COM test report Swisscube

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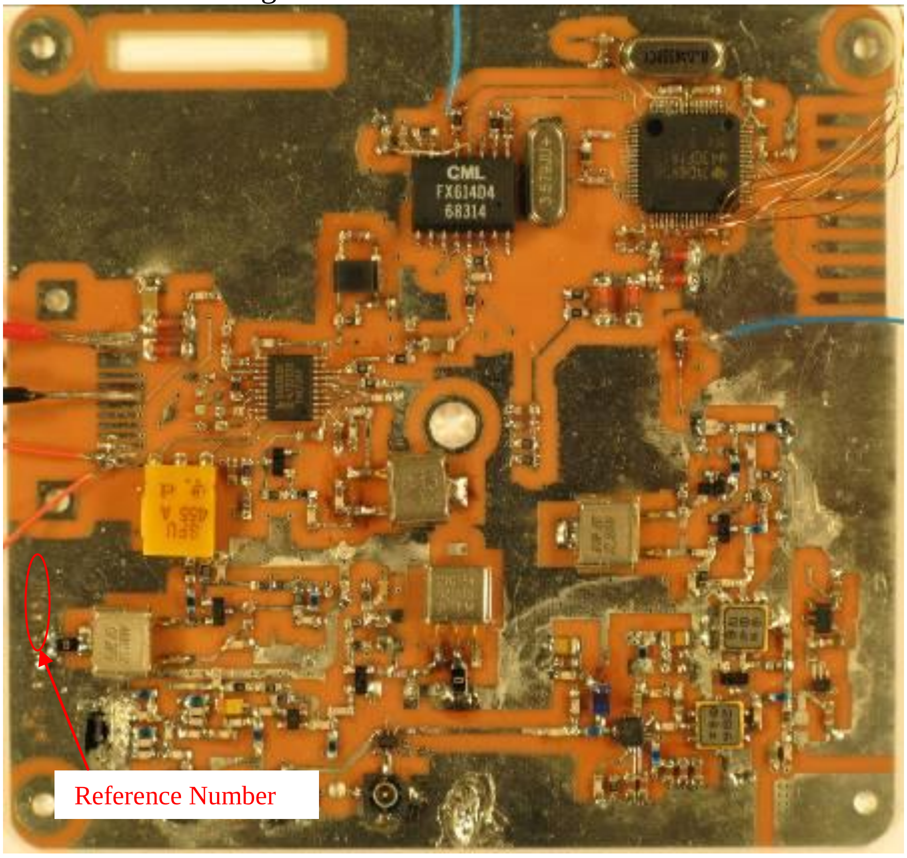
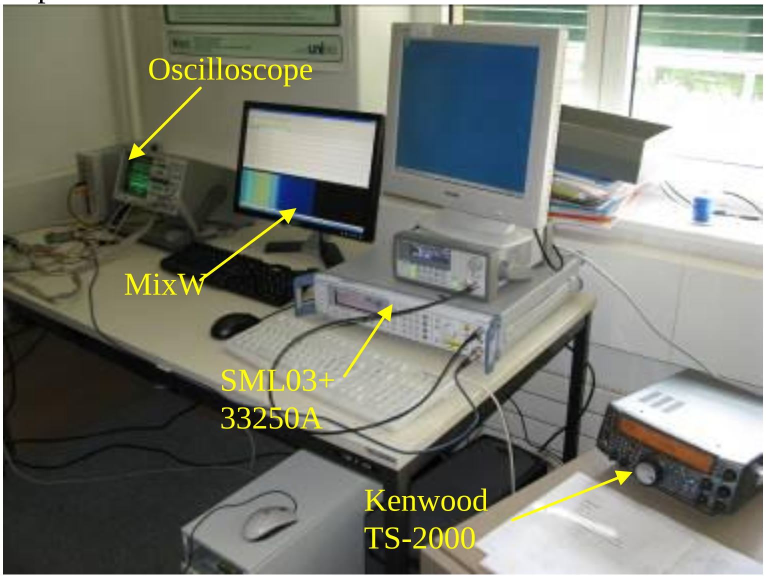
Introduction

Some iterations of the COM board have been developed in order to achieve a final prototype version. This final version is already finished and it has been tested, standalone, communicating with the ground station. A series of temperature tests have also been performed..
This card is shown in the next figure and has a reference number of 0917 marked in red.



The tests have been performed in the IMT facilities.



Transmitter

VCXO

The 437.505MHz VCXO is based on the generation of the 5th harmonic of a 87.501MHz Butler oscillator. The varicap has been changed to a ZC829 in order to be able to lower the control voltage to around 2.0V. The control voltage for 437.505MHz is 1.98V. The power of the 437.505MHz signal at the output of the 2nd SAW filter (input of the PA) is 5dBm, which is slightly above the PA input P1dB. As a consequence, variations of the VCXO power due, for example, to temperature, will have limited impact on the PA output power. The tuning range of the VCXO is around 10kHz.

Power Amplifier

A first set of measurements has been performed by injecting a 437.505MHz signal, generated by an E4438C signal generator, into the RF5110G and measuring the power of the signal at the output of the PA with a N9010A spectrum analyzer. The target 1W output power is achieved for Pin higher than -2dBm. The 437.505MHz signal generated by the VCXO is 5dBm at the output of the second SAW filter (input of the PA). The PA is therefore operated close to its optimum efficiency point and, since in compression, is less insensitive to variations of the signal's power.

