Ruis, wat kan je ermee?

Ruis, wat kan je ermee?

Ruis, wat kan je ermee?

Ruis is er altijd en overal

- Thermische ruis =>

  beweging elektronen afh. temperatuur

- “Shot noise” => fluctuaties in stroom (PN junctie)
- “Flicker noise” => 1/f ruis, laag frequent
- Fase ruis

➢ Voor het gemak gaan we uit van “witte ruis” = breedbandig / hele spectrum

Ruis (/) Temperatuur

- Hogere temperatuur => Meer ruis
- Hoeveel ruis? :

$$U_{THERMAL} = \sqrt{4kTR\left(BW\right)}$$

(Johnson-Nyquist ruis)

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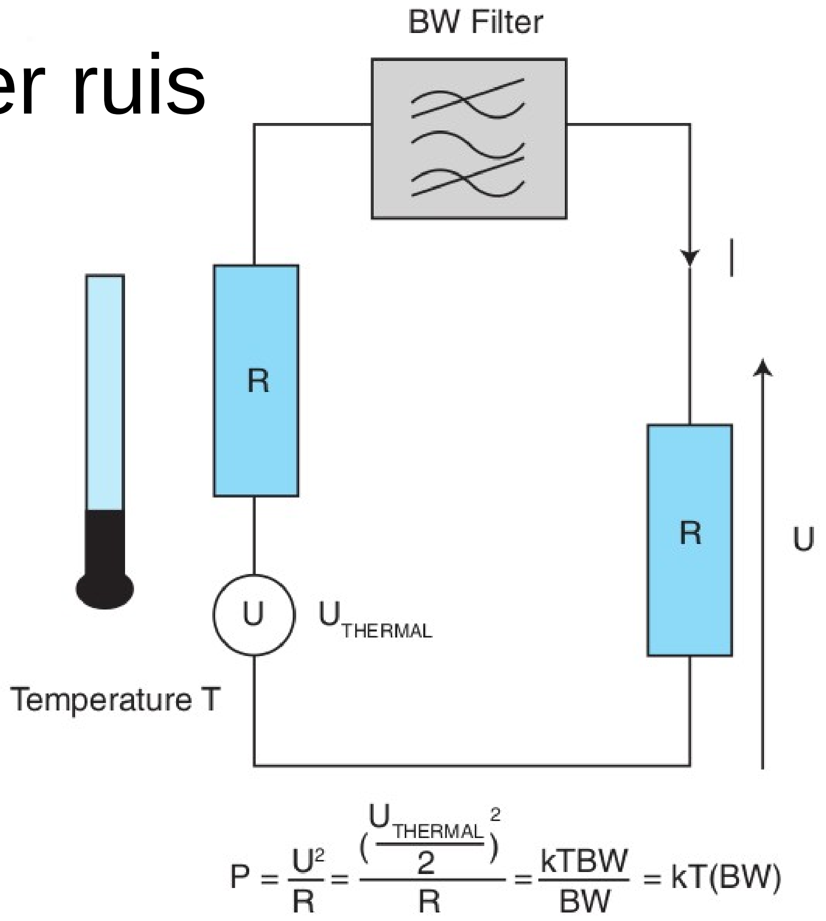

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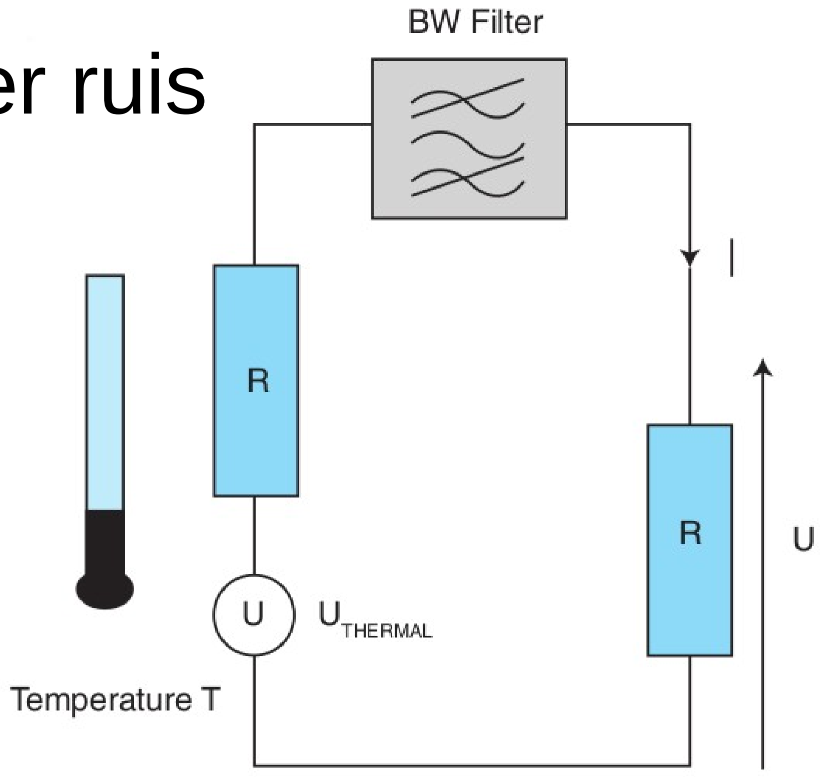

$$P = \frac{U^2}{R} = \frac{\left(\frac{U_{THERMAL}}{2}\right)^2}{R} = \frac{kTBW}{BW} = kT(BW)$$

