Beacon description for web site

Object:
This technical note describes the data contained in the “beacon” telemetries which will the transmitted by UVSQ-SAT satellite after its launch. The beacon aims to provide data to be used for UVSQ-SAT health monitoring around the Earth. Beacons will be transmitted on 437,020 MHz with BPSK G3RUH modulation (1200 or 9600 bps).

Document status

Action	Name	Function	Date	Signature
Prepared	André-Jean VIEAU	OBSW Engineer	05/01/2020	
Reviewed	Emmanuel BERTRAN	Project Manager	05/01/2020	BERTRAN E.
Approved	Mustapha MEFTAH	Principal Investigator	05/01/2020	

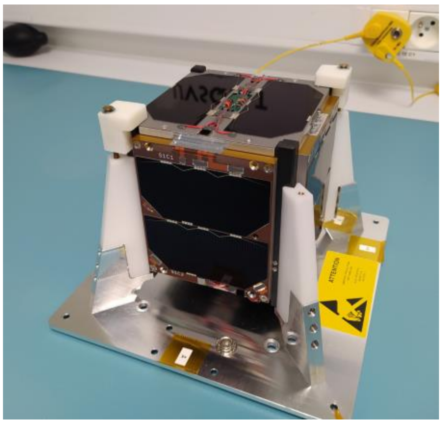
1. Change record

Version / Revision	Date	Author	Comments
v1r0	16/12/2020	EB	First issue for AMSAT-F data decoder.
v1r1	05/01/2021	AJV	TBD replaced.
v1r2	05/01/2021	EB	Official version for online publication.

2. Introduction

2.1. Applicability

This document is only applicable to **UVSQ-SAT** satellite.



UVSQ-SAT flight model

2.2. UVSQ-SAT description

UVSQ-SAT is a French nanosatellite designed to observe the Sun and the Earth. It is a demonstrator of space technology under the responsibility of LATMOS. The mission is part of the International Satellite Program in Research and Education (INSPIRE) program: INSPIRE-Sat5

The objectives of the mission are of a scientific, technological and academic nature. It is based on the triptych "Research-Innovation-Training". The main objectives of the UVSQ-SAT satellite are:

- To measure the Infrared (IR) flux emitted by the Earth and the solar flux that it reflects.
- To measure solar irradiance in the Ultraviolet (UV) spectrum.
- To increase the technological maturity of a detector associated with a medical device program.
- To provide space platform with a transponder for Ham-Radio community.

2.3. Reference documents

Provided information are extracted from these documents:

- UVSQSAT-IF-LAT-0048_v1r0 --- TMTC plan (23/11/2020)
- UVSQSAT-DP-LAT-0159 --- UVSQSAT platform datapack

3. Beacon description

3.1. Data encapsulation

The UVSQ-SAT on-board software encapsulates all data in a telemetry structure defined by **CCSDS standard**. Then the UVSQ-SAT radio board encapsulates all telemetries with the **AX25 protocol**.

packet primary header							packet data field	
	packet ID			packet sequence control				
packet version number	packet type	secondary header flag	application process ID	sequence flags	packet sequence count or packet name	packet data length	packet secondary header	user data field
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	variable	variable

CCSDS telemetry structure

3.2. Useful data of the beacon

These data are contained in the “User Data Field” of the CCSDS telemetry structure.

Beginning of the beacon			
HK	**Data Description**	**Detail**	**Size in bits**
iOBC Status	SW Mode	MODE_INIT = 0 MODE_DETUMBLING = 1 MODE_STANDBY = 2 MODE_OPERATIONAL = 3 MODE_SAFE = 4 MODE_TRANSPONDER = 5	8
	Last Reset Reason	First start = 0 TC Init received = 0x80 No TC since 4 days = 0x81 Unknown reason = 0xFE	8
	Reset order	Order by TC = 0xCA No order = 0	8
	nbReset	Value	8
	FormatSdcard Order	Order to Format SdCard 0 = 0 Order to Format SdCard 1 = 1 Order to NOT Format SdCard 0 = 0xAC Order to NOT Format SdCard 1 = 0xAD	8
	Deploy Antennas system	Nominal = 0 No deploy = 0x11 Deployment Debug = 0xDB	8
	Nb Tm since first start	Value	32
	Nb Tc since first start	Value	32
	Nb Tc Ping since first start	Value	32
	Nb Bad Tc since first start	Value	32
	Nb Tm in Sdcard	Value	32

