# Wideband Compact Cryogenic receiver QRFH SN03 FAT

# REPORT

| | | |
|---|---|---|
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| **Prepared by** | **:** | **Thomas BONHOURE** |
| **Reviewed/Approved by** | **:** | **Steve Rawson** |
| **Approval Signature** | **:** | Stephen A Rawson<br>Digitally signed by Stephen A Rawson<br>DN: cn=Stephen A Rawson, c=FR, o=Callisto, email=rawson@callisto-space.com<br>Date: 2017.03.18 22:02:55 +01'00' |

Callisto
12 Av.de Borde Blanche
Villefranche de Lauragais F-31290
Tel. +33 561 800 807
www.callisto-space.com

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| 0.1 | 26.01.17 | 4042 | Draft |
| 1.0 | 14.02.17 | 4042 | First issue after internal review |
| 1.1 | 24.02.17 | 4042 | The initial NT measurement was not relevant due to bad weather condition. Addition of NT measurement done the 23-02-17 |

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# 1. INTRODUCTION

## 1.1 Purpose & Summary

Tests have been conducted on the Wideband Compact Cryogenic Receiver QRFH SN03 in Callisto laboratory and outside for the noise temperature according to the procedures described in test plan 1.2.1.

The tests included RF testing and cryogenic testing.

The tests have been performed from 23.Jan.2017 to 09.Feb.2017. Thermal and RF tests have been performed both indoor and outdoor. The FAT results are successful, within the specification.

The receiver operation and performance are validated.

## 1.2 Applicable & Reference Documents

This section lists other documents which are referred to in the main body of this document. In cases when the document cited is listed without an issue number, revision number or date, then the reader should refer to the latest available issue.

### 1.2.1 Applicable Documents

| | |
|---|---|
| AD1 | Callisto Proposal , Ref. PRP/685/3606 issue 1.0 dated 11th April 2016 |
| AD2 | User Manual, QRFH Compact Wideband Cryogenic Receiver, DOC/1704/3991 |
| AD3 | Test Plan Procedure QRFH Compact Receiver, TST/1704/3990, Issue 1.0 |
| AD4 | Interface Control Document, ICD/1704/3992, issue 1.0 |

## 2. TEST RESULTS SUMMARY

**Result "R" column** = Passed (P), Marginal (M), Failed (F)

| Parameter | Specifications | Results | Verification Method | R | Comments |
|---|---|---|---|---|---|
| **Frequency Band** | 2 – 14 GHz | | AT | | |
| *Port X* | | 2-14GHz | | P | |
| *Port Y* | | 2-14GHz | | P | |
| **Noise Temperature** | <40K | | AT | | at cryogenic temperature |
| *Port X* | | 95% of the meas <40K | | P | TLNA=80K |
| *Port Y* | | 100% of the meas <40K | | P | TLNA=80K |
| **Gain** | >55dB | | AT | | |
| *Port X* | | 56dBmin | | P | Gain extracted from NT meas |
| *Port Y* | | 56dBmin | | P | |
| **Gain Flatness** | 10dBpp | | AT | | |
| *Port X* | | ~7dBpp | | P | Worst case, gain extracted from NT meas. Approximated value due to RFI perturbation. |
| *Port Y* | | ~7dBpp | | P | |
| **Output Return Loss** | 10dBmin | | AT | | |
| *Port X* | | 10.7dBmin | | P | 14dB typical |
| *Port Y* | | 11.4dBmin | | P | 14dB typical |
| **Pout 1dB** | +20dBm | | CT; D | | |

| | | | | | |
|---|---|---|---|---|---|
| *Port X* | | +20dBm | | P | |
| *Port Y* | | +20dBm | | P | |
| **Gain via test input** | | | AT | | No specification defined for this parameter |
| *Port X* | | 20.1dB<G<44.5dB | | | |
| *Port Y* | | 19.4dB<G<44.3 dB | | | |
| **Cooldown Time to reach NT<40K** | <5 hours | | AT | | |
| *Port X* | | 4Hrs | | P | |
| *Port Y* | | 4Hrs | | P | |
| **Noise calibration** | None | | AT | P | The NT measurement performed with the noise diode is comparable with the NT measurement done with the sky method (see Table 3-3) |
| **Phase calibration** | None | | AT | P | The minimum picket level at 14GHz available at the output of the receiver is around -51dBm (see Figure 3-25 and Figure 3-28). |
| **Cold Head Base Temperature** | 80K | 75K | AT | P | |
| **Cooldown Time to base temperature** | not specified | 1h20 | AT | | |
| **Warm-up Time (base temp-->280K)** | not specified | 15Hrs | AT | | |
| **RF Input** | Free space radiation | Ok | D | P | |
| **RF output connector** | SMA | Ok | I | P | |
| *Port X* | | Ok | | P | |
| *Port Y* | | Ok | | P | |

| | | | | | |
|---|---|---|---|---|---|
| **10MHz Phase Calibration Input** | SMA | Ok | I | P | |
| **Dimensions (mm)** | l=612mm * Phi=311mm | | I | P | Excluding supports and connectors |
| **Weight (kg)** | <27kg | 26.8Kg | AT | P | Excluding supports and cables |
| **Operating Orientation** | Any | | D | P | |
| **Operating Temperature** | -10°C to +40°C | | D | P | |
| **Storage Temperature** | -40°C to +60°C | | D | P | |
| **Relative Humidity** | to 90% non condensing | | D | P | |
| **Ventilation Requirement** | Forced air cooling | Ok | I | P | |
| **Max Power Consumption** | 400W | 345W | AT | P | |
| **Input Voltage** | 90—264VAC / 47—63Hz | Ok | D | P | |
| **Distance between receiver and PSU Drawer** | <20m | Ok | AT | P | Split M&C – 5m between receiver and DAQ-PSU enclosure – 20m between DAQ-PSU enclosure and PC enclosure |
| **LMS parameters display** | | Ok | AT | P | |
| **LMS functions** | | Ok | AT | P | |
| **LMS log files** | | Ok | AT | P | |
| **Remote communication** | | Ok | AT | P | |
| **Cryocooler MTTF** | 200,000 hours | | D | P | |
| | | | | | |

**Table 2-1: Test Results Summary**

# 3. DETAILED TESTS RESULTS

## 3.1 Thermal Tests

**Result "R" column** = Passed (P), Marginal (M), Failed (F)

| Ref | Parameter / Requirement | Spec | Result | R | Comments |
|---|---|---|---|---|---|
| | **Date: 09/02/17** | | | | |
| | **Cooldown time** | --- | | | |
| | **to RF specification** | 5 hours | see Table 2-1 | | 5 hours expected to reach RF specification (NT<40K) |
| | **on cold head** | 295K to <100K | 0h23 | - | |
| | **""** | 295K to Base temperature | 1h20 | - | |
| | **on LNA** | 295K to <100K | 0h39 | - | |
| | **""** | 295K to Base temperature | 7hrs | - | |
| | **on feed base plate** | 295K to <150K | 4h46 | - | |
| | **""** | 295K to Base temperature | 15hrs | - | |
| | **Base Temperatures** | **Tset = 75K** | | | |
| | **Cold head** | ~75K±0.5K | 75K | P | @7hours in cooldown |
| | **LNA** | <85K | 80K | P | @7hours in cooldown |
| | **Feed [base]** | <130K | 130K | P | @7hours in cooldown |
| | **Feed [top]** | <150K | 142K | P | @7hours in cooldown |
| | **Cooler Input Power** | | 60W | | |
| | **Compressor Temperature** | <70°C | 8°C | P | Receiver in outdoor condition, winter time |

| Ref | Parameter / Requirement | Spec | Result | R | Comments |
|---|---|---|---|---|---|
| | **Ambient(Room) Temperature** | | 3°C | | Receiver in outdoor condition, winter time. |
| | | | | | |
| | **Warmup time (no heaters)** | 100K to 295K<br>No spec. | NA | | Warm-up not logged on this unit. See Unit SN01 FAT report Ref. DOC/1704/3986. |

