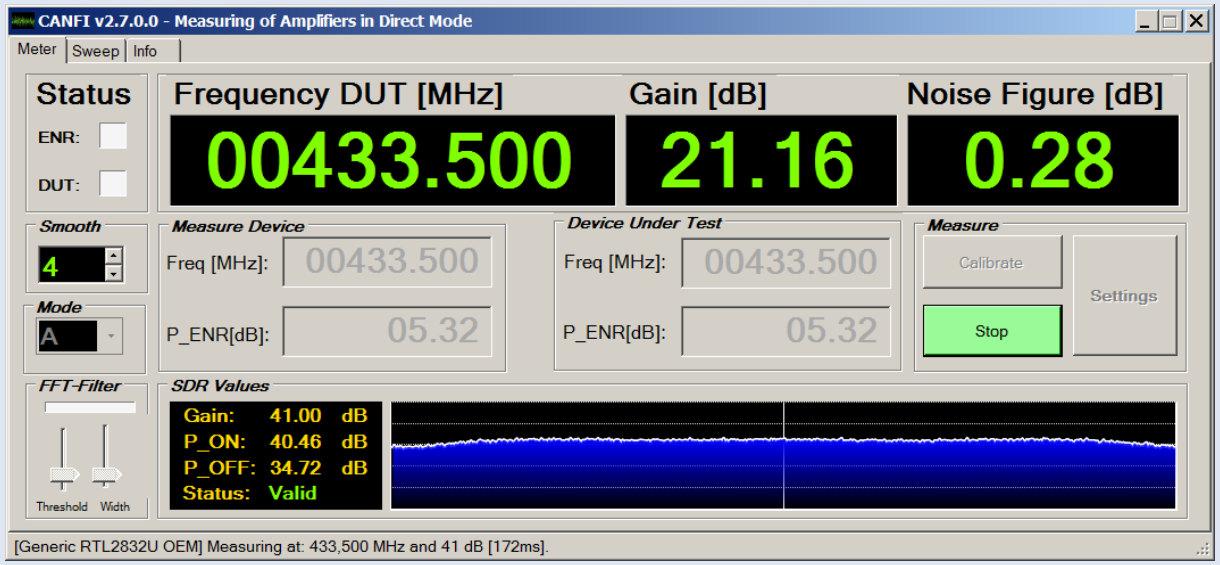
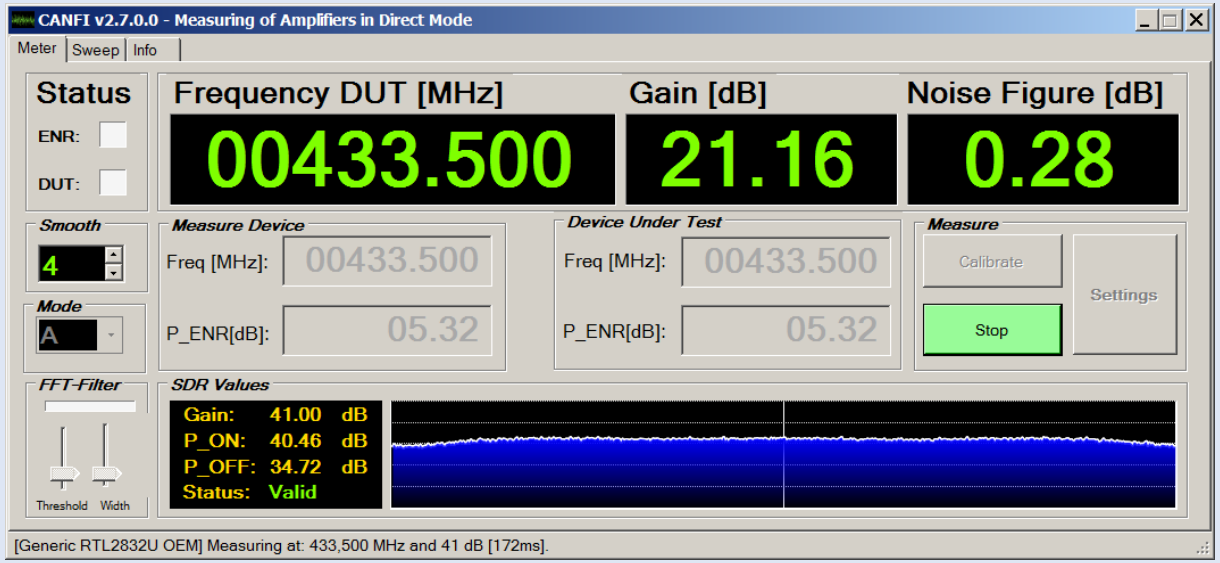
Small Noise Figures Measurement and CANFI