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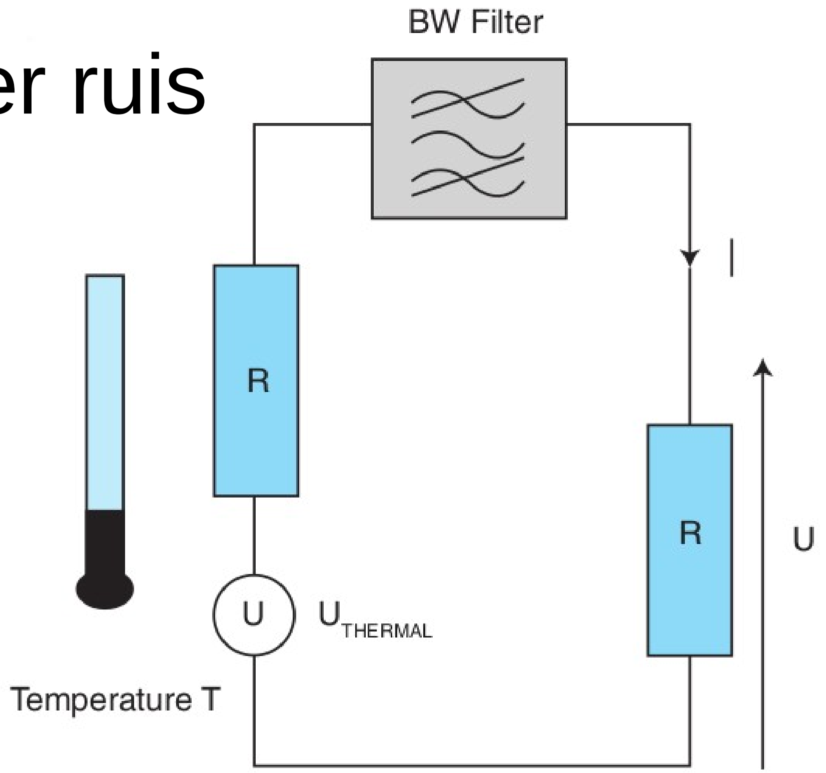

$$P_{THERMAL}(dB) = 10\log_{10}\left(4.05 \times \frac{10^{-21}\,W}{1\,mW}\right) = -174\ \text{dBm per hertz}$$

$$P = \frac{U^2}{R} = \frac{\left(\frac{U_{THERMAL}}{2}\right)^2}{R} = \frac{kTBW}{BW} = kT(BW)$$

Stel je heb een zwak signaal

- Wat gebeurt er na versterking?

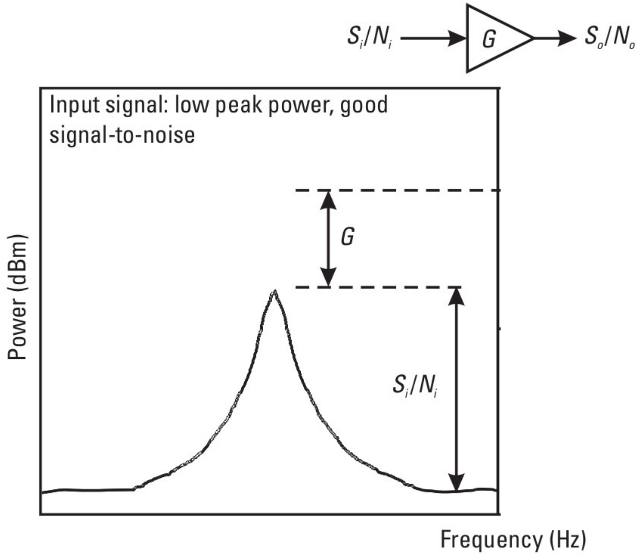

Figure 4.5 Signal-to-noise degradation of a signal passing through a semiconductor device.

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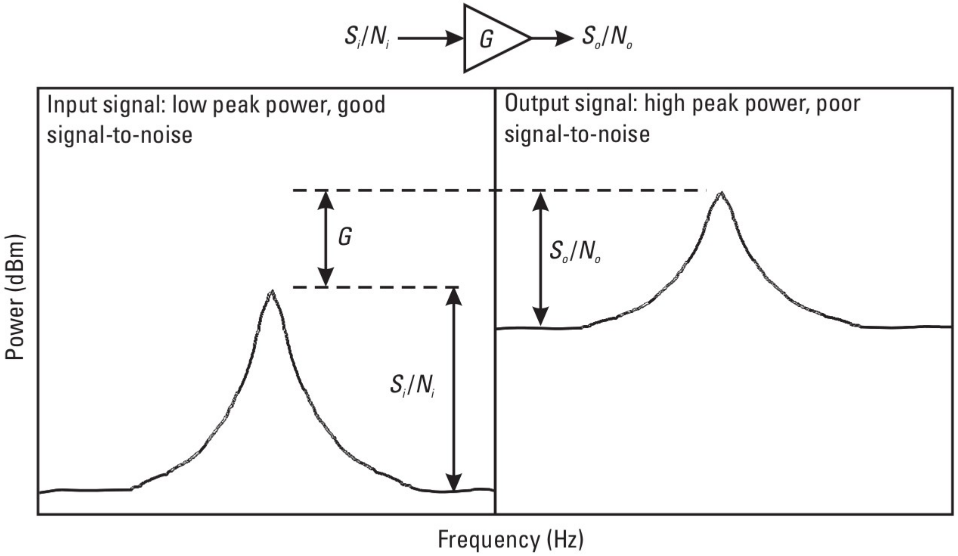


Figure 4.5 Signal-to-noise degradation of a signal passing through a semiconductor device.

Stel je heb een zwak signaal

- Wat gebeurt er na versterking?