TrxvuTx HK	Instantaneous RF reflected power from TX port (Field valid only during transmission)	See "TrxvuTx HK" formula table	12
	Instantaneous RF forward power from TX port (Field valid only during transmission)		12
	Supply voltage		12
	Total supply current		12
	Transmitter current		12
	Receiver current		12
	Power amplifier current		12
	Power amplifier temperature		12
	Local oscillator temperature		12

TrxvuRx HK	Instantaneous received signal Doppler offset at the receiver port	See "TrxvuRx HK" formula table	12
	Instantaneous received signal strength at the receiver port		12
	Supply voltage		12
	Total supply current		12
	Transmitter current		12
	Receiver current		12
	Power amplifier current		12
	Power amplifier temperature		12
	Local oscillator temperature		12

iMTQ HK	iMTQ system state mode	IDLE = 0 SELFTEST = 1 DETUMBLE = 2	8
	Measure Coil X Current	See "iMTQ HK" formula table	16
	Measure Coil Y Current		16
	Measure Coil Z Current		16
	Measure Coil X Temperature		16
	Measure Coil Y Temperature		16
	Measure Coil Z Temperature		16
	MCU Temperature		16

Ants HK	SIDE A - Ants Temperature	See "Ants HK" formula table	16
	SIDE A - Ants deployment status		16

iEPS HK	VOLT_BRDSUPraw *Voltage of internal board supply.*	See "iEPS HK" formula table	16
	TEMPraw *Measured temp provided by MCU internal sensor.*	See "iEPS HK" formula table	16
	VIP_DIST_INPUTraw *Input of V / I / P data taken at the input of the distribution part of the unit in raw form. Negative values indicate output flow.*	See "iEPS HK" formula table	48
	VIP_BATT_INPUTraw *Input of V / I / P data taken at the input of the battery part of the unit in raw form. Negative values indicate output flow.*	See "iEPS HK" formula table	48
	stat_obc_on *Bitflag field indicating channel-on status for the output bus channels.*	Bit n = 1 indicates the channel n is ON (Only 9 firsts bits used)	16
	stat_obc_ocf *Bitflag field indicating overcurrent latch-off fault status for the output bus channels.*	Bit n = 1 indicates a overcurrent on the channel n (Only 9 firsts bits used)	16
	bat_stat *Bitflag field indicating Battery Pack board status.*	Bits from LSB (0) to MSB (15): 0 → Battery cell 1 under voltage 1 → Battery cell 2 under voltage 2 → Battery cell 3 under voltage 3 → Battery cell 4 under voltage 4 → Battery cell 1 over voltage 5 → Battery cell 2 over voltage 6 → Battery cell 3 over voltage 7 → Battery cell 4 over voltage 8 → Battery cell 1 balancing 9 → Battery cell 2 balancing 10 → Battery cell 3 balancing 11 → Battery cell 4 balancing 12 → Heaters active 13 → (Reserved) 14 → (Reserved) 15 → Battery pack enabled (Bitflag is set when the battery is connected to the output bus)	16
	BAT_TEMP2raw *Battery pack temperature in between the center battery cells.*	See "iEPS HK" formula table	16
	volt_vd0 *Voltage of voltage domain 0.*	See "iEPS HK" formula table	16
	volt_vd1 *Voltage of voltage domain 1.*	See "iEPS HK" formula table	16
	volt_vd2 *Voltage of voltage domain 2.*	See "iEPS HK" formula table	16
	VIP_OBC00 *Output V, I and P of output bus channel 00 = VBATT Permanant*	See "iEPS HK" formula table	48
	VIP_OBC01 *V / I / P outputs of output bus channel 01 = 5V Permanant*	See "iEPS HK" formula table	48
	VIP_OBC02 *V / I / P outputs of output bus channel 02 = 3V3 Switchable for Payload*	See "iEPS HK" formula table	48
	VIP_OBC03 *V / I / P outputs of output bus channel 03 = 3V3 Switchable for iMTQ*	See "iEPS HK" formula table	48
	VIP_OBC05 *V / I / P outputs of output bus channel 05 = 3V3 Permanant*	See "iEPS HK" formula table	48
	VIP_OBC06 *V / I / P outputs of output bus channel 06 = 3V3 Switchable for Payload*	See "iEPS HK" formula table	48
	Status_stid *Status Data Cmd : System Type Identifier (STID)*	Value	8
	Status _ivid *Status Data Cmd : Interface Version Identifier (IVID)*	Value	8
	Status _rc *Status Data Cmd : Response code as stated in the header*	Value	8
	Status _bid	Value	8

