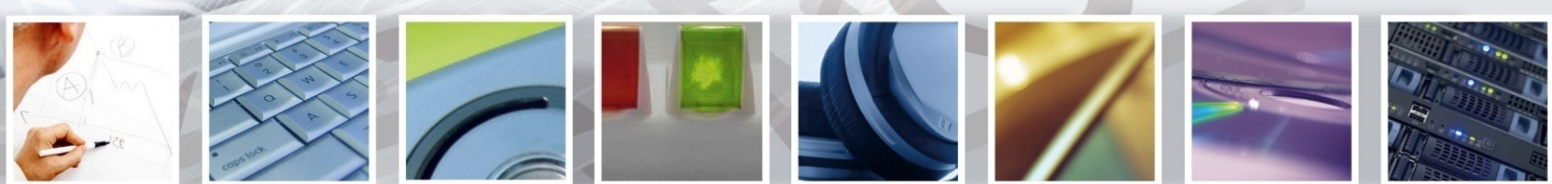
Project Walter ETSI Workshop

Radiated RF measurements in a low-temperature environment

Detlef Fuehrer
JRC

Sophia Antipolis, 7th October 2009



Agenda

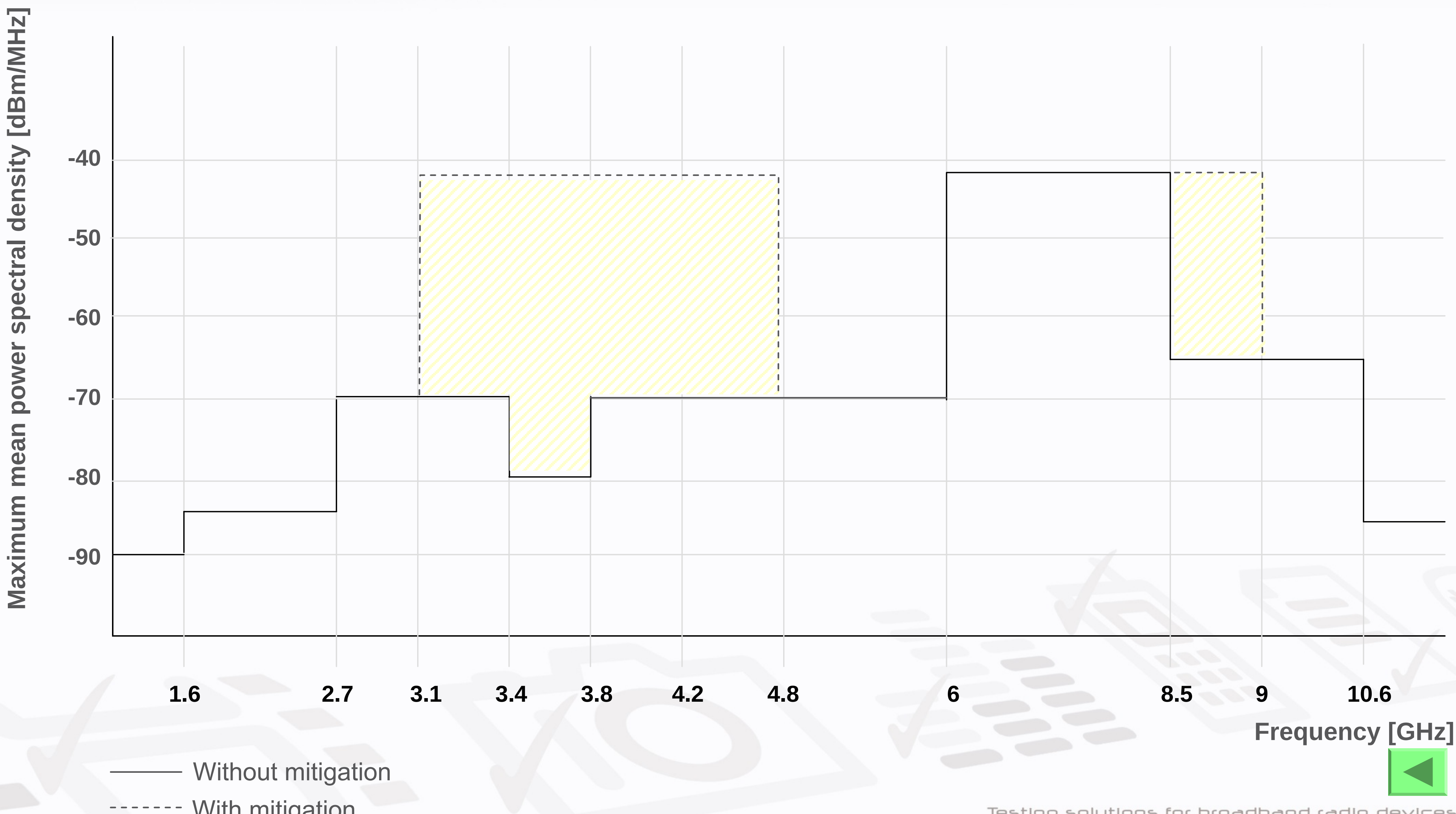
- UWB measurement challenges
- Radiated UWB measurements
- Cryogenic LNA project

UWB measurement challenges

- UWB signal levels to be detected range from -41.3 dBm to -80 dBm
- Signals to be measured must be +6dB above the noise floor of the instrumentation
- Measurement distance must satisfy antenna far-field conditions (typically 3 meters)
  - 3m free-space path loss is 52.6 dB at 3.4 GHz

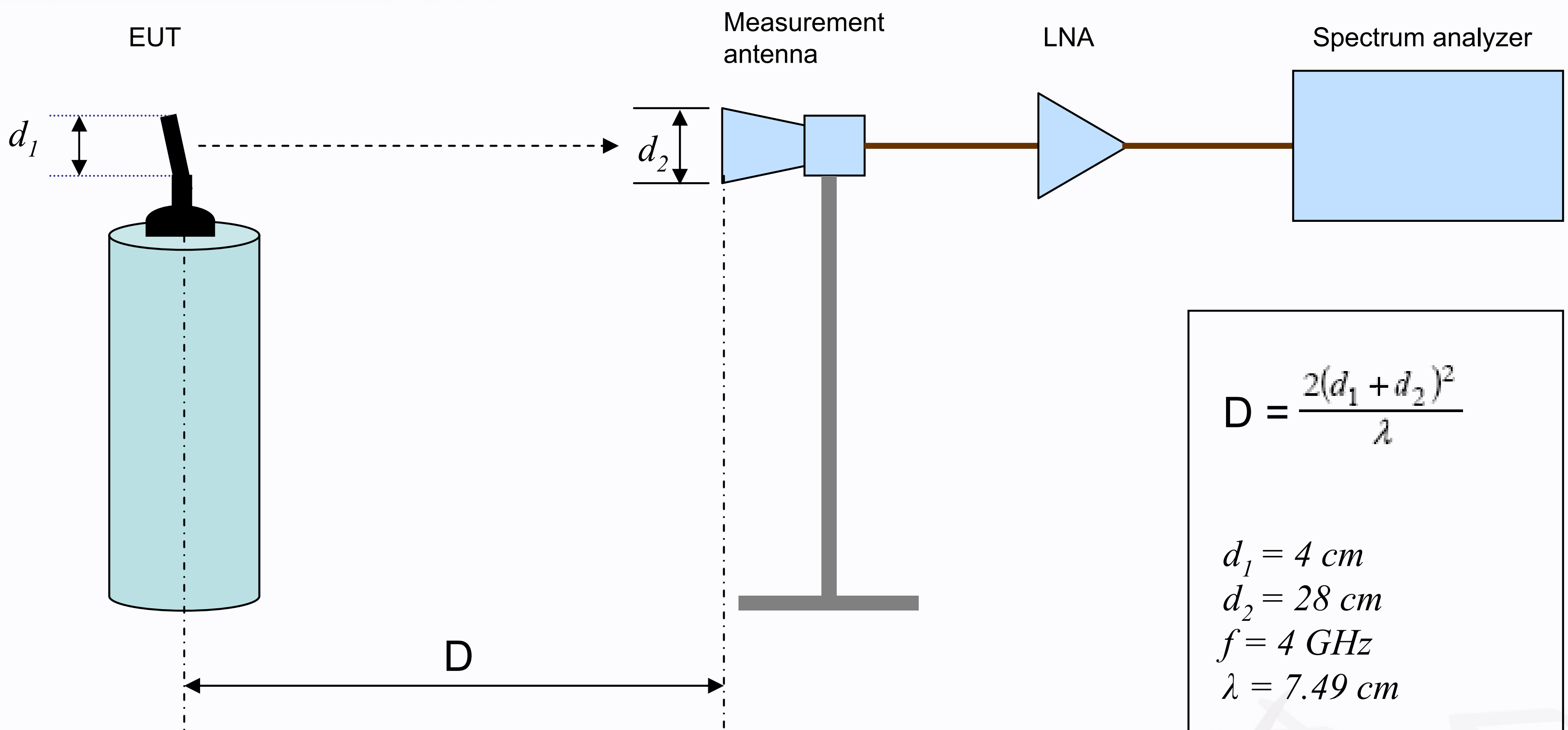
UWB Regulation (Europe)