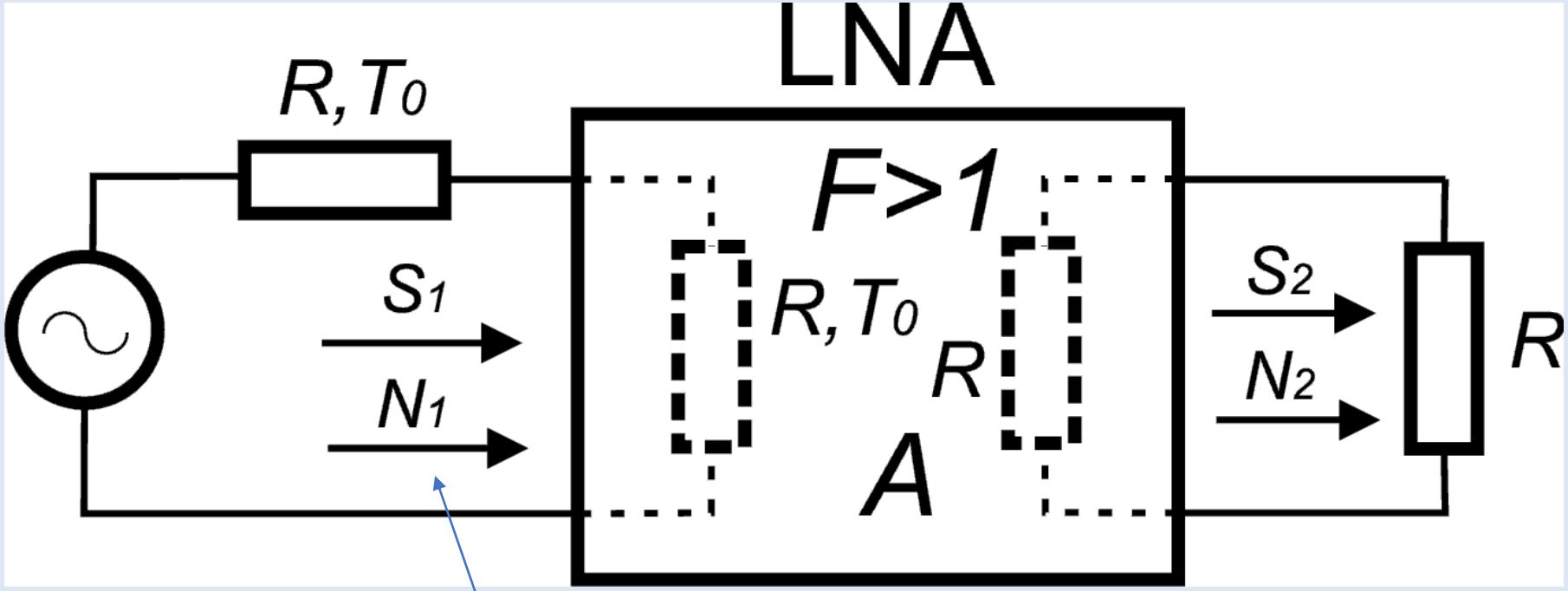
Mirek Kasal, OK2AQ

Měření malých šumových čísel a levný automatický indikátor šumového čísla



Mirek Kasal, OK2AQ

Šumový činitel ***F*** a šumové číslo ***F*[dB]**



$\boldsymbol{R = 50\ \Omega}$

$$\boldsymbol{F} = \frac{S_1/N_1}{S_2/N_2}$$

S_1

$S_2 = S_1.\mathrm{A}$

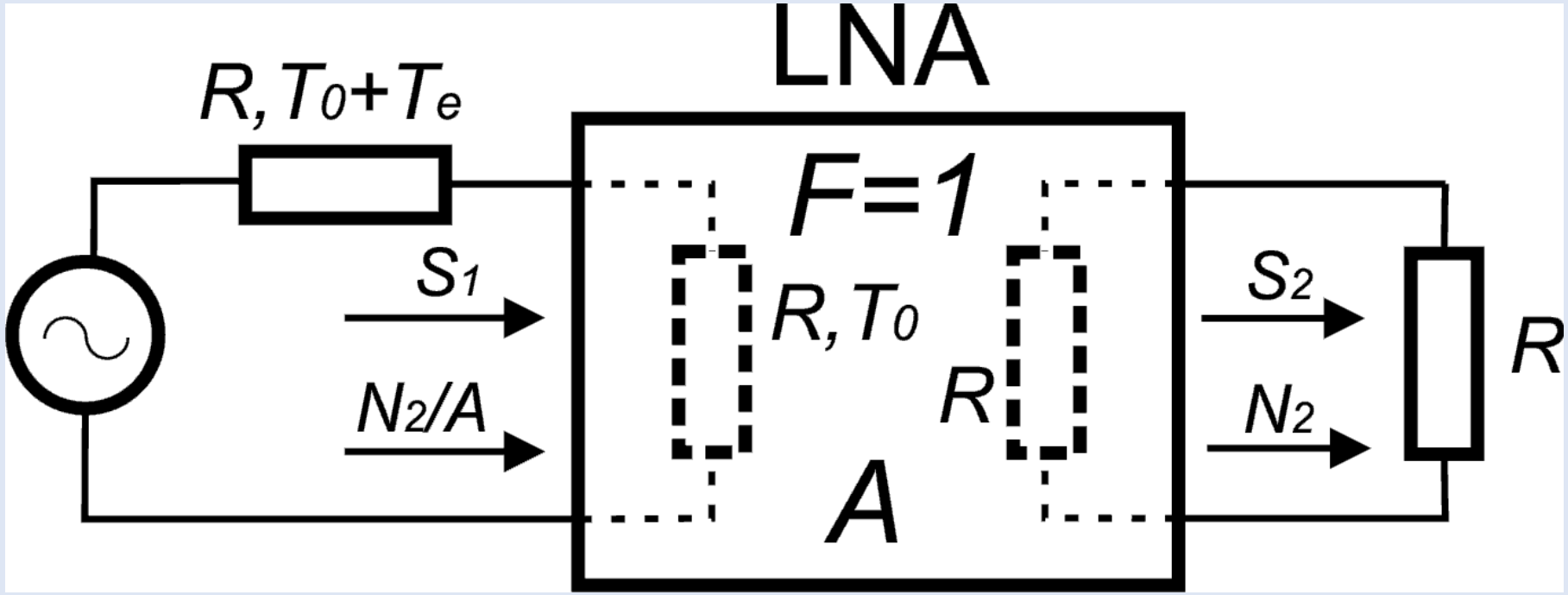
$N_1 = k.T_0.B_n$

$N_2 = k.T_0.B_n.A.\boldsymbol{F}$

$\boldsymbol{T_0 = 290\ \mathrm{K}}$

$\boldsymbol{F}[\mathbf{dB}] = 10.\log F$

Ekvivalentní šumová teplota T_e



$$N_2 = k.T_0.B_n.A.\boldsymbol{F} = (k.T_0.B_n + k.T_e.B_n)A$$

$$F = \frac{T_0 + T_e}{T_0} \qquad T_e = T_0(F-1) \qquad T_0 = 290\ \mathrm{K}$$

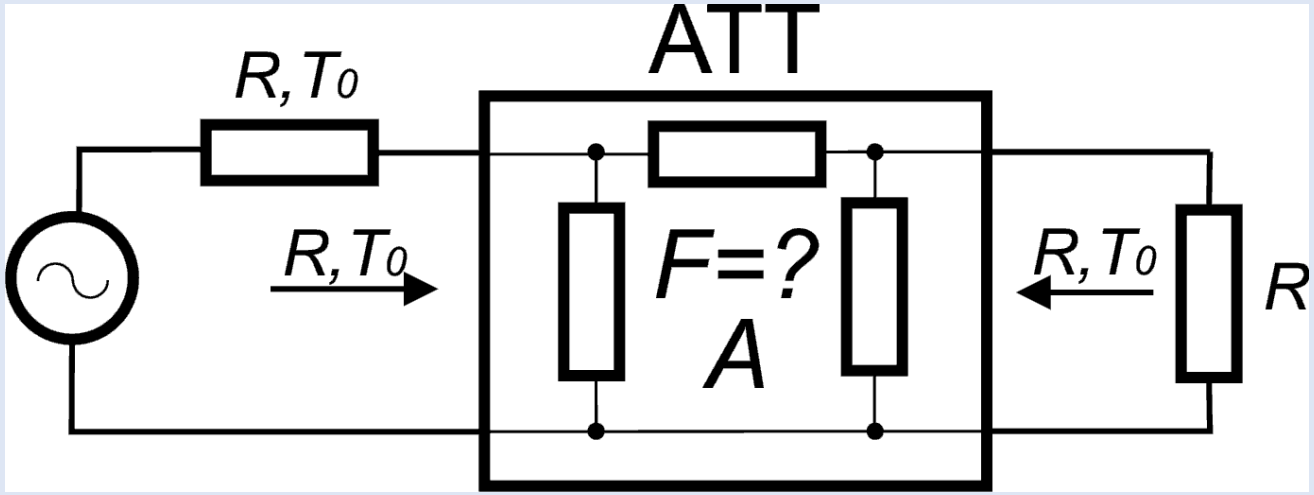
(17° C)

Kaskádní řazení výkonově přizpůsobených dvojbranů

$$F = F_1 + \frac{F_2 - 1}{A_1} + \frac{F_3 - 1}{A_1 A_2} + \cdots + \frac{F_n - 1}{A_1 A_2 \ldots A_{n-1}}$$

$$T_e = T_{e1} + \frac{T_{e2}}{A_1} + \frac{T_{e3}}{A_1 A_2} + \cdots + \frac{T_{en}}{A_1 A_2 \ldots A_{n-1}} \quad . \quad [\mathrm{K}]$$

ATENUÁTOR $F = \dfrac{S_1/N_1}{S_2/N_2} = \dfrac{1}{A}$



S_1

$S_2 = S_1.\mathrm{A}$

$N_1 = k.T_0.B_n$

$N_2 = k.T_0.B_n$

$T_e = T_0(1/A - 1)$

ÚTLUM

$L = 10\log(1/A)$

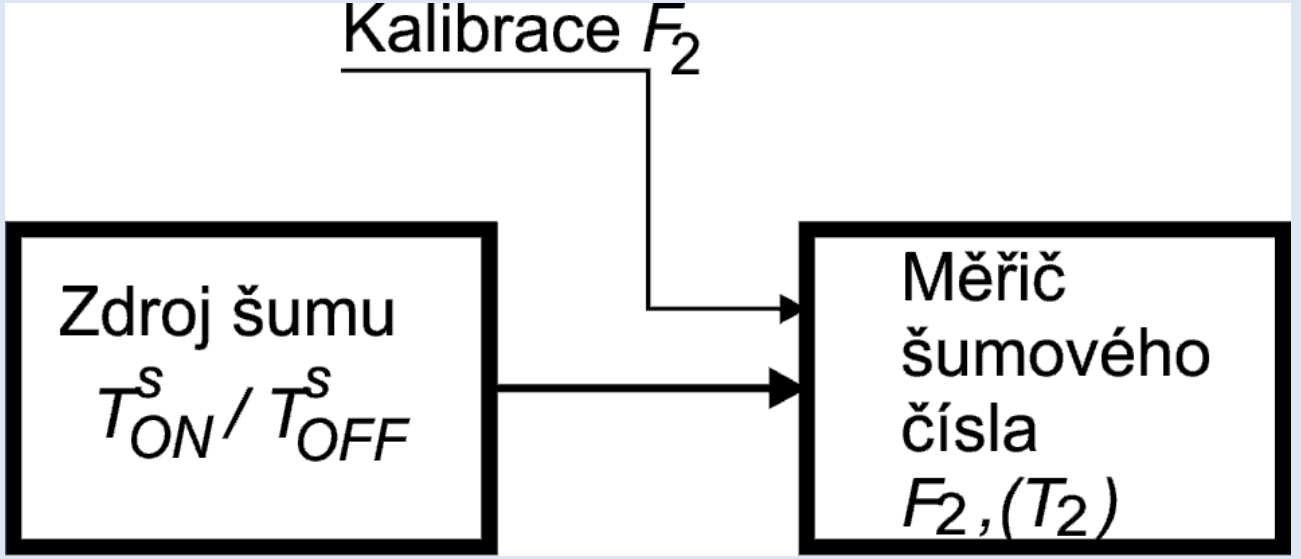
Kalibrace a měření šumového čísla

$$ENR = \frac{T^S_{ON} - T^S_{OFF}}{T_0} \quad [\mathrm{K}] \qquad T_0 = 290\ \mathrm{K}$$