Pin dBm	Pout dBm	Vctrl	I mA	Pcons W	Pout W	Eff %	G dB
-10	26.2	2.6	660	2.2	0.4	19.1	**36.2**
-9	26.9	2.6	710	2.3	0.5	20.9	35.9
-8	27.5	2.6	760	2.5	0.6	22.4	35.5
-7	28.1	2.6	810	2.7	0.6	24.2	35.1
-6	28.5	2.6	860	2.8	0.7	24.9	34.5
-5	29	2.6	900	3.0	0.8	26.7	34.0
-4	29.3	2.6	940	3.1	0.9	27.4	33.3
-3	29.7	2.6	980	3.2	0.9	28.9	32.7
-2	29.9	2.6	1020	3.4	1.0	29.0	31.9
-1	**30.2**	2.6	1060	3.5	1.0	29.9	31.2
0	**30.4**	2.6	1090	3.6	1.1	30.5	30.4
1	**30.6**	2.6	1120	3.7	1.1	31.1	29.6
2	**30.7**	2.6	1140	3.8	1.2	31.2	28.7
3	**30.8**	2.6	1160	3.8	1.2	31.4	27.8
4	**30.9**	2.6	1180	3.9	1.2	31.6	26.9
5	**31**	2.6	1190	3.9	1.3	**32.1**	26.0
6	**31**	2.6	1210	4.0	1.3	31.5	25.0
7	**31.1**	2.6	1230	4.1	1.3	31.7	24.1
8	**31.2**	2.6	1240	4.1	1.3	32.2	23.2
9	**31.2**	2.6	1250	4.1	1.3	32.0	22.2
10	**31.2**	2.6	1260	4.2	1.3	31.7	21.2

A second set of measurements has been performed by using the signal generated by the VCXO to drive the PA. Interestingly, the Vctrl could be lowered to 2.3V in order to spare power (a measure of the power consumption would have been of interest here).

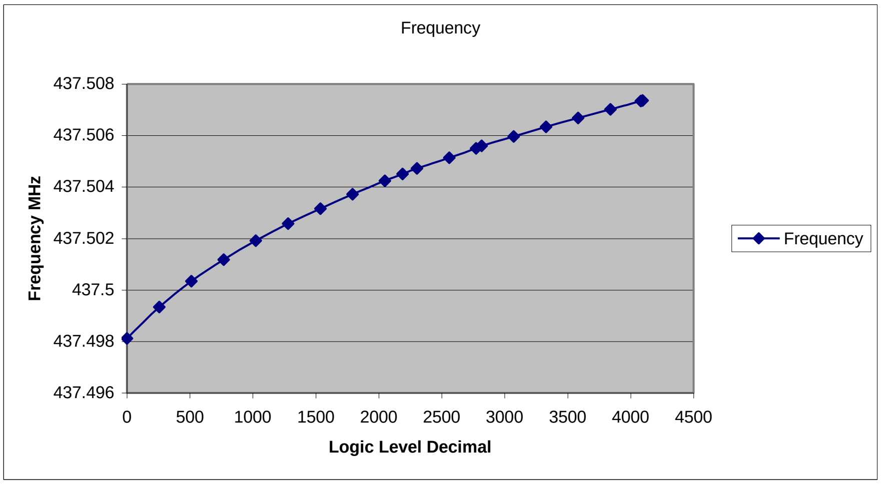
Pin dBm	Vctrl V	Pout dBm	G dB
5	1	-10.0	-15.0
5	1.1	-9.6	-14.6
5	1.2	-10.2	-15.2
5	1.3	10.0	5.0
5	1.4	19.0	14.0
5	1.5	23.2	18.2
5	1.6	24.7	19.7
5	1.7	25.8	20.8
5	1.8	27.0	22.0
5	1.9	27.9	22.9
5	2	28.5	23.5
5	2.1	29.1	24.1
5	2.2	29.7	24.7
5	2.3	30.1	25.1
5	2.4	30.5	25.5
5	2.5	30.7	25.7
5	2.6	30.9	25.9
5	2.7	31.1	26.1
5	2.8	31.3	26.3

The second harmonic of the 437.505MHz signal has been measured and is 39dB below the signal's power.

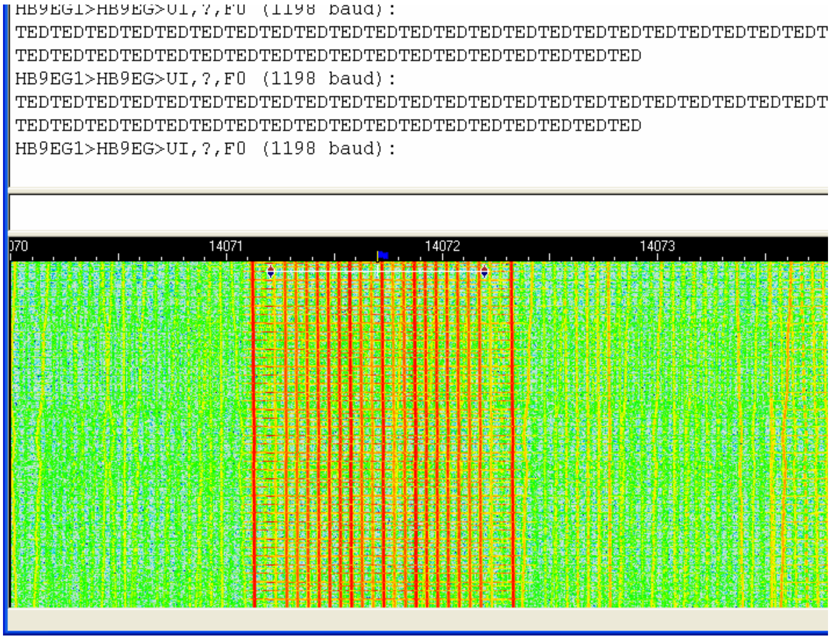
Transmitter communication (downlink) test

This measurement has been performed using the ground station as a 437.505MHz receiver and MixManager to see the frame sent by the microcontroller in the COM board.It has first been necessary to identify the logical levels at which the output frequency of the VCXO was 437.5055MHz and 437.50495MHz. The results are reported in the table below.The logic values that matched with the deviation expected of 437.5045MHz and 437.5055MHz were 088D and 0AD5 respectively.