	Status Data Cmd : Board Identifier (BID)		
	Status _cmderr *Status Data Cmd : CmdErr of Response Status Information (STAT)*	Value	4
	Status _stat *Status Data Cmd : Response Status Information (STAT)*	Value	4
	MODE	0 = Startup 1 = Nominal 2 = Safety 3 = Emergency low power	8
	CONF *Read/write configuration parameters have been changed by the EPS master since the last parameters load/save operation.*	0 = Parameters have not been altered since the last load/save. 1 = Parameters have been altered since the last load/save. *Note: At system startup a config load operation is performed, resetting this flag to 0.*	8
	RESET_CAUSE *Cause of last reset.*	0 = Power-on; system returned from an unpowered state (e.g. power cycle). 1 = Watchdog; system was reset due to watchdog timeout, caused by a too-long delay between command interactions with the parent system. 2 = Commanded; system was reset after having received a reset command. 3 = Control system reset; an upset in the EPS control system caused a reset. 4 = Emlopo; emergency low power mode was engaged because the input voltage dropped below the threshold.	8
	UPTIME *Uptime in second, since system start expressed in seconds. Will wrap around to zero on overflow.*	Value	32
	ERROR *First internal error encountered during the system control cycle. Information purposes only.*	Value	16
	RC_CNT_PWRON *Counter indicating amount of power-on reset occurrences since beginning-of-life. Stored in non-volatile memory.*	Value	16
	RC_CNT_WDG *Counter indicating amount of watchdog reset occurrences since beginning-of-life. Stored in non-volatile memory.*	Value	16
	RC_CNT_CMD *Counter indicating amount of commanded reset occurrences since beginning-of-life. Stored in non-volatile memory.*	Value	16
	RC_CNT_MCU *Counter indicating amount of EPS controller resets that occurred since beginning of life.*	Value	16
	RC_CNT_EMLOPO *Counter indicating amount of reset occurrences due to emergency low power mode since beginning of life.*	Value	16
	PREVCMD_ELAPSED *Time in second, elapsed between reception of the previous and this command.*	Value	16

iOBC HK	Solar panel Photodiode 1 (X-)	Raw value	16
	Solar panel Photodiode 2 (X+)		16
	Solar panel Photodiode 3 (Y-)		16
	Solar panel Photodiode 4 (Y+)		16
	Solar panel Photodiode 5 (Z-)		16
	Solar panel Photodiode 6 (Z+)		16
	Solar panel Temperature 1 (X-)	See “iOBC HK” formula table	32
	Solar panel Temperature 2 (X+)		32
	Solar panel Temperature 3 (Y-)		32
	Solar panel Temperature 4 (Y+)		32
	Solar panel Temperature 5 (Z-)		32
	Solar panel Temperature 6 (Z+)		32
	Total bits size		**1600**
End of the beacon			

