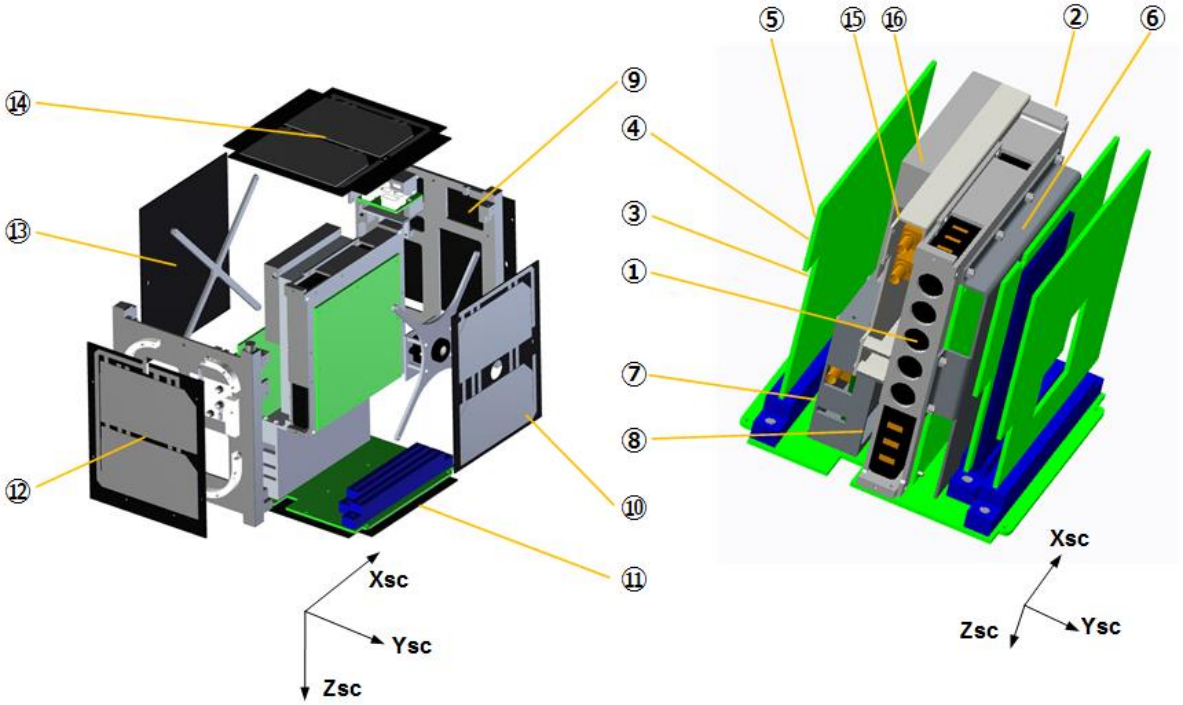
$$\begin{aligned} \text{Tdata} &= 5 \times \text{data} \div 4096 \\ \text{Temp [℃]} &= A \times \text{Tdata} + B \end{aligned} \tag{5}$$

Here, A and B are values unique to the sensor. This value is shown in the table below.

Table 3 Temperature sensor parameter

No.	Contents	A	B
①	Battery temperature 1	-37.50	127
②	Battery temperature 2	-36.83	126
③	5V regulator temperature 1	-37.38	127
④	5V regulator temperature 2	-37.06	126
⑤	3.5V regulator temperature	-36.95	125
⑥	Power amplifier temperature in transponder	-37.19	126
⑦	QPSK transmitter temperature	-37.56	128
⑧	FSK transmitter temperature	-36.89	125
⑨	+x Solar panel temperature	-37.33	127
⑩	+y Solar panel temperature	-37.35	127
⑪	+z Solar panel temperature	-37.14	126
⑫	-x Solar panel temperature	-37.27	127
⑬	-y Solar panel temperature	-37.02	125
⑭	-z Solar panel temperature	-37.04	127
⑮	Bus transmitter temperature	-37.67	126
⑯	Bus receiver temperature	-37.72	128

The attachment position of the temperature sensor is shown below.



No.	Contents	No.	Contents
①	Battery temperature 1	⑨	+x Solar panel temperature
②	Battery temperature 2	⑩	+y Solar panel temperature
③	5V regulator temperature 1	⑪	+z Solar panel temperature
④	5V regulator temperature 2	⑫	-x Solar panel temperature
⑤	3.5V regulator temperature	⑬	-y Solar panel temperature
⑥	Power amplifier temperature in transponder	⑭	-z Solar panel temperature
⑦	QPSK transmitter temperature	⑮	Bus transmitter temperature
⑧	FSK transmitter temperature	⑯	Bus receiver temperature

Figure 3 The attachment position of the temperature sensor

2.1.8. Gyro sensor temperature

Gyro sensor temperature can be converted by the following formula by handling the corresponding data as a signed integer of 10 bits.