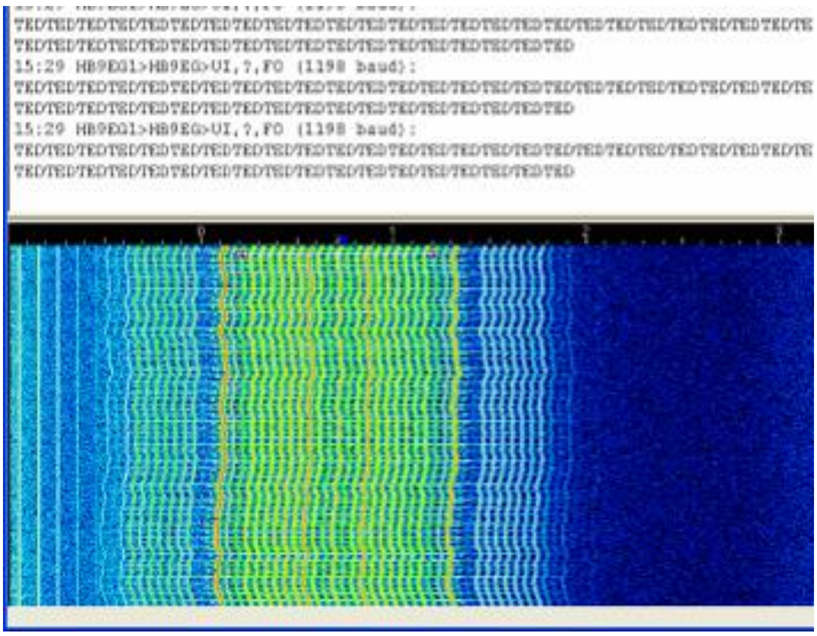
@ 3.3 Volts of reference			
Logic Level Hexadecimal	**Logic Level Decimal**	**Volts**	**Frequency MHz**
0000	0	0	437.49812
0100	256	0.2	437.49934
0200	512	0.41	437.50034
0300	768	0.61	437.50118
0400	1024	0.82	437.50192
0500	1280	1.03	437.50258
0600	1536	1.24	437.50316
0700	1792	1.45	437.50372
0800	2048	1.65	437.50424
088D	2189	1.76	437.504503
0900	2304	1.86	437.50472
0A00	2560	2.06	437.50514
0AD5	2773	2.23	437.505504
0B00	2816	2.27	437.5056
0C00	3072	2.47	437.50596
0D00	3328	2.68	437.50634
0E00	3584	2.89	437.50668
0F00	3840	3.09	437.50702
0FF0	4080	3.28	437.50734
0FFF	4095	3.29	437.50736



Once the logic values were identified, the transceiver has been tuned to receive the maximum power of the COM and to identify the two deviation frequencies and the central frequency. For communication tests, the PA was turned-off and a small wire antenna was used for the transceiver. The power measured at the transceiver's input was around -80dBm. The frames have been received successfully by the transceiver using the MixManager as shown in the next figure. Some new characters have been added to see some changes in the frame. These characters were "HW".



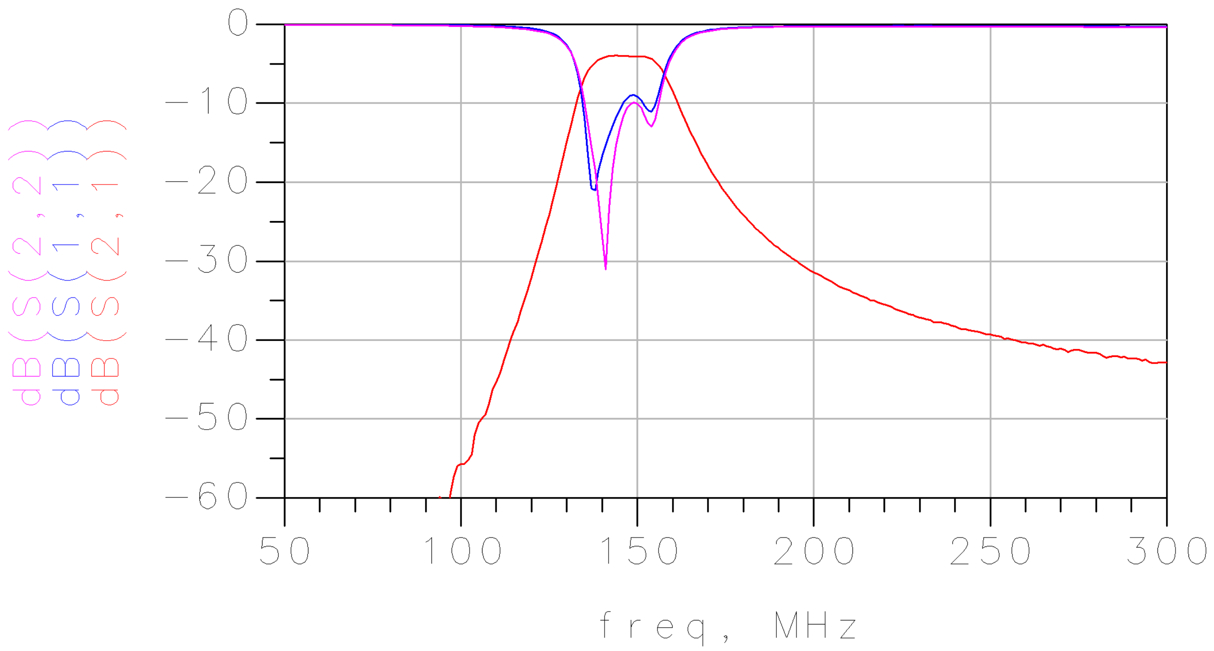
Another interesting point is the impact of the PA temperature on the transmission frequency. To measure this change, it has first been necessary to enable the PA, and therefore to generate a 1kHz signal with the microcontroller to set Vctrl equal to 2.6V. The measured frequency shift when the PA is turned on is around 400Hz.
Finally, the switch (PE4259) has also been implemented at the output of the PA and the measured output power was still in the 30dBm range.