4. Decoding formulas

TrxvuTx HK:

Parameter	Conversion	Unit	Error
RF reflected power	20 * log10(ADC * 0.00767)	dBm	±1.5 dB
	ADC * ADC * 5.887 10^{-5}	mW	±150 mW
RF forward power	20 * log10(ADC * 0.00767)	dBm	±1.5 dB
	ADC * ADC * 5.887 10^{-5}	mW	±150 mW
Power bus voltage	ADC * 0.00488	V	±55 mV
Total current consumption	ADC * 0.16643964	mA	±4 mA
Transmitter current consumption	ADC * 0.16643964	mA	±4 mA
Receiver current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
Local oscillator temperature	ADC *-0.07669 + 195.6037	°C	±1 °C

TrxvuRx HK:

Parameter	Conversion	Unit	Error
Received signal Doppler offset	ADC * 13.352- 22300	Hz	±1 kHz
Received signal strength	ADC * 0.03 – 152	dBm	±3 dB
Power bus voltage	ADC * 0.00488	V	±55 mV
Total current consumption	ADC * 0.16643964	mA	±4 mA
Transmitter current consumption	ADC * 0.16643964	mA	±4 mA
Receiver current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier current consumption	ADC * 0.16643964	mA	±4 mA
Power amplifier temperature	ADC *-0.07669 + 195.6037	°C	±1 °C
Local oscillator temperature	ADC *-0.07669 + 195.6037	°C	±1 °C

iMTQ HK:

The basic conversion from raw adc counts to engineering units uses a two-step process. First the raw value is converted to a voltage using the following formula:

$$ADC_{volt}[V] = \frac{2.5[V]}{4095} \times ADC_{raw}$$

Second, the ADC voltage is used in a formula specific for each measurement. These formulas are given in Table 3-7.

Table 3-7: Raw to Engineering Value Conversion Formulas

Raw Value	Conversion Formula
Digital/Analog Voltage	$Dig.Volt.[V] = 2 \times ADC_{volt}[V]$
Digital/Analog Current	$Dig.Curr.[V] = ADC_{volt}[V]/(10[V/A])$
Measured Coil Current	$I_x = (ADC_{volt}[V] - 1.03[V])/(2[V/A])$ $I_y = (ADC_{volt}[V] - 1.03[V])/(2[V/A])$ $I_z = (ADC_{volt}[V] - 1.03[V])/(0.48[V/A])$
Measured Coil Temp.	$Temp_{x/y/z} = -(ADC_{volt}[V] - 1.567[V])/(0.0081[V/{}^{o}C])$
MCU Temperature	$Temp_{mcu} = -(ADC_{volt}[V] - 0.680[V])/(0.00225[V/{}^{o}C])$ note: IMTQ internal conversion uses factory calibrated values for bias and gain that might deviate from the typical values stated in this formula. Taking reference temperature measurements with the specific IMTQ unit is recommended when only using raw hk and high precision on the MCU temperature measurement is required.

Ants HK:

1) Ants Temperature

- Vout = Vcc/1023 *Raw_data. The nominal value for Vcc is 3.3V.
- See table below for the relationship between Vout and the measured temperature.

Temp (DegC)	Vout (mV)
-50	2616
-49	2607
-48	2598
-47	2589
-46	2580
-45	2571
-44	2562
-43	2553
-42	2543
-41	2533
-40	2522
-39	2512
-38	2501
-37	2491
-36	2481
-35	2470
-34	2460
-33	2449
-32	2439
-31	2429
-30	2418
-29	2408
-28	2397
-27	2387
-26	2376
-25	2366
-24	2355
-23	2345
-22	2334
-21	2324
-20	2313
-19	2302