ENR - Excess Noise Ratio

$$ENR[\mathrm{dB}] = 10.\log\left[\frac{T^S_{ON} - T^S_{OFF}}{T_0}\right]$$

KALIBRACE

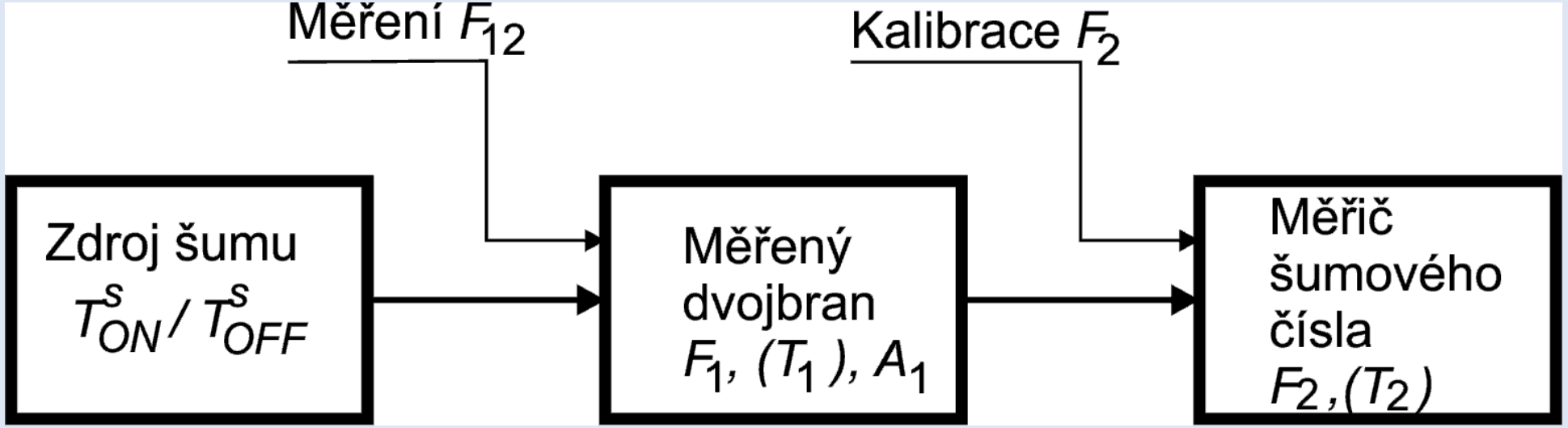


$$\mathbf{Y}=\frac{T_{2ON}}{T_{2OFF}}=\frac{T_{ON}^{S}+T_2}{T_{OFF}^{S}+T_2}$$

$$T_2=\frac{T_{ON}^{S}-Y_2T_{OFF}^{S}}{Y_2-1}$$

$$F_2 \overset{T_{OFF}^{S}=T_0}{=} \frac{ENR}{Y_2-1}$$

Měření *F*



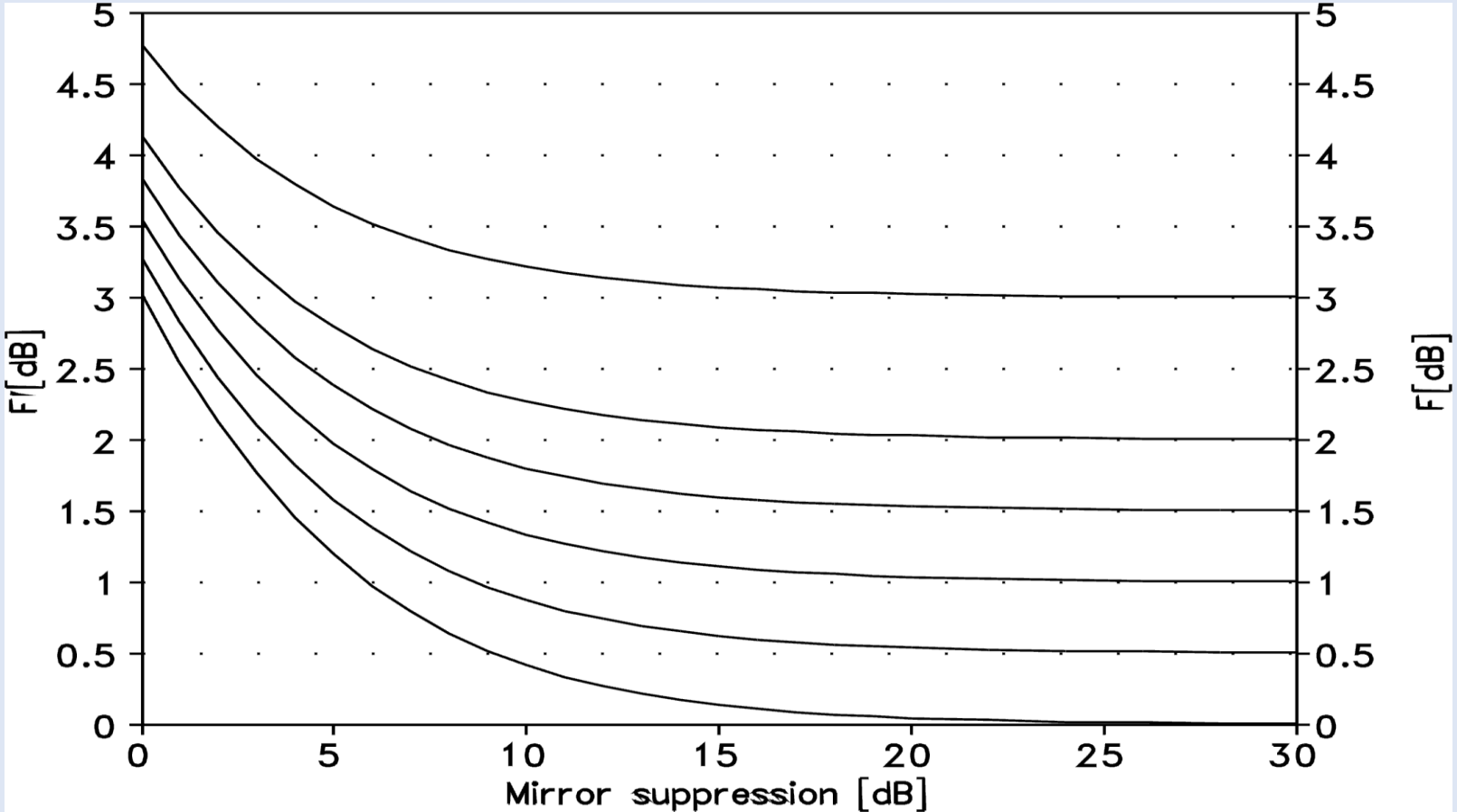
$$Y_{12} = \frac{T_{12ON}}{T_{12OFF}} \qquad T_{12} = \frac{T_{ON}^{S} - Y_{12}T_{OFF}^{S}}{Y_{12} - 1} \qquad F_{12} \overset{T_{OFF}^{S} = T_0}{=} \frac{ENR}{Y_{12} - 1}$$

$$A_1 = \frac{N_{12ON} - N_{12OFF}}{N_{2ON} - N_{2OFF}} \qquad T_1 = T_{12} - \frac{T_2}{A_1} \qquad F_1 = 1 - \frac{T_1}{290}$$

$$\boldsymbol{A_1[\mathrm{dB}]} = 10.\log A_1 \qquad \boldsymbol{F_1[\mathrm{dB}]} = 10.\log F_1$$

Chyby měření

- Impedanční nepřizpůsobení
- ENR co nejmenší, přijímač musí být lineární
- Kvalitní přechodky na vstupu DUT, pokud jsou potřeba
- Co největší šířka pásma (obvykle 3 – 4 MHz), kratší doba nutná pro averaging
- Pro DUT se směšovačem měření SSB/DSB:
- $T_A \neq T_0$



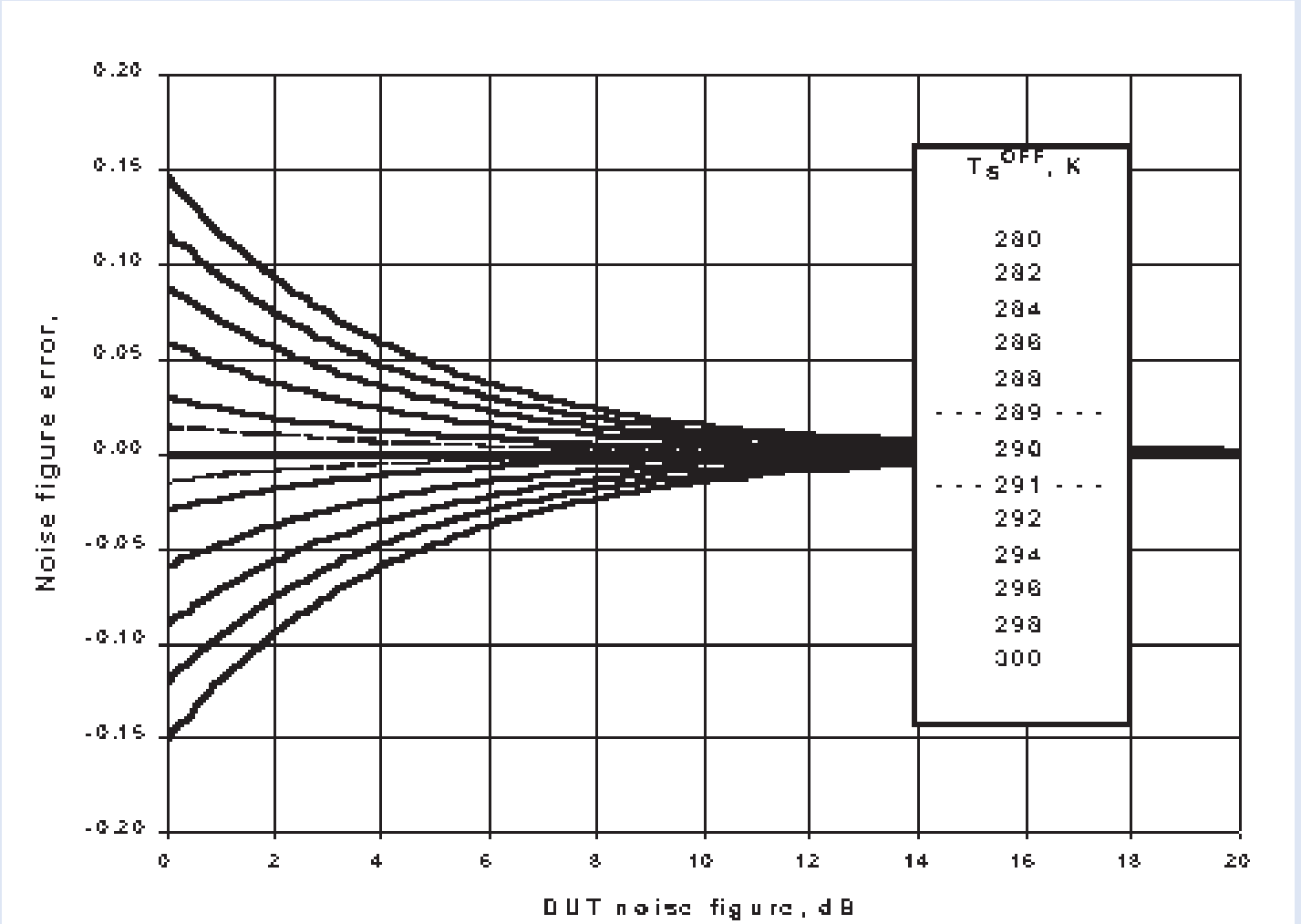
– $T_0 \neq 290$ K

Je-li teplota okolí T_A : $ENR' = \frac{T_0}{T_A} ENR$; $ENR'[\mathrm{dB}] = 10 \log \frac{T_0}{T_A} + ENR[\mathrm{dB}]$

$$F'_{12} = \frac{ENR}{Y_{12}-1} + 1 - \frac{T_A}{T_0}$$

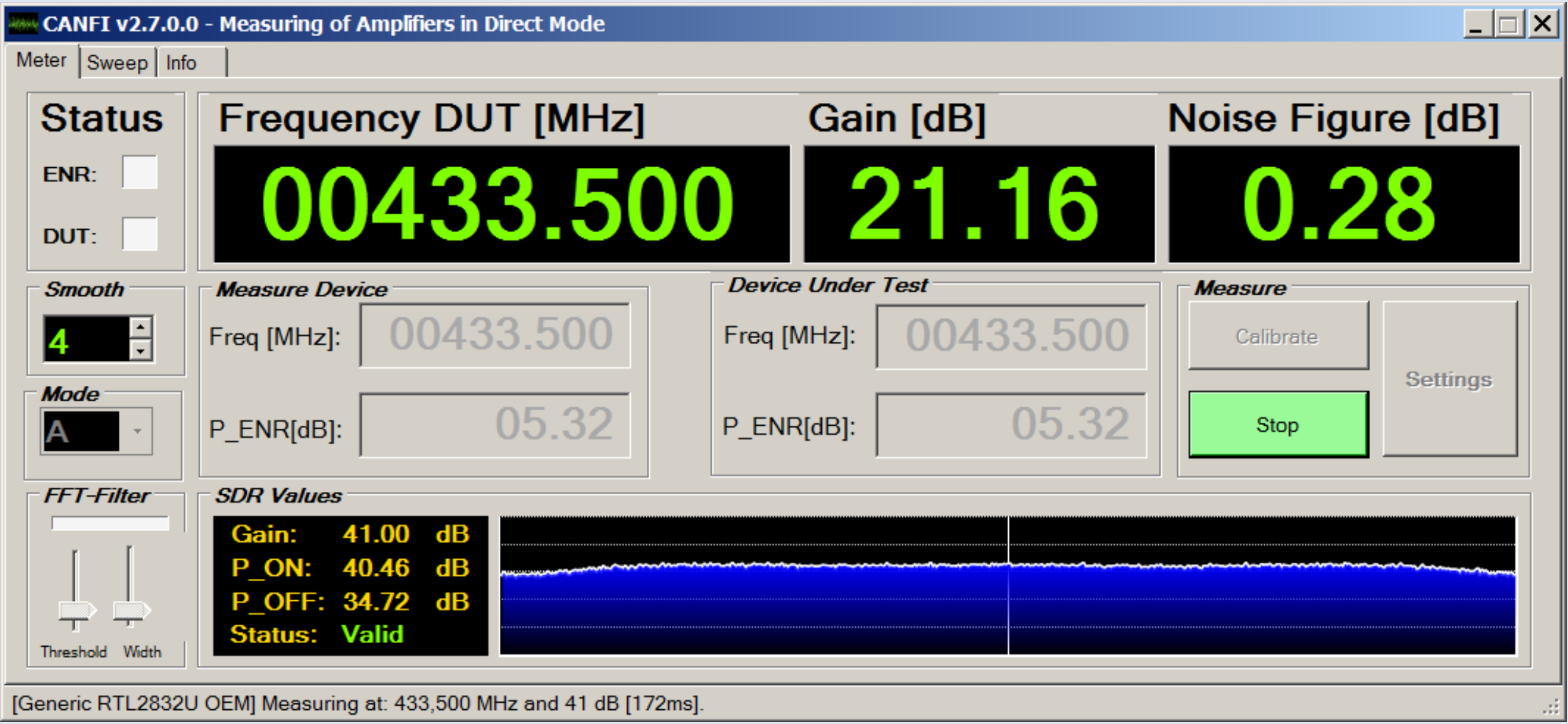
a s kalibrací

$$F'_1 = F'_{12} - \frac{F_2 - \frac{T_A}{T_0}}{A_1}$$



	HLAVA			**DUT**			RX	
ENR	4	6 dB	F_1	1,26	1 dB	F_2	2	3 dB
T_0	290 K		T_1	75,4 K		Y_2	3	
T_{ON}^s	1450 K		A_1	40	16 dB	T_2	290 K	
T_{OFF}^s	290 K							
			Y_{12}	4,11				
		$T_A = T_0 = 290$ K	T_{12}	82,65 K				
			F_{12}	1,285	1,09 dB			
			F_{12}'	1,25				
		$T_A = 300$ K	F_1'	1,226	0,885 dB			