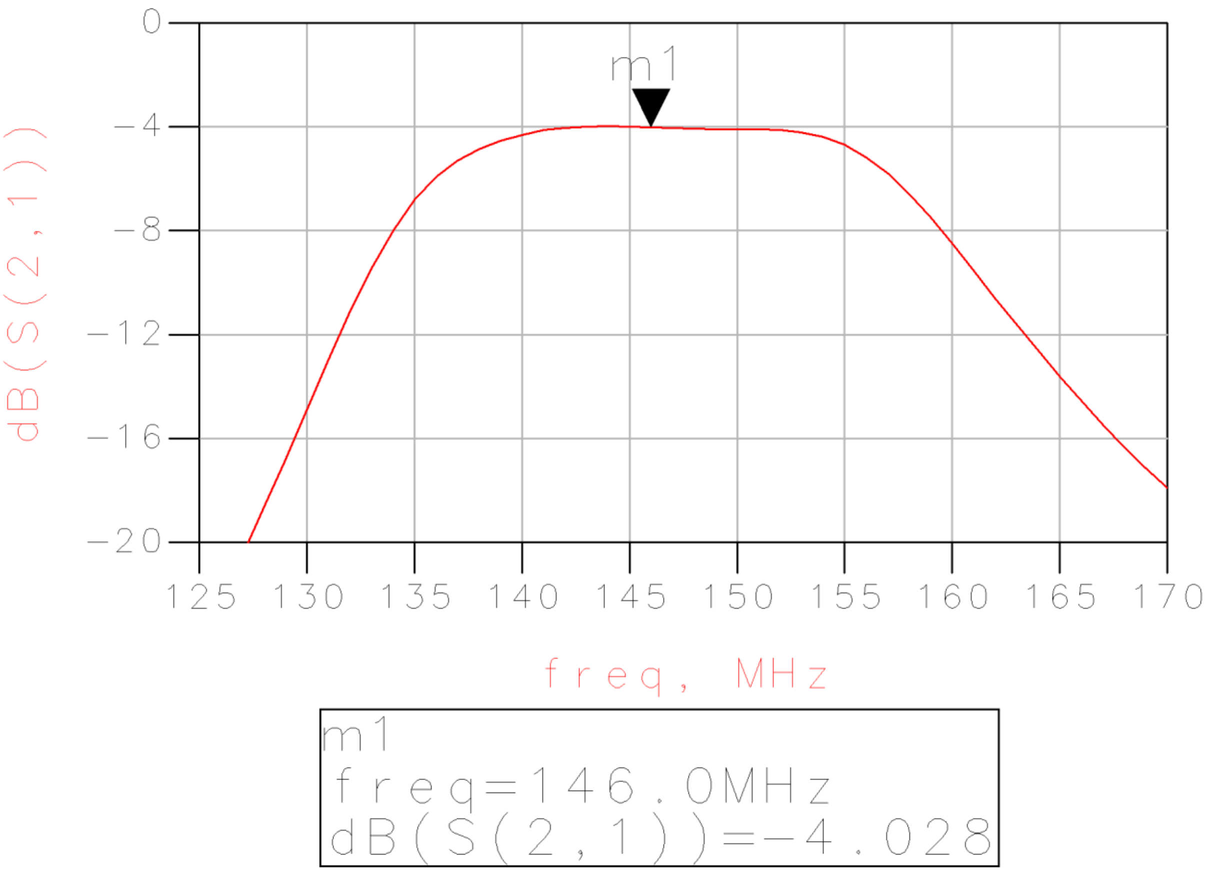


Receiver

RF filter

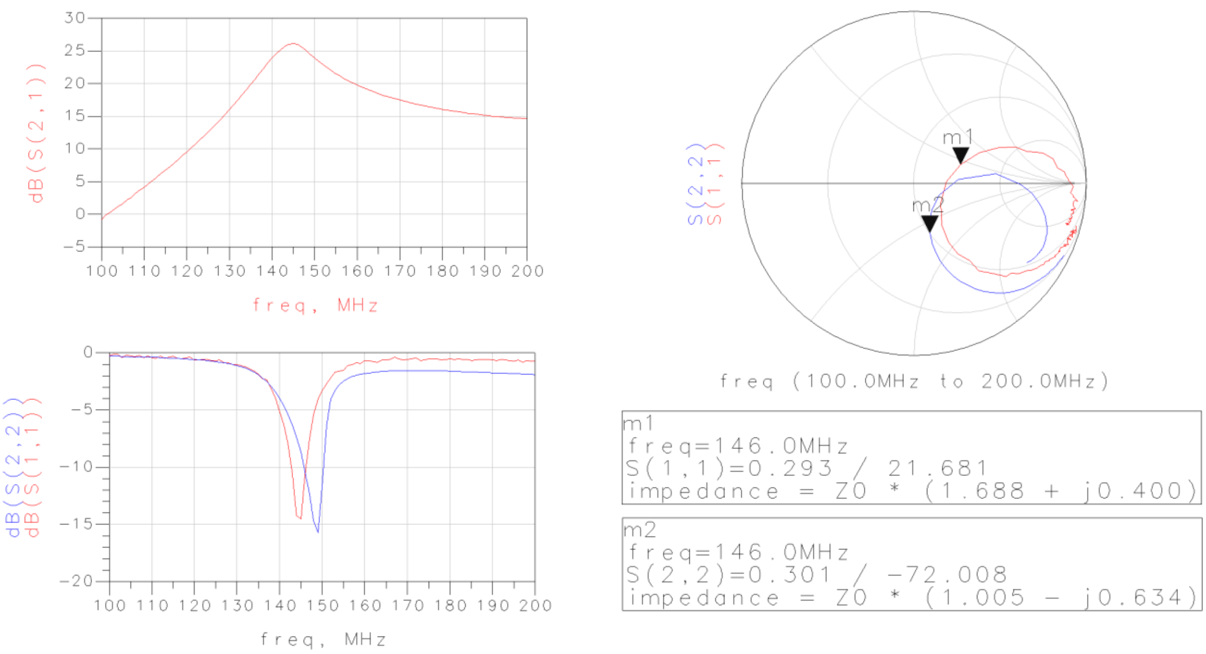
This is the measured S-parameter of the 145.98MHz filter. The frequency response is well centered at 145.98MHz and the 3dB bandwidth around 25MHz. The insertion loss around 4dB.