✓ UWB PSD mask



Radiated measurement setup

Far-field calculation

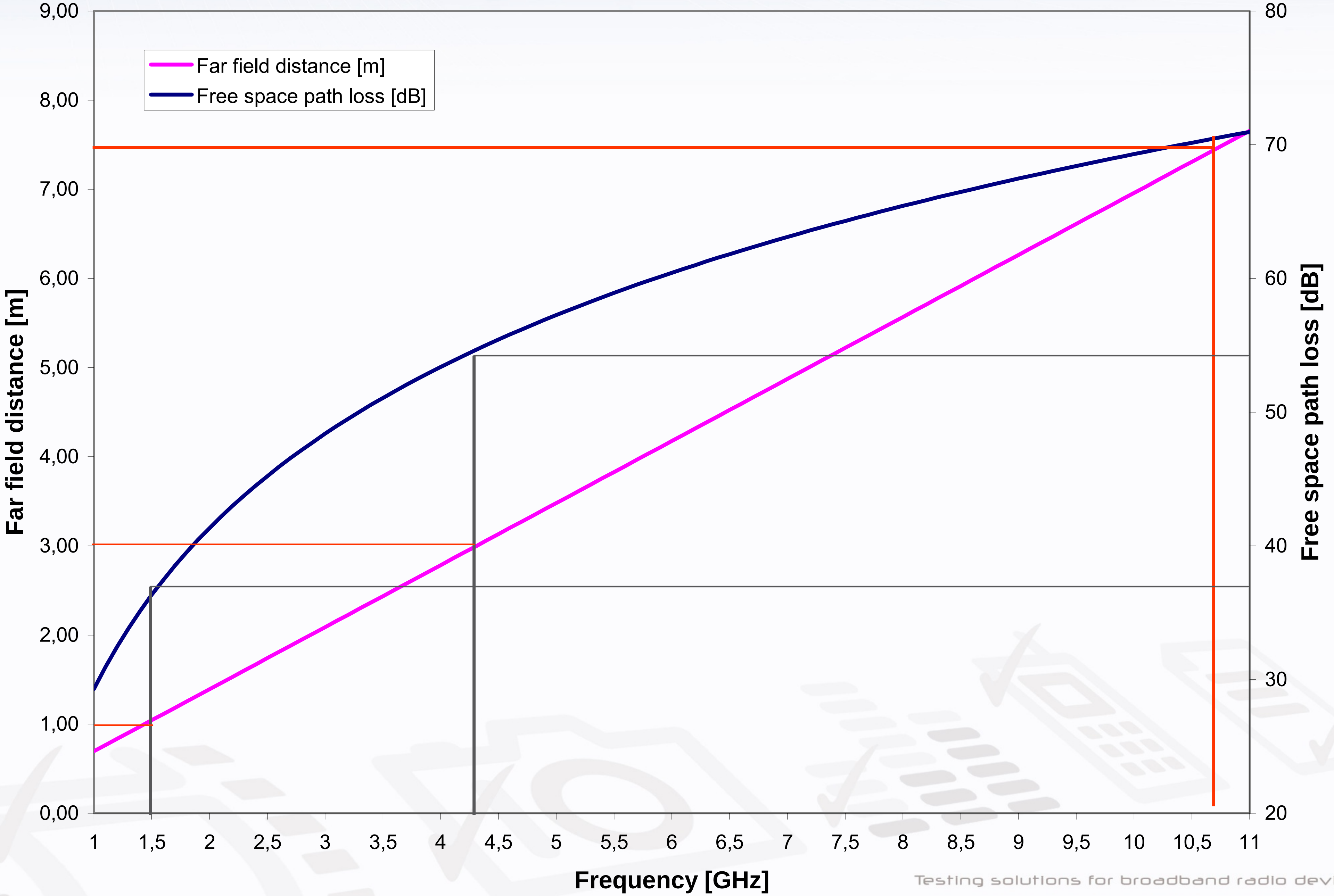


$$D = \frac{2(d_1 + d_2)^2}{\lambda}$$

$d_1 = 4\ cm$
$d_2 = 28\ cm$
$f = 4\ GHz$
$\lambda = 7.49\ cm$

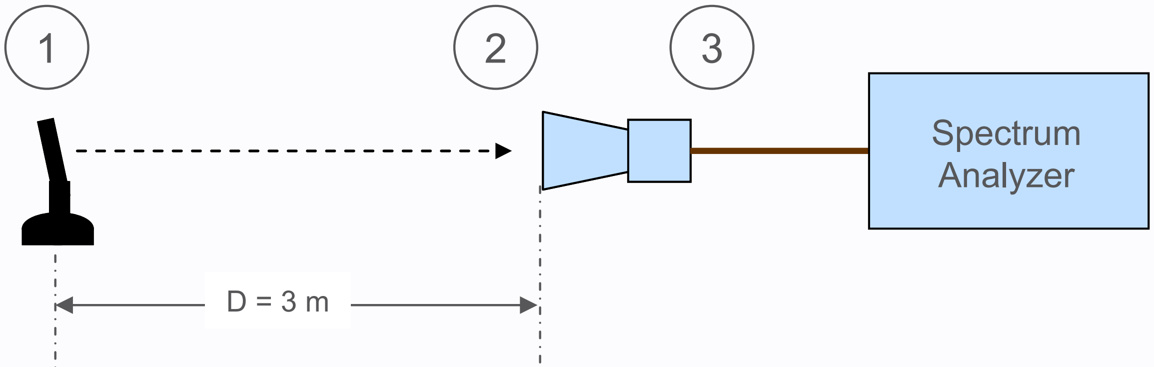
$D = 273\ cm$

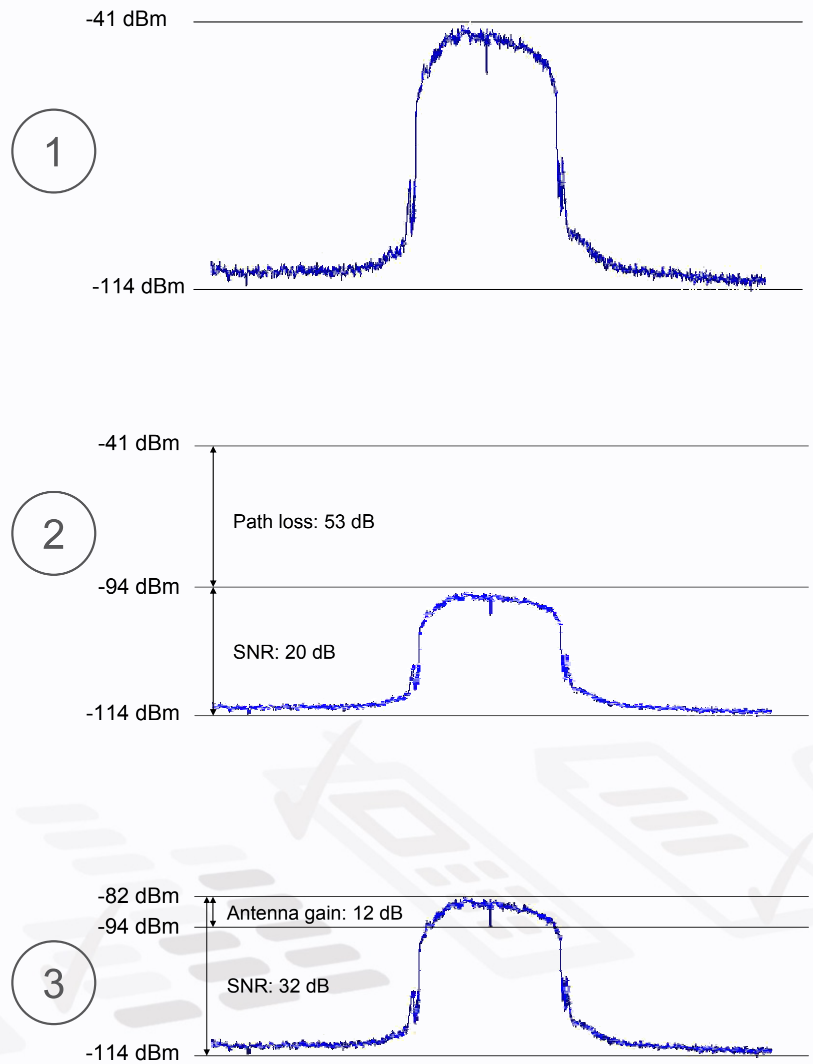
Far field distance & path loss



UWB SNR

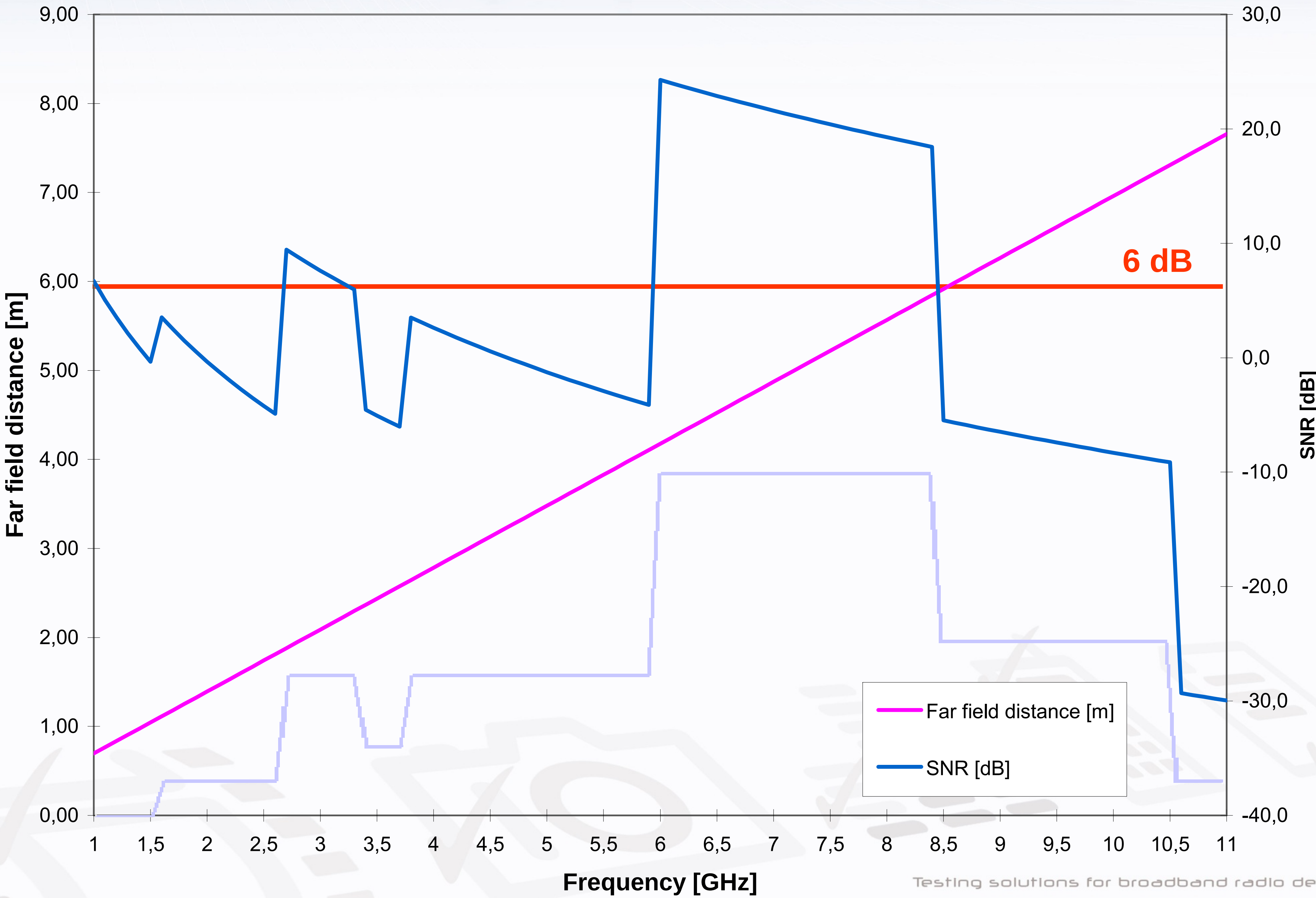
- UWB dynamic range: ~ 49 dB (-41.3 dBm to -90 dBm)
- Lowest signal level to be detected: - 90 dBm
- Required receiver sensitivity: -96 dBm





- Example: 3.5 GHz
  - SNR at SA input: ~ 32 dB
  - Min. UWB level: -80 dBm
  - 13 dB of SNR must be gained

Path loss & SNR



Signal-to-Noise Ratio

- There are several ways to increase the SNR
  - Increase Tx signal power
    - Direct = Amplify Tx signal
    - Indirect = Reduce measurement distance
  - Increase antenna gain
  - Reduce noise