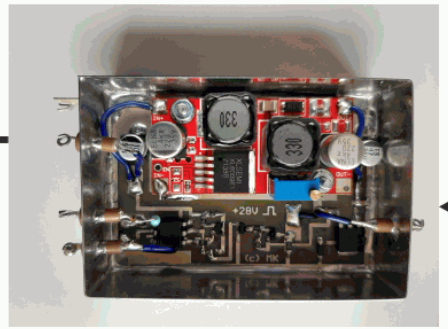
CANFI



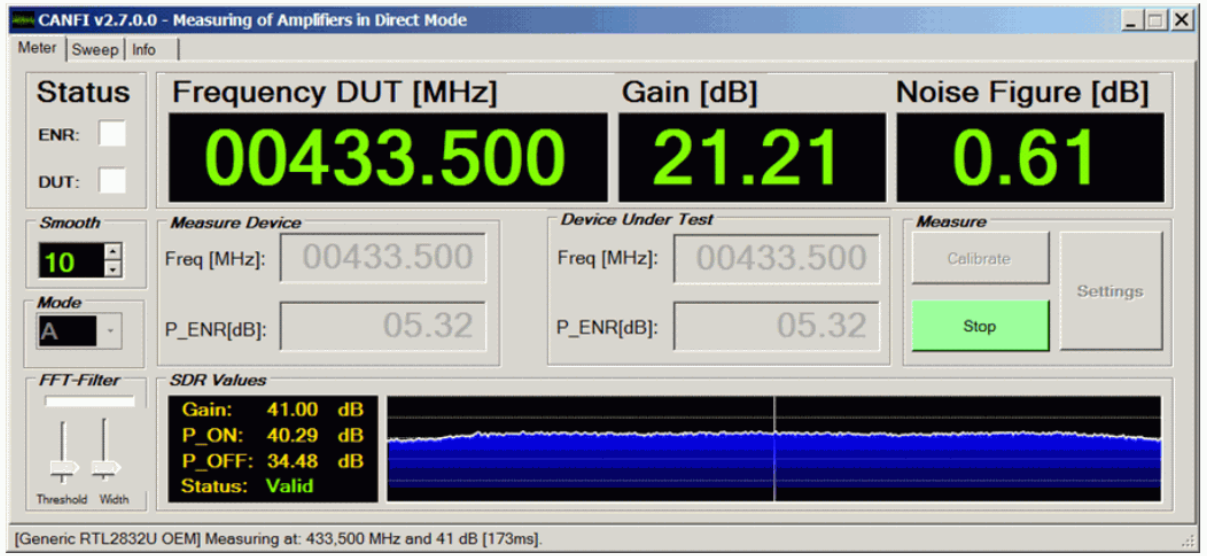
CANFI

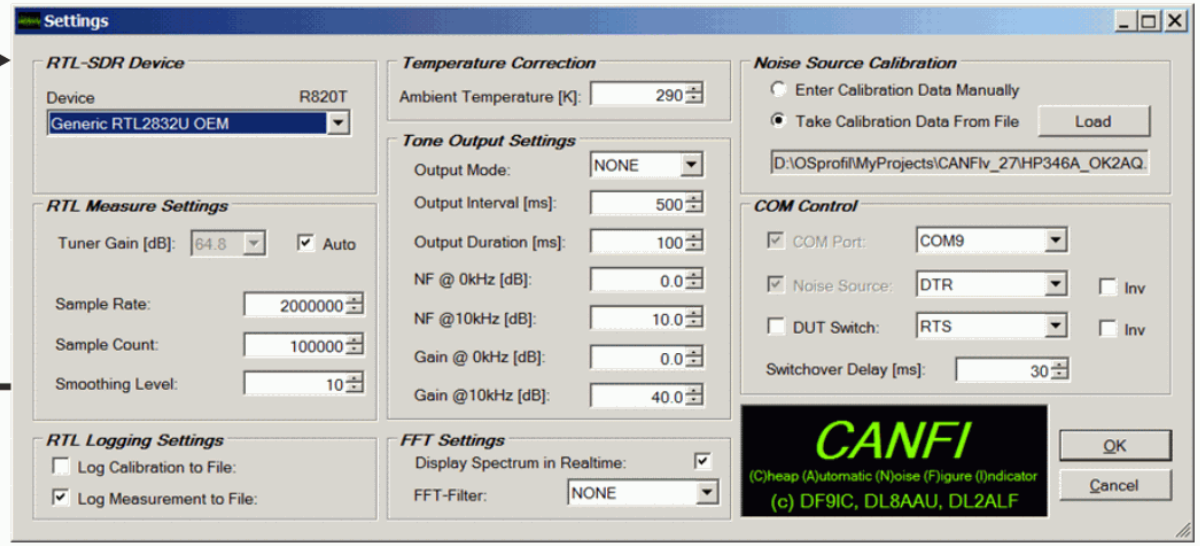
28 V

LNA +
Přijímač SDR
$F_2,(T_2)$



2 x USB





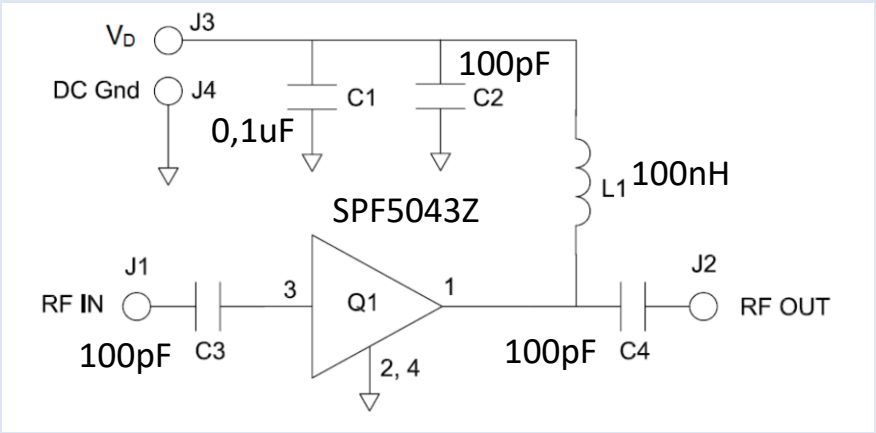
CANFI - Hardware

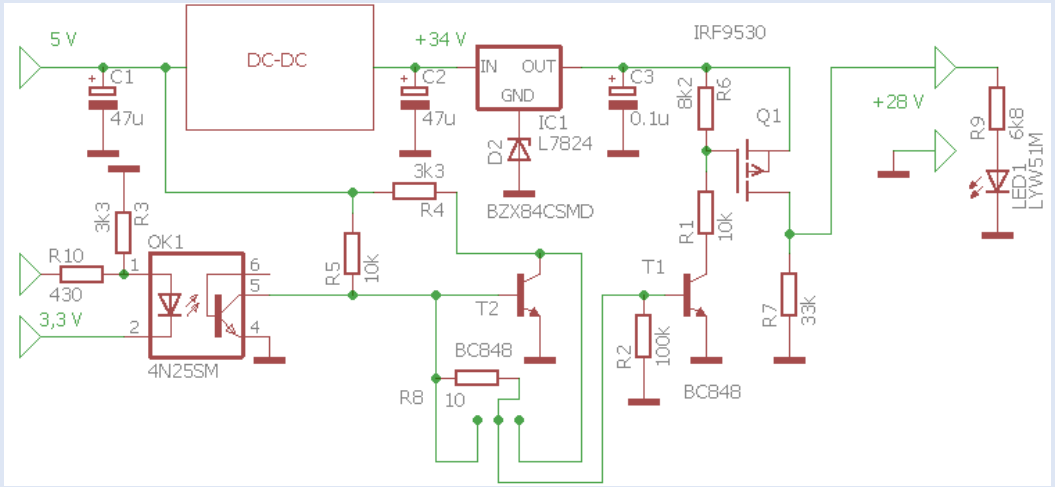
+28 V pulse

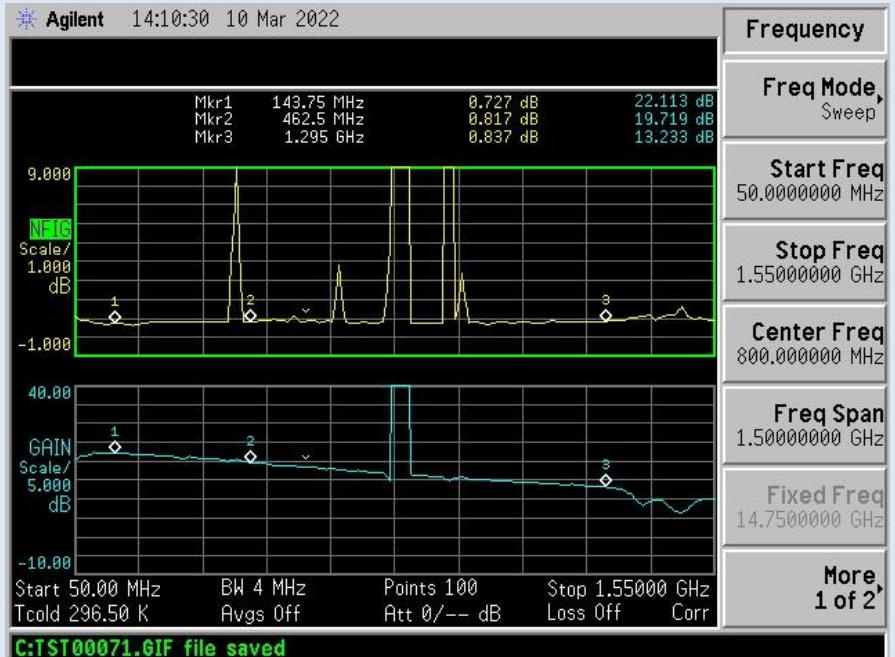
LNA SPF5043


330
330
ELNA 4kz 220 35v
XLSEMI XL6009E1 7138R
EN
IN-
OUT-
+28V
(c) MK

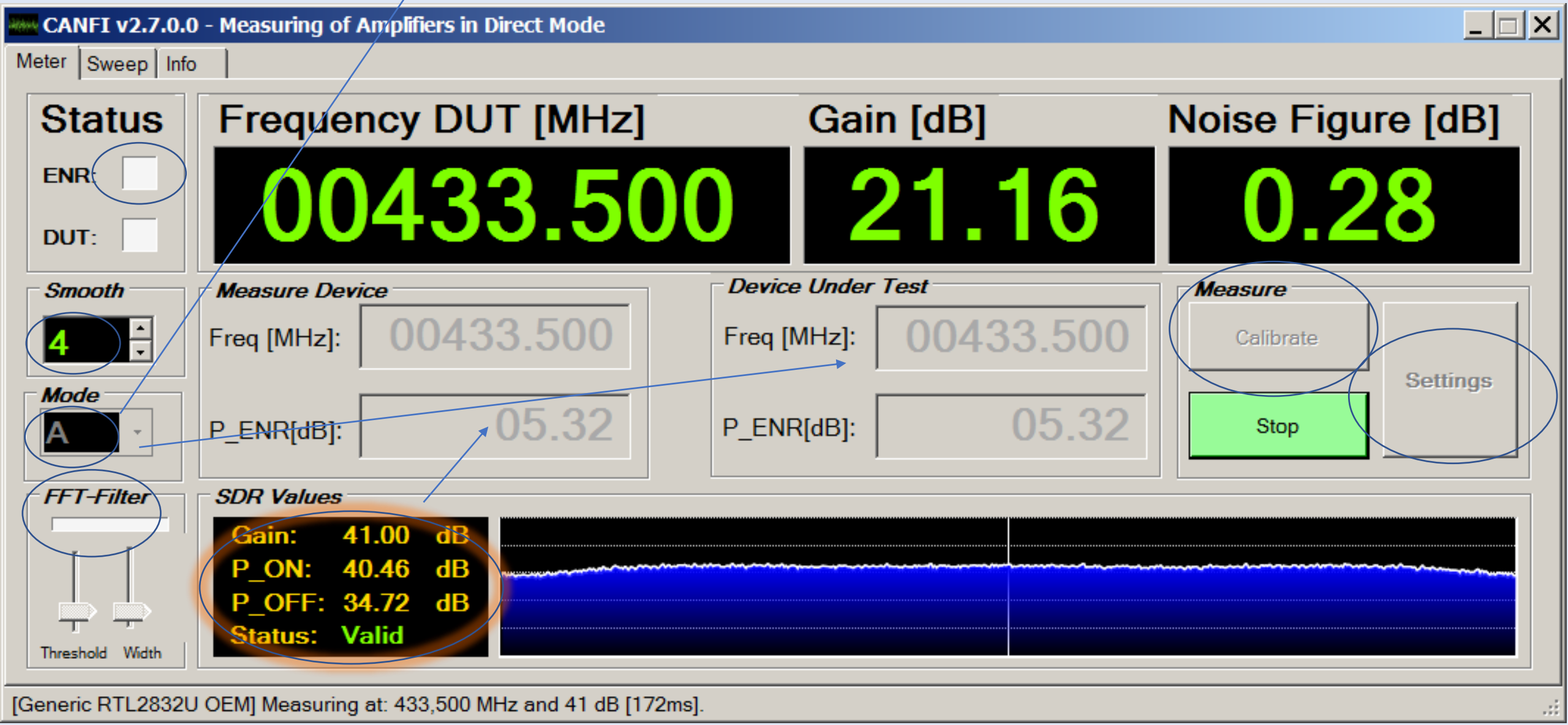

BB AMP (c) MK

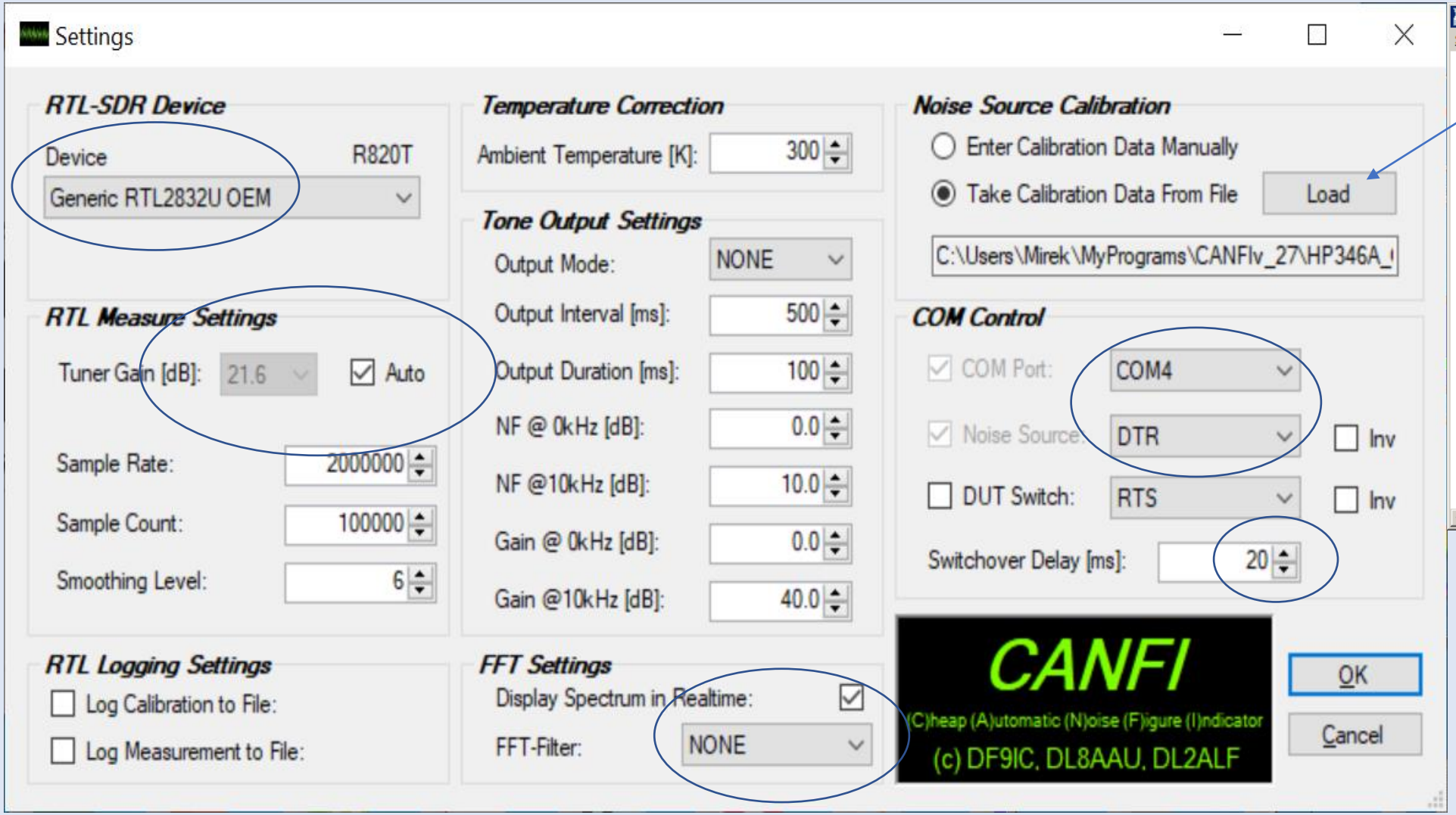

VD
J3
DC Gnd
J4
C1
0,1uF
100pF
C2
L1 100nH
SPF5043Z
J1
RF IN
3
Q1
1
J2
RF OUT
100pF
C3
2, 4
100pF
C4

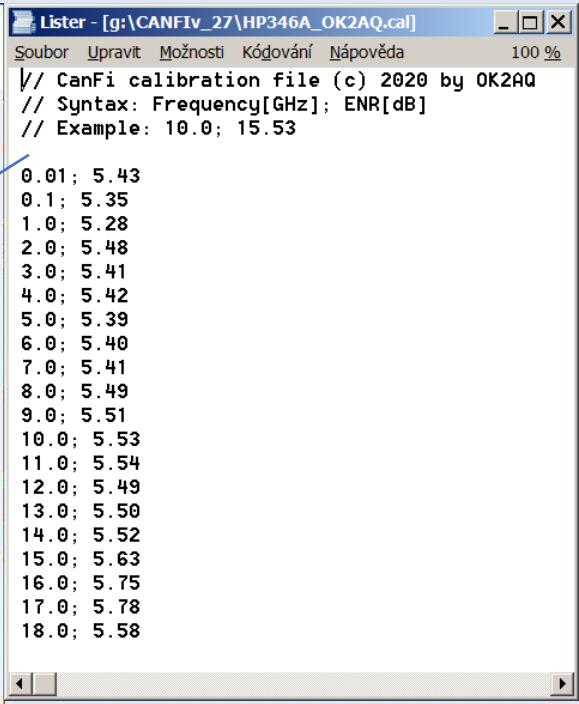

5 V
DC-DC
+34 V
IN
OUT
GND
IC1
L7824