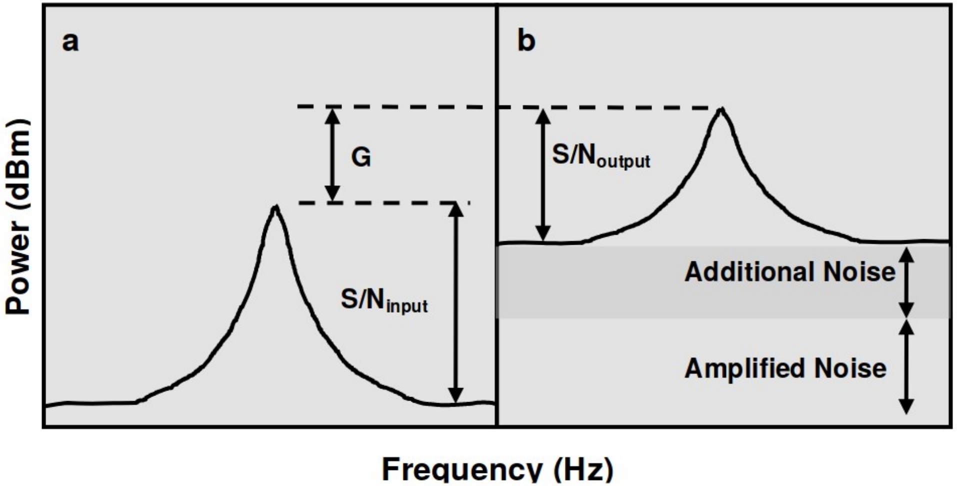


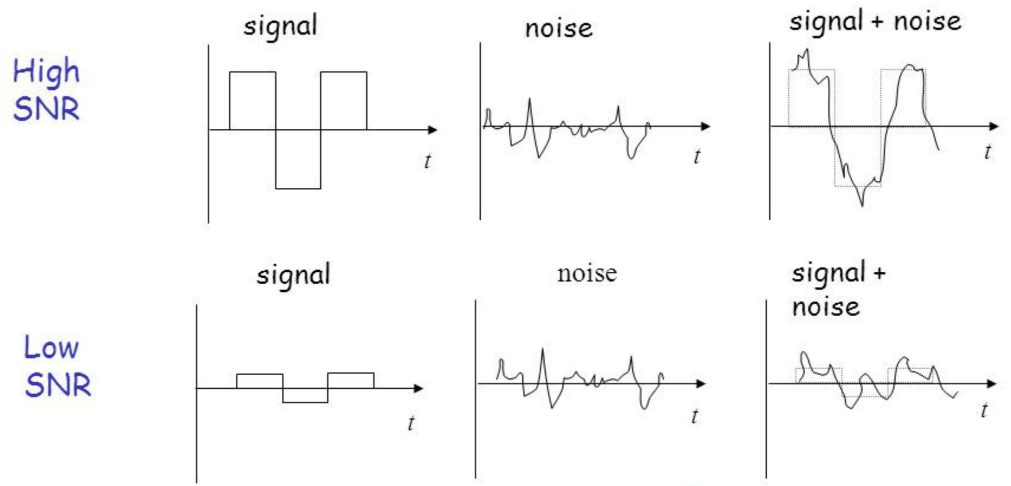
Figure 1 Signal-to-noise degradation of a signal passing through a semiconductor device. The input signal (a) has low peak power and good signal-to-noise properties. The output signal (b) has a higher peak amplitude, but also an increased noise floor, giving overall poor signal-to-noise performance.

Ruis telt op

- Elke component voegt zelf ruis toe aan de aanwezige ruis
- Daarnaast versterkt of verzwakt de component de al aanwezige ruis

Signaal / Ruis verhouding SNR

- We zijn meestal geïnteresseerd in de kwaliteit van het signaal
- De verhouding tussen de sterkte van het signaal en de sterkte van de ruis



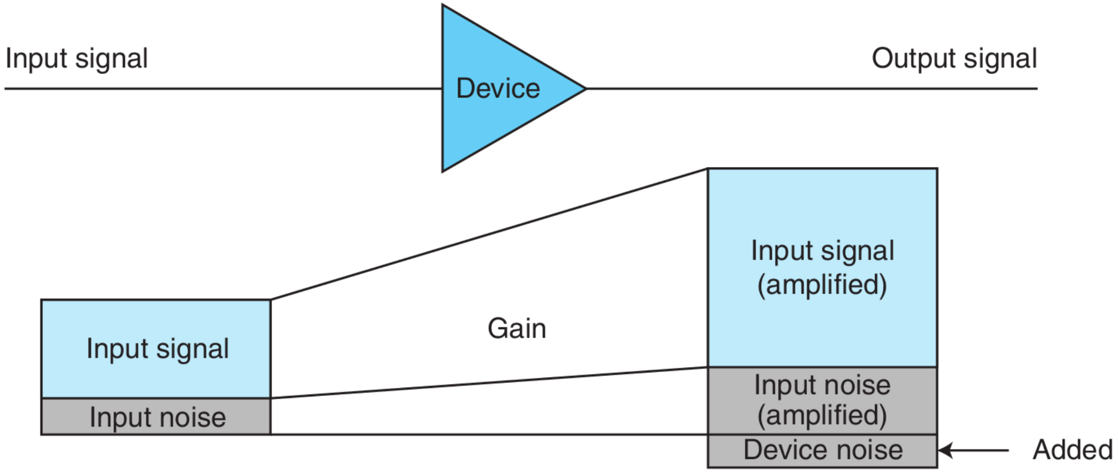
$$SNR = \frac{\text{Average Signal Power}}{\text{Average Noise Power}}$$

$$SNR\ (dB) = 10 \log_{10} SNR$$

Ruisgetal

- Invloed van component op SNR
- Uitgedrukt als verhouding van SNR aan de ingang en SNR aan de uitgang
- Noise Factor = $F = \frac{SNR_{INPUT}}{SNR_{OUTPUT}}$
- Ruisgetal = Noise Figure = $NF\ (dB) = 10\log_{10}(NF) = 10\log_{10}\left(\frac{SNR_{INPUT}}{SNR_{OUTPUT}}\right)$
- Uitgedrukt in dB; ruisvrij component NF = 0 dB
- Definitie: bij een temperatuur van 290K (17 C)