**Table 3-1: Test Result Sheet n°1 - Thermal Tests**

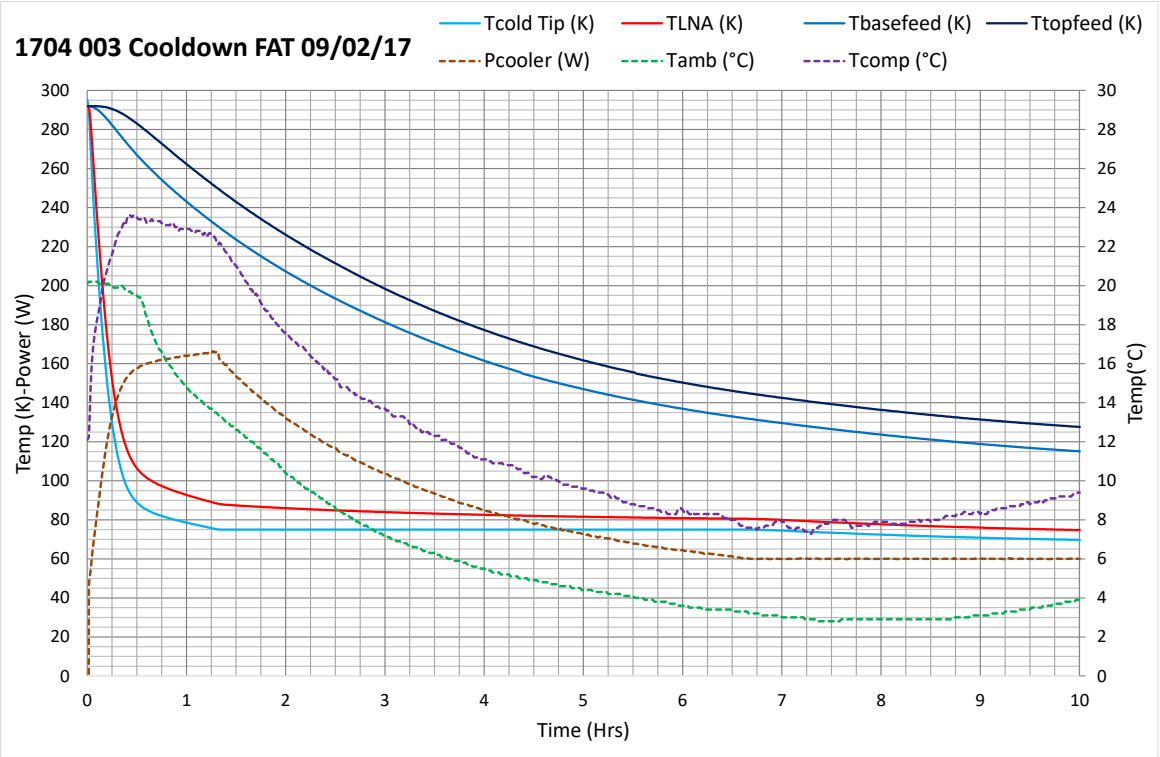



**Figure 3-1 : Cooldown**

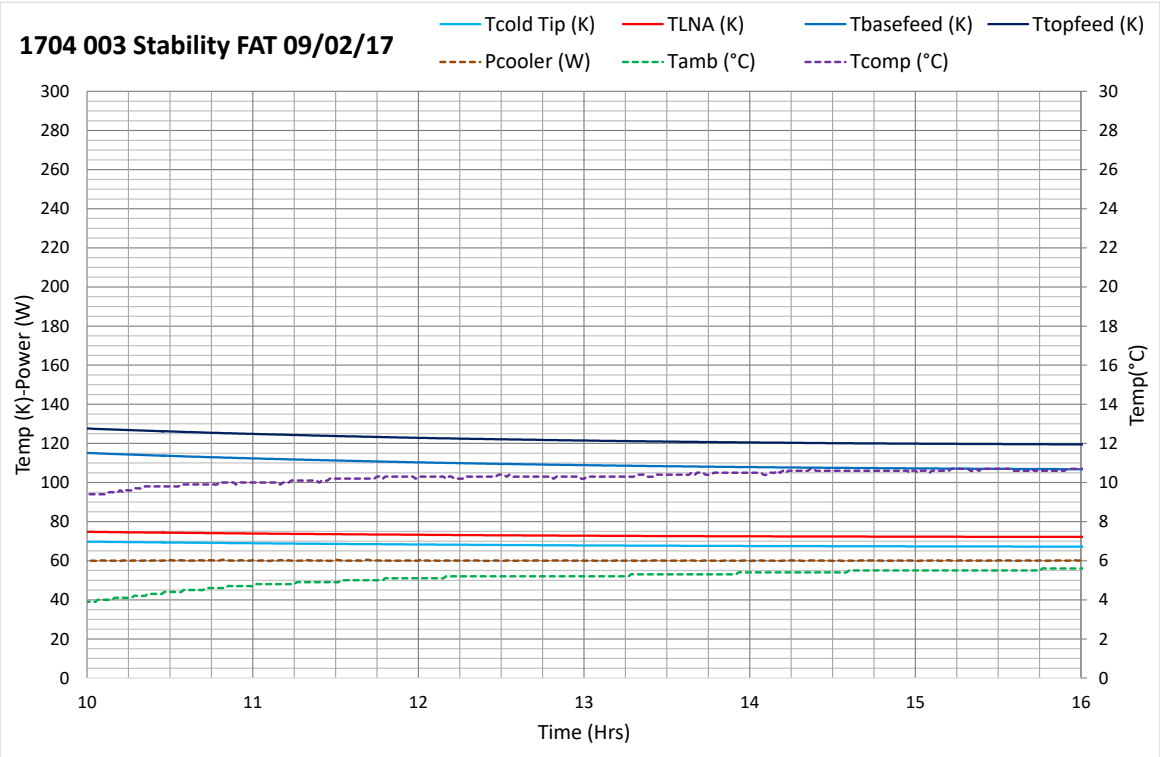



**Figure 3-2: Stabilization – Base Temperature**

## 3.2 RF Tests

**Result "R" column** = Passed (P), Marginal (M), Failed (F)

| Ref | Parameter / Requirement | Spec | Result | | | R | Comments |
|---|---|---|---|---|---|---|---|
| | **Cryogenic Temperature** | --- | | | | | **TcryoLNA = 72K** |
| | **Frequency Band** | 2 – 14 GHz | 2-14GHz | | | | |
| | **Noise Temperature** | Max<40K | | Port X | Port Y | P | Due to winter condition, the physical temperatures of the system were a bit lower than set (75K) (Tcoldtip=74K; TLNA=80K; Tbase feed=121K and Ttopfeed=136K). NT measurement is degraded by the RFI observed at low frequency. (See NT graph Figure 3-15)<br><br>Port X: 95% of the NT measurement is in specification from 3GHz up to 14GHz.<br>Port Y: 100% of the NT measurement is in specification from 3GHz up to 14GHz. |
| | | | Min Meas | 17.3K | 15.7K | | |
| | | | Max Meas | 47.7K | 37.6K | | |
| | | | Mean Meas | 25.8K | 22.6K | | |
| | | | Min Trend | 20K | 15K | | |
| | | | Max trend | 46K | 36K | | |
| | **Gain** | >55dB | Port X | Port Y | | P | Gain extracted from NT meas |
| | | | 56dBmin | 56dBmin | | | |
| | **Gain Flatness** | 10dBpp | ~7dBpp | ~7dBpp | | P | Worst case gain extracted from NT meas |
| | **Output Return Loss** | >10dB | 10.7dB min | 11.4dB min | | P | 14dB typical |
| | **Pout 1dB** | +20dBm | +20dBm | | | P | By design |
| | **Gain via test input (Port X)** | - | 20.1dB<Gain<44.5dB | | | | |
| | **Gain via test input (Port Y)** | - | 19.4dB<Gain<44.3 dB | | | | |
| | | | | | | | |

| Ref | Parameter / Requirement | Spec | Result | R | Comments |
|---|---|---|---|---|---|
| | **Gain via test input stability (Port X)** | - | @2GHz / 60min: 0.03dBpp<br>@8GHz / 60min: 0.03dBpp<br>@14GHz / 60min: 0.04dBpp<br>@2GHz / 60sec: 0.03dBpp<br>@8GHz / 60sec: 0.03dBpp<br>@14GHz / 60sec: 0.04dBpp | | Two measurement session have been performed, one with the VNA calibrated between 1GHz and 9GHz and the second session with the VNA calibrated from 13.5GHz up to 14.5GHz. |
| | **Gain via test input stability (Port Y)** | - | @2GHz / 60min: 0.03dBpp<br>@8GHz / 60min: 0.04dBpp<br>@14GHz / 60min: 0.06dBpp<br>@2GHz / 60sec: 0.02dBpp<br>@8GHz / 60sec: 0.03dBpp<br>@14GHz / 60sec: 0.03dBpp | | Two measurement session have been performed, one with the VNA calibrated between 1GHz and 9GHz and the second session with the VNA calibrated from 13.5GHz up to 14.5GHz. |

