Calibration High ENR Diode Noise Sources for the C-X and the K-Ka Band Yebes Receivers

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1. Abstract

The new C-X (4-12 GHz) and K-Ka (18-36 GHz) wideband receivers being built for the 40m Yebes antenna will employ high ENR (≈30 dB, ≈300000 K) switched noise sources injected thru ≈30 dB cooled directional couplers for their noise calibration. The noise sources are commercially available of-the-shelf components which are provided with a calibration performed by the manufacturer. The accuracy of this calibration is generally not quoted and very often the data is only provided at some sparse frequency points across the bandwidth. This report presents the results of the calibration of the mentioned diode noise sources using the most advanced and accurate calibration technique available in our laboratory. The results are presented for the stand-alone sources and also with the addition of an isolator connected to the output. The measurements are presented at cardinal frequency points spaced by 500 MHz in the band of interest for an adequate evaluation of the ENR ripple. The estimated 2σ calibration error is also included in the tables. The results obtained 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).
- 11904S Adapter Set, 2.4 mm to 2.92 mm, DC to 40 GHz (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 only the most relevant details and differences will be presented 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] is the high value of the ENR of the present sources. According with the error evaluation performed with [2], if special care is not taken the dominant error source would be the compression of the noise receiver of the PNA-X. To avoid that, the selection of gain for that receiver was changed from “high” to “low”. That improves the ENR accuracy from ±0.4 dB to the ±0.1 dB level approximately without compromising the rest of the contributions.

The measurements were performed with male-male transitions attached to the output port of the noise sources and the isolators. Those should be considered an integral part of the noise sources if ultimate accuracy is desired. The transitions are included in the calibration and not de-embedded.

4. Results

Appendix I presents the results of the calibration in graphs and tables for both sources without and with isolators. Some photos are including for helping in identifying the parts and the configuration.

The NW1G18-26-CS (C-X receiver) is relatively flat when used alone but the ripple deteriorates considerably when the isolator is added. However, the reflection coefficient is quite poor and changes considerably from ON to OFF. The isolator helps in reducing the reflection change and in improving its value, but its inclusion in the system should be critically studied according with this data. Note that the ENR values given by the manufacturer are clearly underestimated at least by 1 dB.

The NW1G18-26-CS (K-Ka receiver) shows a moderate ripple (≈2.5 dBpp) across the band and a much better value of reflection coefficient, although some change from ON to OFF can be clearly appreciated. The inclusion of the isolator adds some periods to the ripple but the peak to peak value remains similar. It is interesting to note that the isolator deteriorates the reflection instead of improving it, although the change from ON to OFF is reduced. In this case it appears that the isolator may not be necessary in the system. The calibration data from the manufacturer follows quite well the shape and values of our calibration in this case.

The different behavior of both noise sources and in particular the values of the reflection coefficient suggest that the design approach is different for each one. The NW1G18-26-CS (C-X receiver) behaves like a genuine noise diode connected without much attenuation while the NW1G18-26-CS (K-Ka receiver) appears to be an amplified noise source.

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

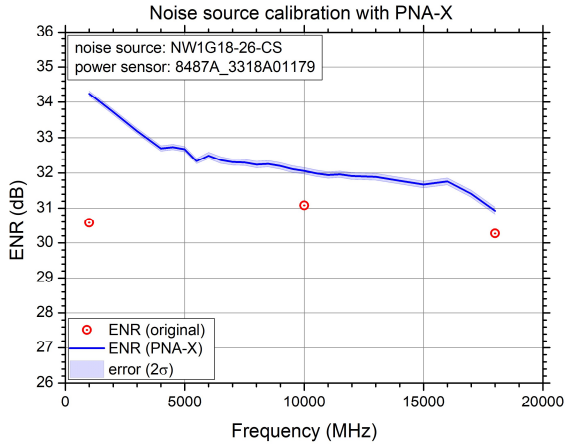
[2] PNA-X Noise Figure Uncertainty Calculator, version A.02.01.25, 2018-02-14.