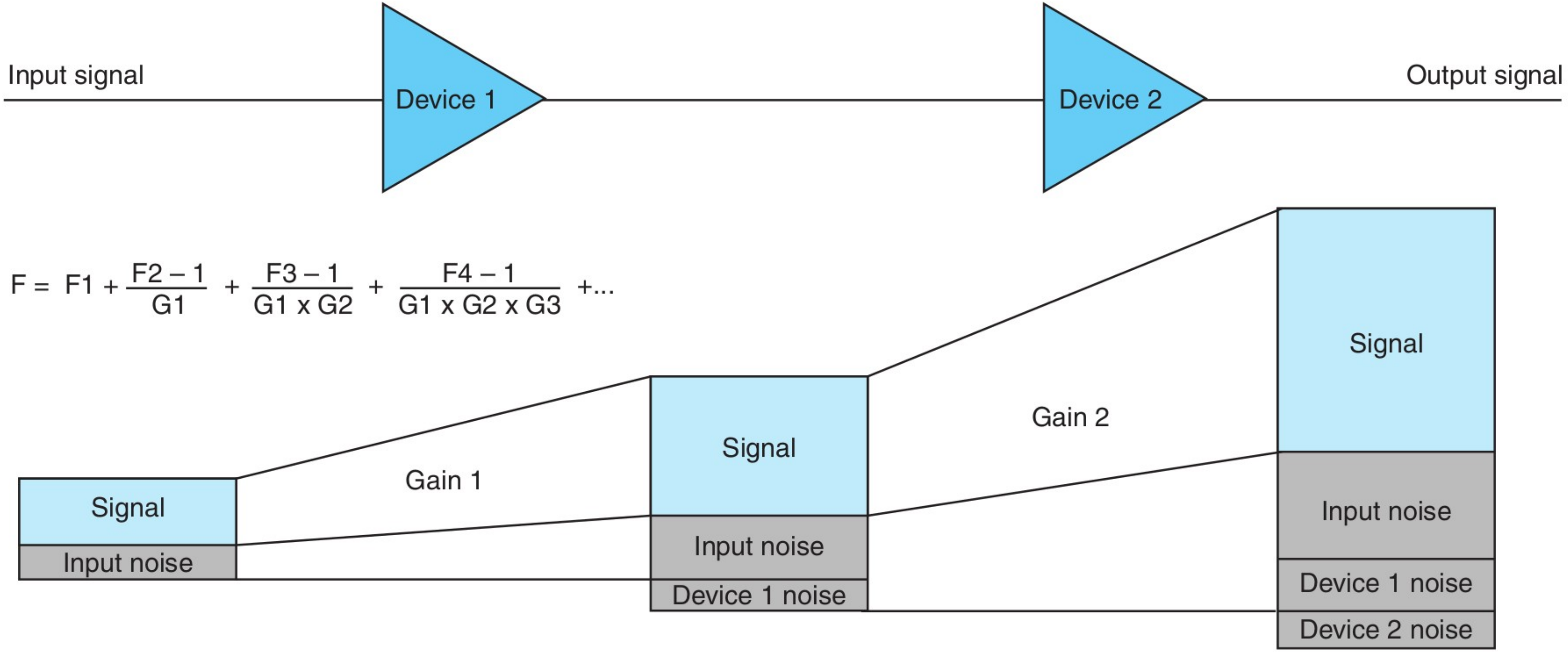
Ruis in een versterkertrap (1)



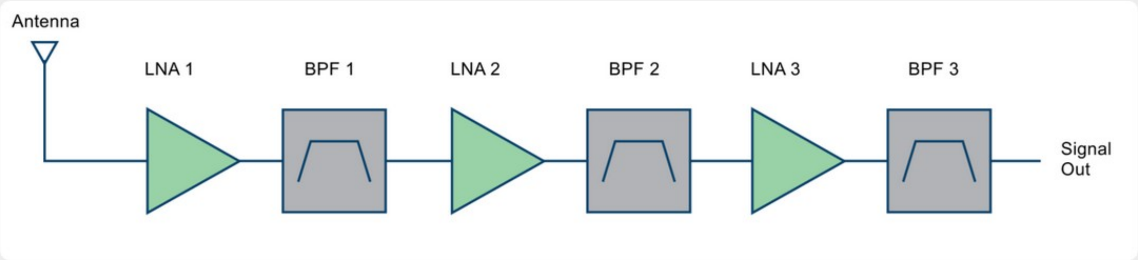
$$\text{Input SNR} = \frac{\text{P (input signal)}}{\text{P (input noise)}} > \text{Output SNR} = \frac{\text{P (input signal)}}{\text{P (total output noise)}}$$

$$\text{Noise factor F} = \frac{\text{input SNR}}{\text{ouput SNR}}$$

Ruis in een versterkertrap (2)



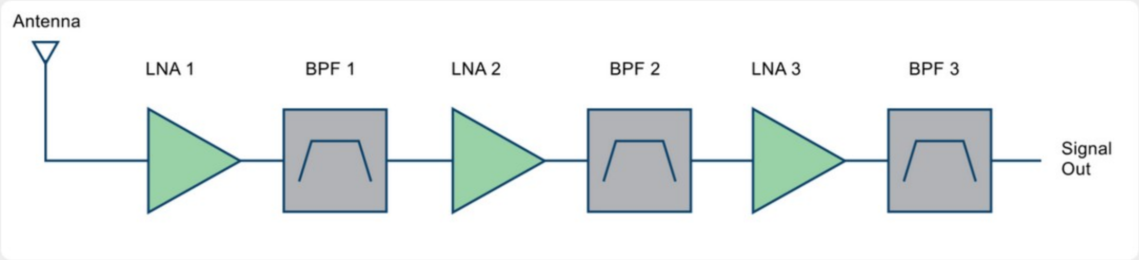
Ruis in een versterkertrap (3)



Stage	NF (dB)	Gain (dB)	Overall NF (dB)	Overall Gain (dB)
Antenna Cable	4	-4	6	-4
LNA 1	2	16	6.07	12
BPF 1	3	-3	6.15	9
LNA 2	2	16	6.15	25
BPF 2	1.5	-1.5	6.15	23.5
LNA 3	2	10	6.15	33.5
BPF 3	3	-3	6.15	30.5

$$F = F1 + \frac{F2-1}{G1} + \frac{F3-1}{G1 \times G2} + \frac{F4-1}{G1 \times G2 \times G3} + \ldots$$

Ruis in een versterkertrap (3)



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BPF 2	1.5	-1.5	6.15	23.5
LNA 3	2	10	6.15	33.5
BPF 3	3	-3	6.15	30.5

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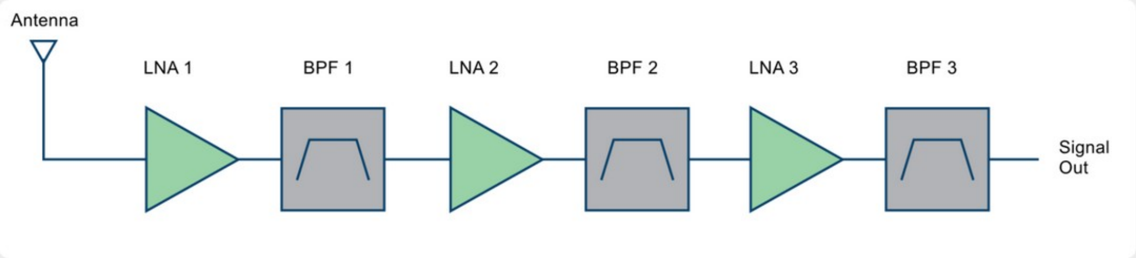