C1
47u
C2
47u
C3
0.1u
IRF9530
R6
8k2
Q1
+28 V
R9
6k8
LED1
LYW51M
D2
BZX84CSMD
3k3
R4
3k3
R3
R10
430
OK1
4N25SM
3,3 V
R5
10k
R1
10k
T1
T2
BC848
R8
10
R2
100k
BC848
R7
33k

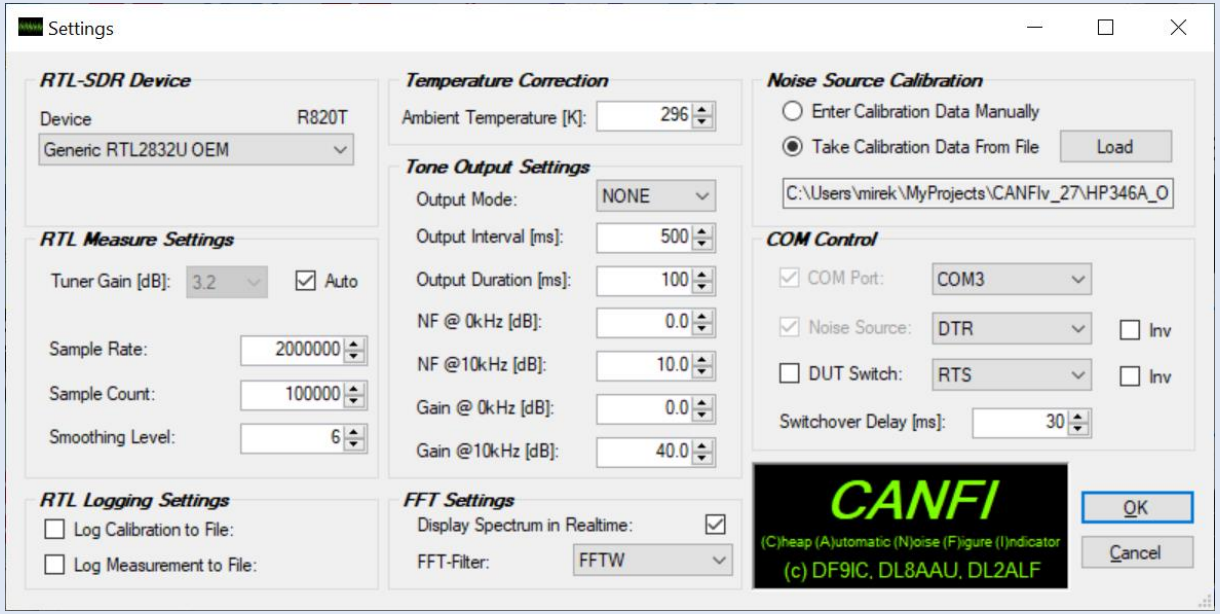

Agilent 14:10:30 10 Mar 2022
Mkr1 143.75 MHz 0.727 dB 22.113 dB
Mkr2 462.5 MHz 0.817 dB 19.719 dB
Mkr3 1.295 GHz 0.837 dB 13.233 dB
9.000
NFIG
Scale/
1.000
dB
-1.000
40.00
GAIN
Scale/
5.000
dB
-10.00
Start 50.00 MHz
Tcold 296.50 K
BW 4 MHz
Avgs Off
Points 100
Att 0/-- dB
Stop 1.55000 GHz
Loss Off
Corr
C:TST00071.GIF file saved
Frequency
Freq Mode
Sweep
Start Freq
50.0000000 MHz
Stop Freq
1.55000000 GHz
Center Freq
800.000000 MHz
Freq Span
1.50000000 GHz
Fixed Freq
14.7500000 GHz
More
1 of 2