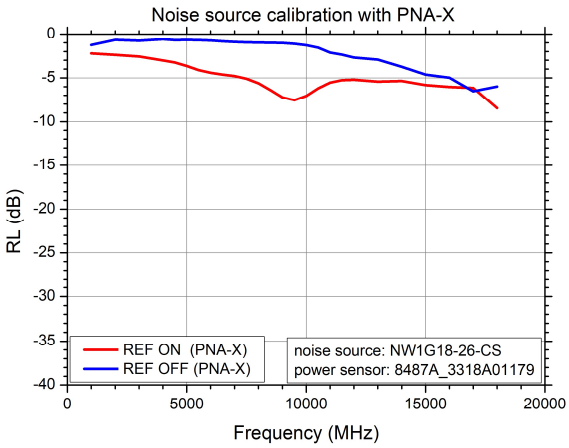
6. Appendix I: Measurements

C-X Band Receiver NoiseWave NW1G18-26-CS Noise Source calibration

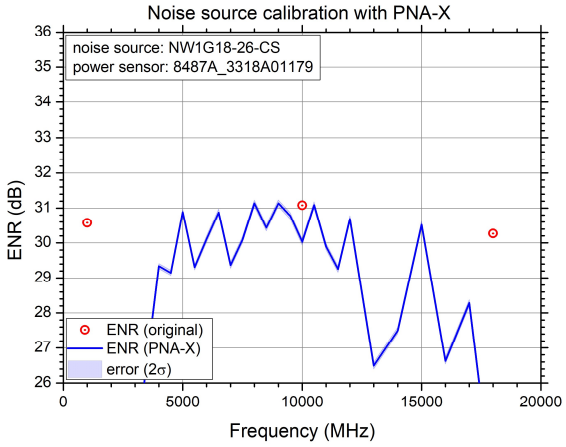
02/03/2021 BW= 4 MHz, AVG=200, 2.92 mm cal, Power Meter cal, 1 GHz-18 GHz