**Table 3-2: Test Result Sheet n°2 – RF Tests**

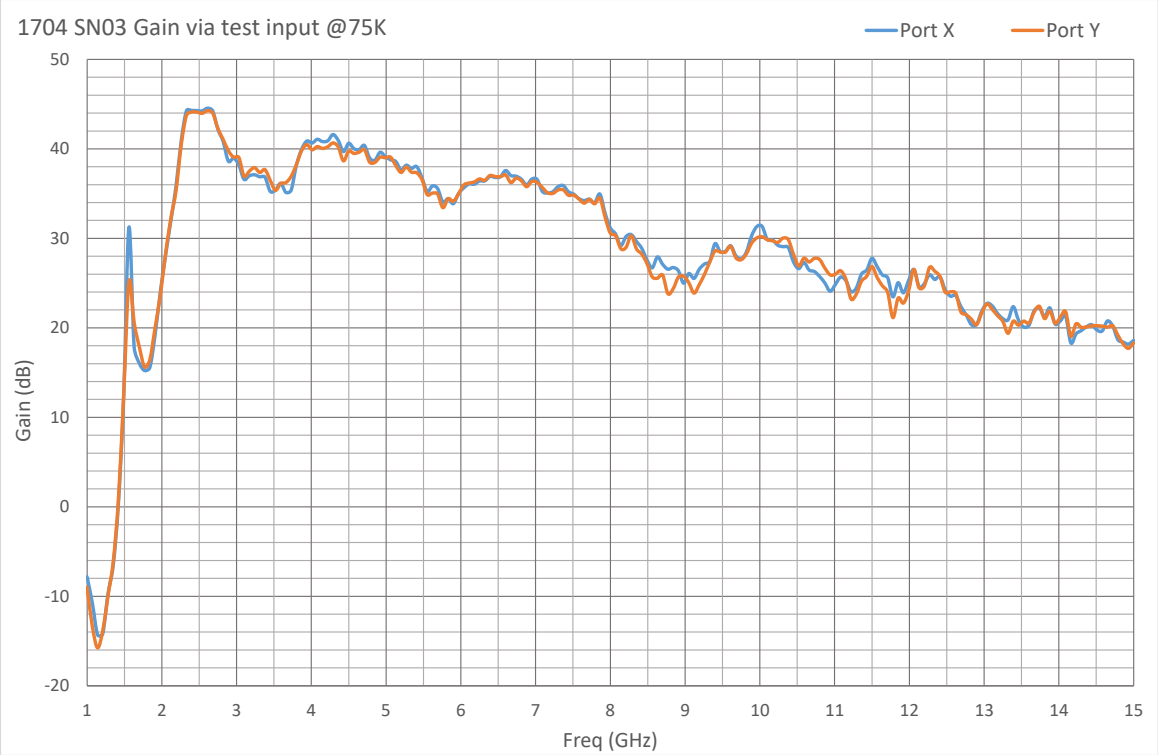



**Figure 3-3: Gain via test input for TLNA=76K**

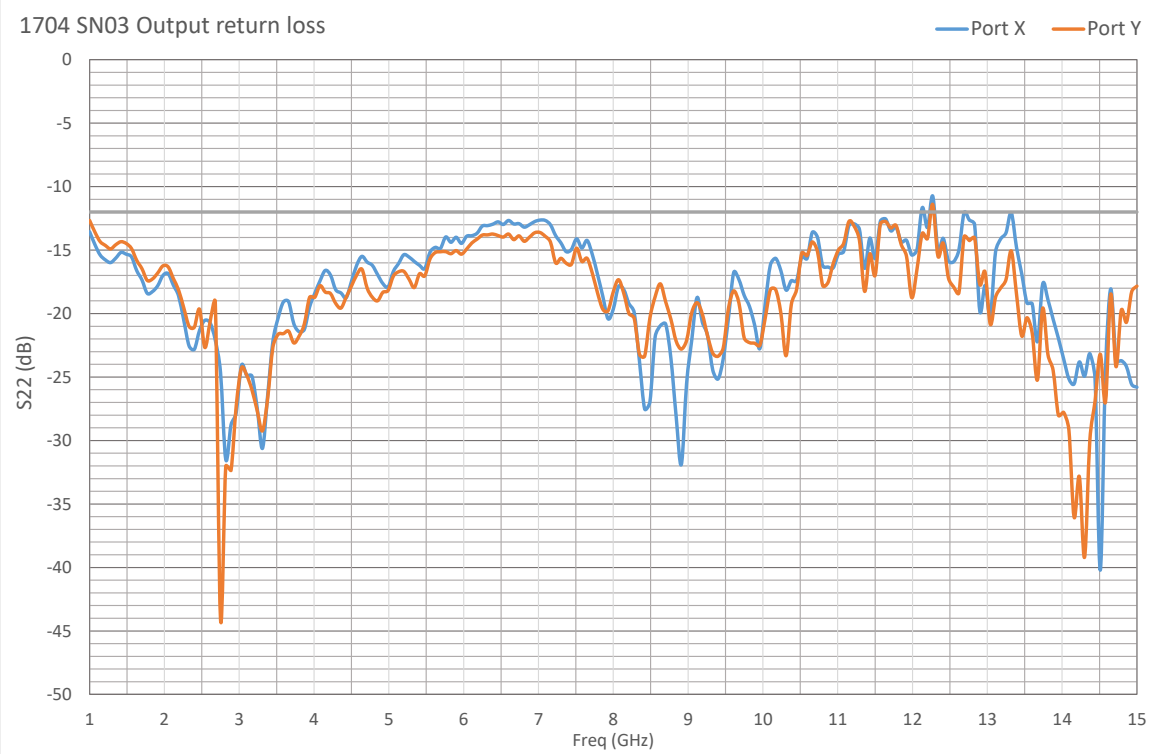



**Figure 3-4: Output Return Loss**

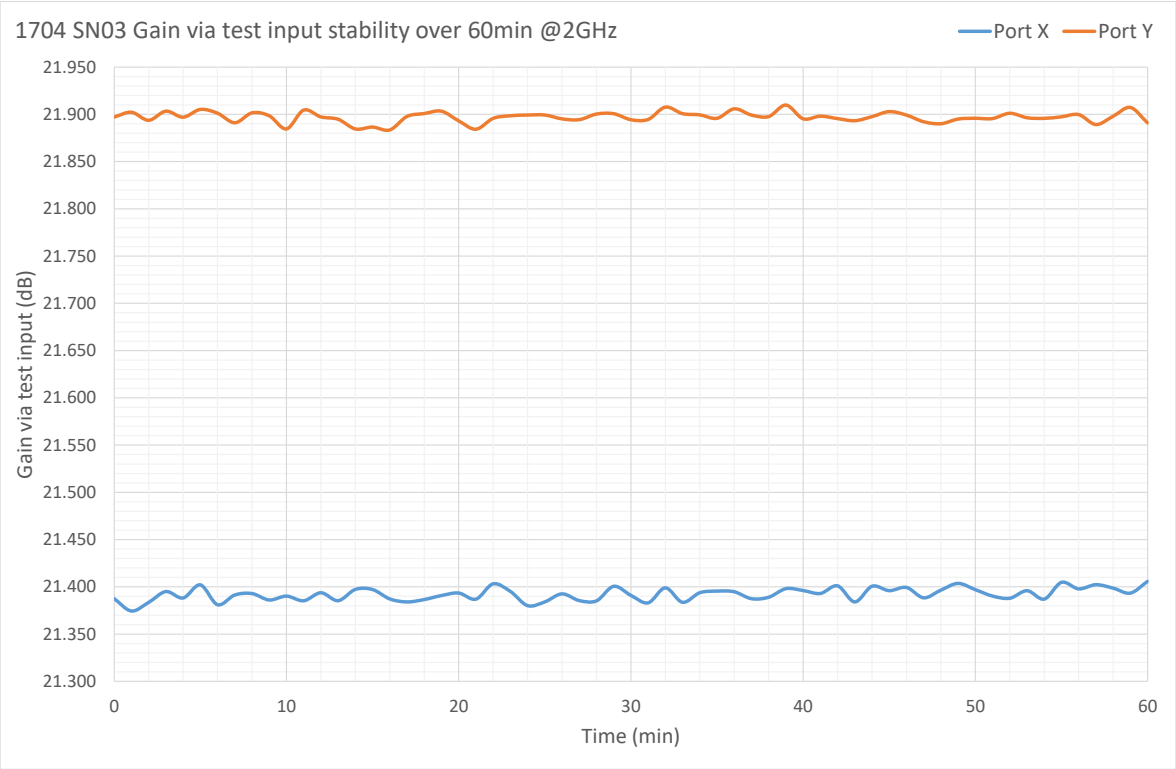



**Figure 3-5: Gain via test input stability over 60min (1 sample per min) @2GHz**

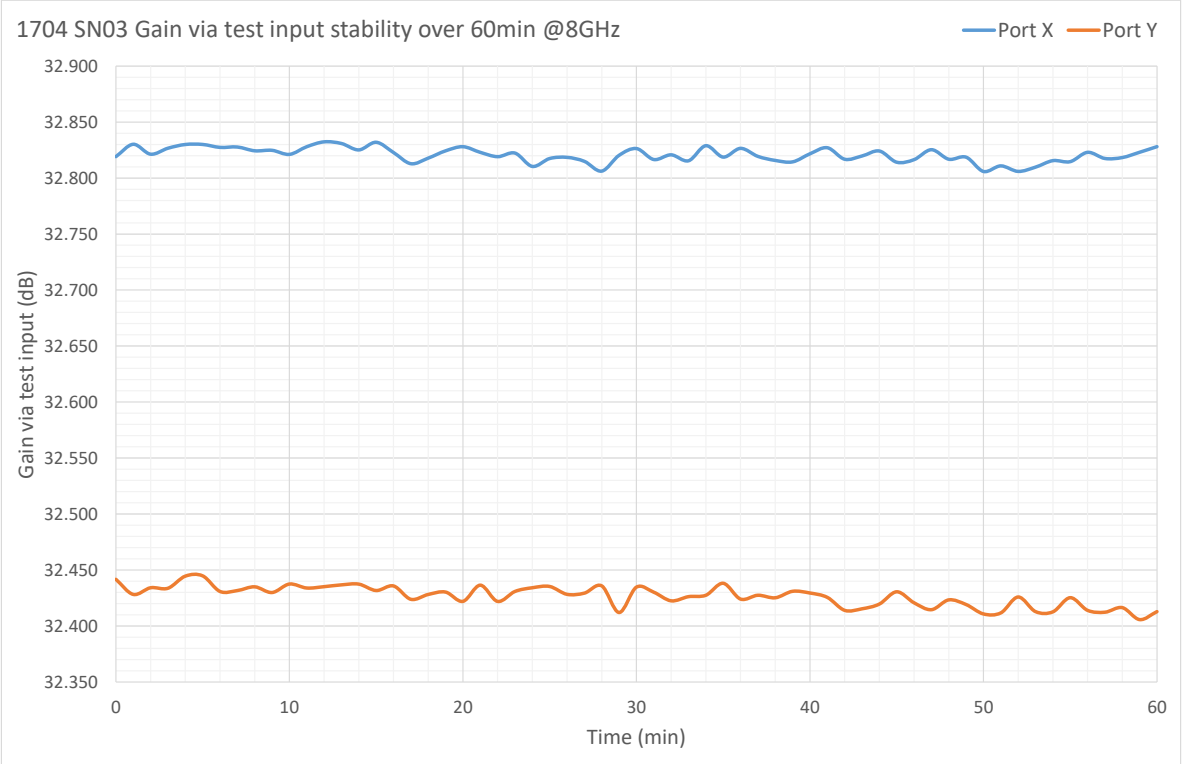



**Figure 3-6: Gain via test input stability over 60min (1 sample per min) @8GHz**

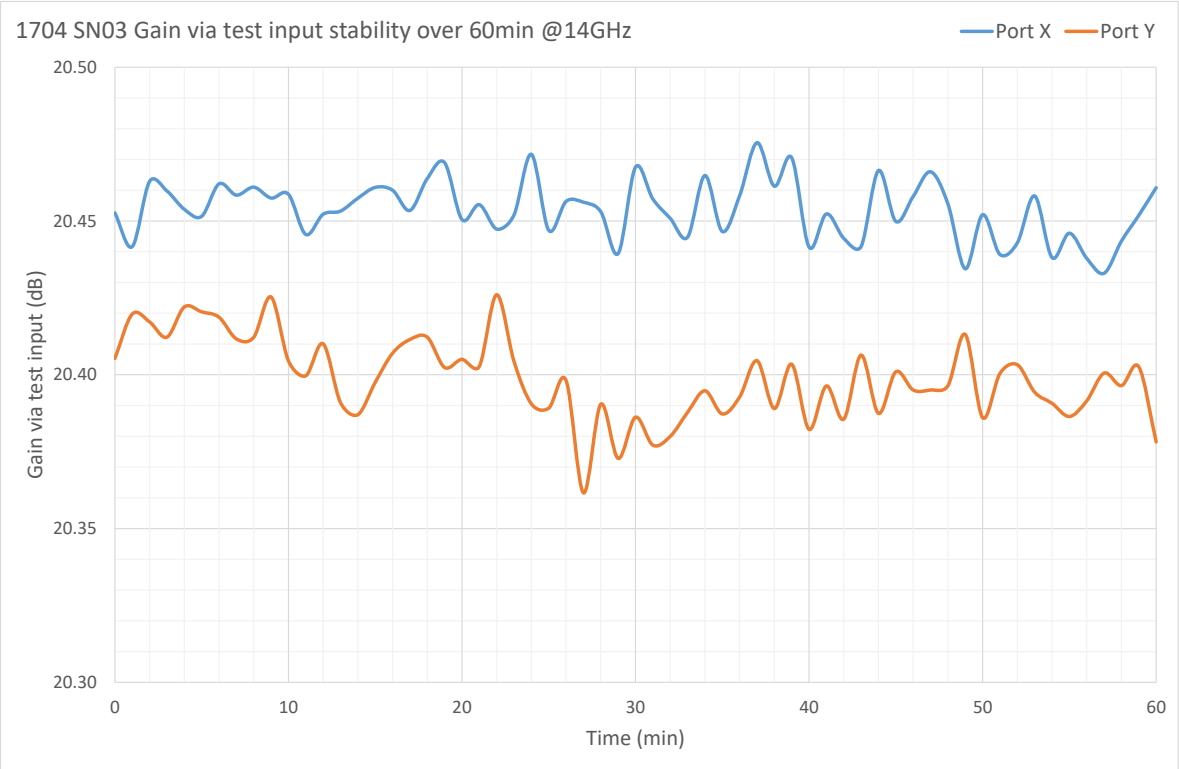



**Figure 3-7: Gain via test input stability over 60min (1 sample per min) @14GHz**

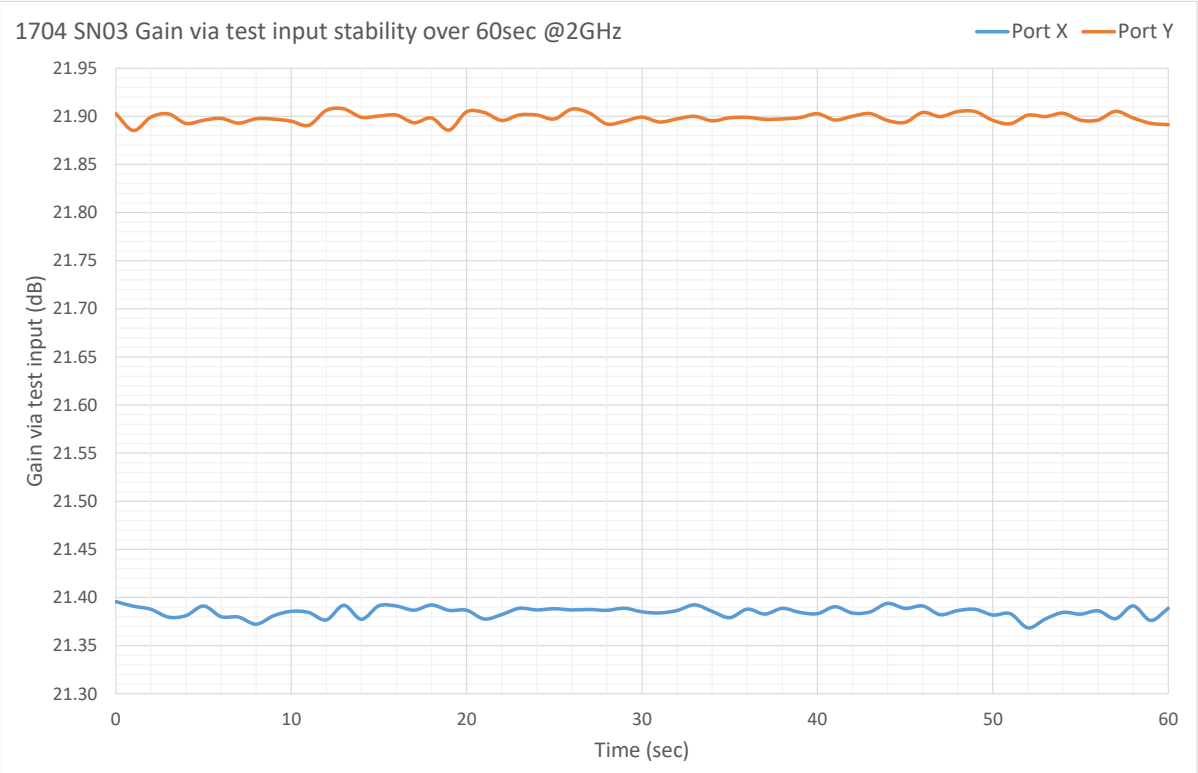



**Figure 3-8: Gain via test input stability over 60sec (1 sample per sec) @2GHz**

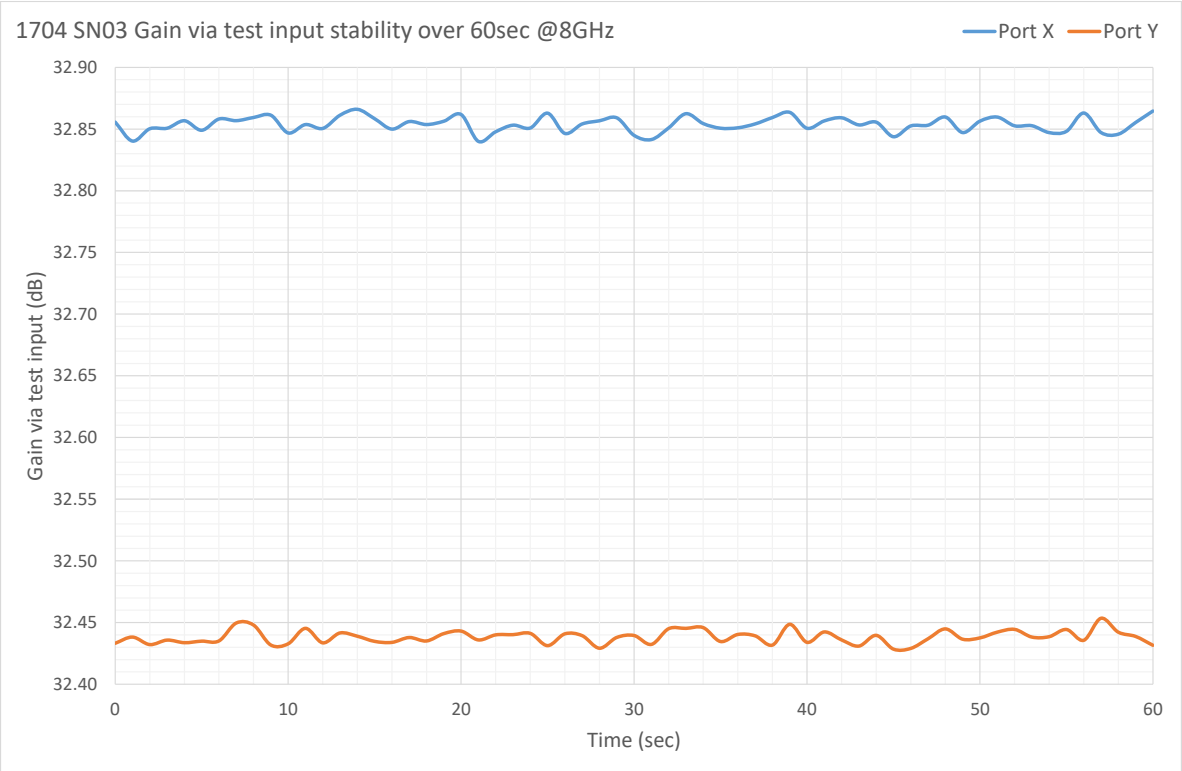



**Figure 3-9: Gain via test input stability over 60sec (1 sample per sec) @8GHz**

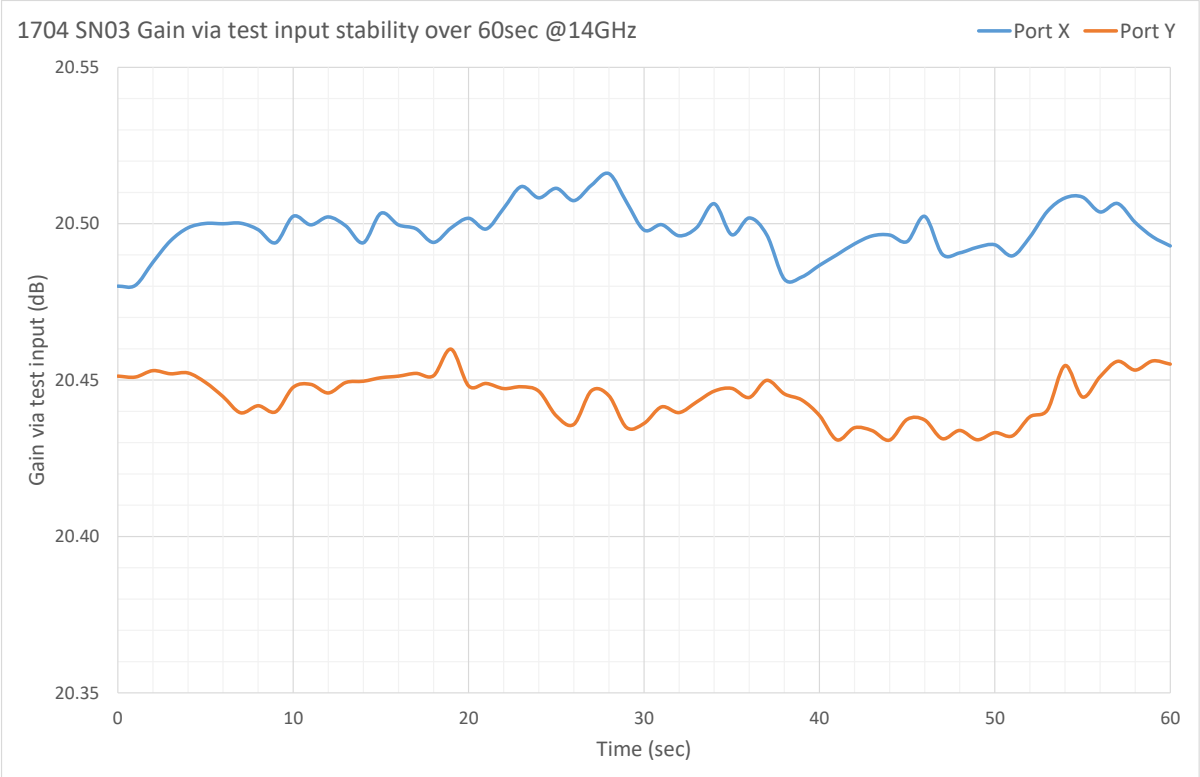



**Figure 3-10: Gain via test input stability over 60sec (1 sample per sec) @14GHz**

The gain of the receiver has been extracted from the noise temperature measurement using the following formula:

$$G = \frac{P_{hot}}{(T_e - T_{hot}) \times B \times k}$$

With:

- G = Gain of the receiver
- Phot = Power measure at the output of the receiver when the hot load is in front of the receiver
- Te = Noise temperature of the receiver
- Thot = Noise temperature of the hot load
- B = Bandwidth (Resolution Band Width set on the spectrum analyser)
- K = Boltzmann constant

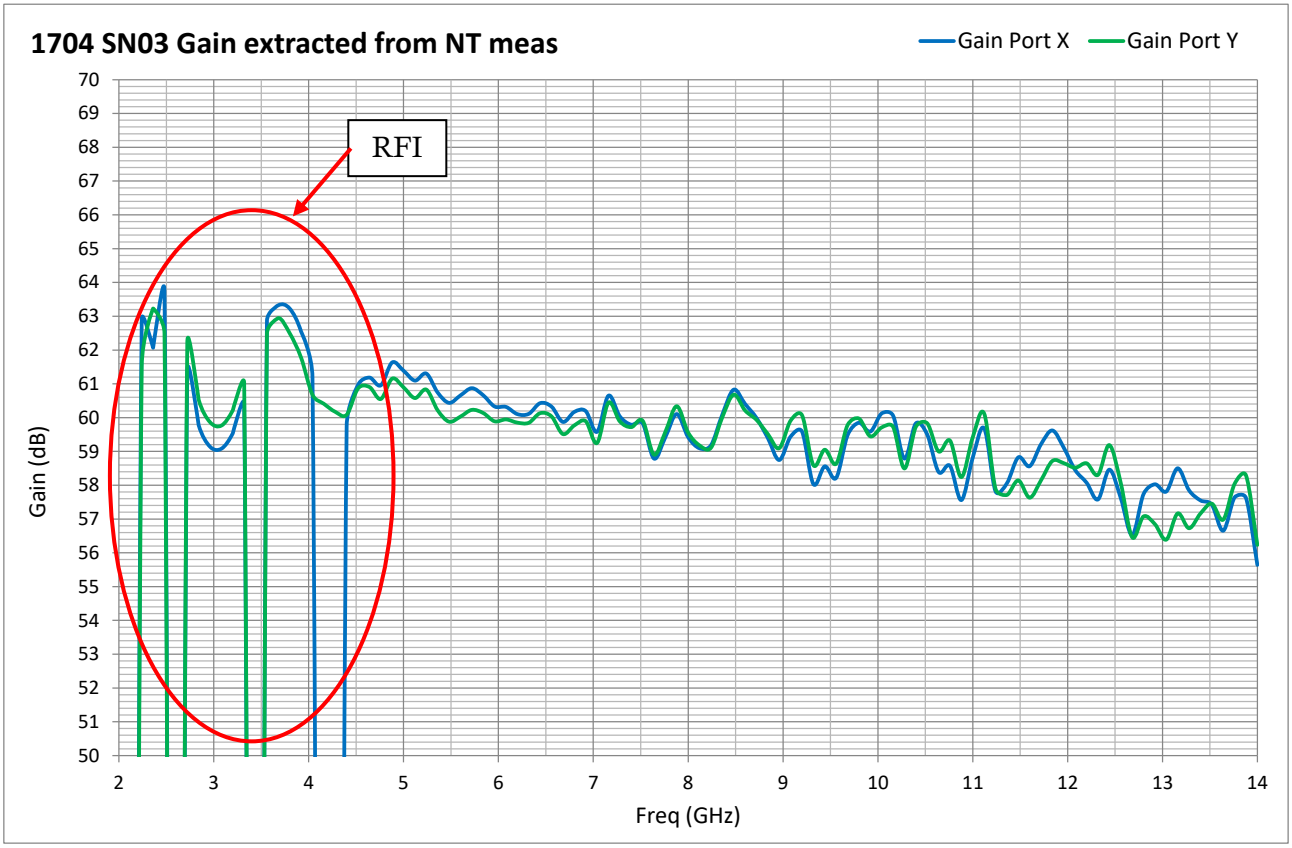



**Figure 3-11: Gain extracted from NT measurement.**

The gain extracted from the NT measurement is noisy but it gives a good trend for the overall gain of the receiver.

### 3.2.1 Noise temperature measurement

Due to the increase of mobile phone antenna installations nearby Callisto's premises it is becoming more and more difficult to make clean and valuable noise temperature measurements on the QRFH receiver. Indeed, the increase of RFI measured in the Callisto laboratory is problematic for this type of measurement:

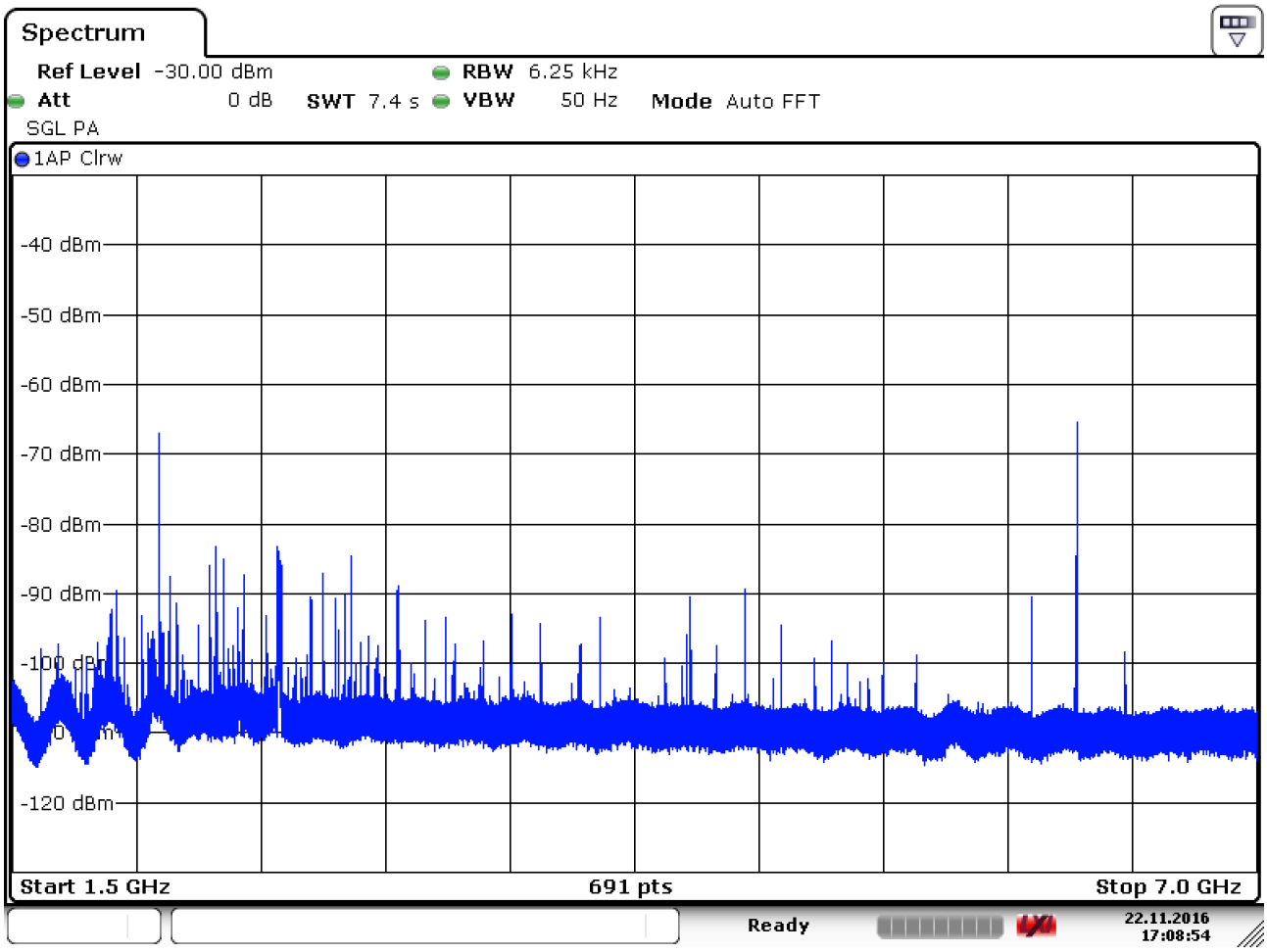



**Figure 3-12: RFI survey in the Callisto laboratory, output of an amplifier, at low frequency the RFI are mixed by the amplifier.**

The RFI have a direct impact on the NT measurement (noise peak) but the RFI are also mixed by the amplifiers of the receiver and so the overall noise floor increases.

It is difficult for us to find a convenient place without RFI to make the NT measurement but we have tried to move to a place with less RFI in thecountryside:

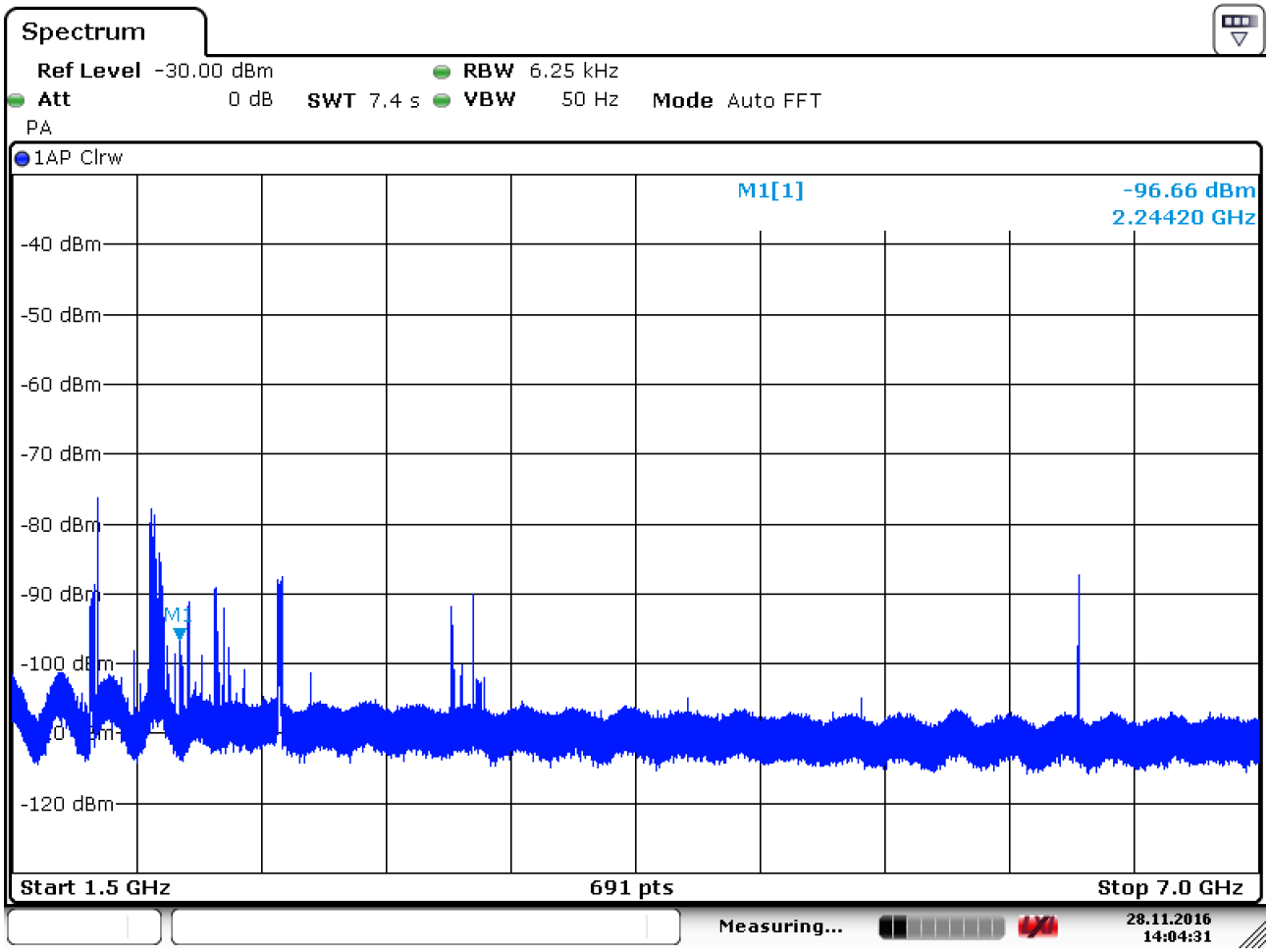



**Figure 3-13: RFI survey of the NT measurement location.**

**Figure 3-14: NT measurement test set-up.**

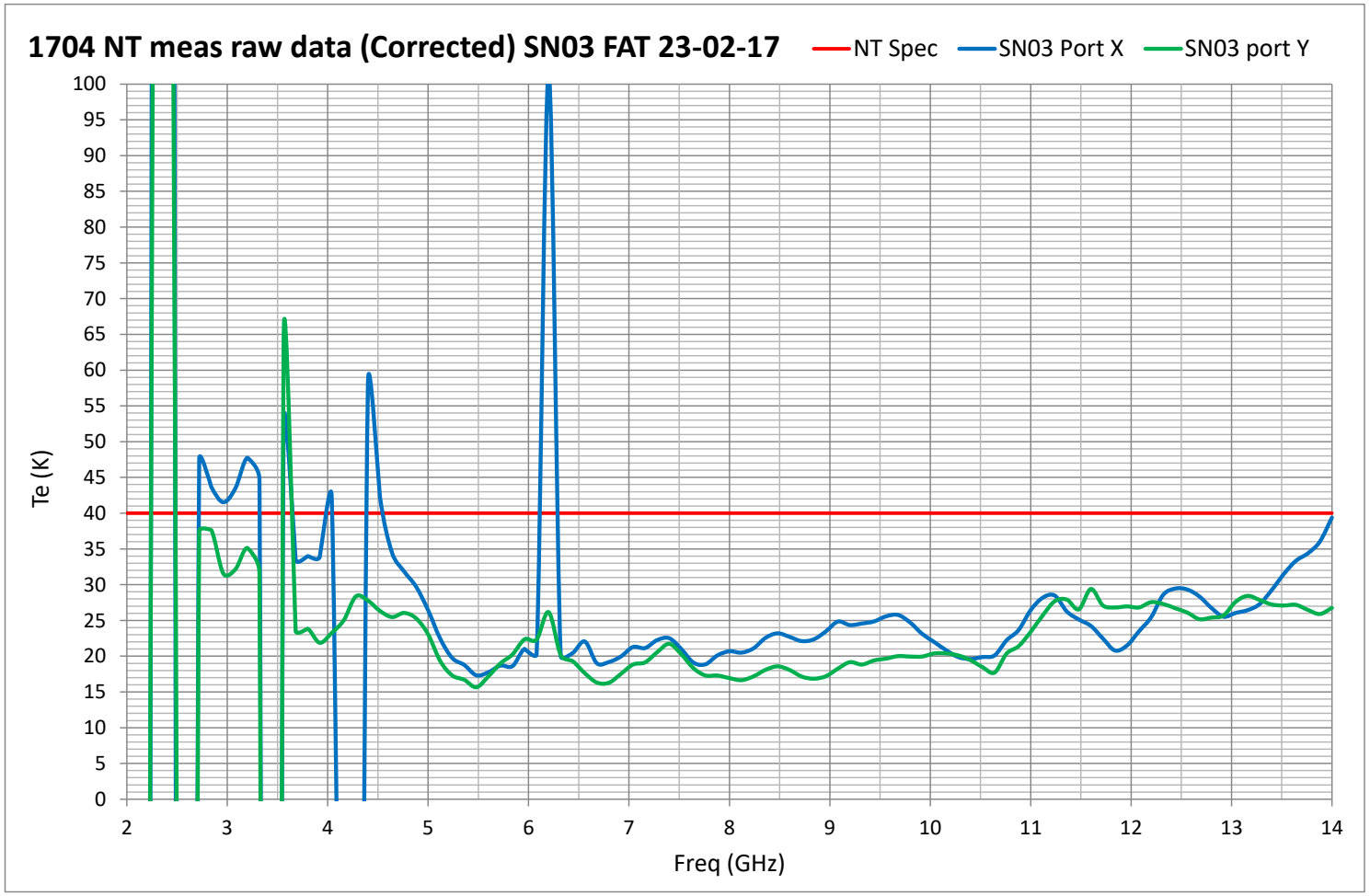



**Figure 3-15: NT Measurement raw data for TLNA=80K**

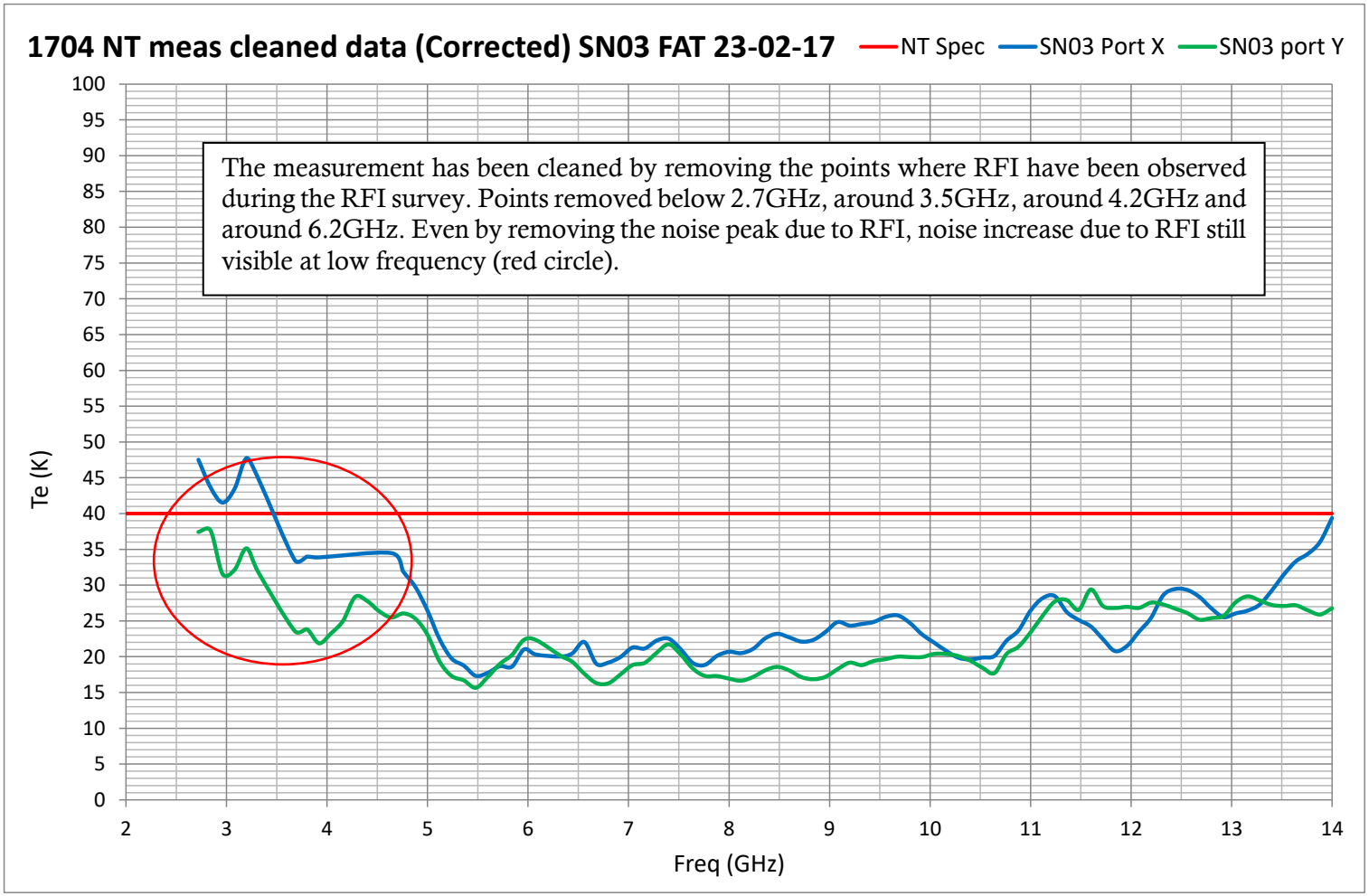



**Figure 3-16: NT Measurement cleaned data for TLNA=80K**

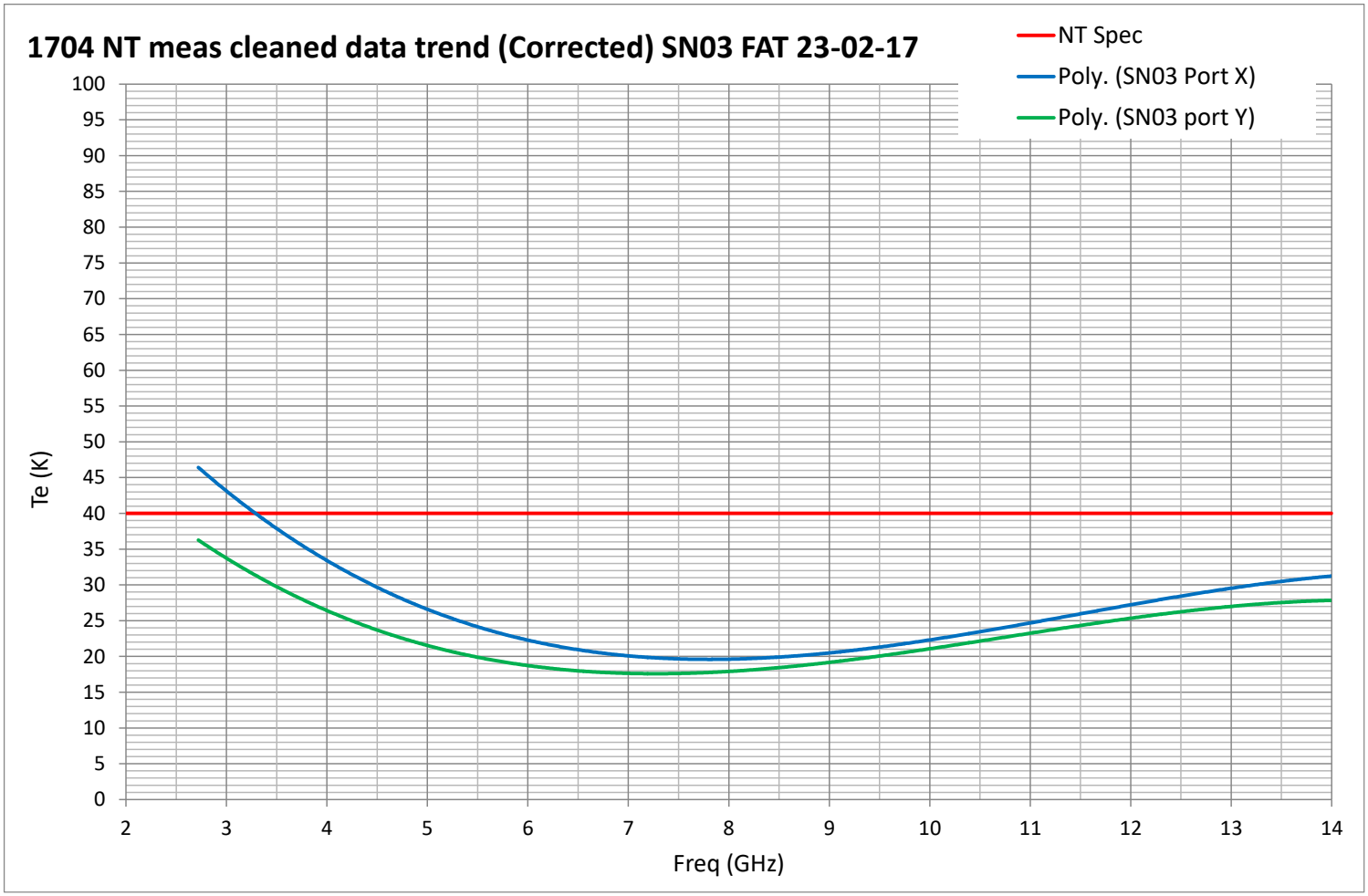



**Figure 3-17: NT Measurement cleaned data trend for TLNA=80K**

### 3.2.2 Noise Calibration

The purpose of this circuit is to inject two levels of noise in the QRFH receiver in order to do a noise measurement using the Y-factor method. The noise is generated by a noise diode and the level of noise is set using a variable attenuator. This noise signal is injected inside the QRFH feed by a probe antenna.