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AppCAD

AppCAD - [NoiseCalc]

File Calculate Application Examples Options Help

NoiseCalc

Set Number of Stages = 8 Calculate [F4]

Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
			A36		M7x			H73xx	
Stage Name:		FBAR Duplexer	Avago ATF-36xxx	Image Filter	Avago MGA-72543	Avago HPMX-7102	IF Filter	Avago HPMX-730x	Filter
Noise Figure	dB	4	2	3	2	0	1.5	2	3
Gain	dB	-4	16	-3	16	0	-1.5	10	-3
Output IP3	dBm	100	14.5	0	9.8	20	100	12	100
dNF/dTemp	dB/°C	0	0	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0	0	0
Stage Analysis:		0	0	0	0				
NF (Temp corr)	dB	4.00	2.00	3.00	2.00	0.00	1.50	2.00	3.00
Gain (Temp corr)	dB	-4.00	16.00	-3.00	16.00	0.00	-1.50	10.00	-3.00
Input Power	dBm	-50.00	-54.00	-38.00	-41.00	-25.00	-25.00	-26.50	-16.50
Output Power	dBm	-54.00	-38.00	-41.00	-25.00	-25.00	-26.50	-16.50	-19.50
d NF/d NF	dB/dB	0.64	0.97	0.03	0.05	0.00	0.00	0.00	0.00
d NF/d Gain	dB/dB	-0.36	-0.03	-0.02	0.00	0.00	0.00	0.00	0.00
d IP3/d IP3	dBm/dBm	0.00	0.00	0.04	0.16	0.02	0.00	0.74	0.00

Enter System Parameters:

Input Power	-50	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	10	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	30.50	dB
Noise Figure =	6.15	dB
Noise Temp =	905.34	°K
SNR =	57.82	dB
MDS =	-107.82	dBm
Sensitivity =	-97.82	dBm
Noise Floor =	-167.82	dBm/Hz

Input IP3 =	-22.70	dBm
Output IP3 =	7.80	dBm
Input IM level =	-104.61	dBm
Input IM level =	-54.61	dBC
Output IM level =	-74.11	dBm
Output IM level =	-54.61	dBC
SFDR =	56.75	dB

Maar hoe meet ik het?

- We willen weten: Ruisbijdrage van de versterker

1) Signal Generator Twice-Power Methode (alleen bij grote NF)

2) Directe methode (Gain methode)

3) Y factor
   a) Handmatig
   b) Noise Figure meter

Directe methode / Gain Method

- Werkt alleen bij flinke versterking van te meten component
- Gebruik een SA met pre-amplifier met lage NF

1. Meet de gain op de operationele frequentie
2. Meet de ruisvloer met component met juiste afsluiting aan input
3. Dan volgt de NF uit de dB waardes:

$$NF = P_{NOISE\ MEASURED} + 174\ DbM/hZ - 10\log_{10}(RBW) - Gain$$

Spectrum Analyzer

You can make approximate measurement of noise figure with just a spectrum analyzer and a preamp. Using just a spectrum analyzer, a preamp and a signal generator that cover the frequency(-ies) of the device being tested. The accuracy of this technique, while not as good as the Y factor technique calling for a calibrated noise source, is about as good as the analyzer's amplitude accuracy at the frequency(-ies) of interest. Here are the steps:

1. Use the signal generator and spectrum analyzer set to the frequency you wish to measure noise figure to measure the gain of the device. Call this value Gain(D).
2. Similarly, measure the gain of the preamp. Call this value Gain(P).
3. Disconnect any input from the spectrum analyzer and set its input attenuation to 0 dB. With no connection to the preamp's input, connect its output to the spectrum analyzer's input. You should see the displayed average noise level of the analyzer increase when you make this connection.
4. Terminate the input of the device to be tested with its characteristic impedance and connect its output to the preamp's input. When you do this, the noise level displayed on the spectrum analyzer should increase.
5. Set the spectrum analyzer's video bandwidth (VBW) to be 1% or less the value for the resolution bandwidth. Press the Marker Function (MKR FCTN) key, then the Noise Marker On soft key. Position the marker to the frequency where you wish to measure noise figure. Read the marker noise power density reading in dBm/Hz and call it Noise(O).
6. The noise figure, NFig of the device under test can then be computed as: NFig = Noise(O) - Gain(D) - Gain(P) + 174 dBm/Hz

Spectrum Analyzer aandachtspunten

- Meting hangt af van detector mode: RMS, peak etc.
- Meting hangt af van middelen van meerdere metingen
- Meting hangt af van filter shape correctie
- Breedbandige ruisbron kan ingang oversturen

Note voor HP856X Spectrum Analyzers:

1. The resolution bandwidth (RBW) filter's near-Gaussian shape is corrected to a rectangular equivalent noise bandwidth (NBW) that passes the same noise power. This correction factor is 1.128 times the 3 dB bandwidth for filters > or = 1 kHz.