Noise reduction

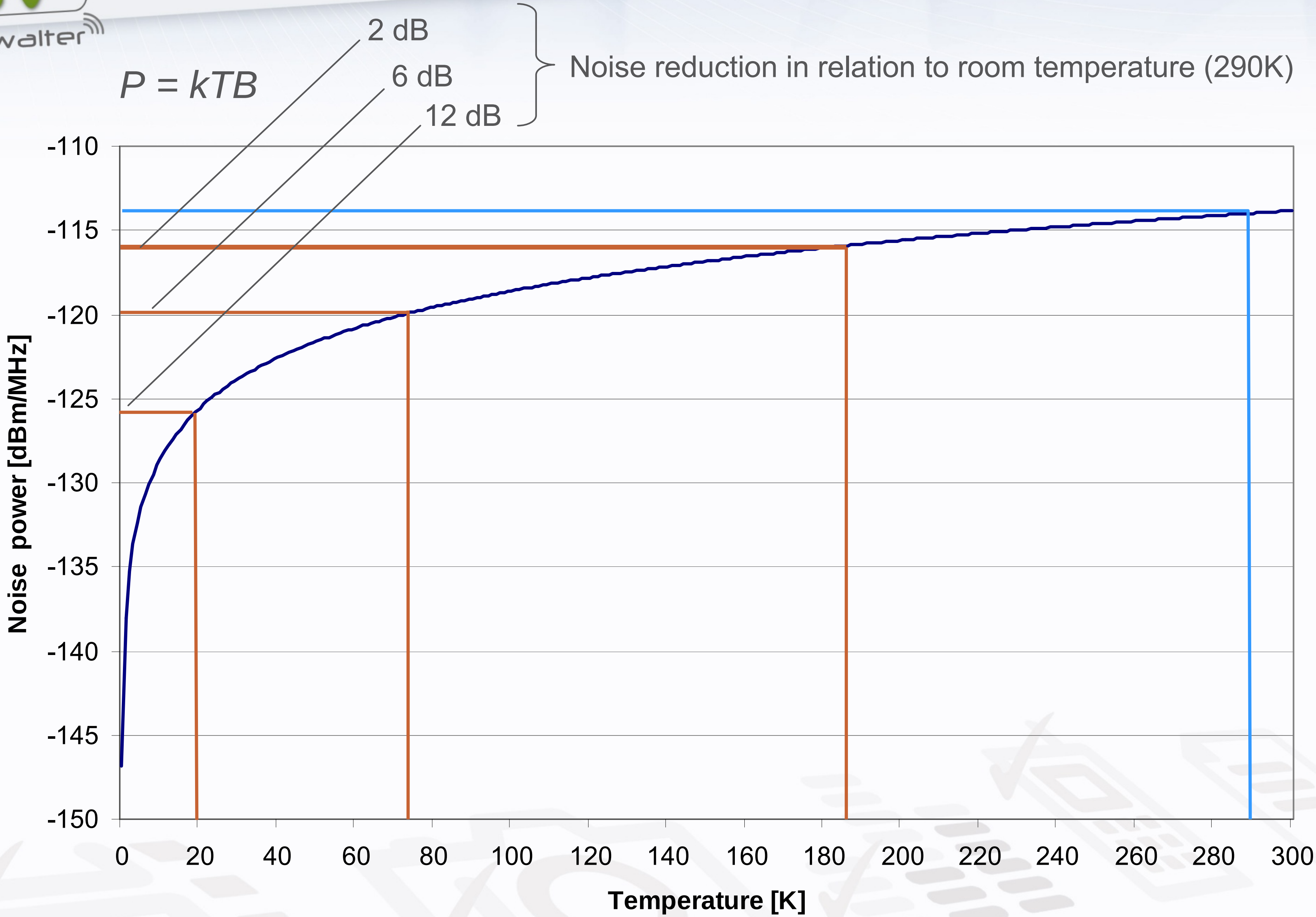
walter

- Ambient noise
  - Filtering
  - Spectral subtraction
  - Temperature reduction

- Receiver noise
  - Use of low-loss, low-noise components
  - Filtering
  - Temperature reduction

Noise and temperature

P = kTB

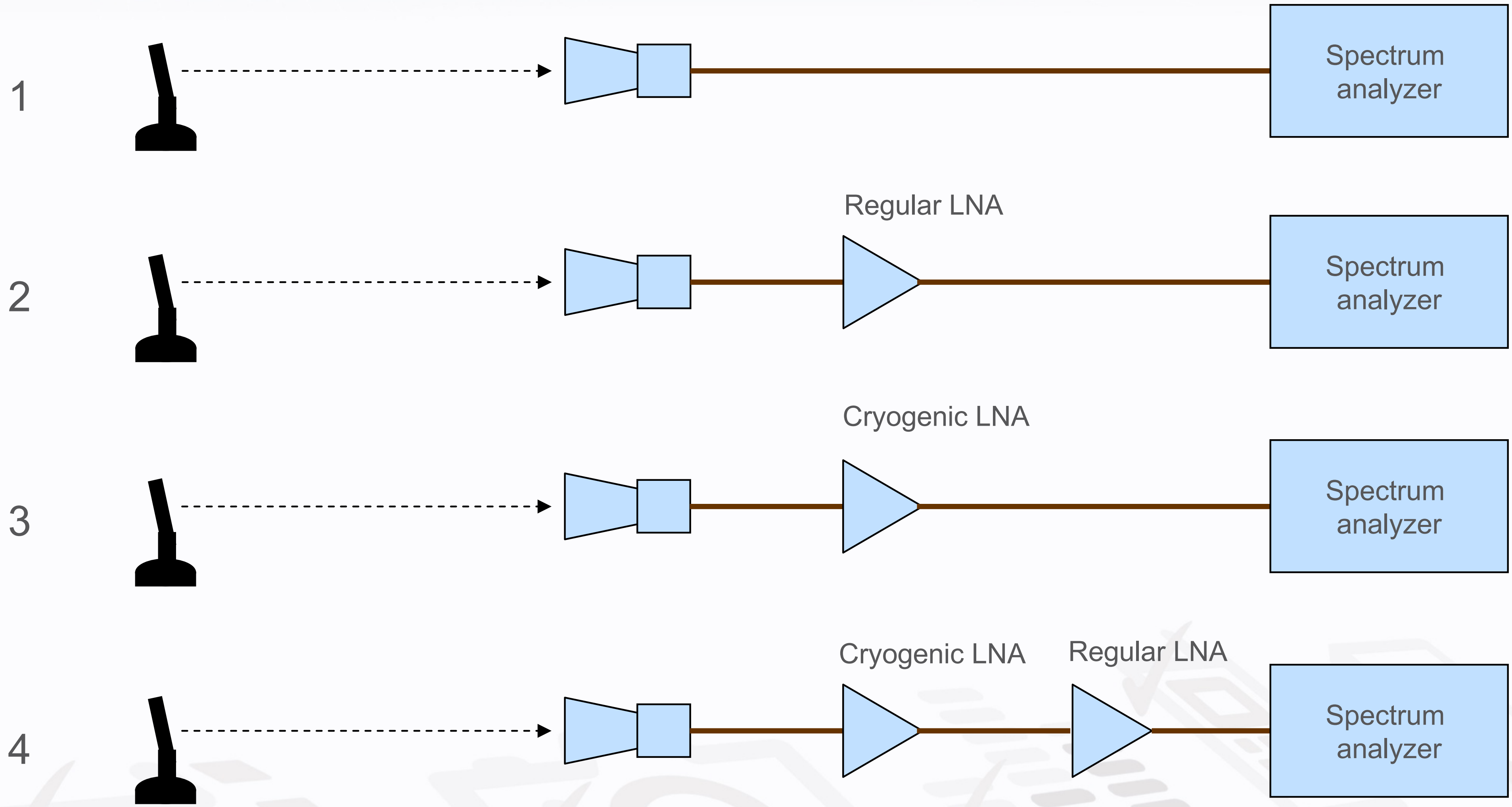


Receiver noise reduction

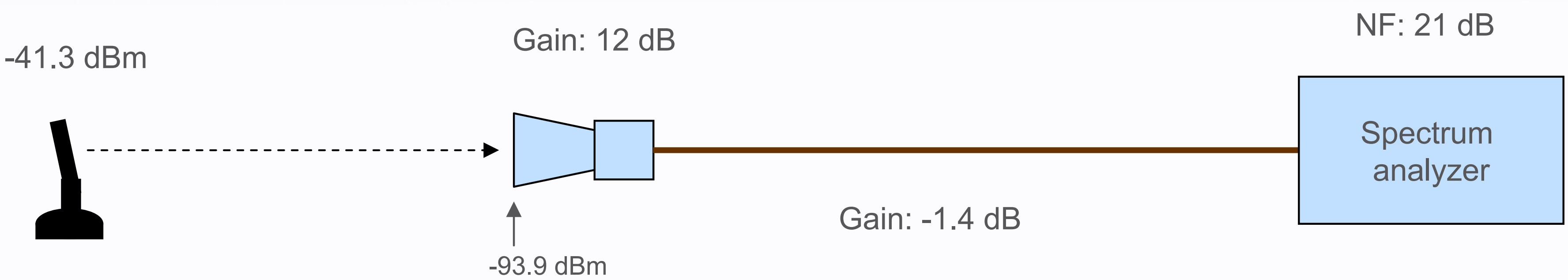
- Cooling (Cryogenic LNAs)
  - There is a number of cooling options
    - Helium cooling ~ 4K
    - Nitrogen cooling ~ 77K
    - CO_2 cooling ~ 195K
    - Peltier cooling ~ 170K
- First measurements carried out by CTL in 2008
  - Helium-cooled astronomy microwave sensor
- Second run: JRC low-cost cryogenic LNA project
  - Peltier and CO_2 cooling

