Calibration of Q-Band Waveguide Noise Sources

J.D. Gallego, C. Diez González, I. López,
I. Malo, R. Amils.

IT-CDT 2021-3

Observatorio de Yebes
Apdo. 148 19080 Guadalajara
SPAIN
Phone: +34 949 29 03 11
Fax: +34 949 29 00 63

Change Record

Revision	Date	Affected Paragraphs(s)	Reason/Initiation/Remarks
A	2020-03-15	All	First Issue

TABLE OF CONTENTS

1. Abstract

Yebes Observatory laboratory can calibrate the ENR of coaxial diode noise sources using the dedicated noise receiver of the PNA-X available in the laboratory. The calibration obtained is referenced to the absolute calibration of a power sensor. The frequency is limited by the coverage of the noise receiver to the 10 MHz to 50 GHz range. Different types of noise sources, including some with high ENR and poor reflection coefficient, have been calibrated with excellent results and a good accuracy. However we did not attempt until now performing the calibration of noise sources with waveguide interface. This report presents the results obtained from the calibration of two Q-band (33-50 GHz) waveguide noise sources a) a precision HP Q347B unit and b) a Micronetics NCI53350W (on loan from como EA5JF/EB3FRN) with an attenuator permanently connected to the output. The estimated 2σ calibration error is also included in the tables. The results obtained for a) are compared with the original calibration data provided by the manufacturer.

2. Equipment

- PNA-X N5247A Vector network analyzer (10 MHz-67 GHz) with option 029 (Source-Corrected Noise Figure Measurements) (Keysight).
- N4697F Flexible Cable Set, 1.85 mm (Keysight).
- Q281B Waveguide to 2.4 mm (m) Adapter, Q-Band, 33-50GHz (Keysight).
- N4694A Electronic Calibration Module (ECal), 10 MHz - 67 GHz, 1.85 mm (Keysight).
- N1913A EPM Series Single-Channel Power Meter (Keysight).
- 8487A Power Sensor 50 MHz – 50 GHz, 2.4 mm (Keysight).

3. Measurements

The method used for the calibration of noise sources was described previously in [1] and [3] and only the most relevant details and differences will be mentioned here. The standard to which the calibration is referred is a 50 MHz–50 GHz 8487A Power Sensor and the error is dominated by the absolute accuracy of its calibration. This is generally better than referring the calibration to other noise source. One difficulty that was not present in the measurements shown in [1] and [3] is the fact that the output of the sources is a WR22 waveguide with an UG-383/U flange. To solve that a precision coaxial-waveguide transition (Keysight Q281B) was used. The S parameters of the transition (see figure 1) were previously obtained from combining the results of two calibrations: a) TRL waveguide calibration using two transitions (Q281A and Q281B) and b) 1.85 mm coaxial calibration with an Ecal module. The S parameters were used to de-embed the effect of the transition using a feature built in the PNA-X software.

The results presented in this report (ENR and reflection) are referred to the waveguide port calibration plane.