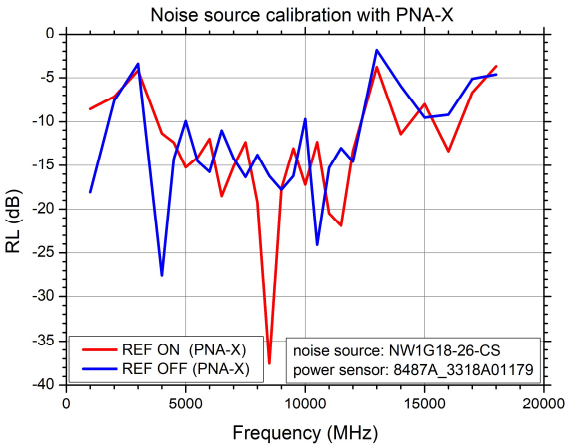
Source NW1G18-26-CS s/n:203826

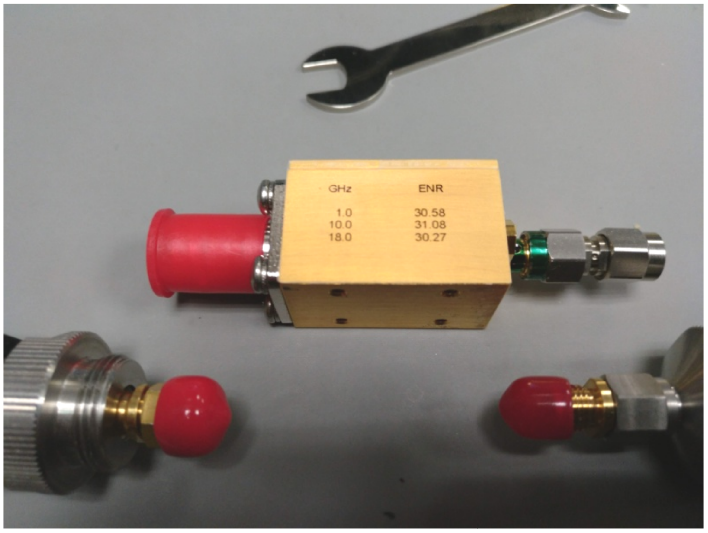


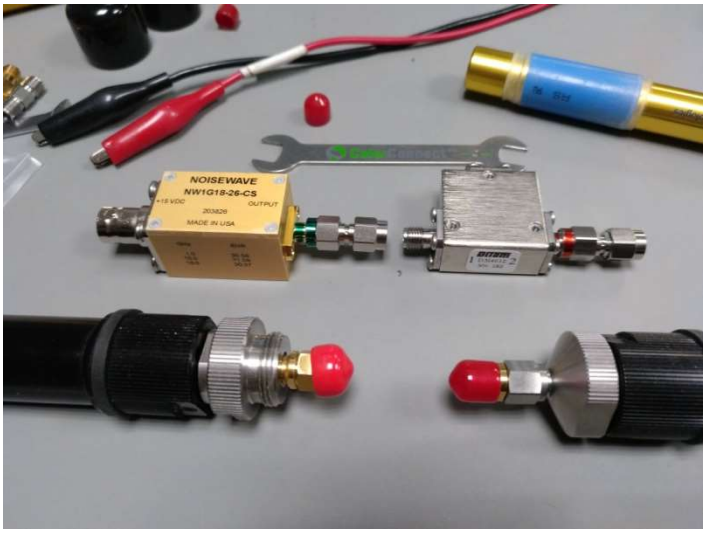


Source NW1G18-26-CS s/n:203826 + 4-12 GHz Isolator









NOTES

- The Gain of the PNA-X noise receiver was set to “low” to avoid the problems caused by compression. Otherwise the contribution of the compression to the overall error becomes important (as predicted by the acquisition software due to the high ENR of the source).
- The measurement of the stand-alone source includes the effect of a male-male SMA transition as shown in the photo. The measurement of the source with isolator includes the effect of two male-male SMA transitions.

TABLE NW1G18-26-CS (NO ISOLATOR)

```
[Filetype ENR]
[Version 1.0]
[Serialnumber 203826]
[Model NW1G18-26-CS.]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210301.16:32:17]
!  Frequency          ENR     Unc.    Refl.    Coef.
!        MHz           dB       dB      Mag    Phase(lin, deg)
        1000 MHz    34.24   0.0739   0.7751   297.67
        2000 MHz    33.72   0.0739   0.7602   158.53
        3000 MHz    33.19   0.0739   0.7432   196.33
        4000 MHz     32.7   0.0739   0.7065   116.98
        4500 MHz    32.74   0.0739   0.6887   291.04
        5000 MHz    32.68   0.0739   0.6567    200.6
        5500 MHz    32.34   0.0739   0.6232   1.3184
        6000 MHz     32.5   0.0924   0.6019   148.57
        6500 MHz    32.37   0.0967   0.5872   239.74
        7000 MHz    32.31     0.09   0.5757   166.26
        7500 MHz     32.3   0.0888   0.5567   144.12
        8000 MHz    32.24   0.0925   0.5243   331.68
        8500 MHz    32.26   0.0929   0.4799   203.51
        9000 MHz     32.2    0.094   0.4349      189
        9500 MHz    32.11   0.0951   0.4187   344.39
       10000 MHz    32.06   0.0903   0.4441    7.207
       10500 MHz    31.99   0.0917   0.4907   41.638
       11000 MHz    31.94    0.091   0.5288   103.67
       11500 MHz    31.96   0.0912   0.5463   94.735
       12000 MHz    31.91    0.095   0.5487   32.706
       13000 MHz    31.89   0.0955   0.5357   159.24
       14000 MHz    31.78   0.0939   0.5394   280.63
       15000 MHz    31.67   0.0924    0.512   217.34
       16000 MHz    31.76   0.0966   0.4988   49.999
       17000 MHz    31.41   0.0977    0.493   253.84
       18000 MHz    30.93   0.0968   0.3771   255.48
```

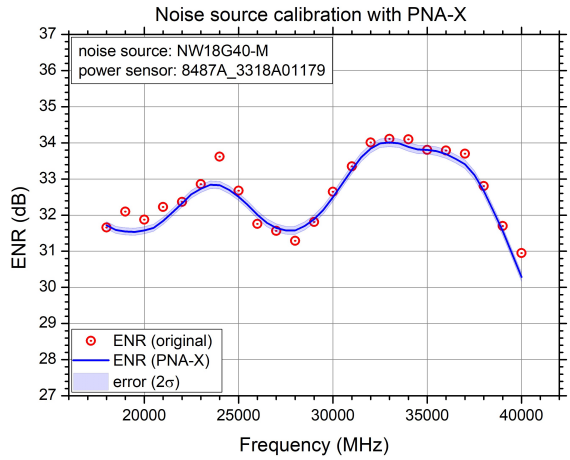
TABLE NW1G18-26-CS (WITH ISOLATOR)