Measurement signal chain

✓ Configurations

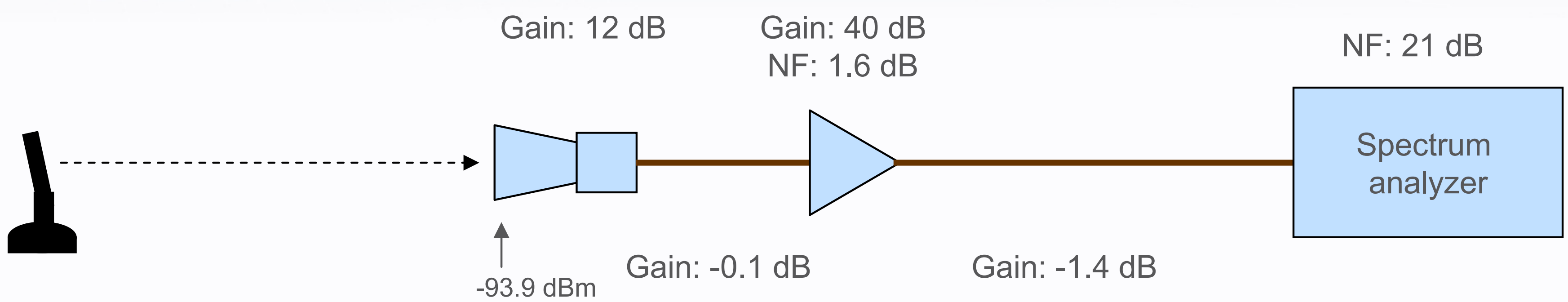


Configuration I



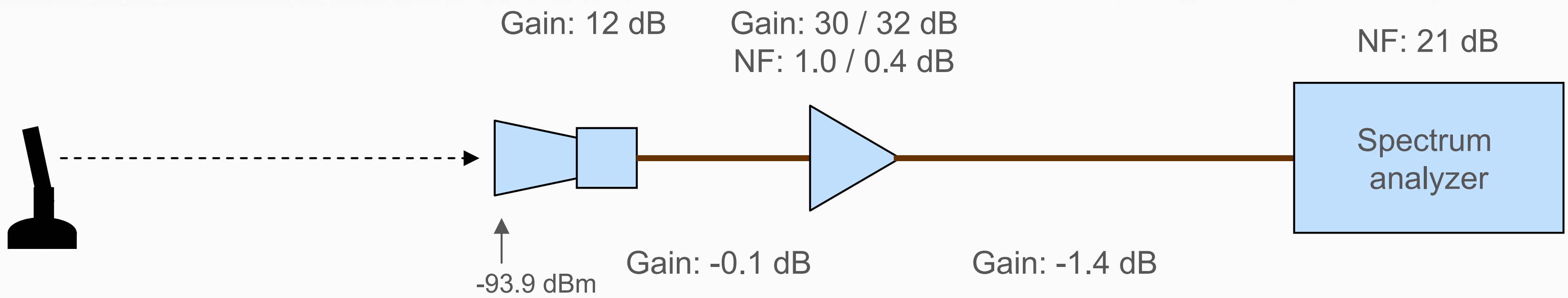
Overall gain:	10.6 dB
Gain (excl. Antenna):	-1.4 dB
Overall noise figure:	22.3 dB
Signal power at SA:	-83.3 dBm
Noise level at SA input:	-114 dBm
SA noise floor:	-93 dBm
SNR:	9.7 dB

Configuration 2



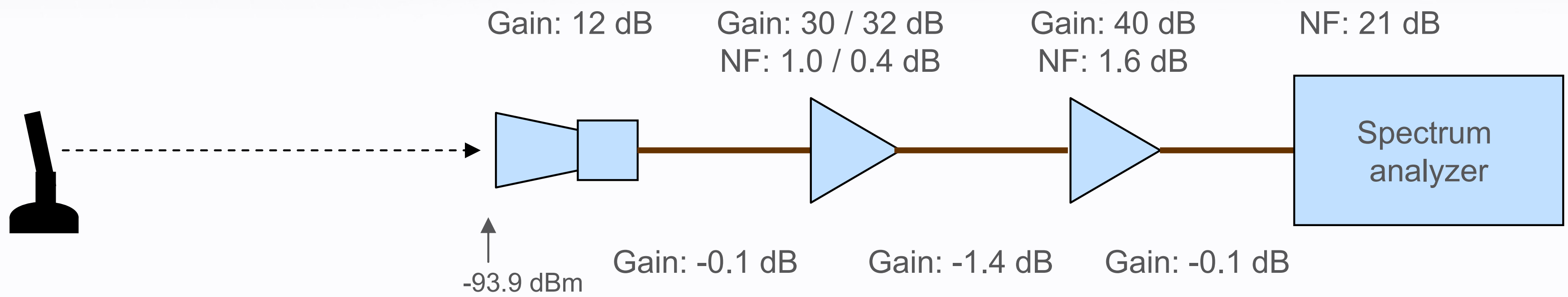
Overall gain:	50.5 dB
Gain (excl. Antenna):	38.5 dB
Overall noise figure:	1.7 dB
Signal power at SA input:	-43.4 dBm
Noise level at SA input:	-73.7 dBm
SA noise floor:	-93 dBm
SNR:	30.3 dB

Configuration 3



290 K		77 K	
Overall gain:	40.5 dB	Overall gain:	42.5 dB
Gain (excl. Antenna):	28.5 dB	Gain (excl. Antenna):	30.5 dB
Overall noise figure:	1.7 dB	Overall noise figure:	0.9 dB
Signal power at SA input:	-53.4 dBm	Signal power at SA input:	-51.4 dBm
Noise level at SA input:	-83.7 dBm	Noise level at SA input:	-82.5 dBm
SA noise floor:	-93 dBm	SA noise floor:	-93 dBm
SNR:	30.3 dB	SNR:	31.1 dB

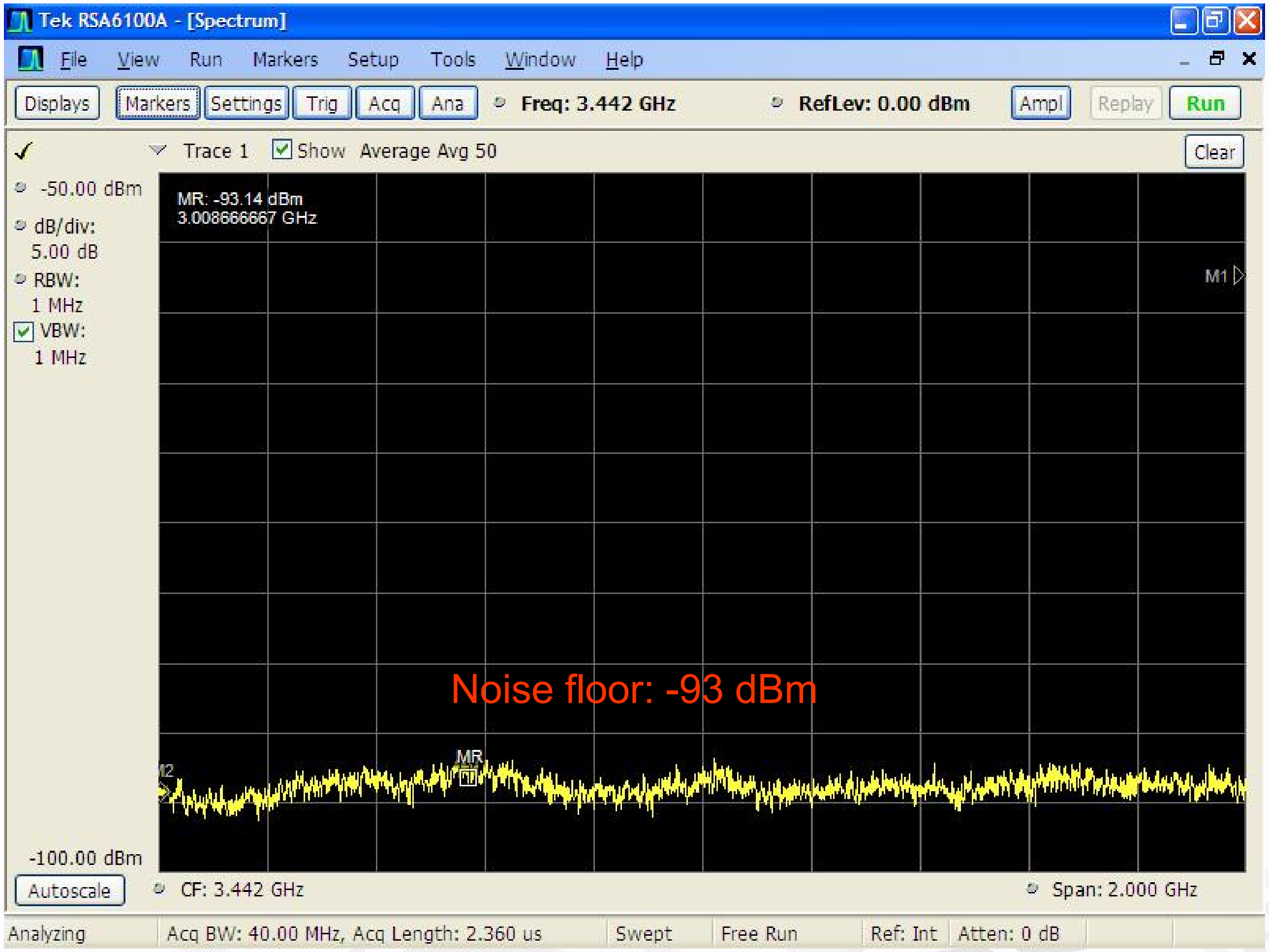
Configuration 4



290 K		77 K	
Overall gain:	80.5 dB	Overall gain:	82.5 dB
Gain (excl. Antenna):	68.5 dB	Gain (excl. Antenna):	70.5 dB
Overall noise figure:	1.1 dB	Overall noise figure:	0.5 dB
Signal power at SA input:	-13.4 dBm	Signal power at SA input:	-11.4 dBm
Noise level at SA input:	-44.3 dBm	Noise level at SA input:	-42.9 dBm
SA noise floor:	-93 dBm	SA noise floor:	-93 dBm
SNR:	30.9 dB	SNR:	31.5 dB