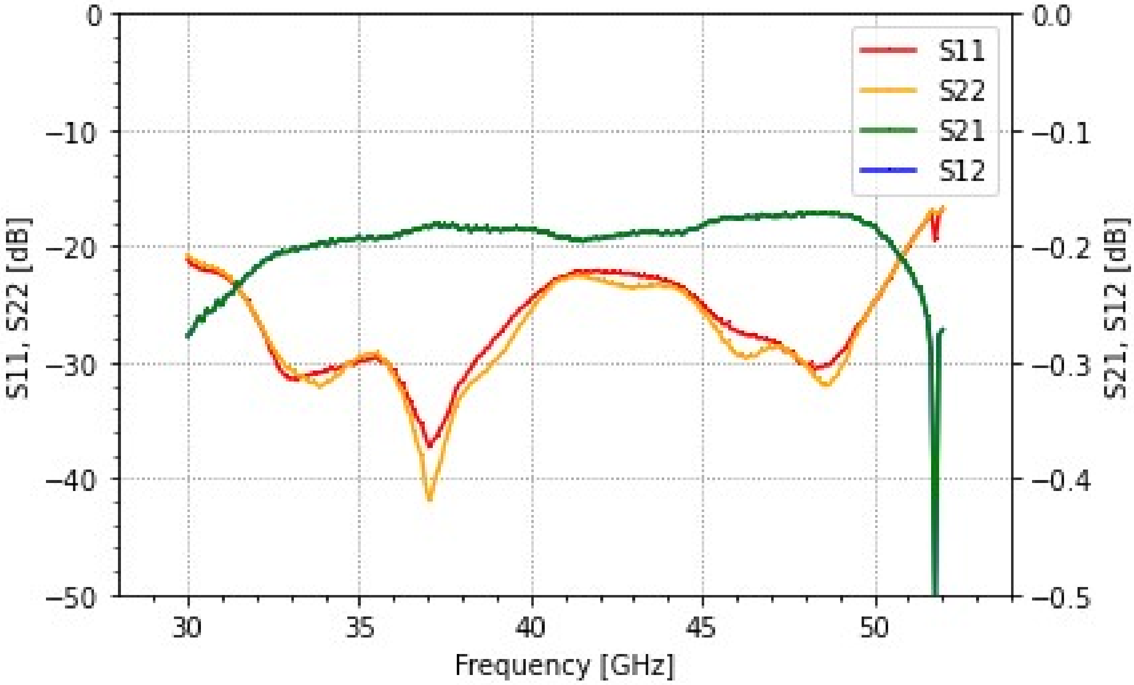


Figure 1: Modulus of the S parameters of the waveguide (port 1, WR22) to coaxial (port 2, male 2.4 mm) transition used in the measurements (model Q281B). The complete S parameter information (modulus and phase) was used in the de-embedding procedure.

4. Results

Appendix I presents the results of the calibration in graphs and tables for both sources. The Q347B is a precision device, 33 years old but treated very carefully and in very good condition. It shows almost a 6 dB slope in the band but the ENR curve is very smooth and predictable. The present calibration appears to be even smoother than the original data which was affected by some ripple probably due to the effect of reflections. The agreement with the original ENR and reflection calibration data is excellent, validating the de-embedding procedure used. In particular the reflection is almost identical to the original data down to the -35 dB level, which is quite remarkable.

The Micronetics NCI53350W with the attenuator permanently attached (on loan from como EA5JF/EB3FRN) has less slope but a more prominent ripple, probably caused by multiple reflections between the source and the attenuator. However, the reflection is lower and it is below the -20 dB level in the entire band.

5. References

[1] J.D. Gallego, C. Díez González, R. Amils, I. López, I. Malo, "Accurate Calibration of Diode Noise Sources with PNA-X Noise Receiver", CDT Technical Report 2020-27. https://icts-yebes.oan.es/reports/doc/IT-CDT-2020-27.pdf

[2] PNA-X Noise Figure Uncertainty Calculator, version A.02.01.25, 2018-02-14.

[3] J.D. Gallego, C. Díez González, R. Amils, I. López, I. Malo, "Calibration High ENR Diode Noise Sources for the C-X and the K-Ka Band Yebes Receivers", CDT Technical Report 2021-1. https://icts-yebes.oan.es/reports/doc/IT-CDT-2021-1.pdf

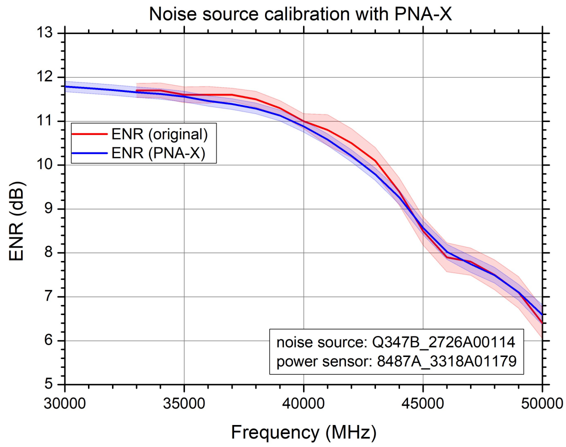
6. Appendix I: Measurements

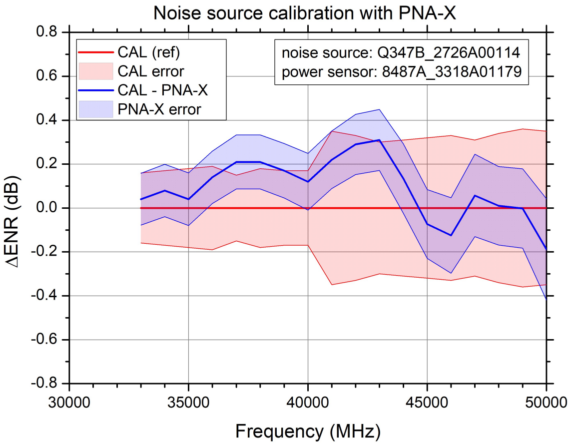
Waveguide Noise Sources calibration with PNA-X