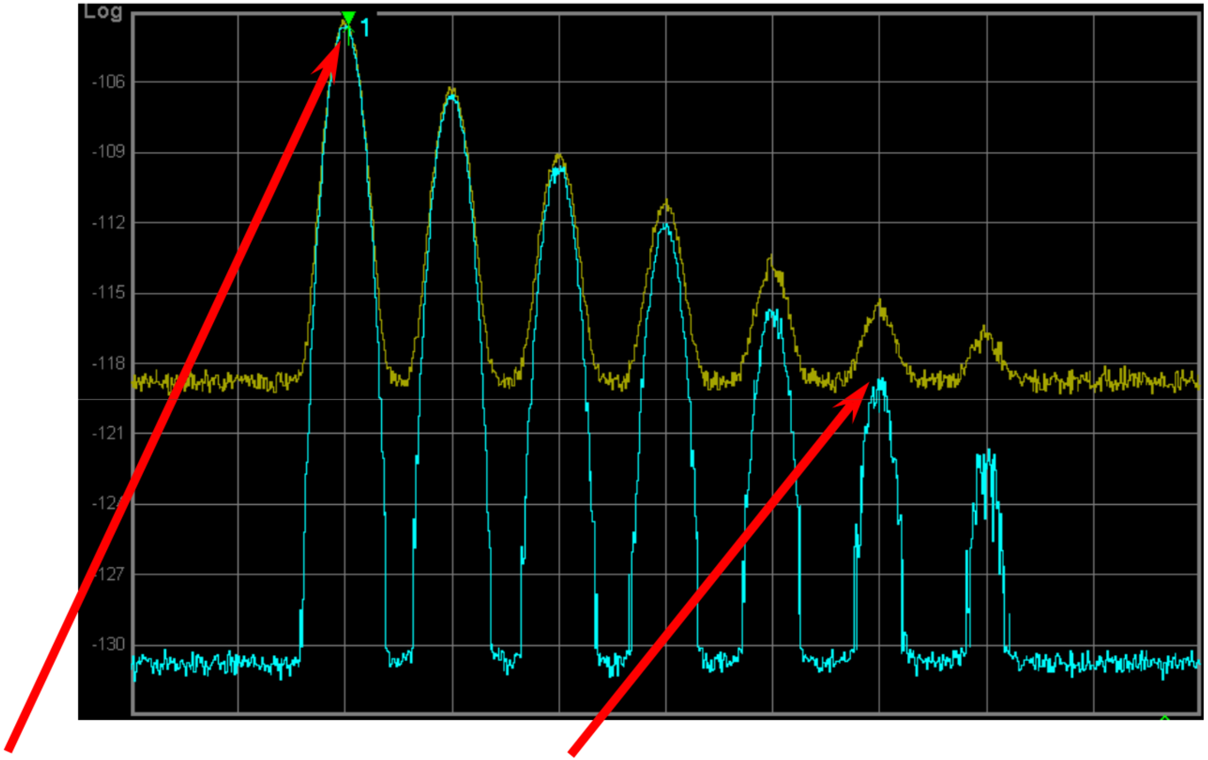
2. Errors due to averaging the log values of the data points, plus display scaling of noise signals result in a 2.51 dB under-response.

Error in Noise Level Measurements, Measured Near Analyzer Noise floor

Actual Noise Ratio	Measurement Error
0 dB	3.01 dB
1 dB	2.54 dB
3 dB	1.76 dB
5 dB	1.19 dB
10 dB	0.41 dB
15 dB	0.14 dB
20 dB	0.04 dB

Note that error is always positive

Multiple Tones Example

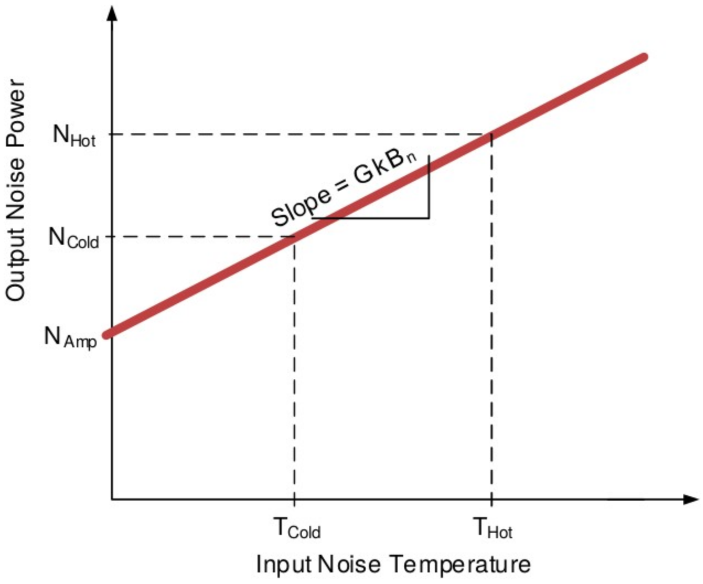


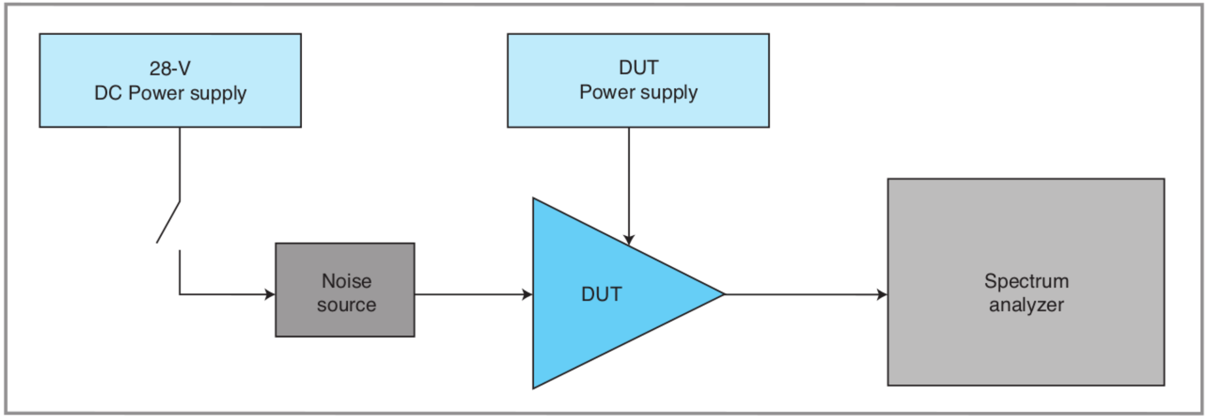
"No" error for best S/N, 3 dB for signal at analyzer DANL