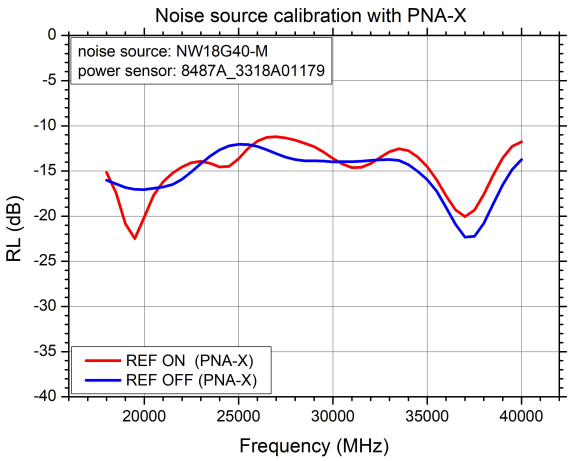
```
[Filetype ENR]
[Version 1.0]
[Serialnumber 203826]
[Model NW1G18-26-CS]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210301.16:39:51]
!  Frequency          ENR     Unc.    Refl.    Coef.
!        MHz           dB       dB      Mag    Phase(lin, deg)
        1000 MHz    20.83    0.074   0.3736   1.4832
        2000 MHz    20.26   0.0741    0.439   294.02
        3000 MHz    23.92    0.074   0.6171   198.02
        4000 MHz    29.34   0.0739   0.2705   208.27
        4500 MHz    29.15   0.0739   0.2402    211.7
        5000 MHz    30.89   0.0739   0.1733   81.749
        5500 MHz    29.31    0.074   0.1971   135.04
        6000 MHz    30.11   0.0908   0.2512   280.04
        6500 MHz    30.88   0.0956   0.1189   258.32
        7000 MHz    29.37   0.0878    0.175   274.77
        7500 MHz    30.09   0.0875   0.2405   340.22
        8000 MHz    31.14   0.0905   0.1093   70.576
        8500 MHz    30.43   0.0905  0.01328   145.82
        9000 MHz    31.14   0.0913   0.1313   333.08
        9500 MHz    30.78   0.0938    0.222   317.04
       10000 MHz    30.03   0.0883   0.1382   41.858
       10500 MHz    31.09   0.0906   0.2415   48.087
       11000 MHz     29.9   0.0882  0.09464   308.41
       11500 MHz    29.26    0.089  0.08042   205.98
       12000 MHz    30.69   0.0932   0.2151    319.1
       13000 MHz    26.49   0.0914   0.6463   163.16
       14000 MHz     27.5   0.0902   0.2677   271.97
       15000 MHz    30.52   0.0918   0.3978   105.67
       16000 MHz    26.63   0.0931   0.2144   112.18
       17000 MHz    28.28    0.095   0.4626   265.46
       18000 MHz    22.81   0.0932   0.6539   319.41
```

K-Ka Band Receiver NoiseWave NW18G40-M Noise Source calibration

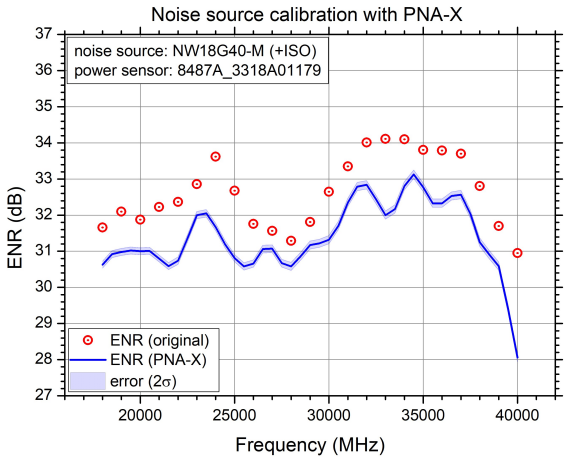
02/03/2021 BW= 4 MHz, AVG=200, 2.92 mm cal, Power Meter cal, 18 GHz-40 GHz