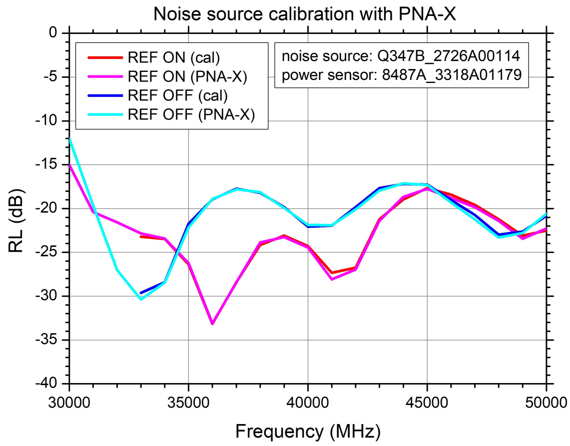
29/01/2021

BW= 4 MHz, AVG=200, 1.85 mm cal, de-embedding coax-WG, Power Meter cal, 30 GHz-50 GHz

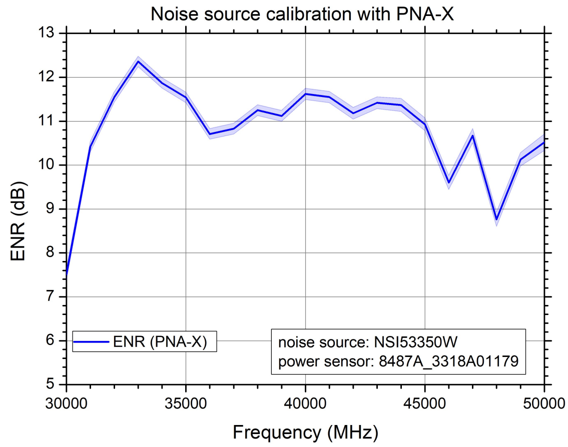
Source HP Q347B_2726A00114 (Waveguide)



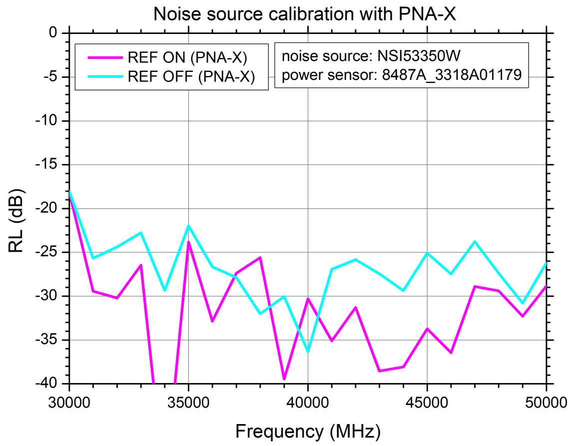




Source Micronetics NCI53350W (Waveguide)



NO PREVIUS CAL DATA AVAILABLE



NOTES

- The Micronetics NCI53350W S/N C35568615 was measured with a waveguide attenuator attached to its output flange.
- A 2.4 mm to WR22 waveguide transition was used for these measurements. The effect of the transition was de embedded using its S parameters.