LNA

Fig. is the LNA's S-parameter measured with a network analyset (PNA-X). The input power was set to -35dBm and two previously calibrated 50Ohm coaxial cables were soldered at the input and output of the LNA. We can see that at 145.98MHz, the gain is better than 25dB and the input/output return loss better than -10dB.



Receiver communication (uplink) test with SML03 and 33250A signal generators.

The goal was to test the output at the modem in the COM board and verify that the demodulation of the AFSK signal was done. An AFSK signal has been generated by the SML03 with a carrier frequency of 145.98MHz with a power of around -98dBm modulated externally by the 33250A with a FSK modulation of a sinus of 1200Hz and a frequency hop of 2200Hz with a FSK rate of 600Hz. The instruments setup was:

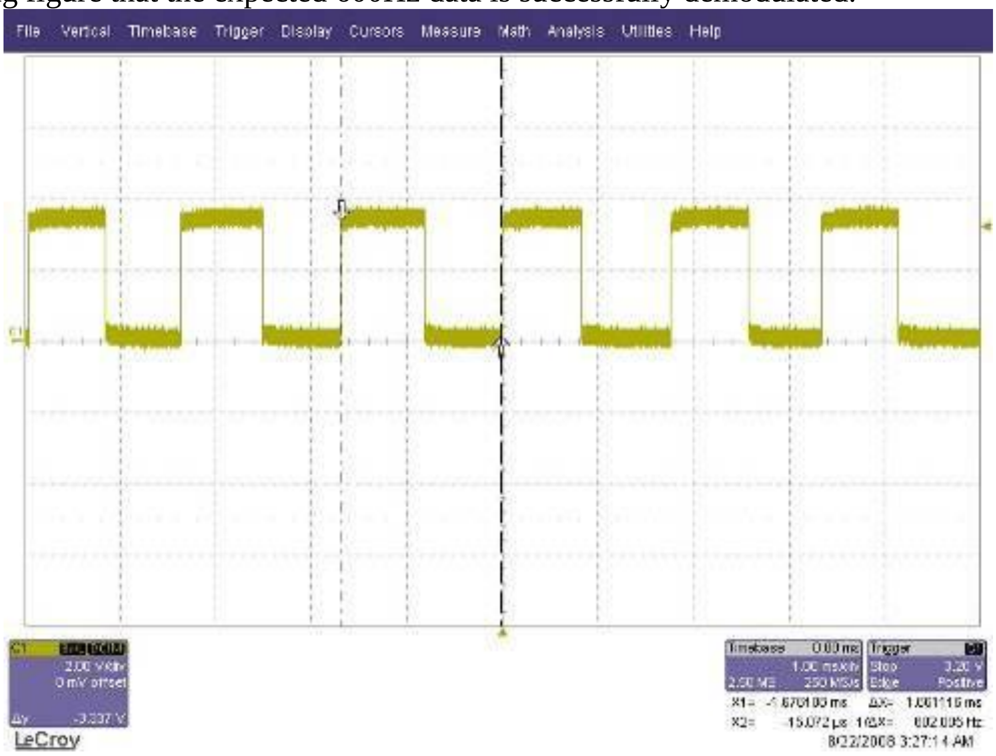
SML03:

- frequency: 145.98MHz
- power: -98dBm
- FM Modulation, with a deviation of 1KHz

33250A:

- 1200Hz sine signal
- FSK modulation
- Hop frequency: 2200Hz
- Data rate: 600Hz

The signal a the output of the modem (MX614) output has been monitored. We can see in the following figure that the expected 600Hz data is successfully demodulated.