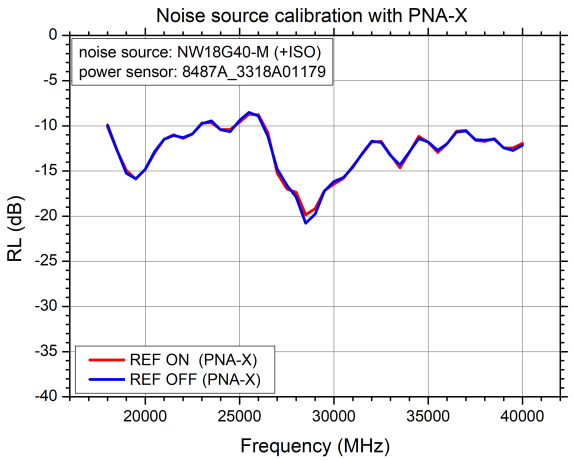
Source NW18G40-M s/n: 205101

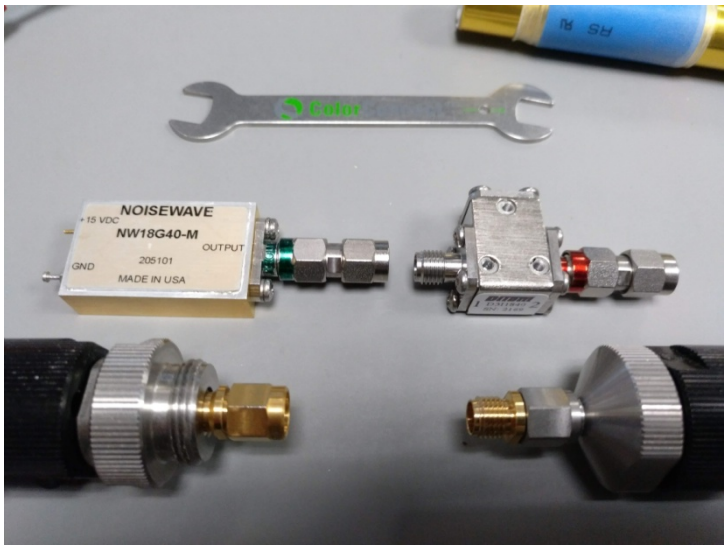




Source NW18G40-M s/n: 205101 + 18-40 GHz Isolator







NOTES

- The Gain of the PNA-X noise receiver was set to “low” to avoid the problems caused by compression. Otherwise the contribution of the compression to the overall error becomes important (as predicted by the acquisition software due to the high ENR of the source).
- The measurement of the stand-alone source includes the effect of a male-male 2.92 mm transition as shown in the photo. The measurement of the source with isolator includes the effect of two male-male 2.92 mm transitions.

TABLE NW1G18-26-CS (NO ISOLATOR)

```
[Filetype ENR]
[Version 1.0]
[Serialnumber 205101]
[Model NW18G40-M]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210301.13:14:09]
```

! Frequency	ENR	Unc.	Refl.	Coef.
! MHz	dB	dB	Mag	Phase(lin, deg)
18000 MHz	31.72	0.0976	0.1746	26.818
18500 MHz	31.59	0.0969	0.1349	17.205
19000 MHz	31.55	0.0974	0.09109	248.33
19500 MHz	31.54	0.0977	0.07515	270.79
20000 MHz	31.58	0.0966	0.09888	19.644
20500 MHz	31.65	0.0969	0.1305	19.006
21000 MHz	31.84	0.0967	0.1553	257.03
21500 MHz	32.08	0.0984	0.1733	329.93
22000 MHz	32.33	0.104	0.1873	34.08
22500 MHz	32.58	0.105	0.1977	124.54
23000 MHz	32.73	0.104	0.2013	259.1
23500 MHz	32.84	0.105	0.1963	326.5
24000 MHz	32.83	0.104	0.1875	17.391
24500 MHz	32.7	0.105	0.1889	317.08
25000 MHz	32.51	0.102	0.2083	338.6
25500 MHz	32.28	0.103	0.2366	14.919
26000 MHz	32.01	0.102	0.2603	269.09
26500 MHz	31.79	0.109	0.273	20.94
27000 MHz	31.65	0.108	0.2753	9.2725
27500 MHz	31.58	0.108	0.2707	188.13
28000 MHz	31.58	0.112	0.2636	315.97
28500 MHz	31.7	0.111	0.2534	216.44
29000 MHz	31.89	0.112	0.2424	329.69
29500 MHz	32.15	0.112	0.2271	112.59
30000 MHz	32.5	0.116	0.2085	307.07
30500 MHz	32.88	0.116	0.1947	154.92
31000 MHz	33.26	0.117	0.186	258.13
31500 MHz	33.6	0.117	0.1863	3.252
32000 MHz	33.84	0.117	0.1957	248.71
32500 MHz	33.99	0.117	0.2117	193.73
33000 MHz	34.01	0.117	0.2272	207.7
33500 MHz	33.99	0.117	0.2361	258.63
34000 MHz	33.89	0.118	0.2304	319.48
34500 MHz	33.82	0.119	0.2126	311.23
35000 MHz	33.81	0.119	0.1879	201.23
35500 MHz	33.77	0.118	0.159	335.69
36000 MHz	33.69	0.117	0.13	105.23
36500 MHz	33.56	0.115	0.1085	61.82
37000 MHz	33.41	0.118	0.09946	186.31
37500 MHz	33.11	0.118	0.1082	144.98
38000 MHz	32.67	0.117	0.1321	354.07
38500 MHz	32.12	0.117	0.1692	330.89
39000 MHz	31.56	0.116	0.2105	350.32
39500 MHz	30.93	0.116	0.2435	5.5042
40000 MHz	30.29	0.119	0.2578	51.372