TABLE Q347B S/N 2726A00114

```
[Filetype ENR]
[Version 1.0]
[Serialnumber 2726A00114]
[Model Q347B]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210128.12:28:00]
!  Frequency          ENR      Unc.     Refl.    Coef.
!        MHz           dB        dB       Mag    Phase(lin, deg)
       30000 MHz    11.79    0.118   0.1776   280.39
       31000 MHz    11.75    0.119  0.09553   171.73
       32000 MHz    11.71    0.118  0.08353   171.82
       33000 MHz    11.66    0.118   0.0722   333.53
       34000 MHz    11.62    0.119   0.0674   145.55
       35000 MHz    11.56     0.12  0.04873   53.789
       36000 MHz    11.46    0.119  0.02208   247.09
       37000 MHz    11.39    0.123  0.03789   205.83
       38000 MHz    11.29    0.123  0.06406   171.99
       39000 MHz    11.13    0.124  0.06875   119.86
       40000 MHz    10.88    0.129  0.05988   265.68
       41000 MHz    10.58    0.131  0.03939   135.31
       42000 MHz    10.21    0.137  0.04492   228.39
       43000 MHz     9.79    0.139  0.08529   58.107
       44000 MHz    9.266    0.158   0.1166    204.9
       45000 MHz    8.573    0.157   0.1296   3.1311
       46000 MHz    8.025    0.172    0.115   299.44
       47000 MHz    7.743    0.188    0.102   21.456
       48000 MHz     7.49    0.179  0.08503   315.56
       49000 MHz    7.102    0.181  0.06719   312.74
       50000 MHz    6.589    0.231    0.077   80.881
```

Q347B S/N 2726A00114 (MANUFACTURER CALIBRATION)

HEWLETT PACKARD
CALIBRATION REPORT

MODEL: Q347B
DATE: 18-MAR-1988

SERIAL NUMBER: 2726A00114
TECHNICIAN: 222473

FREQUENCY (GHz)	ENR (dB)	REFLECTION ON MAG. (units)	REFLECTION ON ANGLE (degrees)	REFLECTION OFF MAG. (units)	REFLECTION OFF ANGLE (degrees)
33.0	11.7	0.069	72.3	0.033	-82.5
34.0	11.7	0.067	-119.8	0.038	22.6
35.0	11.6	0.048	76.0	0.082	171.7
36.0	11.6	0.022	-54.6	0.113	-8.8
37.0	11.6	0.038	-159.7	0.130	175.0
38.0	11.5	0.062	53.7	0.123	4.1
39.0	11.3	0.070	-109.8	0.102	-171.9
40.0	11.0	0.061	81.6	0.079	2.8
41.0	10.8	0.043	-108.7	0.080	168.2
42.0	10.5	0.046	34.8	0.102	-16.4
43.0	10.1	0.087	-148.5	0.131	178.1
44.0	9.4	0.113	47.3	0.138	17.3
45.0	8.5	0.131	-113.7	0.137	-140.1
46.0	7.9	0.120	93.3	0.112	64.5
47.0	7.8	0.105	-70.0	0.092	-103.8
48.0	7.5	0.087	123.0	0.071	81.7
49.0	7.1	0.070	-68.4	0.074	-112.4
50.0	6.4	0.075	100.3	0.091	67.3

TABLE NCI53350W S/N C35568615 (WITH ATTENUATOR)

```
[Filetype ENR]
[Version 1.0]
[Serialnumber C35568615]
[Model NCI53350W]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210128.12:11:05]
!  Frequency          ENR      Unc.    Refl.    Coef.
!        MHz           dB        dB      Mag    Phase(lin, deg)
       30000 MHz    7.514    0.128   0.1241   331.51
       31000 MHz    10.42     0.12  0.03369   107.31
       32000 MHz    11.55    0.118  0.03082    79.53
       33000 MHz    12.36    0.118  0.04749   20.336
       34000 MHz    11.87    0.118  0.00249   79.794
       35000 MHz    11.54     0.12  0.06441   30.619
       36000 MHz    10.71     0.12  0.02274   254.61
       37000 MHz    10.83    0.123  0.04272   49.504
       38000 MHz    11.25    0.123  0.05248   174.94
       39000 MHz    11.12    0.124  0.01065   176.29
       40000 MHz    11.62    0.128   0.0305   285.23
       41000 MHz    11.55    0.129  0.01757   235.57
       42000 MHz    11.18    0.134  0.02725   113.31
       43000 MHz    11.42    0.134  0.01182   259.57
       44000 MHz    11.37    0.148  0.01248   305.16
       45000 MHz    10.93    0.147  0.02062   115.51
       46000 MHz    9.604    0.161  0.01505   204.81
       47000 MHz    10.67    0.162  0.03586   77.937
       48000 MHz    8.767    0.164  0.03392   339.16
       49000 MHz    10.13    0.153  0.02429   186.08
       50000 MHz    10.52    0.188  0.03622   87.836
```