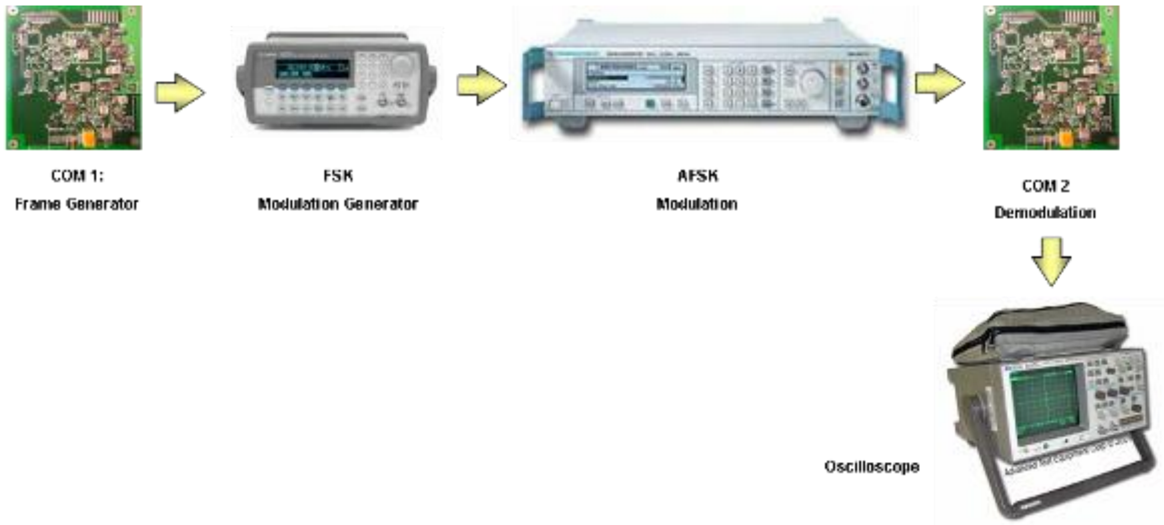


The same measure has been performed successfully with only ones and only zeros transmitted.

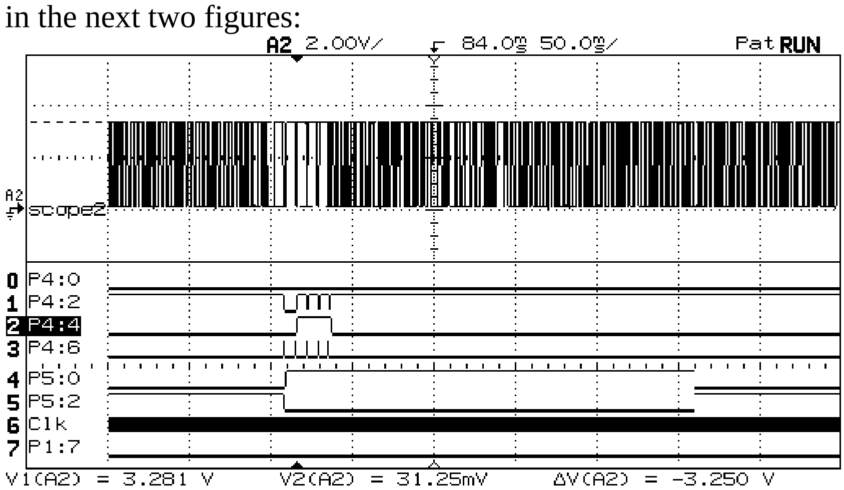
Another important measurement to identify the possible errors in the reception is the jitter. This measurement has been done taking three different periods in one single measurement of the modem's output. The maximum difference between these periods has been calculated as a maximum jitter of 200us. The three periods identified are presented in the next three figures.

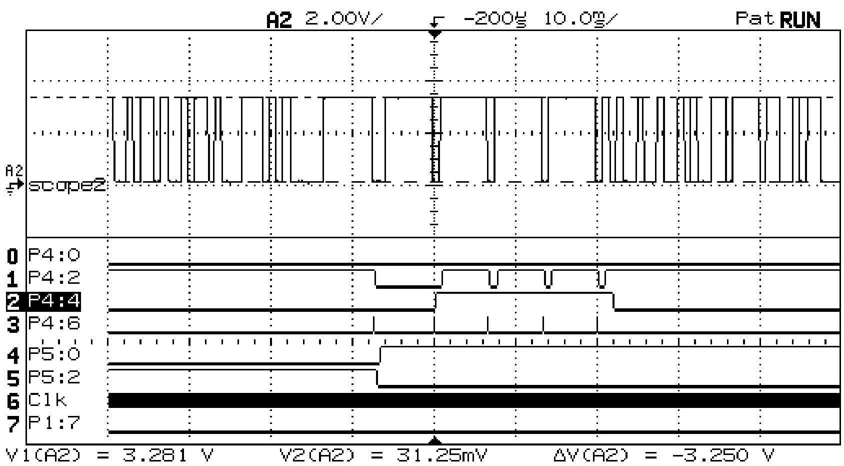
Receiver communication (uplink) test with ground station

This test has been implemented by using the microcontroller of a second COM (COM 1) board as a frame generator. The 33250 was then using this generated data instead of its internal data generator; the 145.98MHz signal was then generated the same way as in the previous test. The signal was then injected in COM 2 and monitored on an oscilloscope.



The frames demodulation at COM_2 has been successfully done. Two signals have been used to confirm and valid the data reception: P5.2 gives a logical high when a frame is received (one frame is equivalent to 23 Bytes); P5.0 changes its state if the received frame was correct. This is shown in the next two figures:

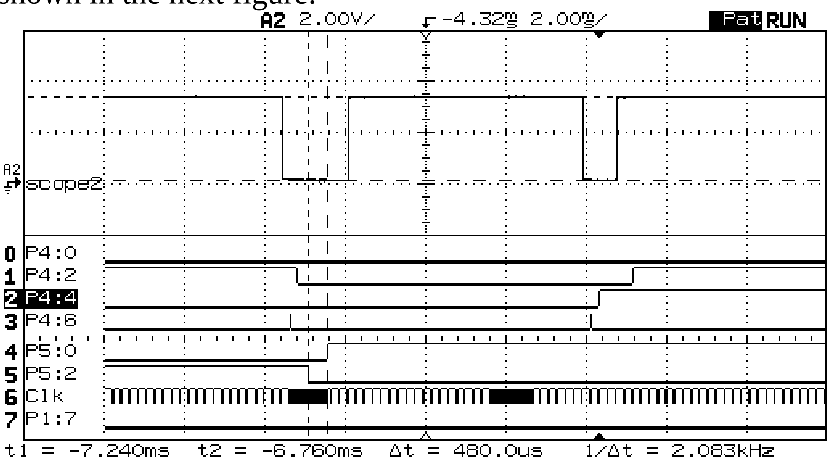




The A2 port is the demodulated signal at the COM's modem; P4.6 represents the flag reception and P4.2 and P4.4 indicate the reception mode:

State	Frame-wait	Data reception	Flag-wait	Flag-wait 2
P4.2	0	1	0	1
P4.4	0	0	1	1

Six invalid frames have been observed during 1 minute when the received signal's power was -100dBm. One invalid frame has been observed in 1 minute when the received signal's power was set to -98dBm.
The maximum delay observed between the reception and validation frame cycles was of 480us. This is shown in the next figure:



A simultaneous uplink and downlink communication test has been performed. The full duplex communication was also possible.