TABLE NW1G18-26-CS (WITH ISOLATOR)

```
[Filetype ENR]
[Version 1.0]
[Serialnumber 205101]
[Model MW18G40-M_ISO]
[Temperature 23C]
[Humidity 50%]
[Caldate 20210301.13:22:57]
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! Frequency	ENR	Unc.	Refl.	Coef.
! MHz	dB	dB	Mag	Phase(lin, deg)
18000 MHz	30.63	0.0962	0.3125	170.29
18500 MHz	30.92	0.0964	0.2306	176.76
19000 MHz	30.98	0.097	0.1795	52.163
19500 MHz	31.02	0.0973	0.1607	272.92
20000 MHz	31	0.0961	0.1817	219.13
20500 MHz	31.01	0.0965	0.224	305.29
21000 MHz	30.8	0.0956	0.2666	289.59
21500 MHz	30.59	0.0966	0.282	230.54
22000 MHz	30.74	0.103	0.2696	299.45
22500 MHz	31.35	0.103	0.2848	157.83
23000 MHz	32	0.102	0.3283	228.24
23500 MHz	32.05	0.104	0.3293	167.35
24000 MHz	31.67	0.102	0.3019	110.19
24500 MHz	31.19	0.103	0.3016	353.94
25000 MHz	30.81	0.101	0.3317	10.371
25500 MHz	30.58	0.101	0.3662	15.612
26000 MHz	30.66	0.1	0.3646	225.73
26500 MHz	31.06	0.108	0.2902	307.25
27000 MHz	31.07	0.107	0.1732	271.19
27500 MHz	30.67	0.107	0.1416	279.16
28000 MHz	30.58	0.111	0.1354	250.78
28500 MHz	30.86	0.11	0.1019	340.61
29000 MHz	31.17	0.111	0.1101	293.73
29500 MHz	31.22	0.111	0.1387	188.51
30000 MHz	31.32	0.115	0.1505	215.5
30500 MHz	31.71	0.115	0.1618	200.95
31000 MHz	32.35	0.115	0.1895	123.96
31500 MHz	32.79	0.115	0.2206	175.81
32000 MHz	32.84	0.116	0.2572	170.41
32500 MHz	32.43	0.115	0.2593	94.373
33000 MHz	32	0.114	0.2185	165.73
33500 MHz	32.17	0.115	0.1856	29.861
34000 MHz	32.81	0.116	0.2264	141.43
34500 MHz	33.13	0.118	0.2765	281.11
35000 MHz	32.77	0.117	0.2568	55.778
35500 MHz	32.33	0.116	0.2253	291.07
36000 MHz	32.33	0.115	0.2514	84.869
36500 MHz	32.53	0.113	0.2951	310.52
37000 MHz	32.57	0.117	0.2987	58.722
37500 MHz	32.03	0.117	0.2628	46.527
38000 MHz	31.25	0.116	0.2598	202.41
38500 MHz	30.91	0.116	0.269	56.129
39000 MHz	30.59	0.116	0.2388	302.09
39500 MHz	29.41	0.115	0.239	124.93
40000 MHz	28.06	0.119	0.2535	176.15

NW1G18-26-CS (MANUFACTURER CALIBRATION)

NOISEWAVE
20 Troy Road
Whippany, NJ 07981
973-386-1119

Customer Name: Milexia Iberica S.A.U.
PO#: 22422OAN-1
Date: 12/22/2020
Option:

Model NO: NW18G40-M
Serial #: 205101
Bias Conditions: 58.3 mA @ 15VDC

GHz	ENR
18	31.66
19	32.10
20	31.88
21	32.23
22	32.37
23	32.86
24	33.62
25	32.68
26	31.76
27	31.57
28	31.29
29	31.81
30	32.65
31	33.35
32	34.01
33	34.11
34	34.10
35	33.81
36	33.79
37	33.70
38	32.81
39	31.70
40	30.95

FLATNESS: +/- 1.58
FLATNESS SPEC: +/- 2 dB Max

TESTED BY: _____
INSPECTED BY: _____