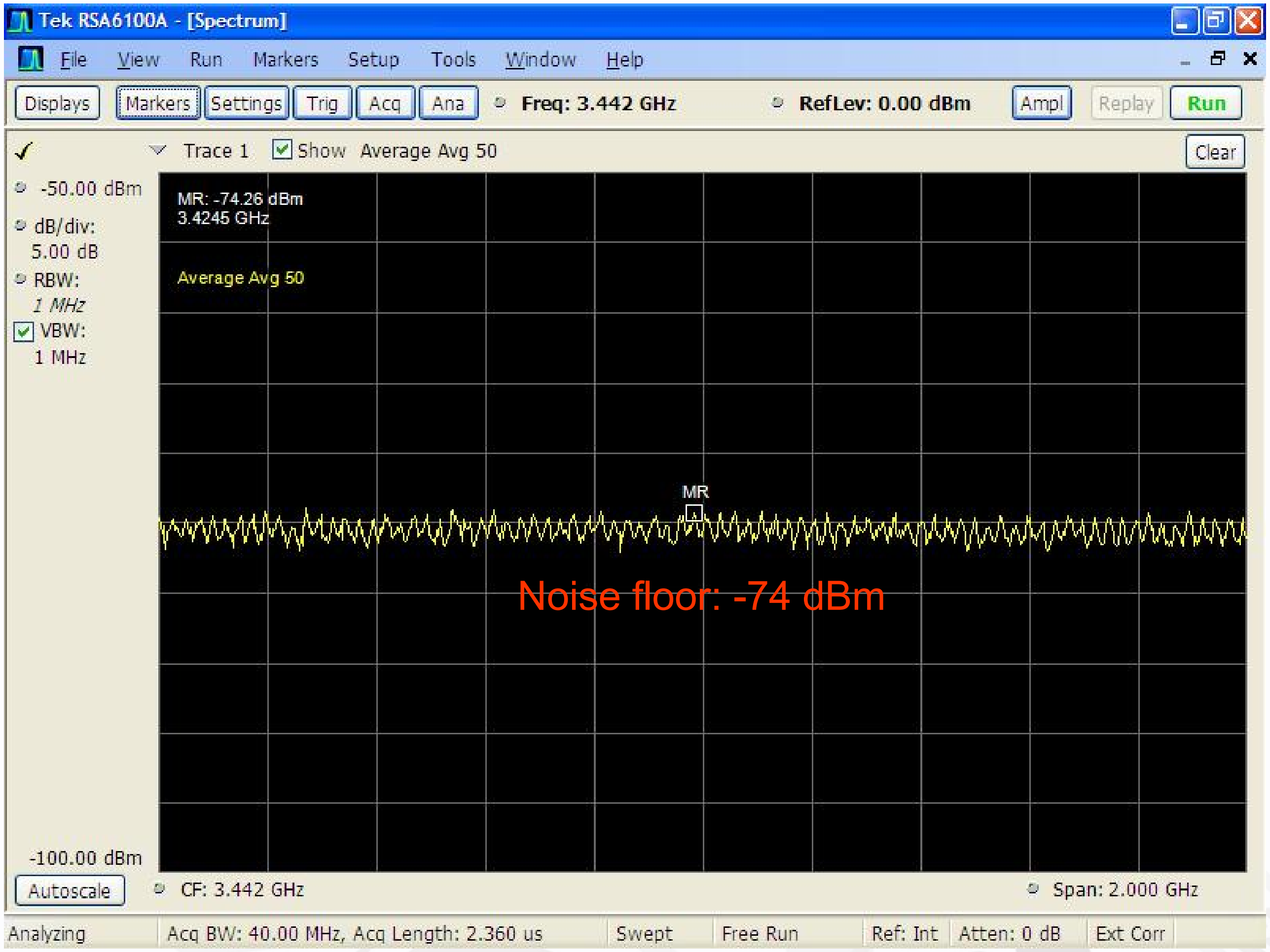
Measurement results I

- Spectrum Analyzer noise floor



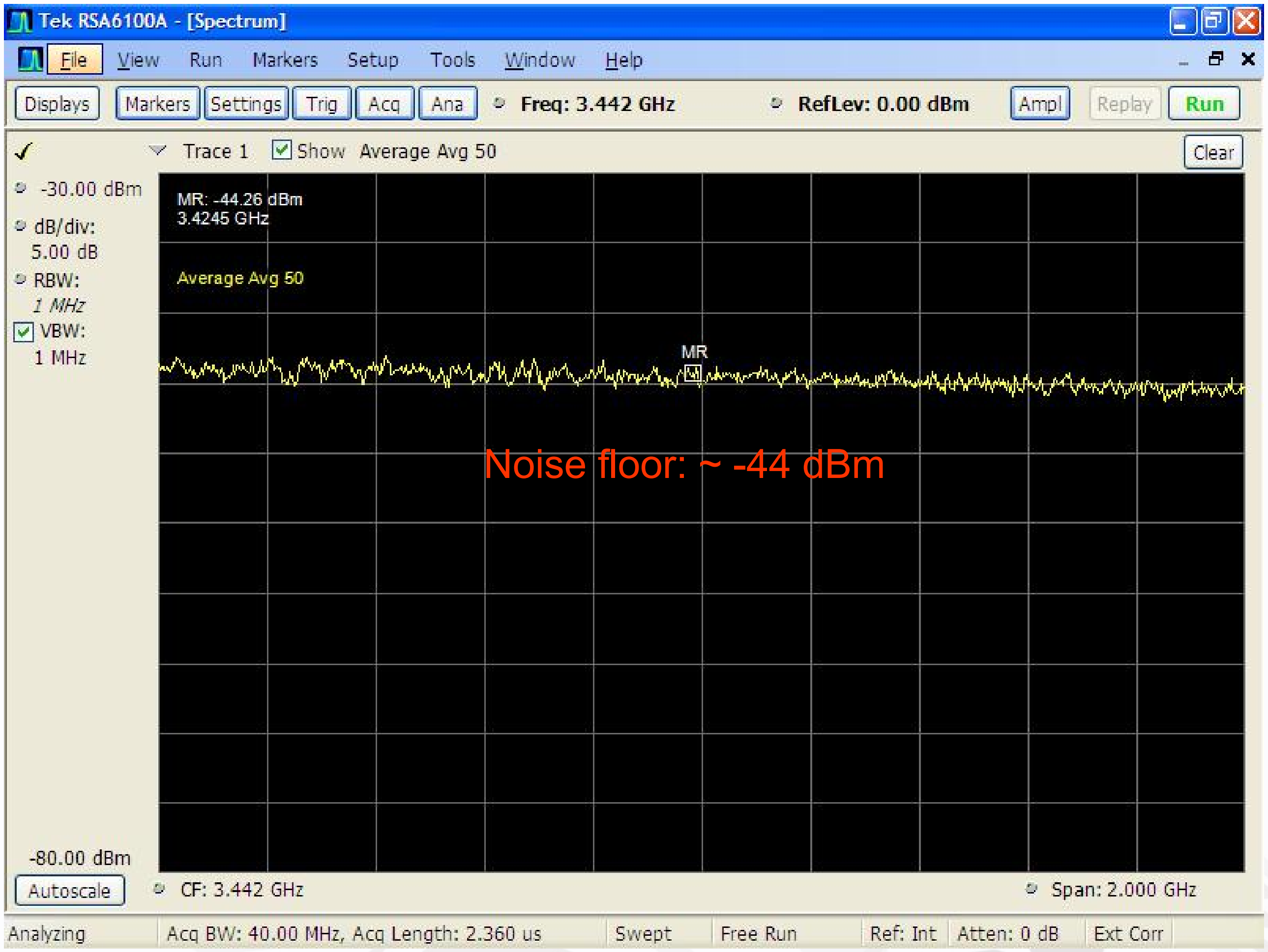
Measurement results 2

- Noise floor, LNA 2 powered on



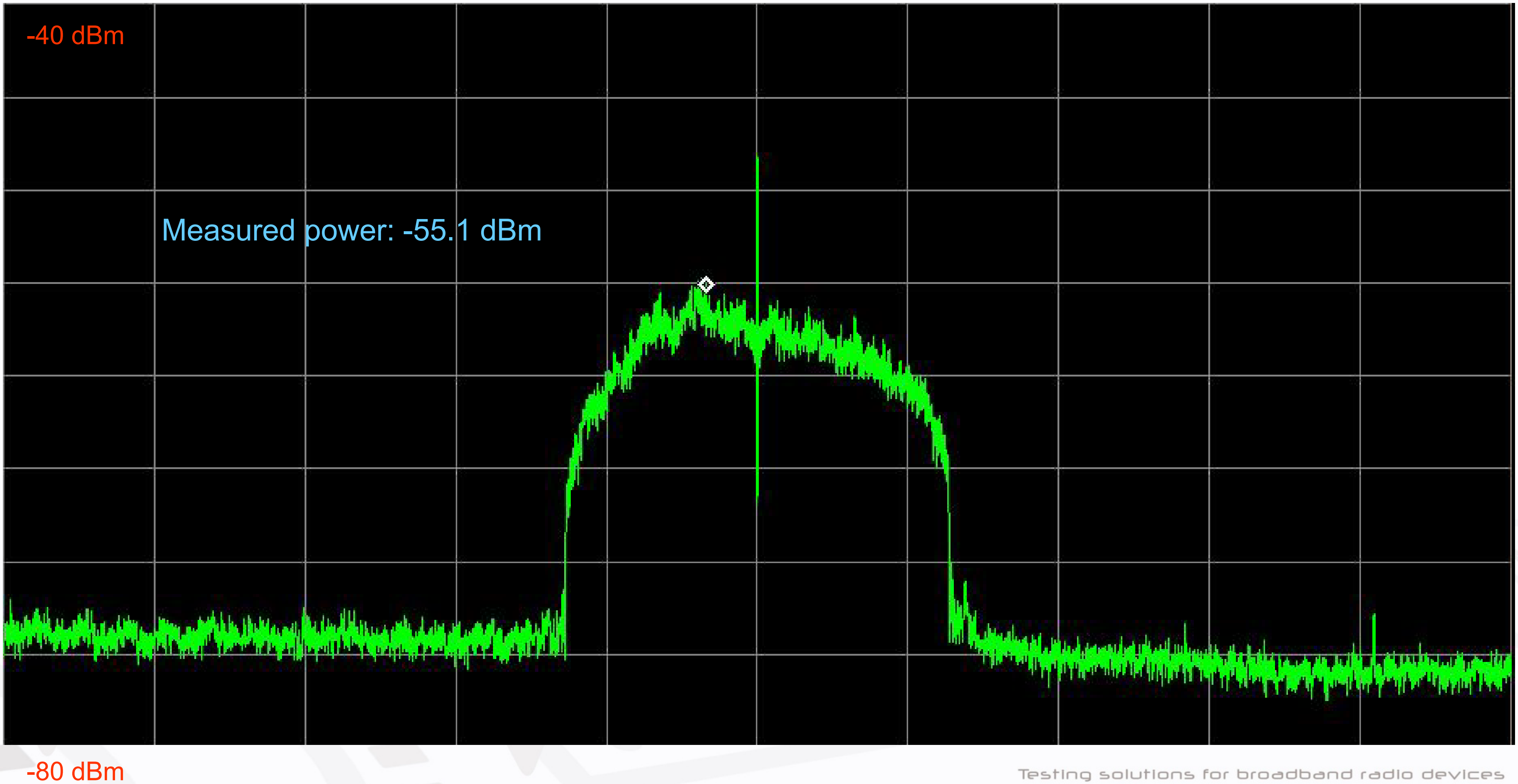
Measurement results 3

- Noise floor, LNA 1 and LNA 2 powered on
  - LNA 1 temperature: +20 °C