Temperature Test of COM board

These tests have been made using the temperature chamber Espec SH-661 in the LMTS laboratory at Neuchâtel.

The equipment used was:

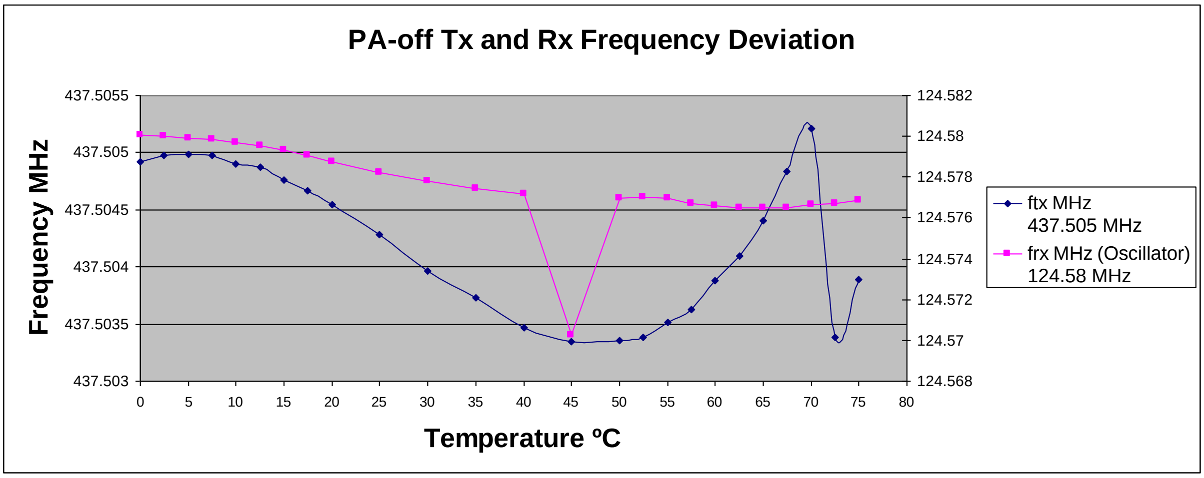
1.- A power supply
2.- A spectrum analyzer FS315
3.- The temperature chamber Espec SH-661


The humidity in the oven has been turned off and the span selected in the spectrum analyzer was of 3 KHz.

The first test has been done with the power amplifier off. The downlink frequency (437.505MHz) and the Rx oscillator's frequency (124.58MHz) have been observed in function of a temperature variation from 0°C to 70°C. The results are shown in the next table and its graph. The maximum frequency deviation for both frequencies has been presented with a temperature of 45°C; these deviations were of 1.7 and 9.8 KHz for Tx and Rx frequencies respectively.

PA-off Tx and RX Frequency Deviation		
Temp ºC	**f_{tx} MHz 437.505 MHz**	**f_{rx} MHz (Oscillator) 124.58 MHz**
0	437.504916	124.580048
2.5	437.504976	124.580024
5	437.504988	124.579916
7.5	437.504976	124.579832
10	437.504904	124.5797
12.5	437.504868	124.579532
15	437.50476	124.579316
17.5	437.504664	124.579052
20	437.504544	124.578764
25	437.50428	124.57822
30	437.50396	124.577818
35	437.503726	124.57746
40	437.503468	124.57719
45	437.503348	124.57024
50	437.50336	124.576988
52.5	437.503384	124.577
55	437.503516	124.576976
57.5	437.503624	124.5767

60	437.503876	124.576592
62.5	437.504092	124.576508
65	437.504404	124.576496
67.5	437.504836	124.576508
70	437.505208	124.576628
72.5	437.503388	124.576724
75	437.503892	124.576868