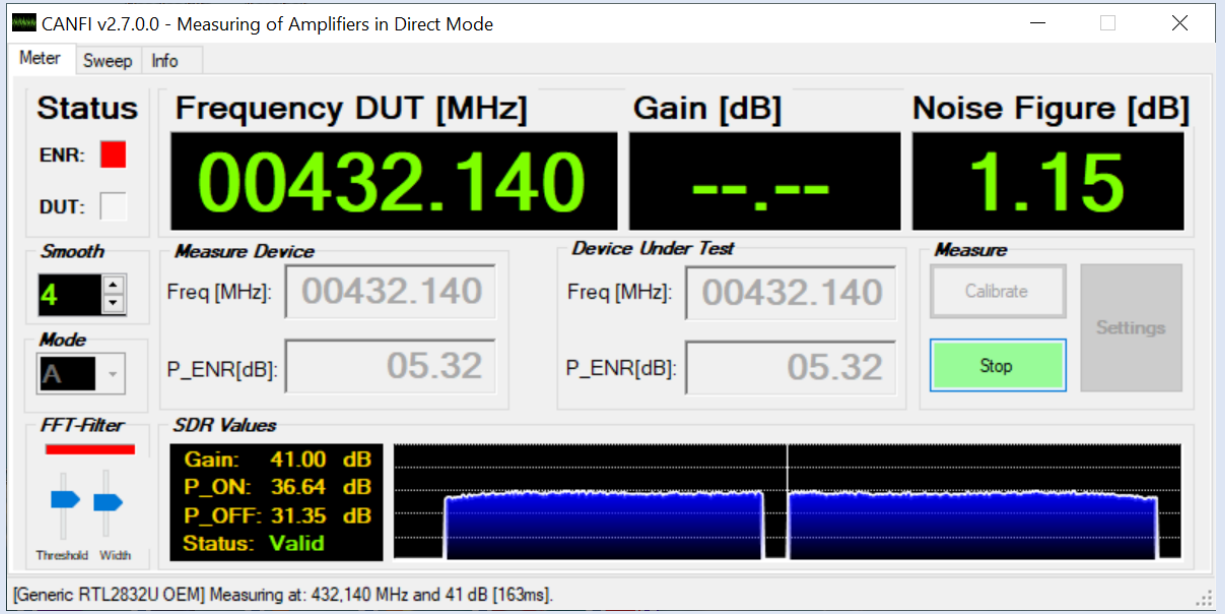
Mode: A – LNA; B – konvertor; C – LNA s konvertorem

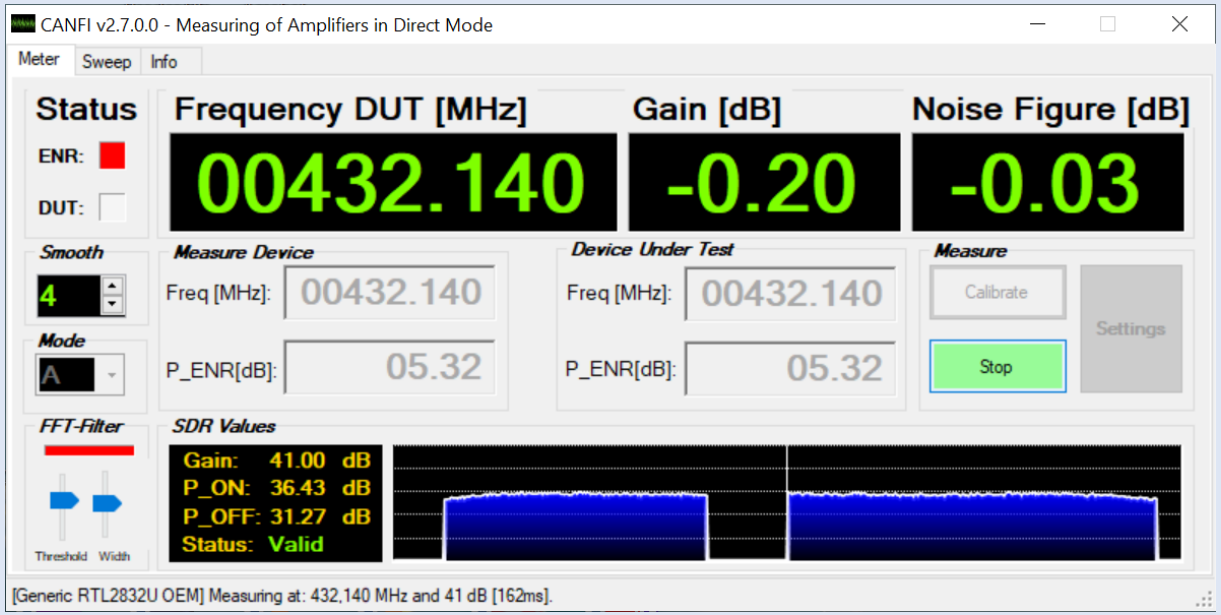


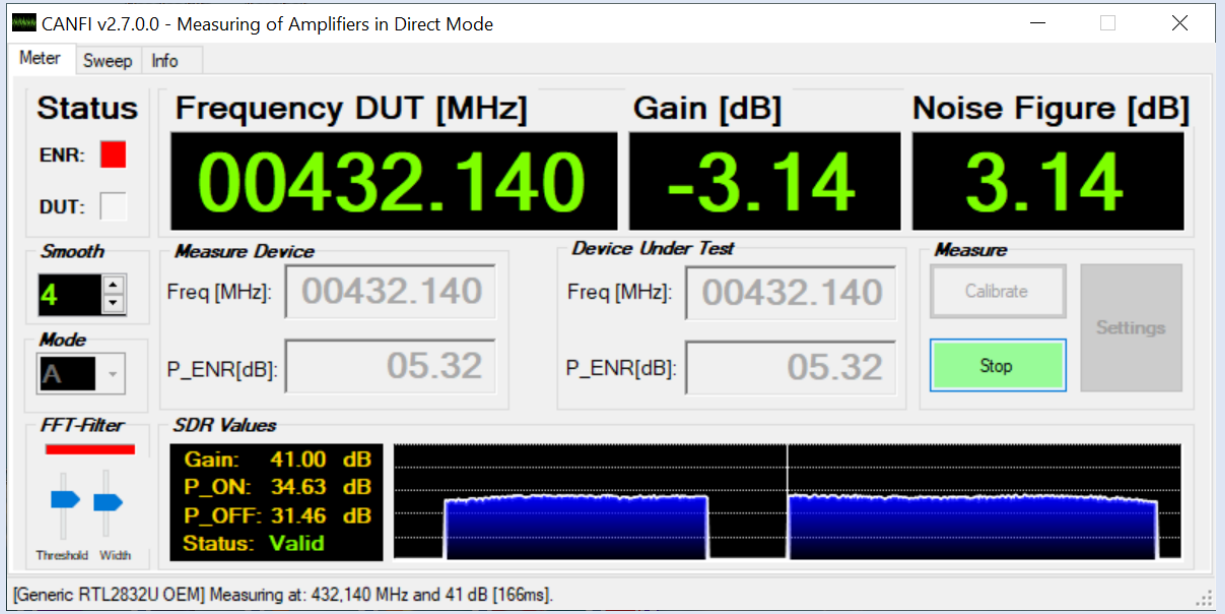

Settings
RTL-SDR Device
Device
R820T
Generic RTL2832U OEM
RTL Measure Settings
Tuner Gain [dB]:
21.6
Auto
Sample Rate:
2000000
Sample Count:
100000
Smoothing Level:
6
RTL Logging Settings
Log Calibration to File:
Log Measurement to File:
Temperature Correction
Ambient Temperature [K]:
300
Tone Output Settings
Output Mode:
NONE
Output Interval [ms]:
500
Output Duration [ms]:
100
NF @ 0kHz [dB]:
0.0
NF @10kHz [dB]:
10.0
Gain @ 0kHz [dB]:
0.0
Gain @10kHz [dB]:
40.0
FFT Settings
Display Spectrum in Realtime:
FFT-Filter:
NONE
Noise Source Calibration
Enter Calibration Data Manually
Take Calibration Data From File
Load
C:\Users\Mirek\MyPrograms\CANFIv_27\HP346A_
COM Control
COM Port:
COM4
Noise Source:
DTR
Inv
DUT Switch:
RTS
Inv
Switchover Delay [ms]:
20
CANFI
(C)heap (A)utomatic (N)oise (F)igure (I)ndicator
(c) DF9IC, DL8AAU, DL2ALF
OK
Cancel