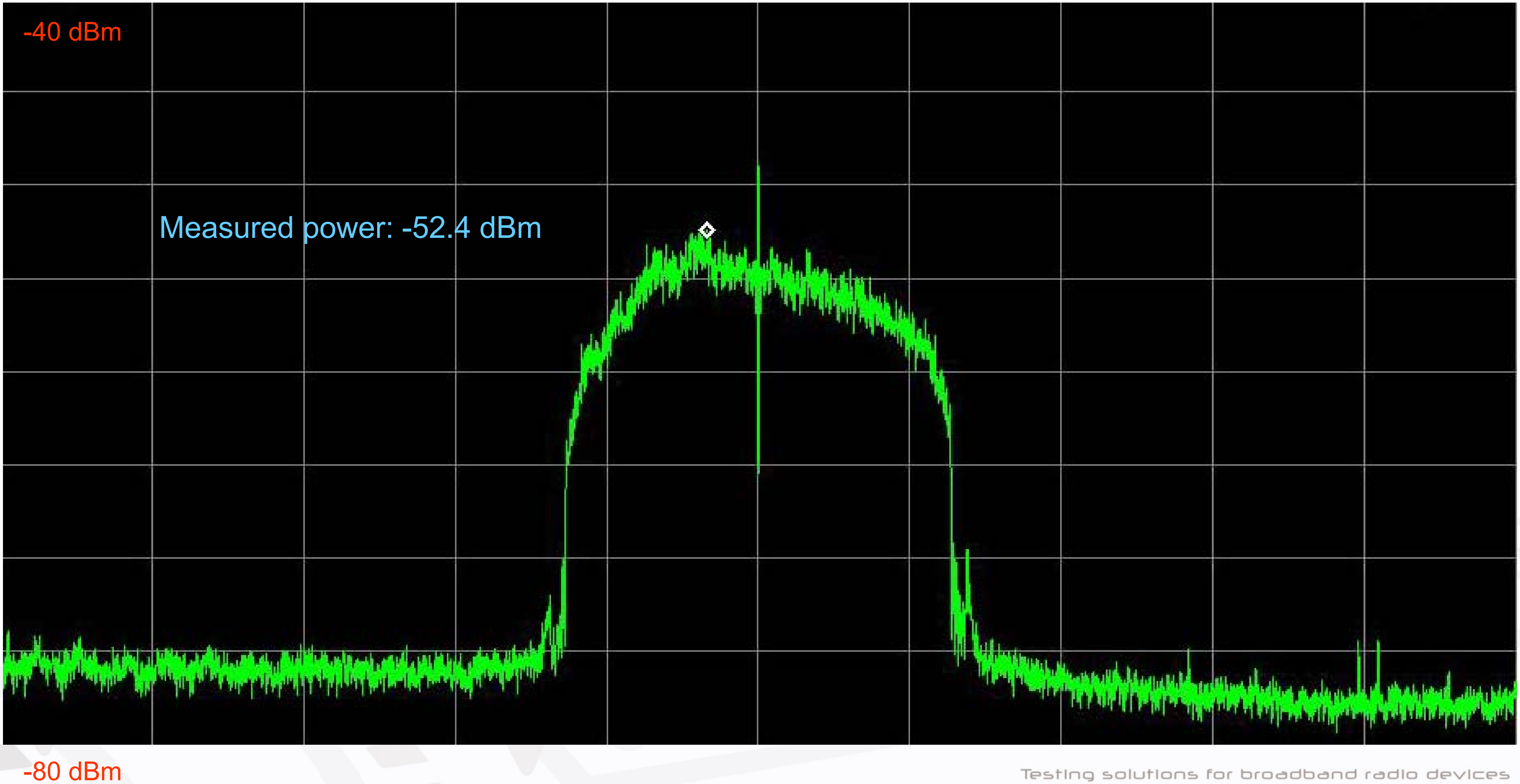
Measurement results 4a

- LNA 1 + LNA 2, measuring distance 3 m
- UWB: TFC 5, Tx Power -55 dBm



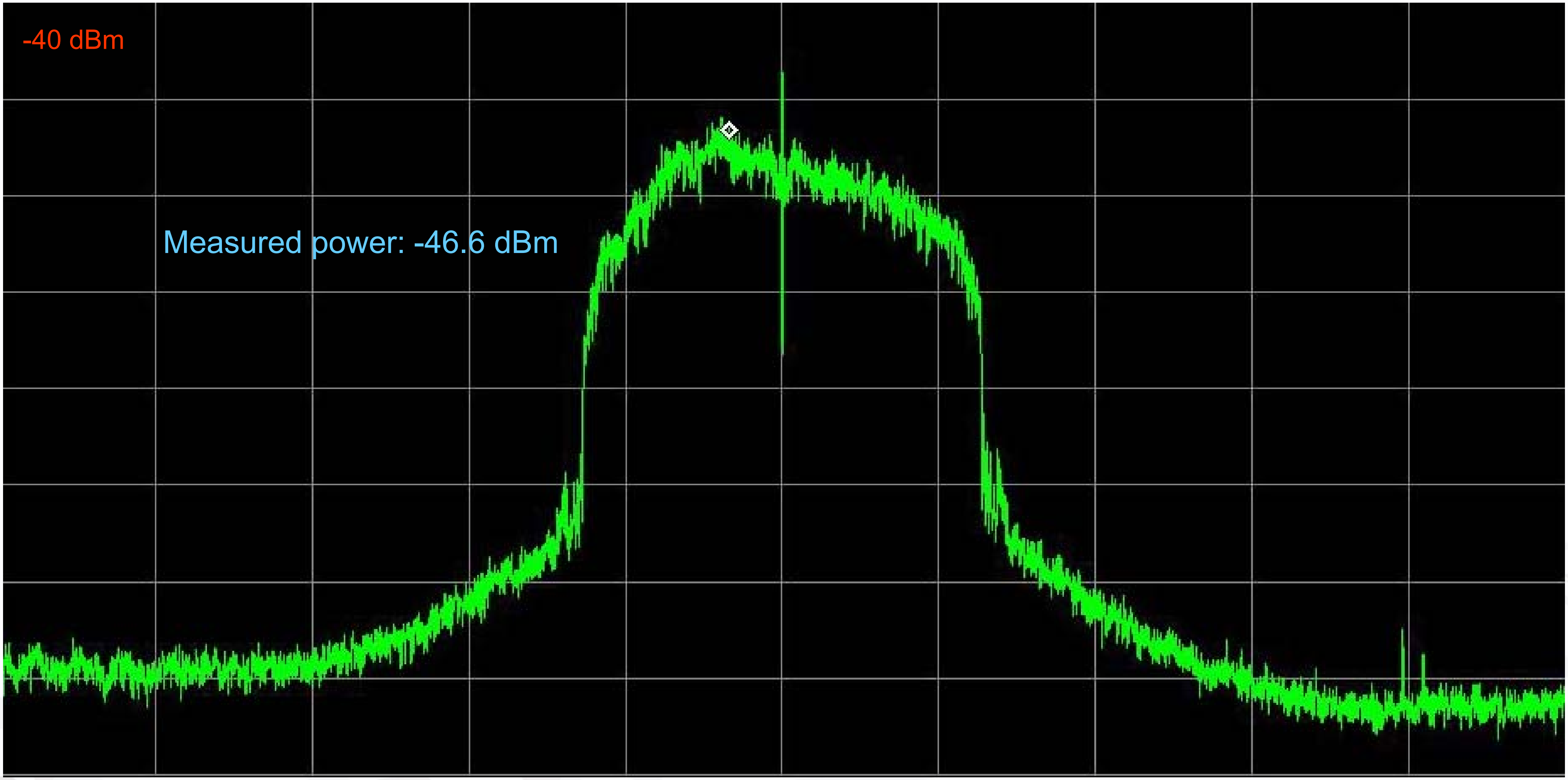
Measurement results 4b

- ✓ LNA 1 + LNA 2, measuring distance 3 m
- ✓ UWB: TFC 5, Tx Power -51 dBm



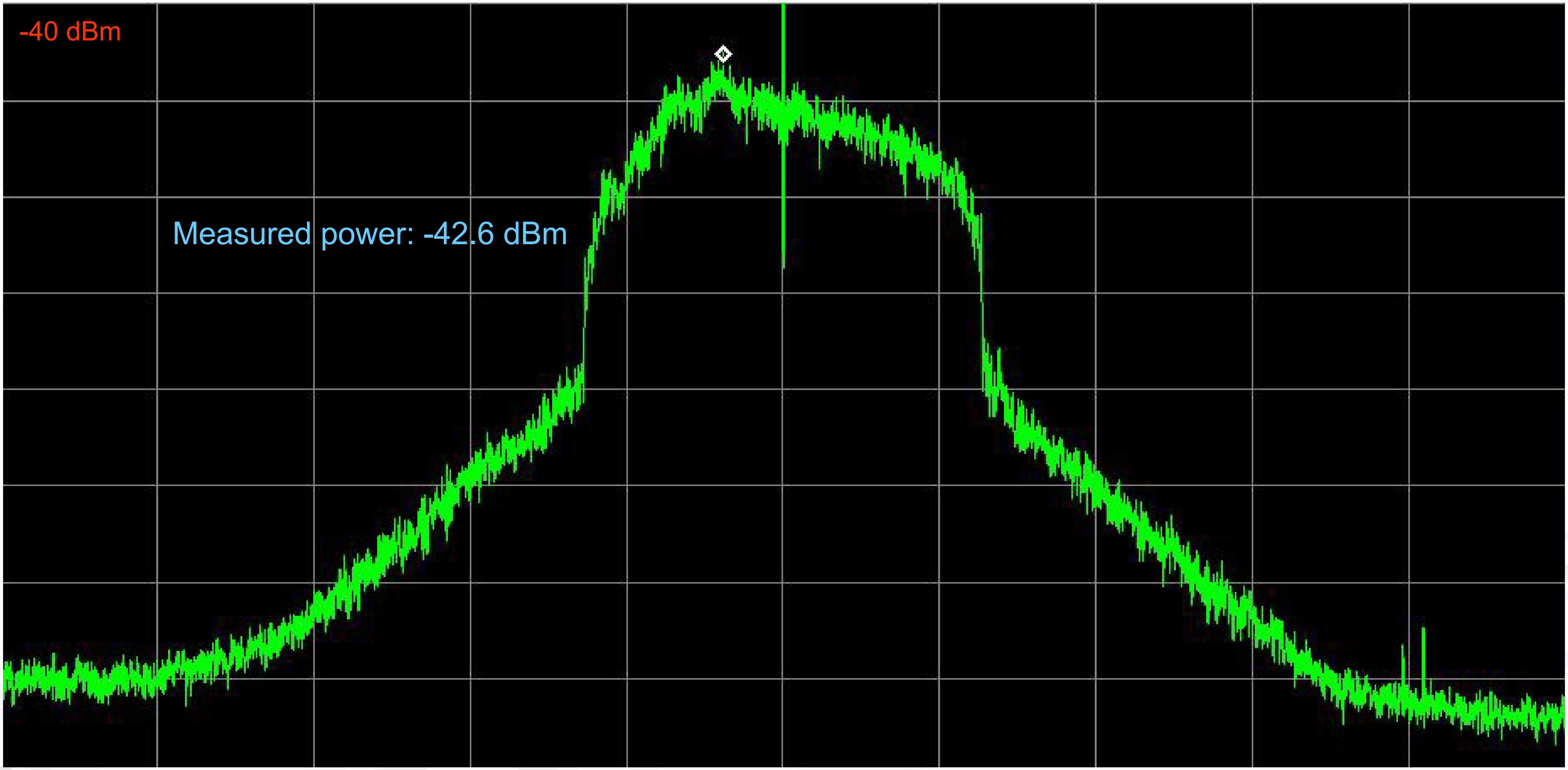
Measurement results 4c