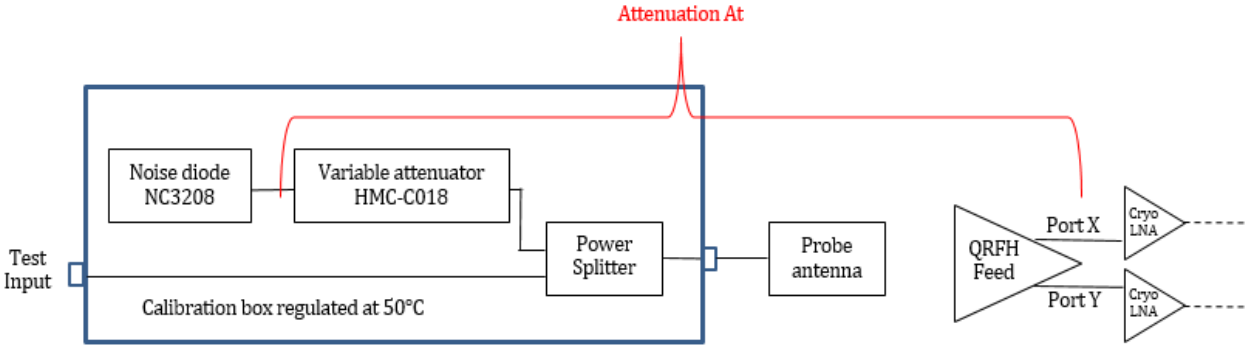



**Figure 3-18: Noise calibration circuit**

The two levels of noise have been defined by UTAS Tn1=10K and Tn2=0.5K. The theoretical attenuation (At) required to achieve Tn1 and Tn2 has been calculated according to the ENR of the noise diode at 50°C from the calibration data given by the noise diode manufacturer. The following tables give the theoretical variable attenuator settings to generate Tn1 and Tn2:

| 1704 QRFH SN03 Attenuator Settings for Noise Calibration Port X (ND AE850) | | | | | | |
|---|---|---|---|---|---|---|
| Freq (GHz) | ND ENR (dB) @50°C | Td ND @50°C (K) | At1 calculated for Tn1=10K (dB) | Theoretical Att1 to set on the attenuator (dB) | At2 calculated for Tn2=0.5K (dB) | Theoretical Att2 to set on the attenuator (dB) |
| 2 | 31.93 | 452560.23 | 46.56 | 10.0 | 59.57 | 23 |
| 3 | 31.74 | 433200.38 | 46.37 | 21.0 | 59.38 | 31.5 |
| 4 | 31.68 | 427260.63 | 46.31 | 14.0 | 59.32 | 27.5 |
| 5 | 31.62 | 421402.37 | 46.25 | 18.0 | 59.26 | 31 |
| 6 | 31.51 | 410870.20 | 46.14 | 14.5 | 59.15 | 27.5 |
| 7 | 31.32 | 393294.93 | 45.95 | 15.5 | 58.96 | 27.5 |
| 8 | 31.12 | 375606.79 | 45.75 | 13.0 | 58.76 | 25.5 |
| 9 | 31.15 | 378208.37 | 45.78 | 8.0 | 58.79 | 20.5 |
| 10 | 31.25 | 387011.22 | 45.88 | 7.5 | 58.89 | 20 |
| 11 | 31.25 | 387011.22 | 45.88 | 6.0 | 58.89 | 19 |
| 12 | 31.43 | 403376.26 | 46.06 | 4.0 | 59.07 | 17.5 |
| 13 | 31.65 | 424321.38 | 46.28 | 1.5 | 59.29 | 14.5 |
| 14 | 31.64 | 423346.14 | 46.27 | 0.0 | 59.28 | 12.5 |

| 1704 QRFH SN03 Attenuator Settings for Noise Calibration Port Y (ND AE850) | | | | | | |
|---|---|---|---|---|---|---|
| Freq (GHz) | ND ENR (dB) @50°C | Td ND @50°C (K) | At1 calculated for Tn1=10K (dB) | Theoretical Att1 to set on the attenuator (dB) | At2 calculated for Tn2=0.5K (dB) | Theoretical Att2 to set on the attenuator (dB) |
| 2 | 31.93 | 452560.23 | 46.56 | 10.0 | 59.57 | 23 |
| 3 | 31.74 | 433200.38 | 46.37 | 21.0 | 59.38 | 31.5 |
| 4 | 31.68 | 427260.63 | 46.31 | 14.0 | 59.32 | 27.5 |
| 5 | 31.62 | 421402.37 | 46.25 | 18.0 | 59.26 | 31 |
| 6 | 31.51 | 410870.20 | 46.14 | 14.5 | 59.15 | 27.5 |
| 7 | 31.32 | 393294.93 | 45.95 | 15.5 | 58.96 | 27.5 |
| 8 | 31.12 | 375606.79 | 45.75 | 13.0 | 58.76 | 25.5 |
| 9 | 31.15 | 378208.37 | 45.78 | 8.0 | 58.79 | 20.5 |
| 10 | 31.25 | 387011.22 | 45.88 | 7.5 | 58.89 | 20 |
| 11 | 31.25 | 387011.22 | 45.88 | 6.0 | 58.89 | 19 |
| 12 | 31.43 | 403376.26 | 46.06 | 4.0 | 59.07 | 17.5 |
| 13 | 31.65 | 424321.38 | 46.28 | 1.5 | 59.29 | 14.5 |
| 14 | 31.64 | 423346.14 | 46.27 | 0.0 | 59.28 | 12.5 |

Find below a description of each column of the table above:

- ND ENR @50°C (dB): ENR of the noise diode @50°C from the calibration data given by the noise diode manufacturer.
- Td ND @50°C (K): Noise generated by the noise diode in Kelvin. Derivate from the noise diode ENR @50°C.
- At1 calculated for Tn1=10K (dB): Attenuation At1 calculated in order to inject Tn1=10K in the QRFH receiver.
- Theoretical Att1 to set on the attenuator (dB): Attenuation to set on the variable attenuator to achieve the closest value of AT1 calculated in order to inject Tn1. The variable attenuator has a minimum resolution of 0.5dB.

The last 4 columns are identical to the previous ones but for the Tn2=0.5K.

It is recommended to do the calibration of the noise circuit in a place clean of RFI. The idea is to perform a NT measurement with the sky and use this measurement as a reference then do a noise temperature measurement with the noise diode to find the variable attenuator setting in order to match the reference NT meas.

The operating of the noise calibration has been tested. The Y-factor of the receiver has been measured when the noise diode is off and when the noise calibration circuit injects Tn=10K. The measurement has been performed at 9GHz on both port. The receiver noise temperature has been calculated using the Noise Adding Radiometer formula:

$$NT(K) = \frac{Tn}{(Y-1)}$$

| | Output Power ND Off (dBm) | Output Power ND On (Tn=10K) (dBm) | Y-factor (dB) | Y-factor (ratio) | NT (K) ND method |
|---|---|---|---|---|---|
| Port X @9GHz | -54.91 | -53.64 | 1.27 | 1.339676687 | 29.4 |
| Port Y @9GHz | -54.5 | -53 | 1.5 | 1.412537545 | 24.2 |

**Table 3-3: Noise diode NT measurement results**

The receiver noise temperatures in the table above are not corrected (Tsky…) and are in the order of magnitude of the measurements performed with the hot/cold method using the sky as a cold load (see Figure 3-16).

The noise calibration circuit is operational.

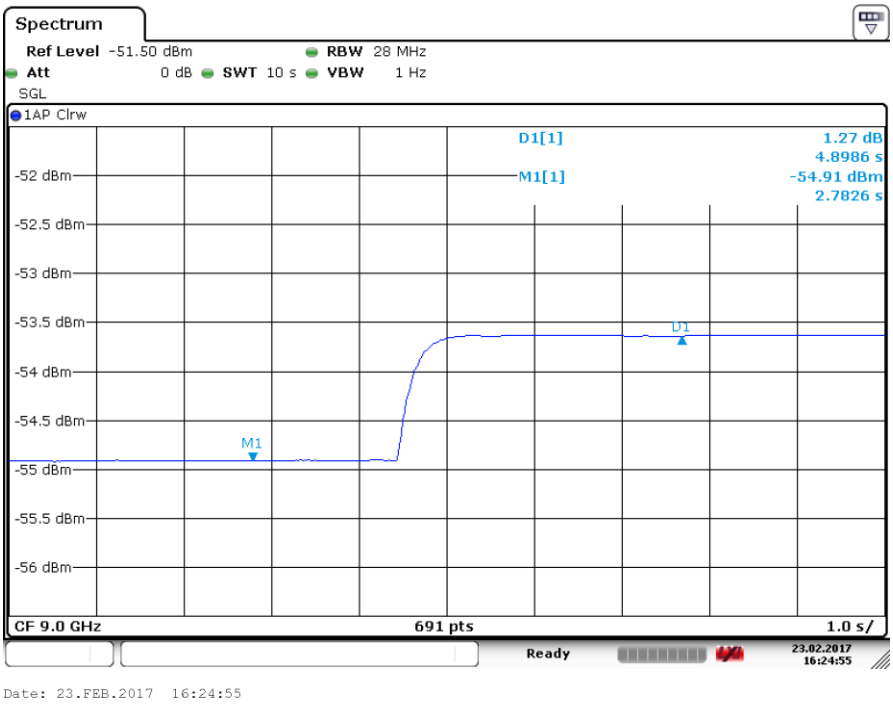



**Figure 3-19: Y-factor measured with the noise diode On (Tn=10K) and off @9GHz port X**

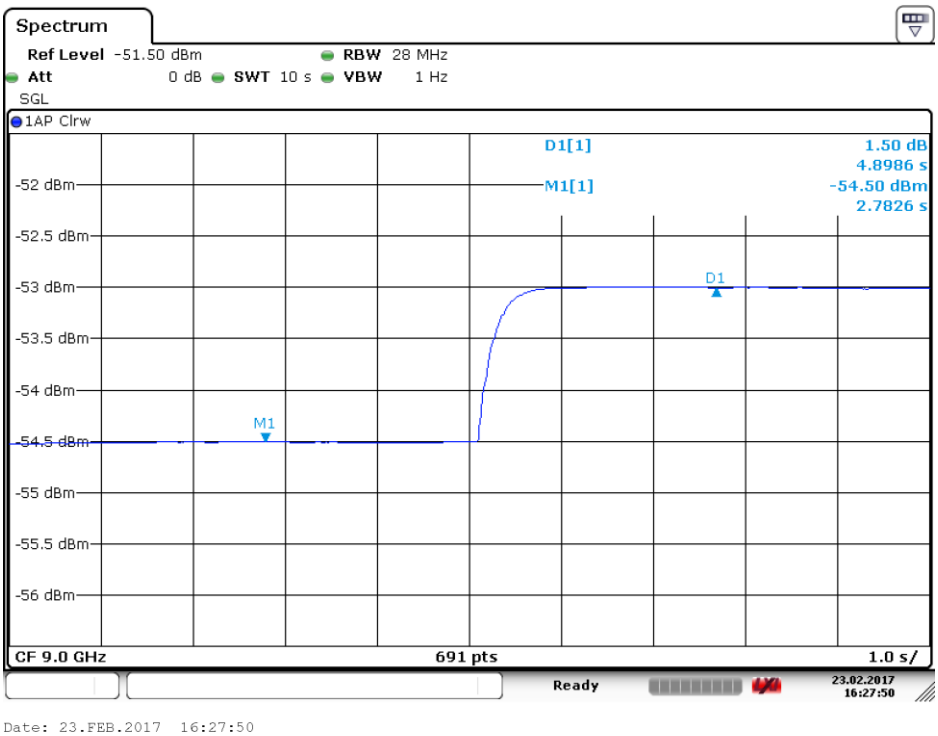



**Figure 3-20: Y-factor measured with the noise diode On (Tn=10K) and off @9GHz port Y**

### 3.2.3 Phase Calibration

The purpose of the phase calibration circuit is to generate a comb spectrum signal up to 14GHz with spectral lines at 10MHz spacing, which are derived from an input reference frequency signal available in the station. The phase calibration circuit configuration is shown below:

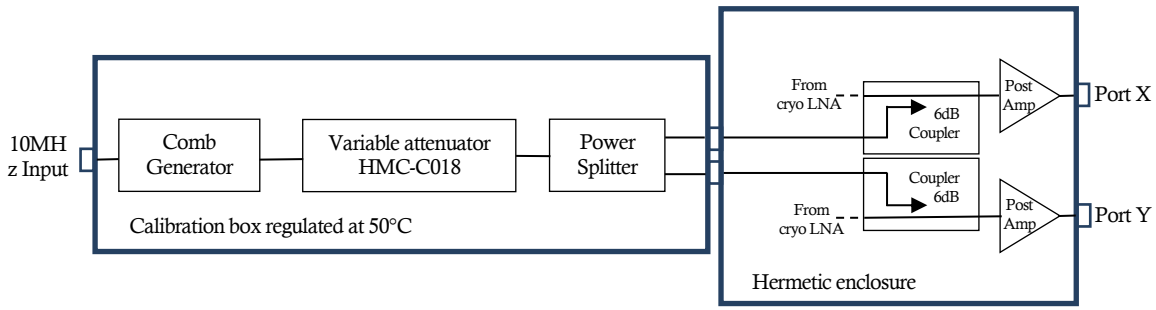
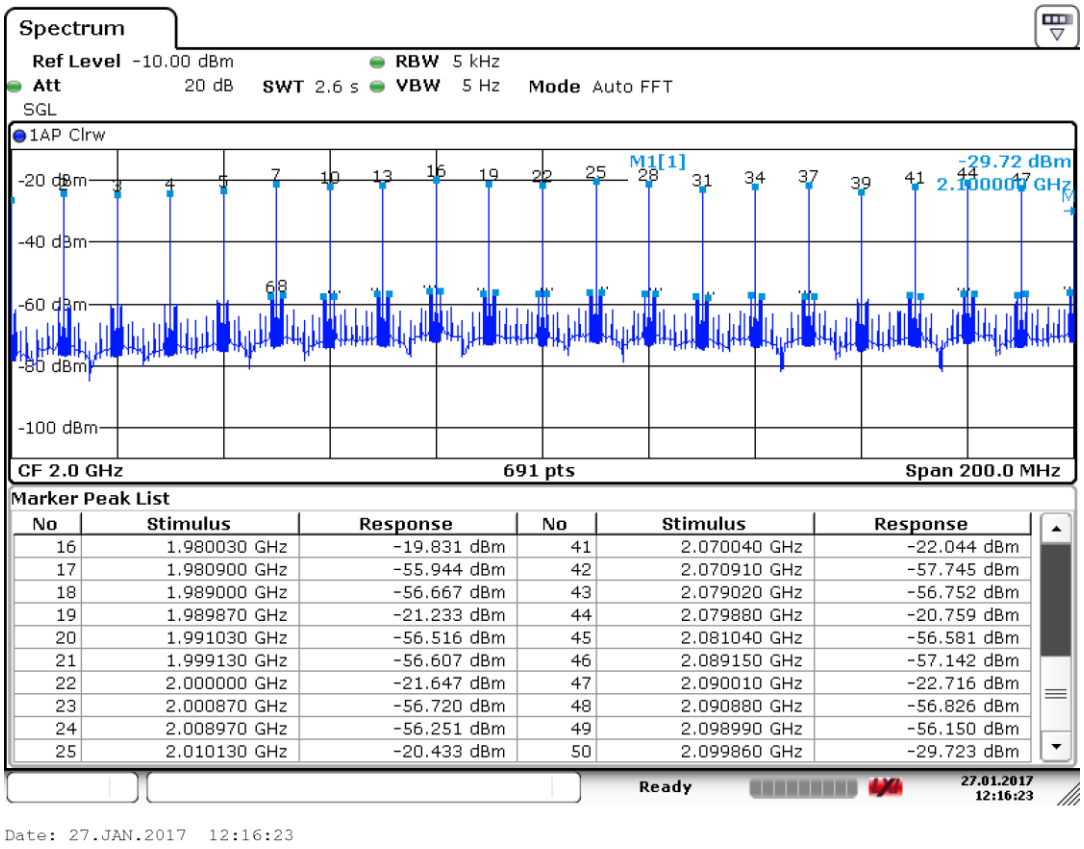



**Figure 3-21: Noise calibration circuit**

In order to validate the phase calibration signal injection, the output of the receiver has been measured with the comb generator on (+10dBm input power) and with the variable attenuator set to the minimum attenuation. The measurement has been performed at 2GHz and 14GHz with various settings of the variable attenuator:




| No | Stimulus | Response | No | Stimulus | Response |
|---|---|---|---|---|---|
| 16 | 1.980030 GHz | -19.831 dBm | 41 | 2.070040 GHz | -22.044 dBm |
| 17 | 1.980900 GHz | -55.944 dBm | 42 | 2.070910 GHz | -57.745 dBm |
| 18 | 1.989000 GHz | -56.667 dBm | 43 | 2.079020 GHz | -56.752 dBm |
| 19 | 1.989870 GHz | -21.233 dBm | 44 | 2.079880 GHz | -20.759 dBm |
| 20 | 1.991030 GHz | -56.516 dBm | 45 | 2.081040 GHz | -56.581 dBm |
| 21 | 1.999130 GHz | -56.607 dBm | 46 | 2.089150 GHz | -57.142 dBm |
| 22 | 2.000000 GHz | -21.647 dBm | 47 | 2.090010 GHz | -22.716 dBm |
| 23 | 2.000870 GHz | -56.720 dBm | 48 | 2.090880 GHz | -56.826 dBm |
| 24 | 2.008970 GHz | -56.251 dBm | 49 | 2.098990 GHz | -56.150 dBm |
| 25 | 2.010130 GHz | -20.433 dBm | 50 | 2.099860 GHz | -29.723 dBm |