Y-factor

- Afleiding met gebruik van ratio's

$$Y = \frac{P_{Hot}}{P_{Cold}}$$



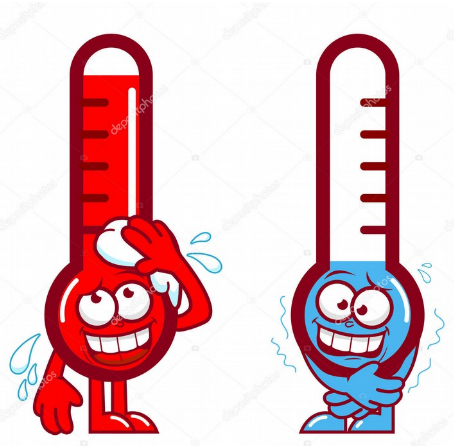


Hot / cold en Zonneruis

- Je kunt ook het heelal als “koud” gebruiken
- En de aarde als “warm”
- De zonneruis kun je gebruiken om de versterking te vinden van je antenne en ingangstrap

➔ Metingen door Sergey Zhutyaev, RW3BP

Ruistemperatuur



- Ruisvermogen P = kTB

- Ruistemperatuur T = P/kB

- Alle het ruisvermogen kan als T geschreven worden: ook bruikbaar voor antennes en heelal

Excess Noise Ratio / Noise source

$$ENR = \frac{T_{Hot} - T_{Cold}}{T_0} \qquad (5\text{-}1)$$

where

T_{Hot} noise temperature when the noise source is in the hot state (powered, on)

T_{Cold} noise temperature when the noise source is in the cold state (unpowered, off)

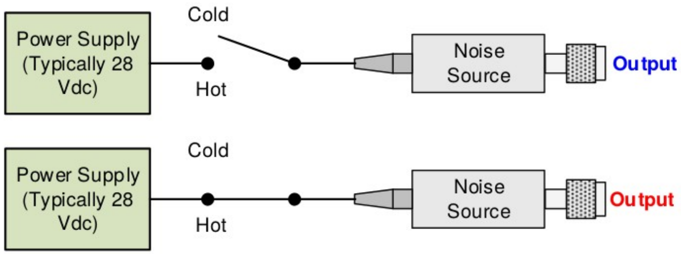


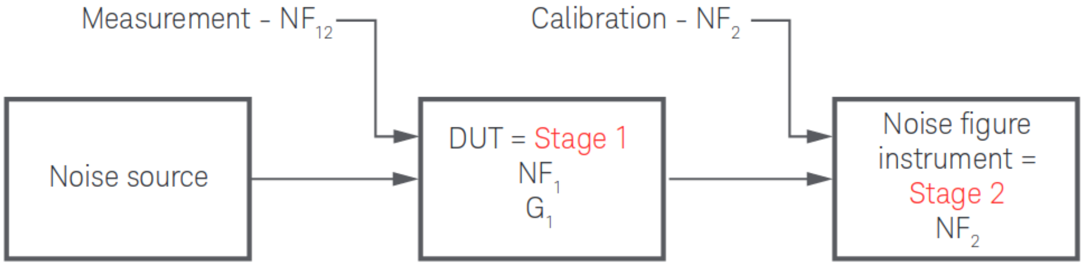
Fig. 5-2 ~ Noise source switching between cold (off) and hot (on) states

ENR normally is given as a logarithmic ratio in dB, or

$$ENR_{dB} = 10 \cdot \log\left(\frac{T_{Hot} - T_{Cold}}{T_0}\right) \qquad T_{Hot} = T_0 \cdot 10^{\left(\frac{ENR_{dB}}{10}\right)} + T_0 = T_0 \cdot \left(10^{\left(\frac{ENR_{dB}}{10}\right)} + 1\right)$$

Van Y naar NF

$$ENR = \frac{(T_S^{ON} - T_S^{OFF})}{T_0}$$



$$Y_2 = \frac{N_2^{ON}}{N_2^{OFF}} = \frac{(T_S^{ON} + T_2)}{(T_S^{OFF} + T_2)}$$

$$Y_{12} = \frac{N_{12}^{ON}}{N_{12}^{OFF}}$$

$$G_1 = \frac{(N_{12}^{ON} - N_{12}^{OFF})}{(N_2^{ON} - N_2^{OFF})}$$

or

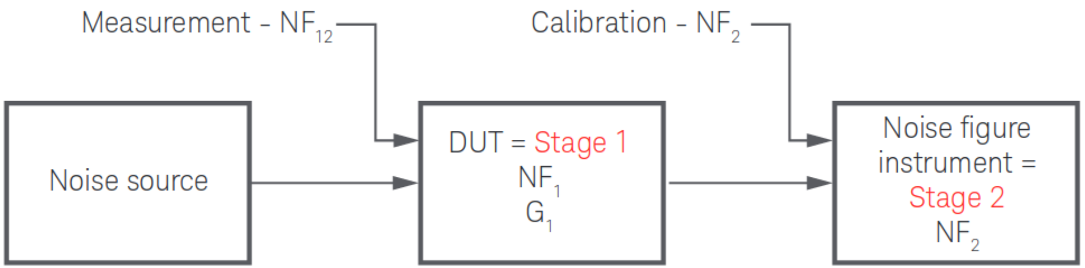
$$T_2 = \frac{(T_S^{ON} + Y_2 T_S^{OFF})}{(Y_2 - 1)}$$

$$T_{12} = \frac{(T_S^{ON} - Y_{12} T_S^{OFF})}{(Y_{12} - 1)}$$

$$T_1 = T_{12} - \frac{T_2}{G_1}$$

Van Y naar NF

$$ENR = \frac{(T_S^{ON} - T_S^{OFF})}{T_0}$$



$$Y_2 = \frac{N_2^{ON}}{N_2^{OFF}} = \frac{(T_S^{ON} + T_2)}{(T_S^{OFF} + T_2)}$$