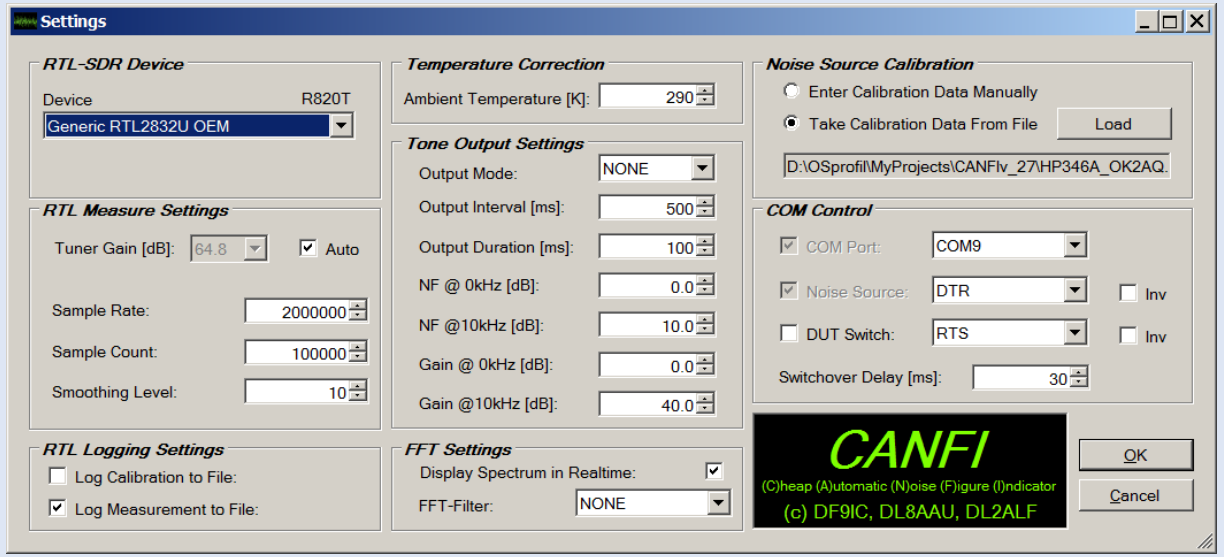

Lister - [g:\CANFIv_27\HP346A_OK2AQ.cal]
Soubor Upravit Možnosti Kódování Nápověda 100 %
// CanFi calibration file (c) 2020 by OK2AQ
// Syntax: Frequency[GHz]; ENR[dB]
// Example: 10.0; 15.53
0.01; 5.43
0.1; 5.35
1.0; 5.28
2.0; 5.48
3.0; 5.41
4.0; 5.42
5.0; 5.39
6.0; 5.40
7.0; 5.41
8.0; 5.49
9.0; 5.51
10.0; 5.53
11.0; 5.54
12.0; 5.49
13.0; 5.50
14.0; 5.52
15.0; 5.63
16.0; 5.75
17.0; 5.78
18.0; 5.58

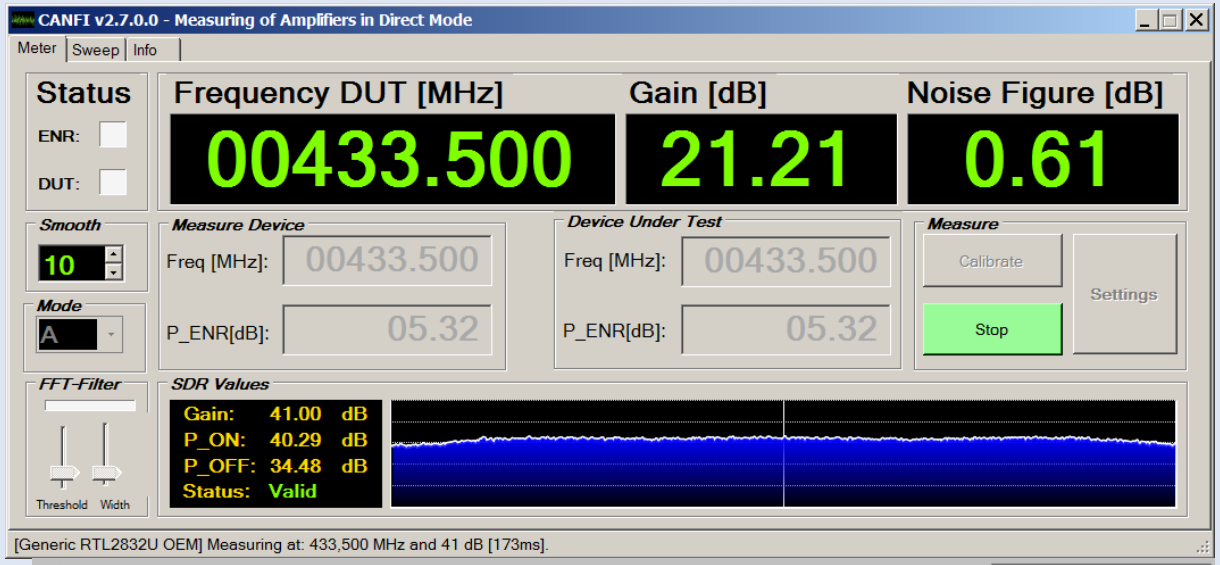

Settings
RTL-SDR Device
Device
R820T
Generic RTL2832U OEM
RTL Measure Settings
Tuner Gain [dB]:
3.2
Auto
Sample Rate:
2000000
Sample Count:
100000
Smoothing Level:
6
RTL Logging Settings
Log Calibration to File:
Log Measurement to File:
Temperature Correction
Ambient Temperature [K]:
296
Tone Output Settings
Output Mode:
NONE
Output Interval [ms]:
500
Output Duration [ms]:
100
NF @ 0kHz [dB]:
0.0
NF @10kHz [dB]:
10.0
Gain @ 0kHz [dB]:
0.0
Gain @10kHz [dB]:
40.0
FFT Settings
Display Spectrum in Realtime:
FFT-Filter:
FFTW
Noise Source Calibration
Enter Calibration Data Manually
Take Calibration Data From File
Load
C:\Users\mirek\MyProjects\CANFIv_27\HP346A_O
COM Control
COM Port:
COM3
Noise Source:
DTR
Inv
DUT Switch:
RTS
Inv
Switchover Delay [ms]:
30
CANFI
(C)heap (A)utomatic (N)oise (F)igure (I)ndicator
(c) DF9IC, DL8AAU, DL2ALF
OK
Cancel

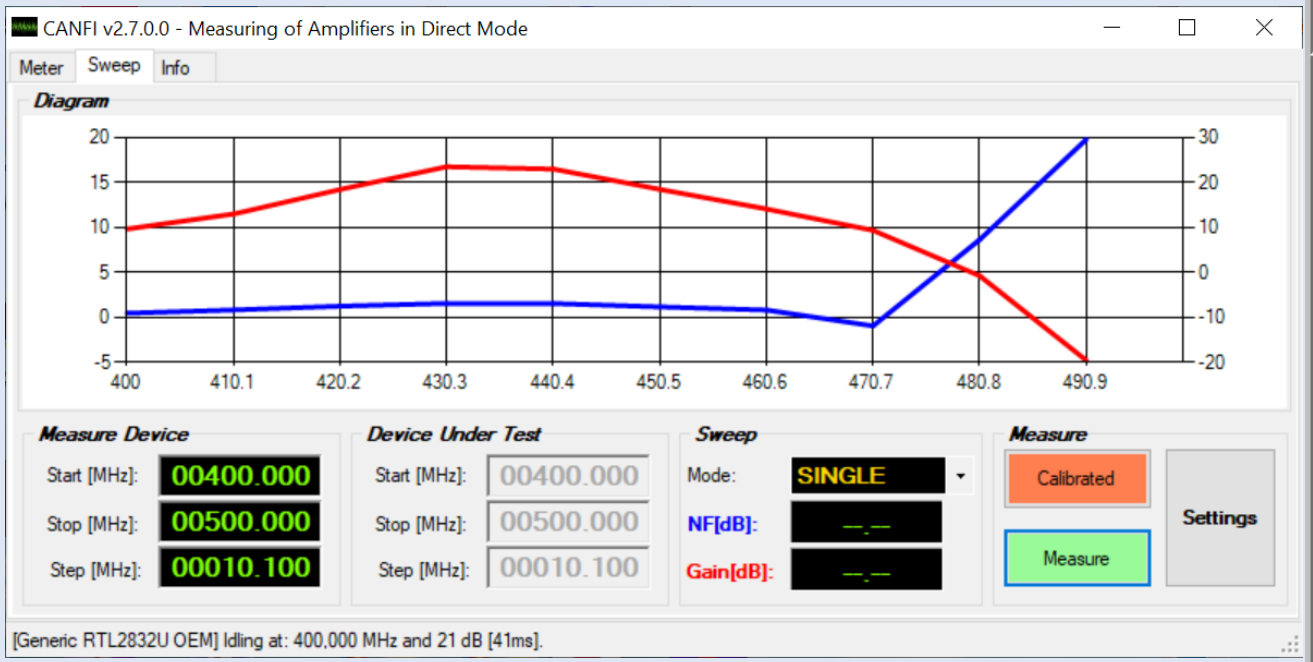

CANFI v2.7.0.0 - Measuring of Amplifiers in Direct Mode
Meter
Sweep
Info
Status
ENR:
DUT:
Frequency DUT [MHz]
00432.140
Gain [dB]
--.--
Noise Figure [dB]
1.15
Smooth
4
Mode
A
Measure Device
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Device Under Test
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Measure
Calibrate
Stop
Settings
FFT-Filter
Threshold
Width
SDR Values
Gain: 41.00 dB
P_ON: 36.64 dB
P_OFF: 31.35 dB
Status: Valid
[Generic RTL2832U OEM] Measuring at: 432,140 MHz and 41 dB [163ms].