**Figure 3-22: Port X output @2GHz when comb generator on and attenuator set to 0dB**

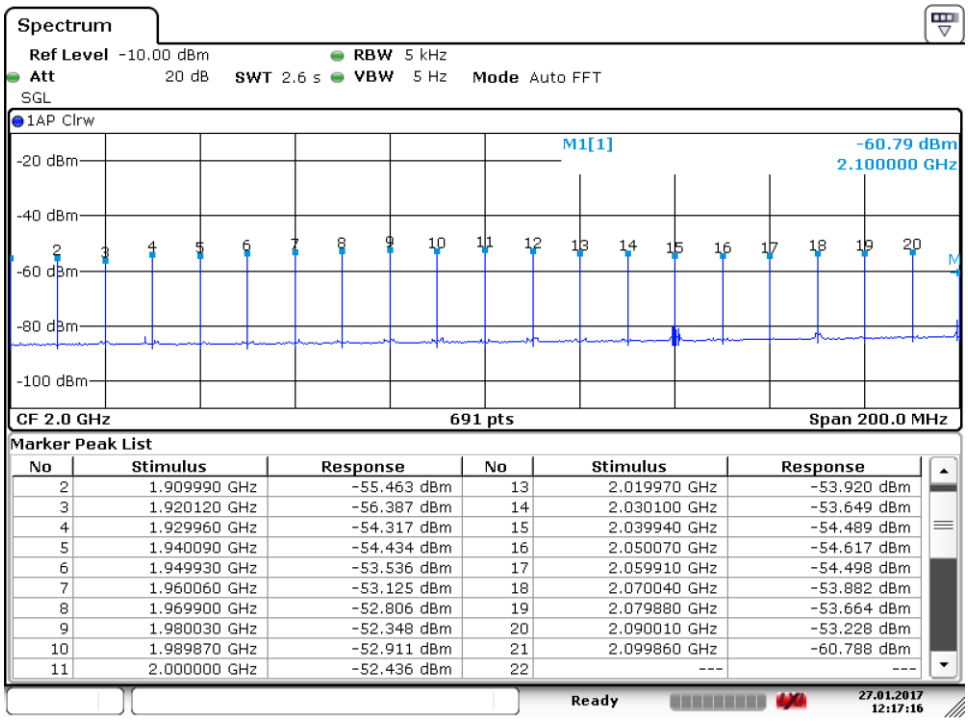



**Figure 3-23: Port X output @2GHz when comb generator on and attenuator set to 31.5dB.**

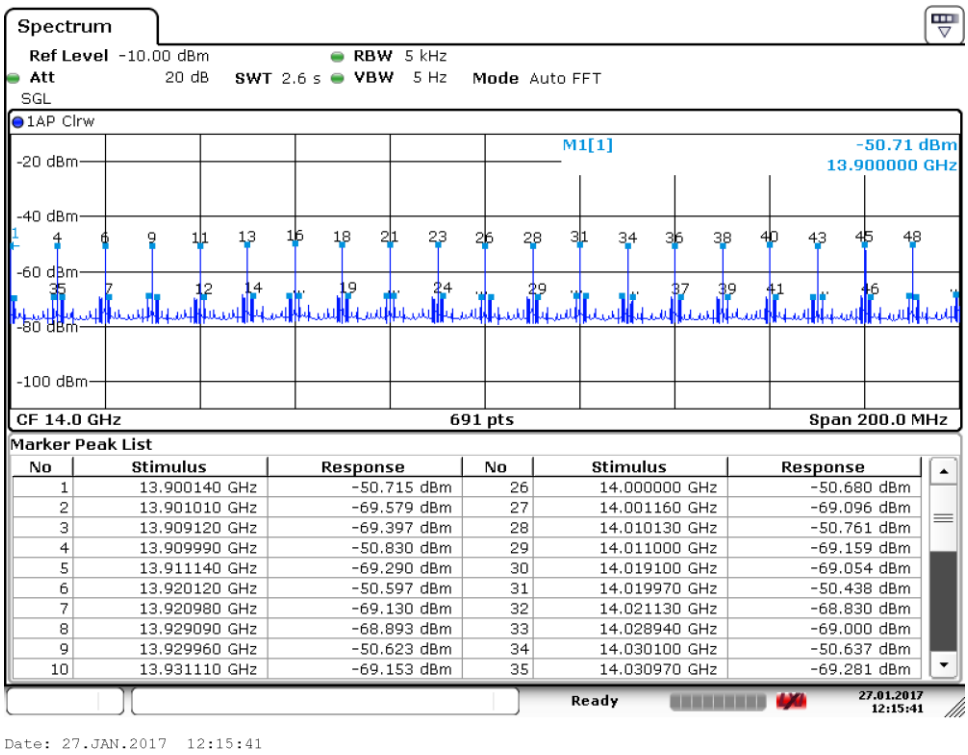



**Figure 3-24: Port X output @14GHz when comb generator on and attenuator set to 0dB.**

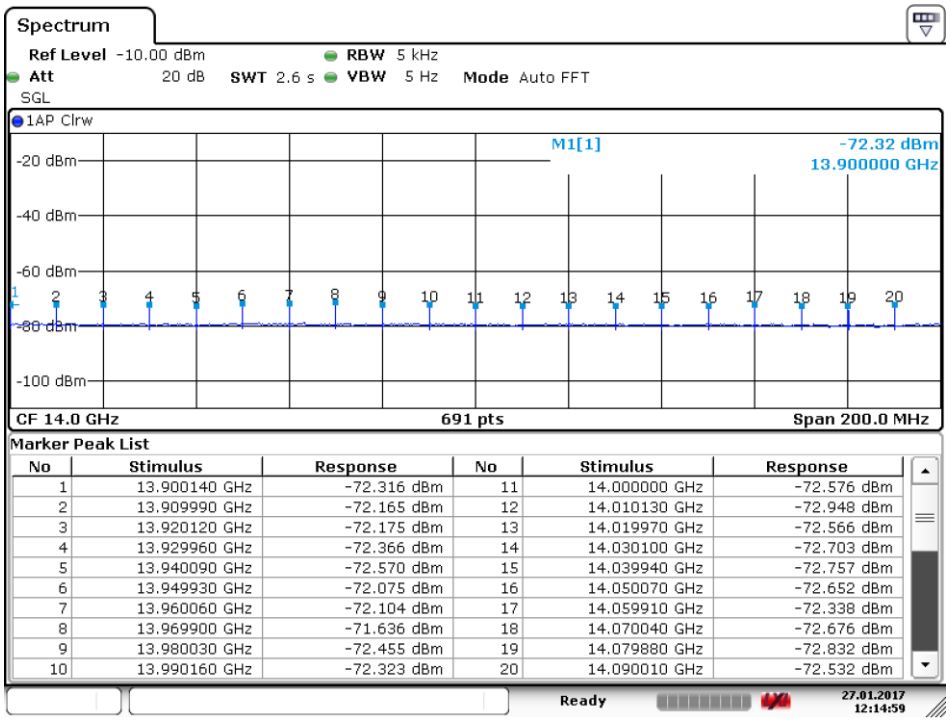



**Figure 3-25: Port X output @14GHz when comb generator on and attenuator set to 14dB.**

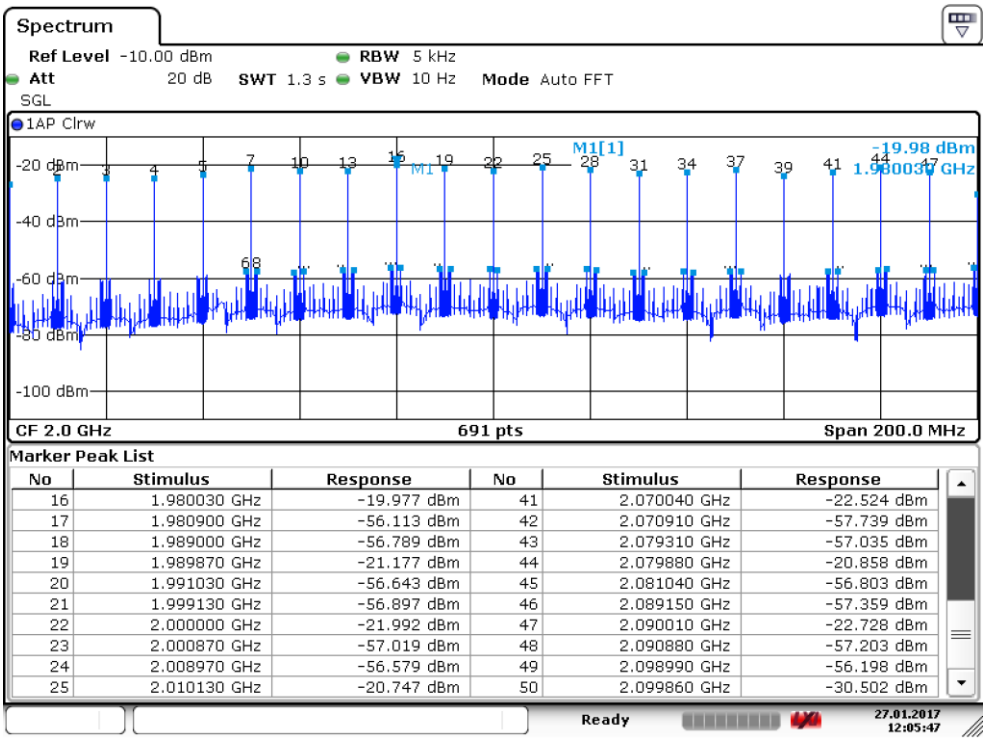



**Figure 3-26: Port Y output @2GHz when comb generator on and attenuator set to 0dB**

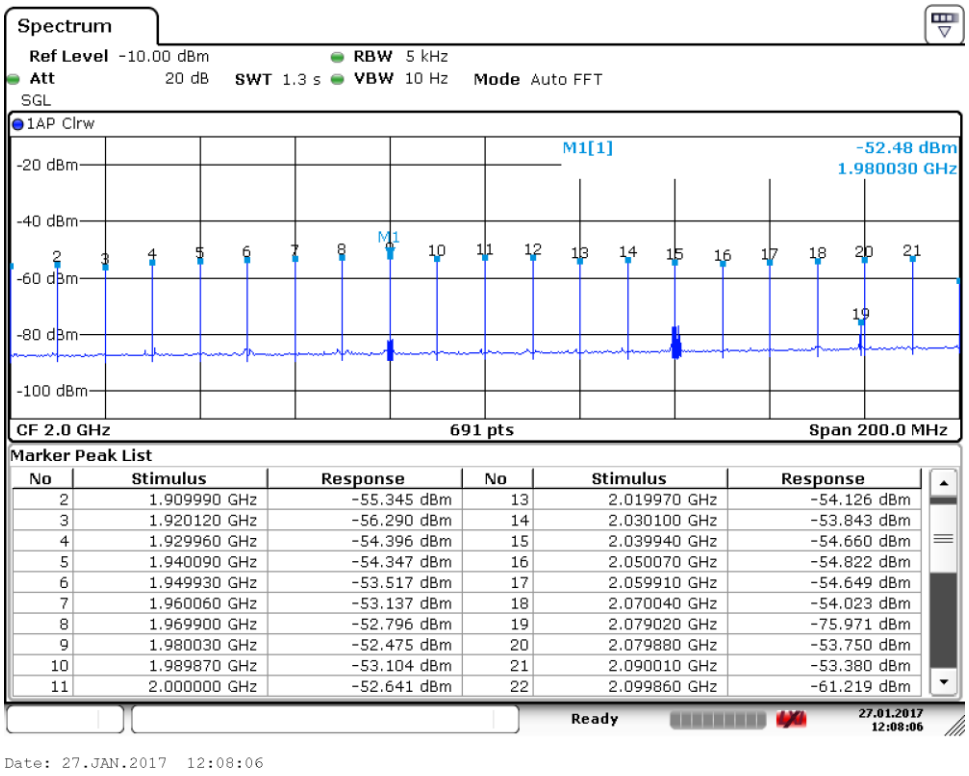



**Figure 3-27: Port Y output @2GHz when comb generator on and attenuator set to 31.5dB.**

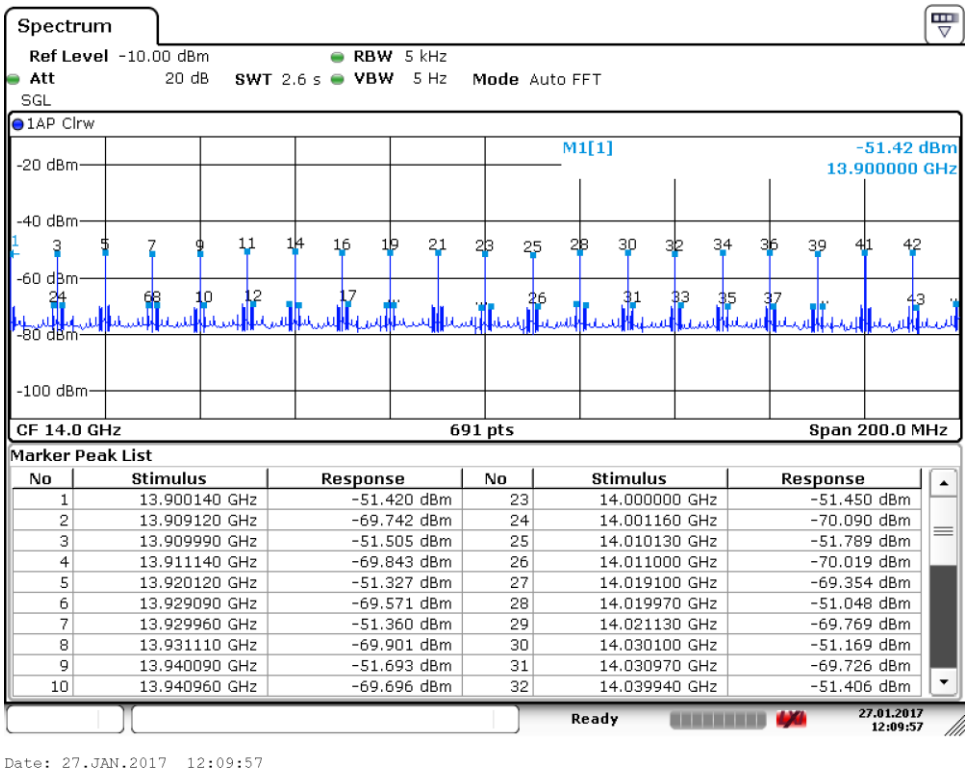
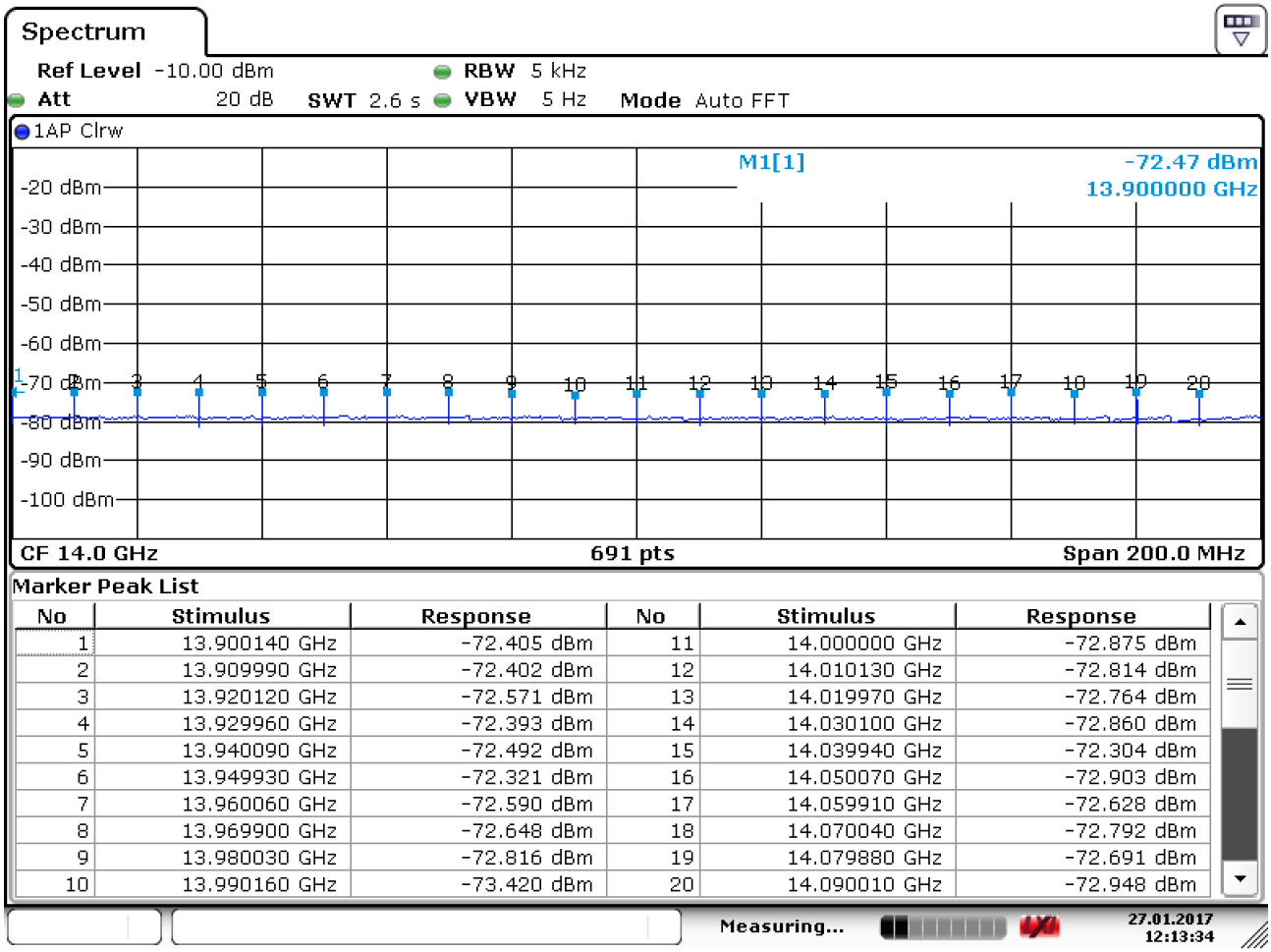



**Figure 3-28: Port Y output @14GHz when comb generator on and attenuator set to 0dB.**




| No | Stimulus | Response | No | Stimulus | Response |
|---|---|---|---|---|---|
| 1 | 13.900140 GHz | -72.405 dBm | 11 | 14.000000 GHz | -72.875 dBm |
| 2 | 13.909990 GHz | -72.402 dBm | 12 | 14.010130 GHz | -72.814 dBm |
| 3 | 13.920120 GHz | -72.571 dBm | 13 | 14.019970 GHz | -72.764 dBm |
| 4 | 13.929960 GHz | -72.393 dBm | 14 | 14.030100 GHz | -72.860 dBm |
| 5 | 13.940090 GHz | -72.492 dBm | 15 | 14.039940 GHz | -72.304 dBm |
| 6 | 13.949930 GHz | -72.321 dBm | 16 | 14.050070 GHz | -72.903 dBm |
| 7 | 13.960060 GHz | -72.590 dBm | 17 | 14.059910 GHz | -72.628 dBm |
| 8 | 13.969900 GHz | -72.648 dBm | 18 | 14.070040 GHz | -72.792 dBm |
| 9 | 13.980030 GHz | -72.816 dBm | 19 | 14.079880 GHz | -72.691 dBm |
| 10 | 13.990160 GHz | -73.420 dBm | 20 | 14.090010 GHz | -72.948 dBm |

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**Figure 3-29: Port Y output @14GHz when comb generator on and attenuator set to 14dB.**

The maximum picket level at 14GHz available at the output of the receiver is around -50.7dBm for the X port and -51.5dBm for the Y port.

The phase calibration circuit is operational.

# LIST OF ABBREVIATIONS

| Acronym | Meaning |
|---|---|
| σ | Standard Deviation |
| AD | Applicable Document |
| AIL | Action Item List |
| AM | Amplitude Modulation |
| AZ | Azimuth |
| BER | Bit Error Rate |
| Bps | Bits per second |
| CCSDS | Consultative Committee for Space Data System |
| CDR | Critical Design Review |
| DC | Direct Current |
| ESA | European Space Agency |
| ESOC | European Space Operations Centre |
| ICD | Interface Control Document |
| IF | Intermediate Frequency |
| k | Boltzman's Constant |
| K | Kelvin |
| Kbps | Kilo bps |
| Kcps | Kilo cps |
| LAN | Local Area Network |
| LNA | Low Noise Amplifier |
| MTBF | Mean Time Between Failure |
| NASA | National Aeronautics and Space Administration |
| NF | Noise Figure |
| PC | Personal Computer |
| QoS | Quality of Service |
| RF | Radio Frequency |
| SoW | Statement of Work |
| TBC | To Be Confirmed |
| TBD | To Be Defined |
| WO | Work Order |
| WP | Work Package |