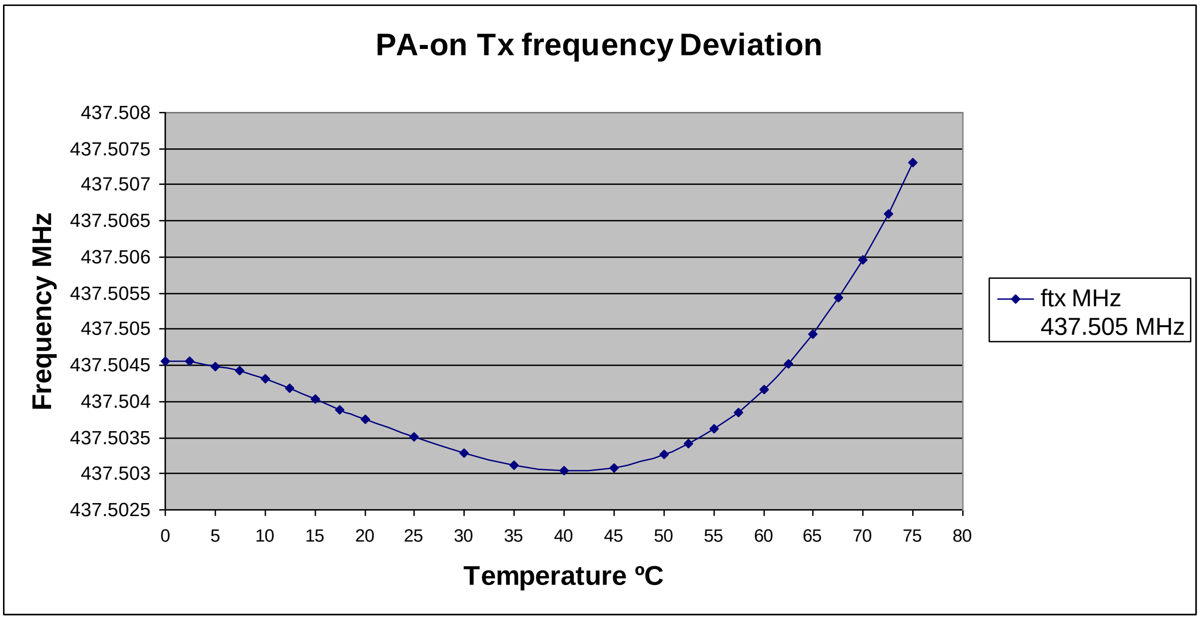


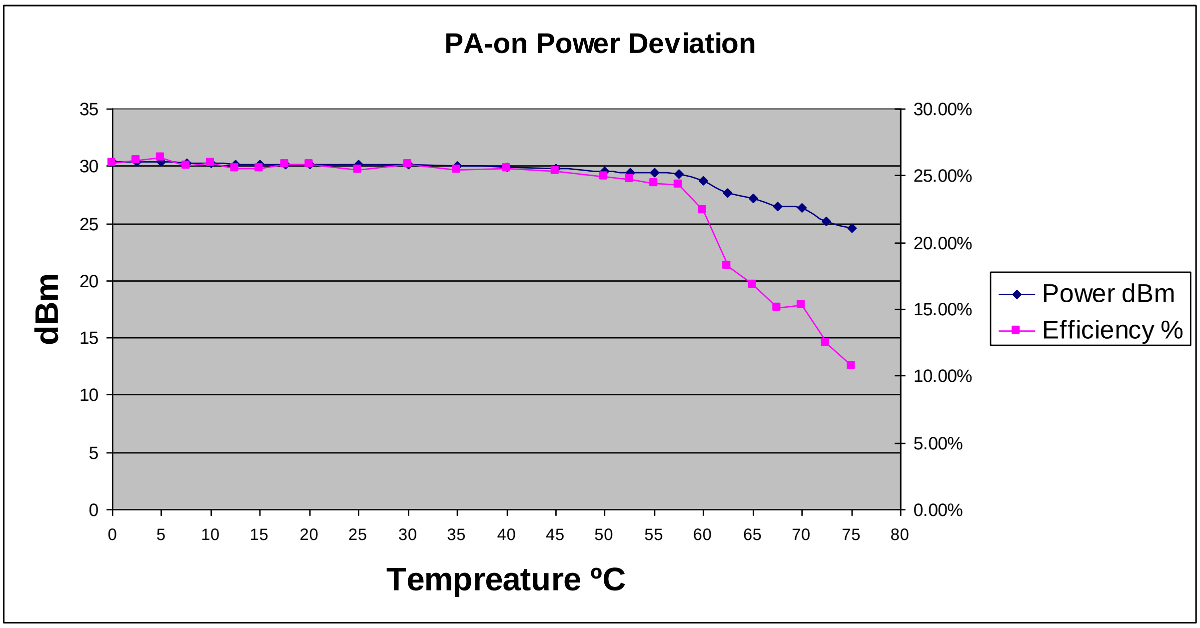
The second test has been done with the power amplifier on. The Tx frequency, its power and the efficiency have been observed in function of the temperature (0°C to 70°C). The results are shown in the next table and its graphs:

PA-on Tx and Power deviation				
Temp ºC	**ftx MHz 437.505 MHz**	**Power dBm**	**Current Amps**	**Efficiency %**
0	437.504564	30.4	1.28	26%
2.5	437.504552	30.4	1.27	26%
5	437.504492	30.4	1.26	26%
7.5	437.504432	30.3	1.26	26%
10	437.504312	30.3	1.25	26%
12.5	437.50418	30.2	1.24	26%
15	437.504036	30.2	1.24	26%
17.5	437.50388	30.2	1.23	26%
20	437.503748	30.2	1.23	26%
25	437.503508	30.1	1.22	25%
30	437.503292	30.1	1.2	26%
35	437.503124	30	1.19	25%
40	437.503046	29.9	1.16	26%
45	437.503082	29.8	1.14	25%
50	437.503262	29.6	1.11	25%
52.5	437.503412	29.5	1.09	25%
55	437.503616	29.4	1.08	24%
57.5	437.503856	29.3	1.06	24%
60	437.504162	28.78	1.02	22%
62.5	437.504522	27.71	0.98	18%
65	437.504936	27.17	0.94	17%

67.5	437.505428	26.53	0.9	15%
70	437.505968	26.39	0.86	15%
72.5	437.506592	25.22	0.81	12%
75	437.5073	24.54	0.8	11%

The maximum frequency deviation of 2 KHz occurs at a temperature of 40°C. The current trends to decrease when the temperature increases, because the PA (RF5110G) has internal temperature compensators to avoid high current values due to high temperatures. For this reason, the efficiency and the power of the signal start to decrease when the temperature is larger than 50°C.





For a temperature deviation observed, in the order of KHz, the system does not require frequency compensation.

Conclusions

The COM board has been successfully tested. Its functionality with the ground station has been performed and this prototype is ready to be tested with the other Swiscube interfaces.