$$Y_{12} = \frac{N_{12}^{ON}}{N_{12}^{OFF}}$$

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or

$$T_2 = \frac{(T_S^{ON} - Y_2 T_S^{OFF})}{(Y_2 - 1)}$$

$$T_{12} = \frac{(T_S^{ON} - Y_{12} T_S^{OFF})}{(Y_{12} - 1)}$$

$$T_1 = T_{12} - \frac{T_2}{G_1}$$

Van Y naar F

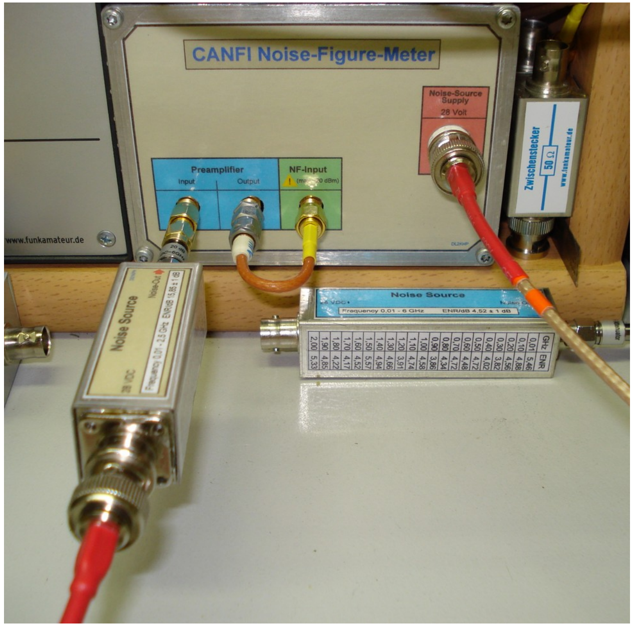
$$F_{sys} = \frac{ENR - Y\left(\frac{T_c}{T_0} - 1\right)}{Y - 1} \quad \Rightarrow \quad F_{sys} = \frac{ENR}{Y - 1}$$

- Fout in ENR is 1-op-1 een fout in F!

Fout bronnen

- mismatch tussen DUT en de rest => reflectie zorgt voor meer gemeten ruis
- T_c is niet gelijk aan T_0
- Bandbreedte meting is groter dan bandbreedte DUT
- Instraling (telt op bij de ruis)
- Oversturing meetingang bij grote versterking met sterke noise source

Noise Figure meters



HP8970B

CANFI

N8973B

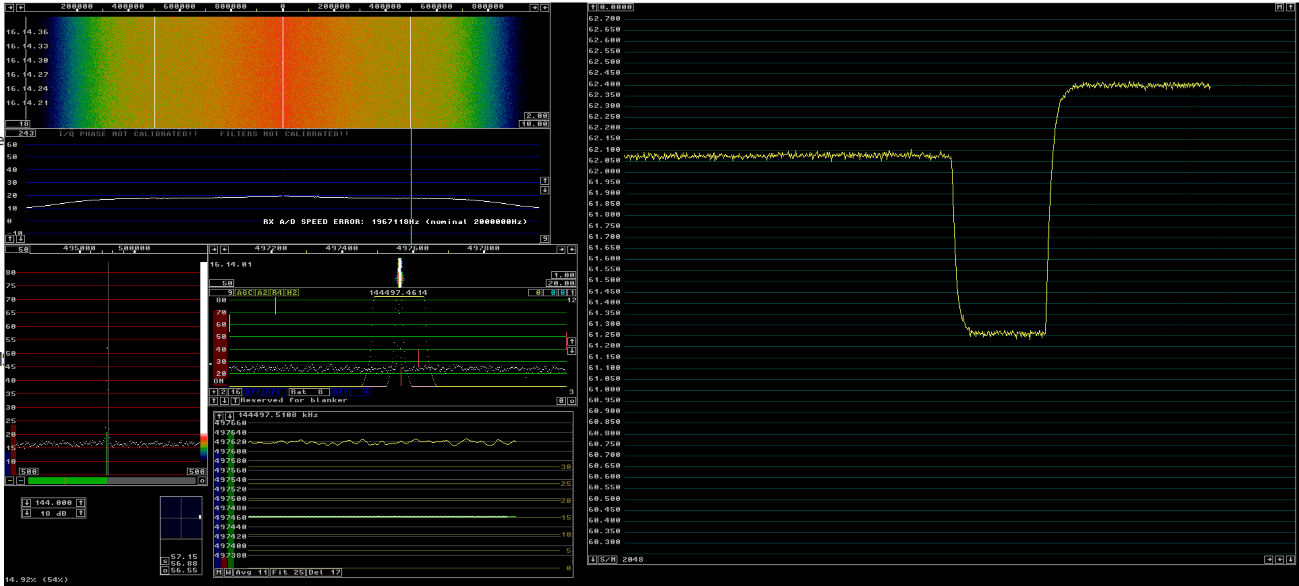
Hiermee worden de beschreven meetstappen geautomatiseerd

Linrad / SM5BSZ

- Metingen met verzwakker in ijs/ kokend water
- Zeer nauwkeurige metingen

Unit (name)	NF (dB)	$NF_{EME2012}$ (dB)	NF_{prev} (dB)	NF_{Rel} (dB)	$Diff_{2012}$ (dB)	$Diff_{prev}$ (dB)	$Diff_{Re}$ (dB)
ATF33143negimp	0.155	0.19	0.180	0.171	-0.035	-0.025	-0.016
FHX05FA/LG	0.184	0.24	0.195	0.206	-0.056	-0.011	-0.022
MGF1425	0.217	0.24	0.271	0.232	-0.023	-0.054	-0.015
ATF33143	0.217	0.21	0.188	0.237	0.007	0.029	-0.020
MGF1801	0.256	0.25	0.267	0.270	0.006	-0.011	-0.014
2xATF33143	0.276	0.28	0.302	0.293	-0.004	-0.026	-0.017
MGF1425old	0.479	0.51	0.567	0.523	-0.031	-0.088	-0.044
Average					-0.019	-0.027	-0.021

RM



Referenties

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  http://www.reeve.com/Documents/Noise/
- Noise Figure 101 (Circuit Cellar 249, 2011)
  https://pdfslide.net/documents/circuit-cellar-no-249.html
- CANFI
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- Precision measurements of Noise Figure
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  http://molphys.leidenuniv.nl/~exter/SVR/svr6.ppt
- Conquering Noise for Accurate RF and Microwave Signal Measurements
  http://anlage.umd.edu/conquering_noise_for_accurate_signal_measurements.pdf
- 1296MHz small EME station with good capability (RW3BP)
  http://www.vhfdx.ru/apparatura/accurate_noise_figure_measurements_1296_mhz