Temp (DegC)	Vout (mV)
1	2089
2	2079
3	2068
4	2057
5	2047
6	2036
7	2025
8	2014
9	2004
10	1993
11	1982
12	1971
13	1961
14	1950
15	1939
16	1928
17	1918
18	1907
19	1896
20	1885
21	1874
22	1864
23	1853
24	1842
25	1831
26	1820
27	1810
28	1799
29	1788
30	1777
31	1766
32	1756

Temp (DegC)	Vout (mV)
51	1547
52	1536
53	1525
54	1514
55	1503
56	1492
57	1481
58	1470
59	1459
60	1448
61	1436
62	1425
63	1414
64	1403
65	1391
66	1380
67	1369
68	1358
69	1346
70	1335
71	1324
72	1313
73	1301
74	1290
75	1279
76	1268
77	1257
78	1245
79	1234
80	1223
81	1212
82	1201

Temp (DegC)	Vout (mV)
101	986
102	974
103	963
104	951
105	940
106	929
107	917
108	906
109	895
110	883
111	872
112	860
113	849
114	837
115	826
116	814
117	803
118	791
119	780
120	769
121	757
122	745
123	734
124	722
125	711
126	699
127	688
128	676
129	665
130	653
131	642
132	630

Temp (DegC)	Vout (mV)
-18	2292
-17	2281
-16	2271
-15	2260
-14	2250
-13	2239
-12	2228
-11	2218
-10	2207
-9	2197
-8	2186
-7	2175
-6	2164
-5	2154
-4	2143
-3	2132
-2	2122
-1	2111
0	2100

Temp (DegC)	Vout (mV)
33	1745
34	1734
35	1723
36	1712
37	1701
38	1690
39	1679
40	1668
41	1657
42	1646
43	1635
44	1624
45	1613
46	1602
47	1591
48	1580
49	1569
50	1558

Temp (DegC)	Vout (mV)
83	1189
84	1178
85	1167
86	1155
87	1144
88	1133
89	1122
90	1110
91	1099
92	1088
93	1076
94	1065
95	1054
96	1042
97	1031
98	1020
99	1008
100	997

Temp (DegC)	Vout (mV)
133	618
134	607
135	595
136	584
137	572
138	560
139	549
140	537
141	525
142	514
143	502
144	490
145	479
146	467
147	455
148	443
149	432
150	420

2) Ants deployment status

	bit 7							bit 0
MSB	A1S	A1T	A1B	0	A2S	A2T	A2B	IG
LSB	A3S	A3T	A3B	INDB	A4S	A4T	A4B	ARM

AxS
1 - This antenna's deployment switch indicates this antenna is NOT deployed
0 - This antenna's deployment switch indicates this antenna is deployed
AxT
The latest deployment system activation for this antenna was stopped because:
1 - a time limit was reached (specified time or safety time limit)
0 - a reason other than reaching a time limit
AxB
1 - This antenna's deployment system is currently active
0 - This antenna's deployment system is currently NOT active
INDB
1 - The antenna system independent burn is currently active.
0 - The antenna system independent burn is currently NOT active.
IG
1 - The antenna system is currently ignoring the antenna deployment switches
0- The antenna system is currently NOT ignoring the antenna deployment switches
ARM
1 - The antenna system is currently armed
0 - The antenna system is currently NOT armed

iEPS HK:

1) VIP definition

Name	Offset [byte]	Size [byte]	Type	Unit	Description
$VOLT_{raw}$	0	2	int16		Channel voltage expressed in raw form, using twos-complement signed format.
$CURR_{raw}$	2	2	int16		Channel current expressed in raw form, using twos-complement signed format.
$POWE_{raw}$	4	2	int16		Channel power expressed in raw form, using twos-complement signed format.