- LNA 1 + LNA 2, measuring distance 3 m
- UWB: TFC 5, Tx Power -47 dBm



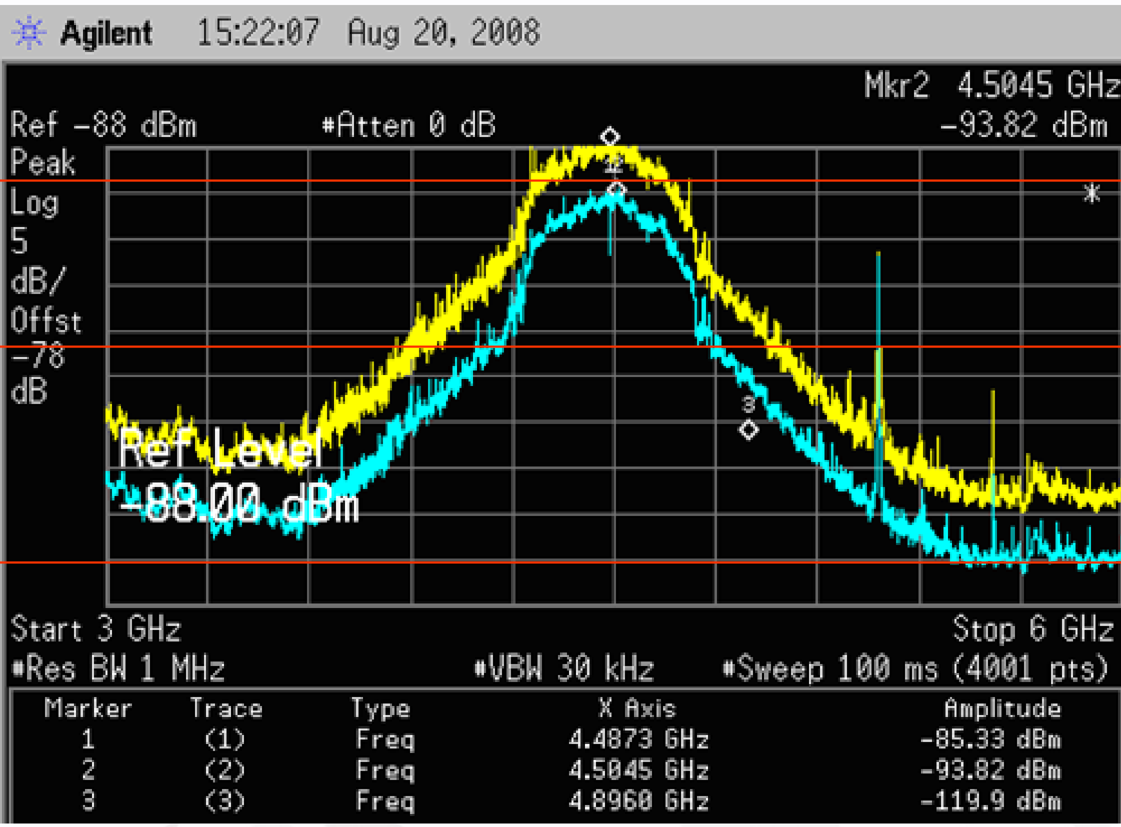
Measurement results 4d

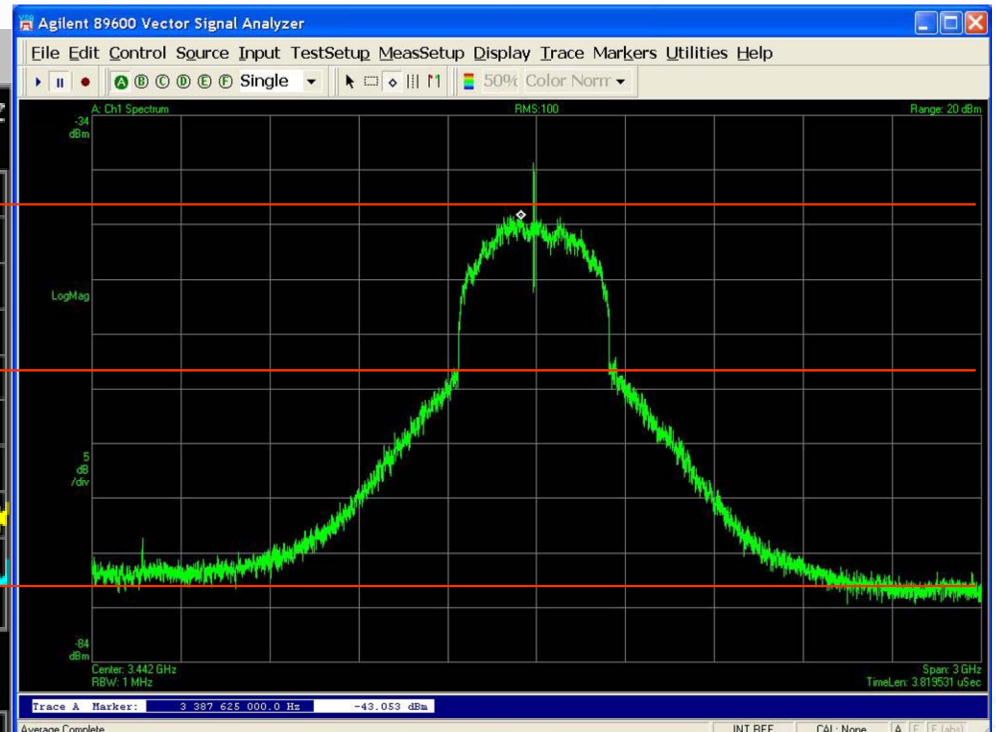
- LNA 1 + LNA 2, measuring distance 3 m
- UWB: TFC 5, Tx Power -41 dBm



Measurement results 5

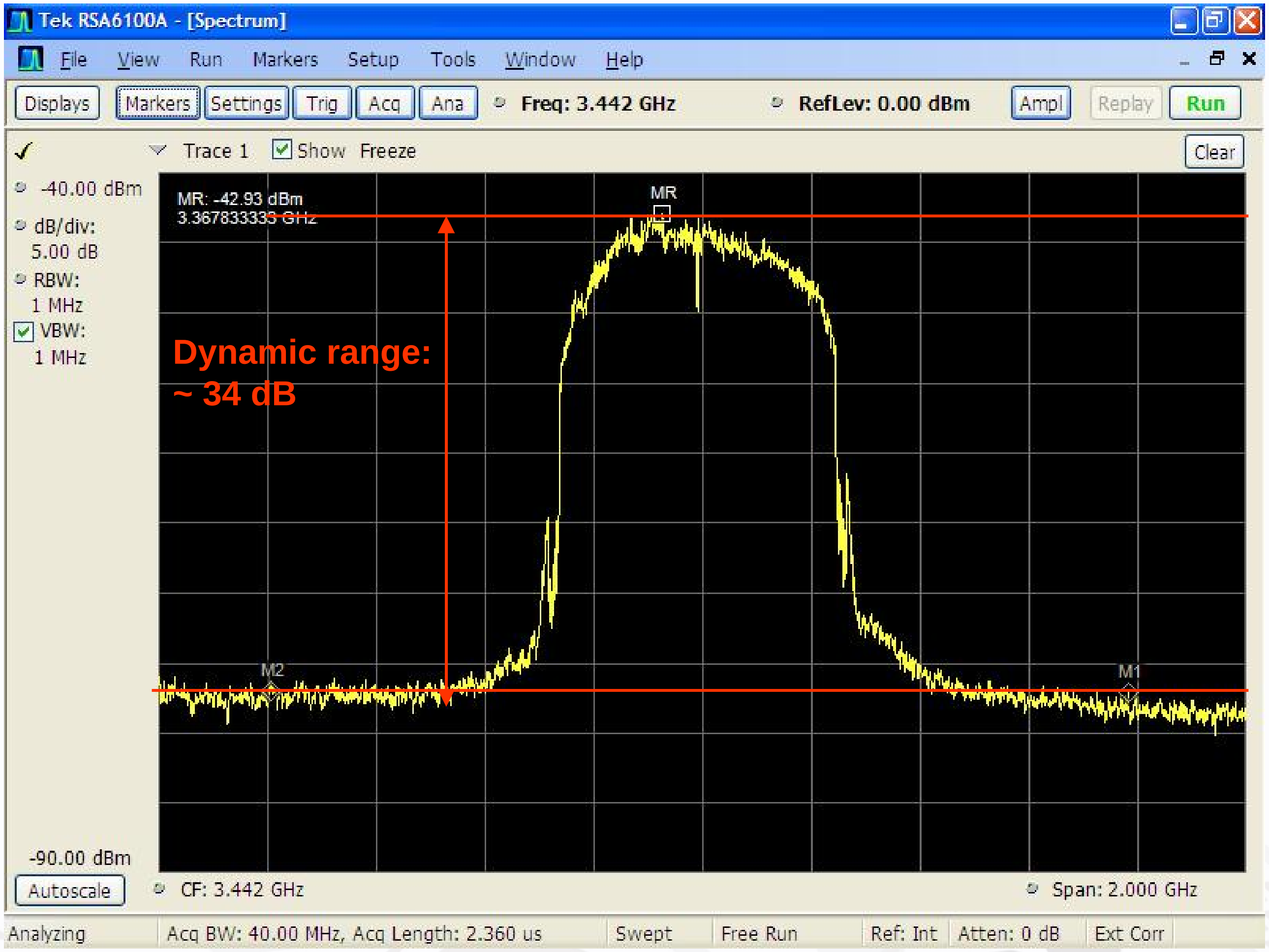
- ✓ Comparison: CTL vs. JRC measurements