$$\text{Gyro Temp} = 0.2 \times \text{data(signed)} + 45 \tag{6}$$

2.1.9. Gyro data

Gyro data can be converted by the following equation by handling the corresponding data as a signed integer.

$$\text{Rate Data [dec/sec]} = \text{data(signed)} \times 0.0125 \tag{7}$$

2.1.10. Magnet data

Magnet data can be converted as follow.

$$\begin{aligned} \text{Mdata} &= 5 \times \text{data} \div 4096 \\ \text{Gauss [nT]} &= \text{Mdata} \div 10\text{e-}5 \end{aligned} \tag{8}$$

2.2. Realtime HK data downlink

HK data is transmitted in real time. The identification number is 0xA1. Data contents in one packet are shown below.

(2) Real Time HK data	0	1	2	3	4	5	⋯	82
	identification num:0xA1	Paket num			Applink num	Sensing num		

Figure 4 Realtime HK data downlink contents(1paket)

For HK data contents, see section 2.1.

2.3. FI data downlink

Downlink the FI (Field Intensity) data stored in C&DH. The identification number is 0xB0. Electric field strength data is a group of 256 bytes. The breakdown of the field strength data is shown below.

(3) FI data downlink	0	1	2	3	4	5	⋯	167
	identification num:0xB0	Paket num			Applink num	FI data		

Figure 5 FI data downlink contents

FI data is 2 bytes in one plot. At the start of measurement, the measurement interval is selected from two of 10 s and 60 s by uplink. When the measurement interval is 10 s, the satellite time at the start of measurement and 126 plots, which is the number of plots for 252 bytes, are saved in C&DH every 10s.

Contents	Data amount
Satellite time	4 bytes
FI data	252 bytes
SUM	256 bytes

Since the FI data is transmitted in hexadecimal notation, it is necessary to convert to the physical quantity, respectively. The conversion formulas are shown in the next section.

2.3.1. Satellite time

For conversion to physical quantity, see section 2.1.1.

2.3.2. FI data

Substitute the data of one plot (2 bytes) into AD of the following formula.

$$V_{in} = \mathrm{AD} \times \frac{2.048}{1024}\ [\mathrm{V}] \tag{9}$$

FI data is obtained from V_{in}[V] as follows.

$$\text{FI data}\ [\mathrm{dbm}] = 121.89 \times V_{in}^3 - 574.69 \times V_{in}^2 + 953.85 \times V_{in} - 607.93 \tag{10}$$

2.4. CAM FEPROM status downlink

Read and transmit the storage status of the FEPROM of the camera system. The identification number is 0xC0. CAM FEPROM status data has a large data capacity, so it is divided into 8 packets and transmitted. The data for 8 packets are shown below.

(4) CAM FEPROM Status	0	1	2	3	4	5	6	⋯	13		
	identification num:0xC0	Paket num			Applink num	ROM num	Sector info				
②	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
③	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
④	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
⑤	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
⑥	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
⑦	0	1	2	3	4	5	6	⋯	19		Repeat 10 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				
⑧	0	1	2	3	4	5	6	⋯	19		Repeat 3 times
	identification num:0xC0	Paket num			Applink num	Sector num	Status Info				

Figure 6 CAM FEPROM status downlink contents(8packet)

About packet ①
ROM num : CAM ROM number
Sector info : Presence or absence of data in each sector (0 - 63)

About packet ②-⑧
Sector num : CAM ROM Sector number
Status info : A breakdown of status information is shown in Table 4.

Table 4 CAM Sector status info

Contents	Details	Data amount
Shooting time	Time taken photographs saved in this sector	4 bytes
Image format	See Table 5 for details.	1 byte
Continuous shooting num	Number of shots taken for continuous shooting	2 bytes
Data size	Data size of photos saved in this sector	3 bytes
Storage start address	Storage start address of photos saved in this sector	3 bytes

Table 5 CAM image format

Image format(dec)	contents
0	JPEG, QVGA
1	JPEG, VGA
2	JPEG, SVGA
3	JPEG, HD
4	JPEG, FHD
5	JPEG, max1(2592×1944)
6	RGB565, QVGA
7	RGB565, VGA
8	RGB565, SVGA
9	RGB565, HD
10	RGB565, FHD
11	RGB565, max2(2203×1652)

A total of 15 sectors of sector number and status information are transmitted for 63 sectors. It is divided into seven packets ② to ⑧ and transmitted.

2.5. Image data downlink

Read out and send the image data stored in C & DH. The identification number is 0xC1. Data contents in one packet are shown below.

(5) Image data downlink	0	1	2	3	4	5	⋯	167
	identification num:0xC1	Paket num			Applink num	Image data		

Figure 7 Image data downlink contents(1packet)