2) Raw to engineering:

The raw data can be converted to engineering values using a bias and a gain value. The full computation has the following form:

$$Eng = G \times (Raw - Bias) = \frac{PreMul}{PostDiv} \times (Raw - Bias)$$

To retain precision while applying integer arithmetic, the conversion is actually implemented with the multiplication applied before the division:

$$Eng = \frac{PreMul \times (Raw - Bias)}{PostDiv}$$

Field	Bias	PreMul	PosDiv	Unit	Notes
VOLT_BRDSUP	0	1000	819	1e-3 V	
TEMP	1168	220	9	1e-2 °C	MCU factory provided calibration values[1] could cause slight deviaton in engineering hk data
VIP VOLT	0	125	128	1e-3 V	
VIP CURR	0	3125	10240 20480	1e-3 A	= VIP_INPUT/OUTPUT & VIP_VDx = VIP_OBC
VIP POWE	0	3125	3200 6400	1e-2 W	= VIP_INPUT/OUTPUT & VIP_VDx = VIP_OBC
VOLT_CELLx	512	3	2	1e-3 V	
BAT_TEMP1	1969	75	4	1e-2 °C	
BAT_TEMP2 BAT_TEMP3					Non-linear. See Figure 3-8 and/or Table 3-12.
VOLT_IN_MPPT VOLT_OUT_MPPT	0	2625	128	1e-3 V	
CURR_IN_MPPT CURR_OUT_MPPT	41	625	192	1e-3 A	

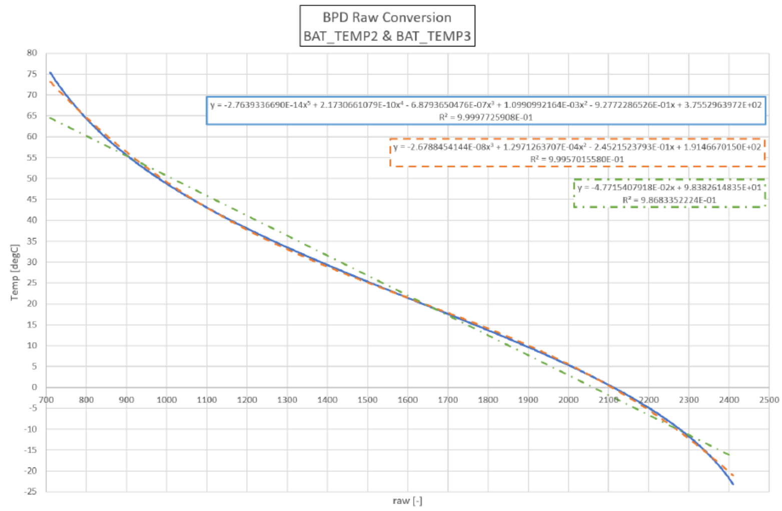


Figure 3-8: BPD raw data to temperature relation for BAT_TEMP2 and BAT_TEMP3

The non-linear relation between the raw and temperature of the NTC battery pack temperature sensors is shown in Figure 3-8 and Table 3-12. The blue solid line shows the actual relation. Several polynomial fits are applied to this curve of which the corresponding equations and R^2 values are shown. These fits allow selection of a desired accuracy versus computational performance. Alternatively a static look-up table can be constructed using the 5th degree poly, which minimizes computational burden while maximizing accuracy, at the expense of digital storage space for the look-up table.

Table 3-12: Polynomial Fit to BPD: BAT_TEMP2 and BAT_TEMP3

Linear fit $y = -2.7639336690E-14x^5 + 2.1730661079E-10x^4 - 6.8793650476E-07x^3 + 1.0990992164E-03x^2 - 9.2772286526E-01x + 3.7552963972E+02$
Third degree fit $y = -2.6788454144E-08x^3 + 1.2971263707E-04x^2 - 2.4521523793E-01x + 1.9146670150E+02$
Fifth degree fit $y = -4.7715407918E-02x + 9.8382614835E+01$

iOBC HK:

Solar panel temperature:

The temperature value can be calculated from the raw value with this formula:

Temp (°C) = RawValue / 1024