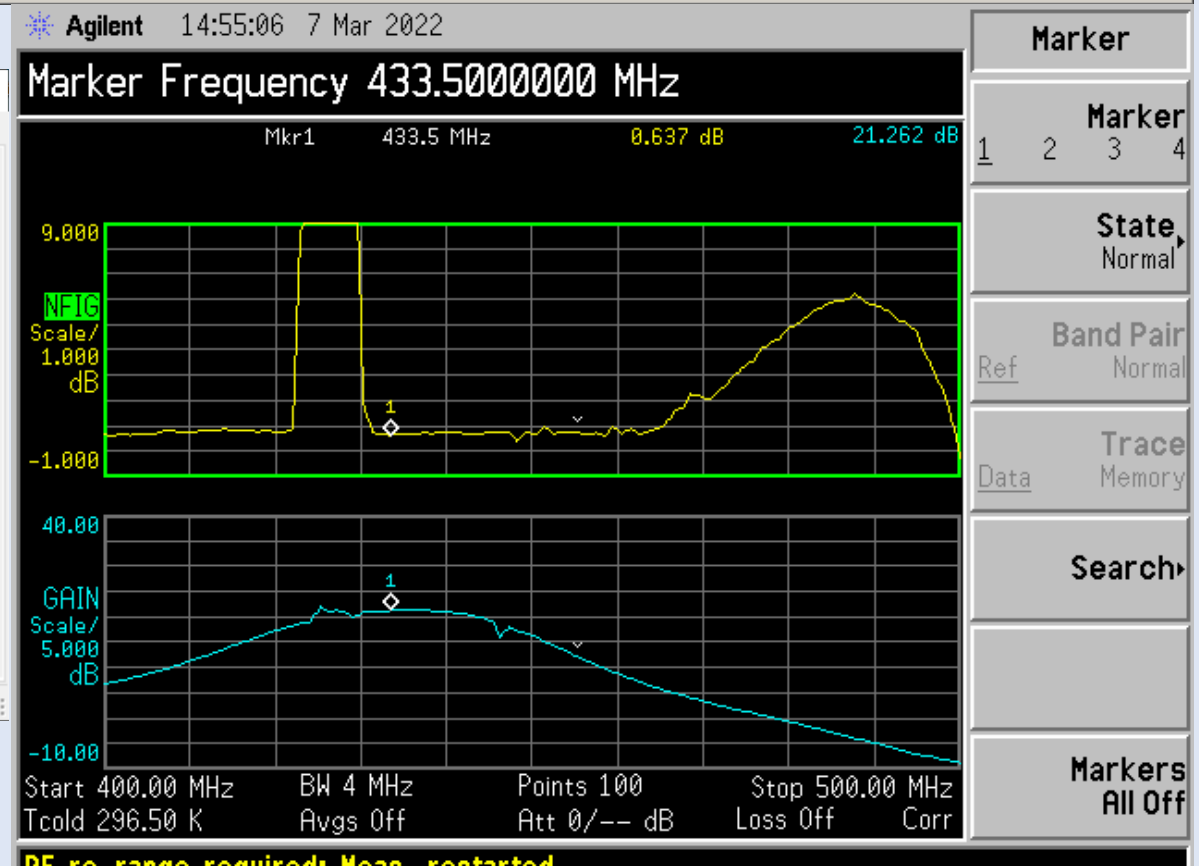

CANFI v2.7.0.0 - Measuring of Amplifiers in Direct Mode
Meter
Sweep
Info
Status
ENR:
DUT:
Frequency DUT [MHz]
00432.140
Gain [dB]
-0.20
Noise Figure [dB]
-0.03
Smooth
4
Mode
A
Measure Device
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Device Under Test
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Measure
Calibrate
Stop
Settings
FFT-Filter
Threshold
Width
SDR Values
Gain: 41.00 dB
P_ON: 36.43 dB
P_OFF: 31.27 dB
Status: Valid
[Generic RTL2832U OEM] Measuring at: 432,140 MHz and 41 dB [162ms].


CANFI v2.7.0.0 - Measuring of Amplifiers in Direct Mode
Meter
Sweep
Info
Status
ENR:
DUT:
Frequency DUT [MHz]
00432.140
Gain [dB]
-3.14
Noise Figure [dB]
3.14
Smooth
4
Mode
A
Measure Device
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Device Under Test
Freq [MHz]:
00432.140
P_ENR[dB]:
05.32
Measure
Calibrate
Stop
Settings
FFT-Filter
Threshold
Width
SDR Values
Gain: 41.00 dB
P_ON: 34.63 dB
P_OFF: 31.46 dB
Status: Valid
[Generic RTL2832U OEM] Measuring at: 432,140 MHz and 41 dB [166ms].


Settings
RTL-SDR Device
Device
R820T
Generic RTL2832U OEM
RTL Measure Settings
Tuner Gain [dB]:
64.8
Auto
Sample Rate:
2000000
Sample Count:
100000
Smoothing Level:
10
RTL Logging Settings
Log Calibration to File:
Log Measurement to File:
Temperature Correction
Ambient Temperature [K]:
290
Tone Output Settings
Output Mode:
NONE
Output Interval [ms]:
500
Output Duration [ms]:
100
NF @ 0kHz [dB]:
0.0
NF @10kHz [dB]:
10.0
Gain @ 0kHz [dB]:
0.0
Gain @10kHz [dB]:
40.0
FFT Settings
Display Spectrum in Realtime:
FFT-Filter:
NONE
Noise Source Calibration
Enter Calibration Data Manually
Take Calibration Data From File
Load
D:\OSprofil\MyProjects\CANFIv_27\HP346A_OK2AQ.
COM Control
COM Port:
COM9
Noise Source:
DTR
Inv
DUT Switch:
RTS
Inv
Switchover Delay [ms]:
30
CANFI
(C)heap (A)utomatic (N)oise (F)igure (I)ndicator
(c) DF9IC, DL8AAU, DL2ALF
OK
Cancel


CANFI v2.7.0.0 - Measuring of Amplifiers in Direct Mode
Meter
Sweep
Info
Status
ENR:
DUT:
Frequency DUT [MHz]
00433.500
Gain [dB]
21.21
Noise Figure [dB]
0.61
Smooth
10
Mode
A
Measure Device
Freq [MHz]:
00433.500
P_ENR[dB]:
05.32
Device Under Test
Freq [MHz]:
00433.500
P_ENR[dB]:
05.32
Measure
Calibrate
Stop
Settings
FFT-Filter
Threshold
Width
SDR Values
Gain: 41.00 dB
P_ON: 40.29 dB
P_OFF: 34.48 dB
Status: Valid
[Generic RTL2832U OEM] Measuring at: 433,500 MHz and 41 dB [173ms].

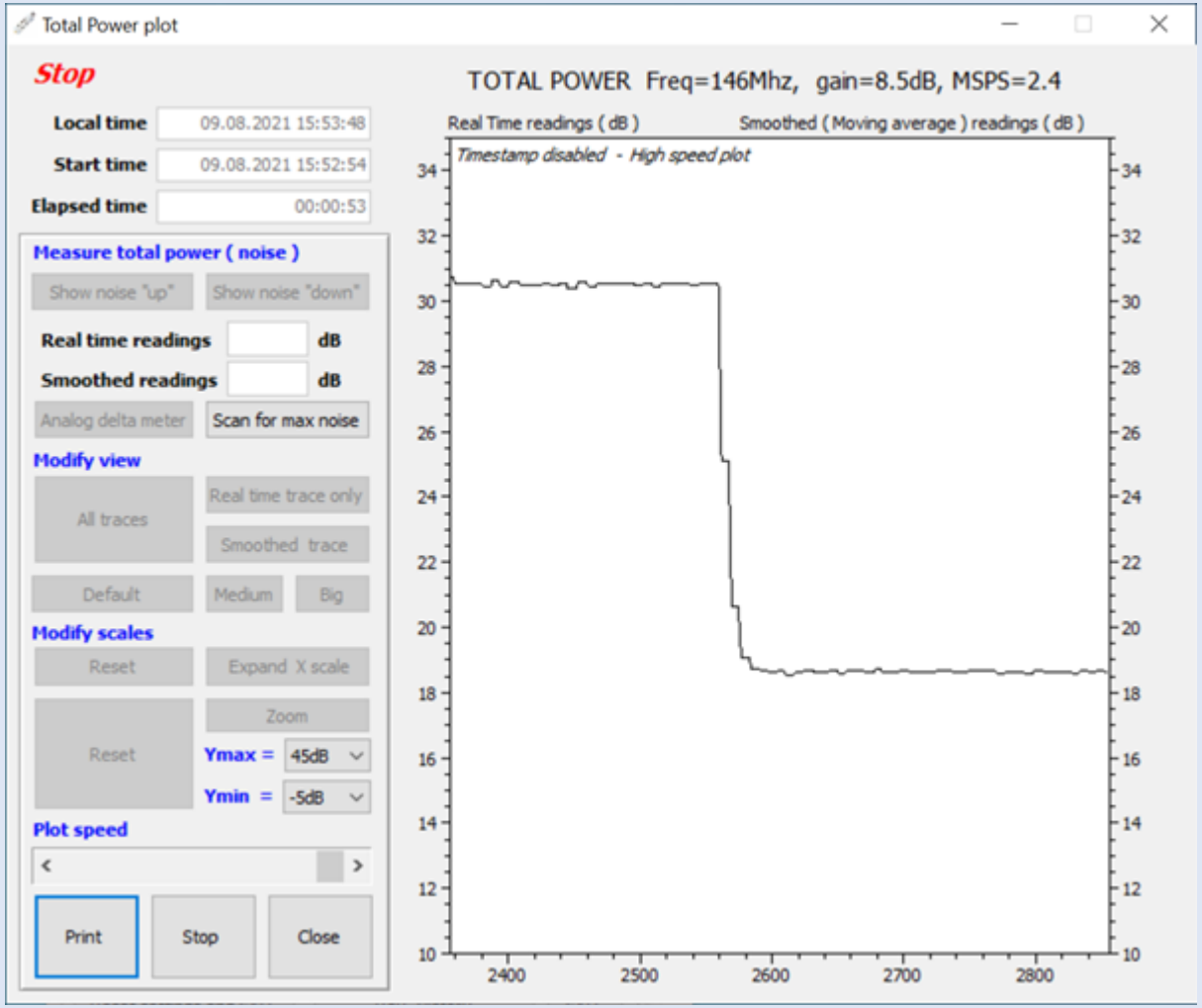

CANFI v2.7.0.0 - Measuring of Amplifiers in Direct Mode
Meter
Sweep
Info
Diagram
20
15
10
5
0
-5
30
20
10
0
-10
-20
400
410.1
420.2
430.3
440.4
450.5
460.6
470.7
480.8
490.9
Measure Device
Start [MHz]:
00400.000
Stop [MHz]:
00500.000
Step [MHz]:
00010.100
Device Under Test
Start [MHz]:
00400.000
Stop [MHz]:
00500.000
Step [MHz]:
00010.100
Sweep
Mode:
SINGLE
NF[dB]:
Gain[dB]:
Measure
Calibrated
Measure
Settings
[Generic RTL2832U OEM] Idling at: 400,000 MHz and 21 dB [41ms].


Agilent
14:55:06
7 Mar 2022
Marker Frequency 433.5000000 MHz
Mkr1
433.5 MHz
0.637 dB
21.262 dB
9.000
NFIG
Scale/
1.000
dB
-1.000
40.00
GAIN
Scale/
5.000
dB
-10.00
Start 400.00 MHz
BW 4 MHz
Points 100
Stop 500.00 MHz
Tcold 296.50 K
Avgs Off
Att 0/-- dB
Loss Off
Corr
Marker
Marker
1
2
3
4
State
Normal
Band Pair
Ref
Normal
Trace
Data
Memory
Search
Markers
All Off

RTL-SDR s LNA na vstupu lze využít
ke všem dalším aplikacím bez omezení.

Zajímavé je použití s programem
Total Power od I0NAA
pro měření šumu Slunce, Měsíce a ….

http://i0naa.altervista.org/index.php/downloads



Reference

[1] Agilent Technologies: Noise Figure Measurement Accuracy – The Y-Factor Method. Application Note: AN 57-2, https://www.testworld.com/wp-content/uploads/noise-figure-measurement-accuracy-the-y-factor-method.pdf

[2] Keysight Technologies: Fundamentals of RF and Microwave Noise Figure Neasurements. AN 5952-8255, https://www.keysight.com/zz/en/assets/7018-06808/application-notes/5952-8255.pdf

[3] Keysight Technologies: Noise Figure Uncertainty.

[4] https://rfmw.em.keysight.com/NFUcalc

[5] http://www.canfi.eu/index.html

DĚKUJI VÁM ZA POZORNOST
THANK YOU FOR YOUR ATTENTION