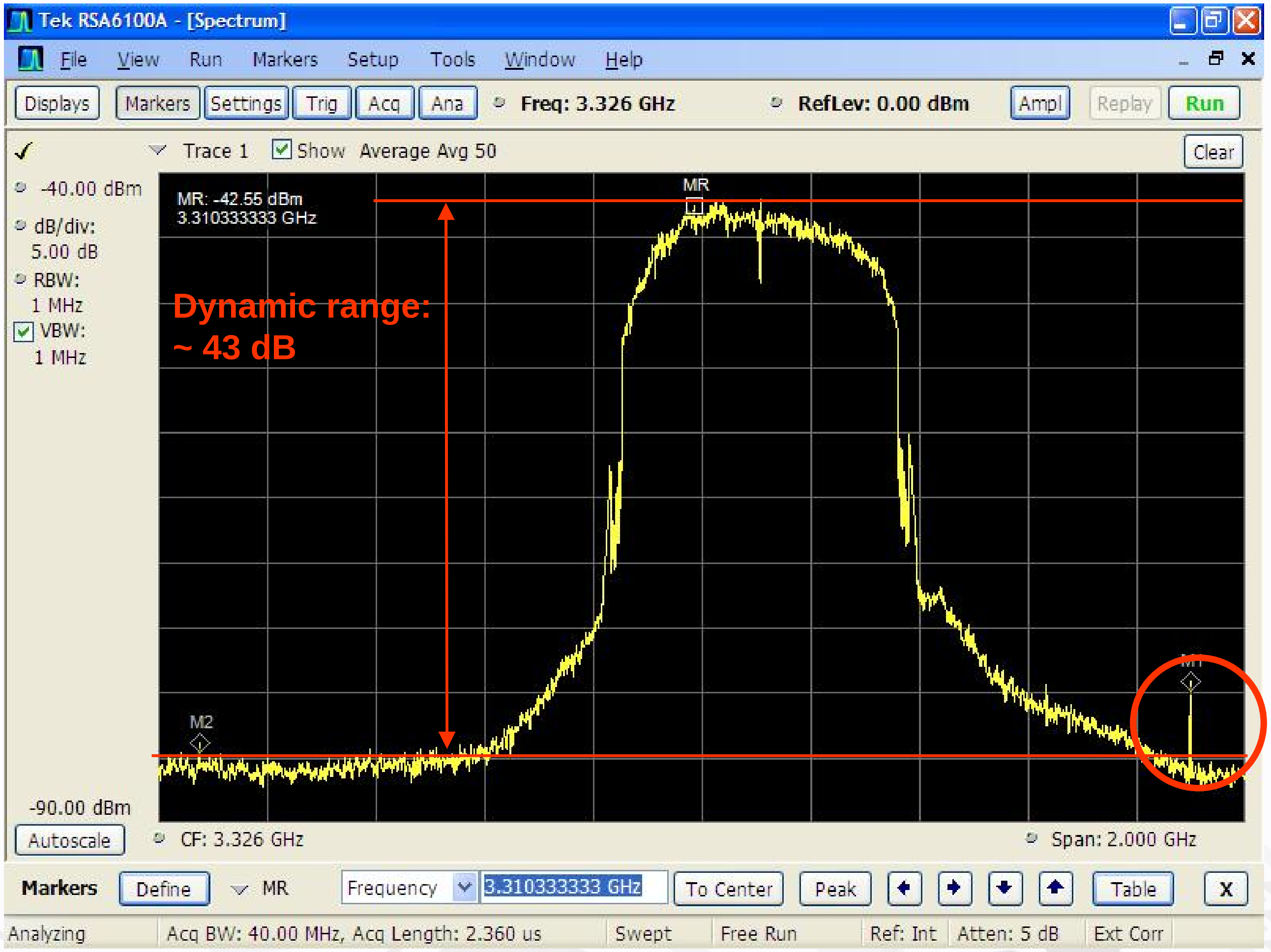
Measurement results 6

- LNA 1 only, measuring distance 3 m



Measurement results 7

✓ LNA 1 only, measuring distance 1 m

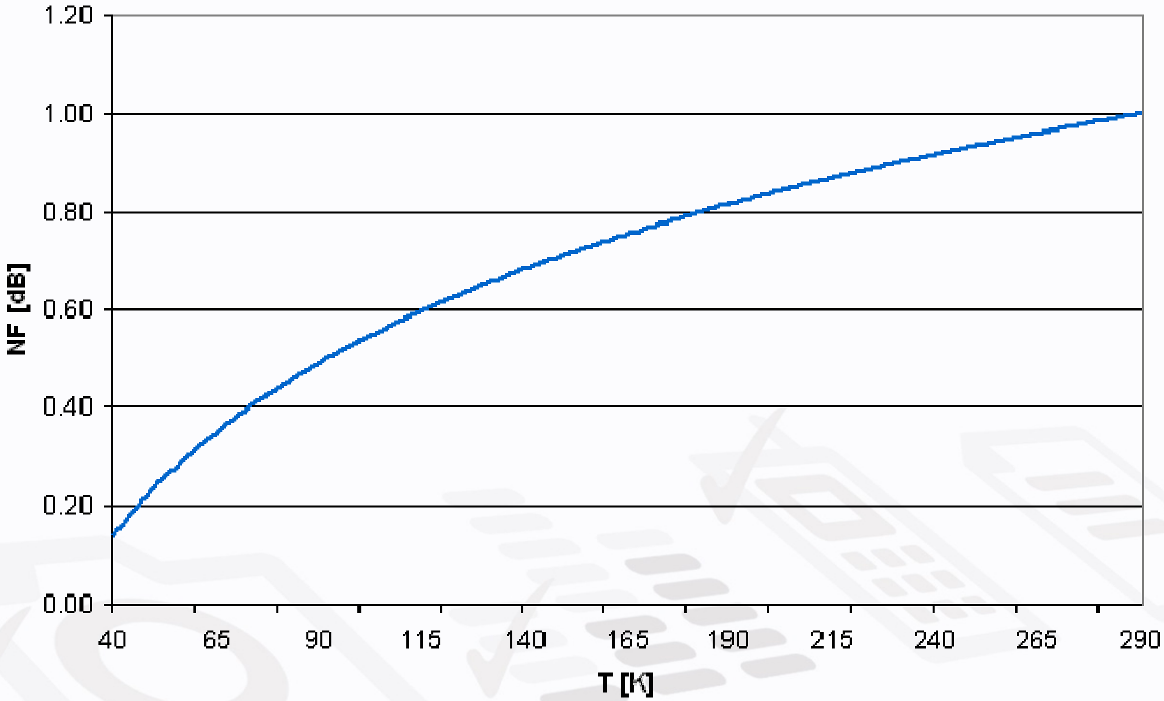


Cryogenic LNA

- Based on Amplitech cryogenic microwave LNA
- Uses two 3-stage Peltier modules plus active cooling
- Temperature control and monitoring unit for exact setting of target temperature

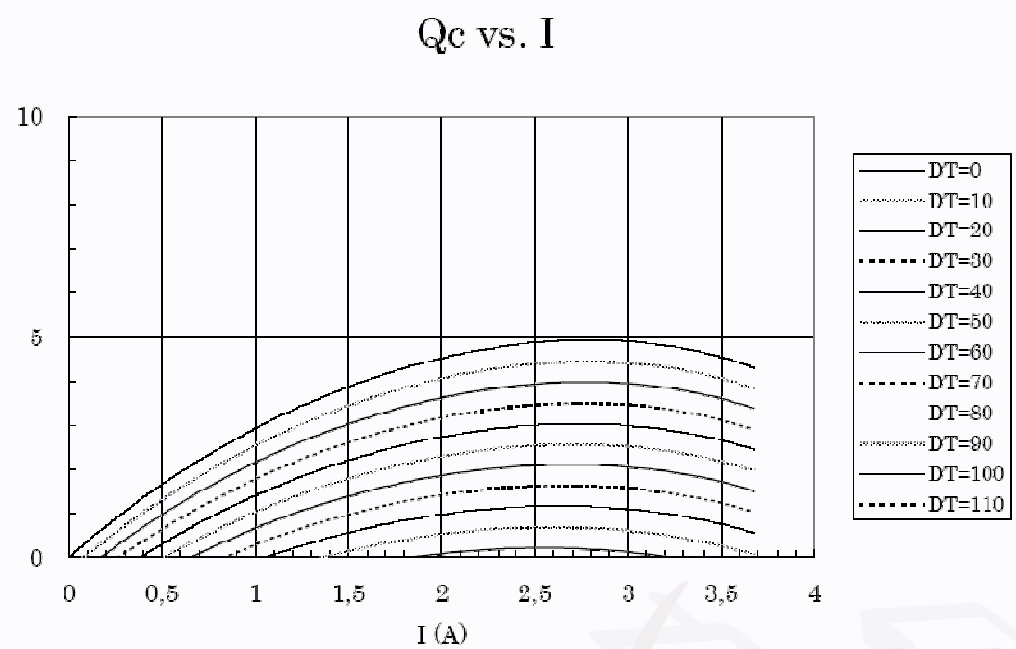
Cryogenic LNA - Device

- Amplitech cryogenic microwave LNA
  - Low NF (1 dB at 290K, 0.4 db at 77K)
  - Operates at temperatures down to 5 K
  - Power consumption ~640 mW
  - Operating frequency range: 0.1 – 6 GHz

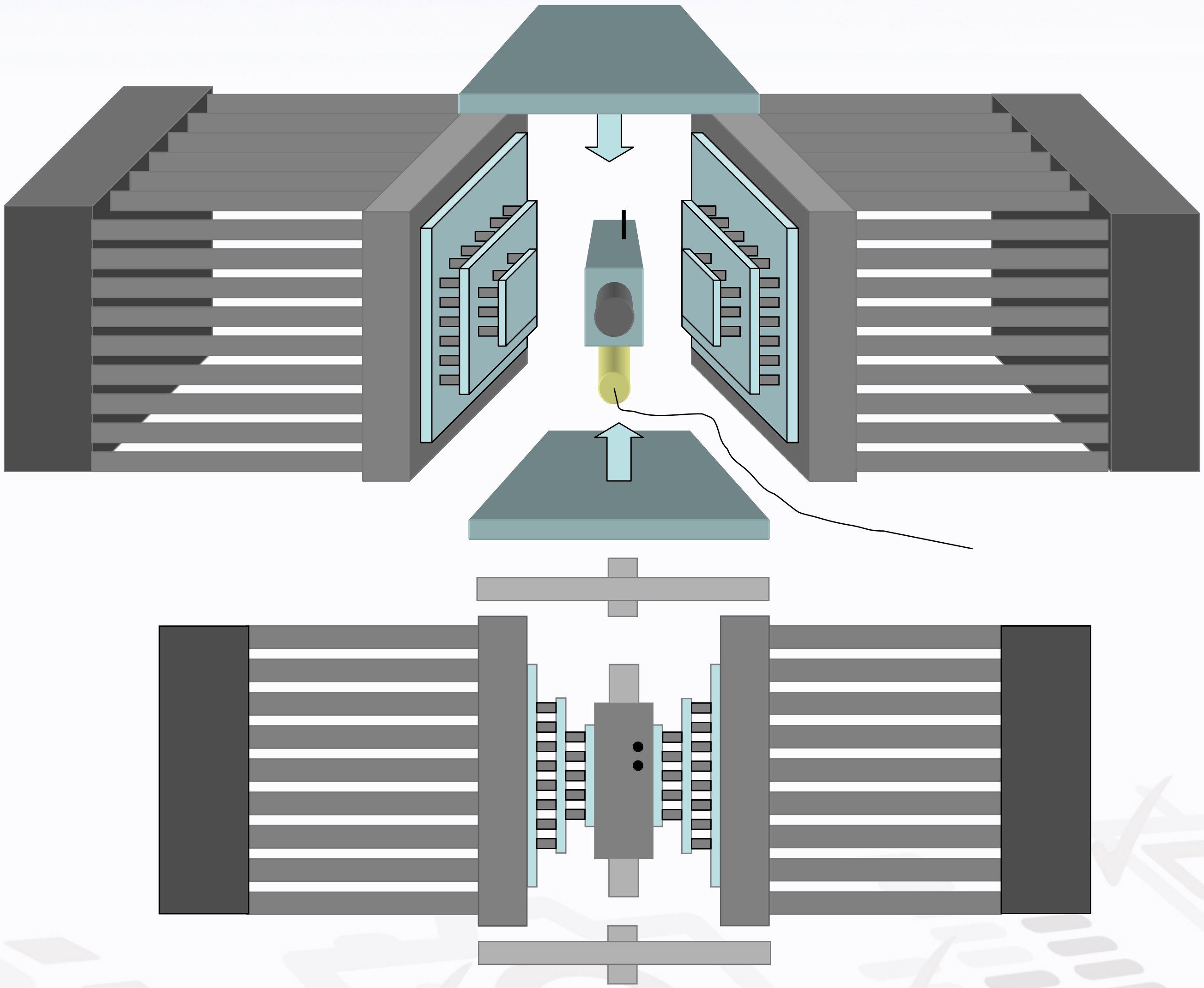


Cryogenic LNA - Peltier

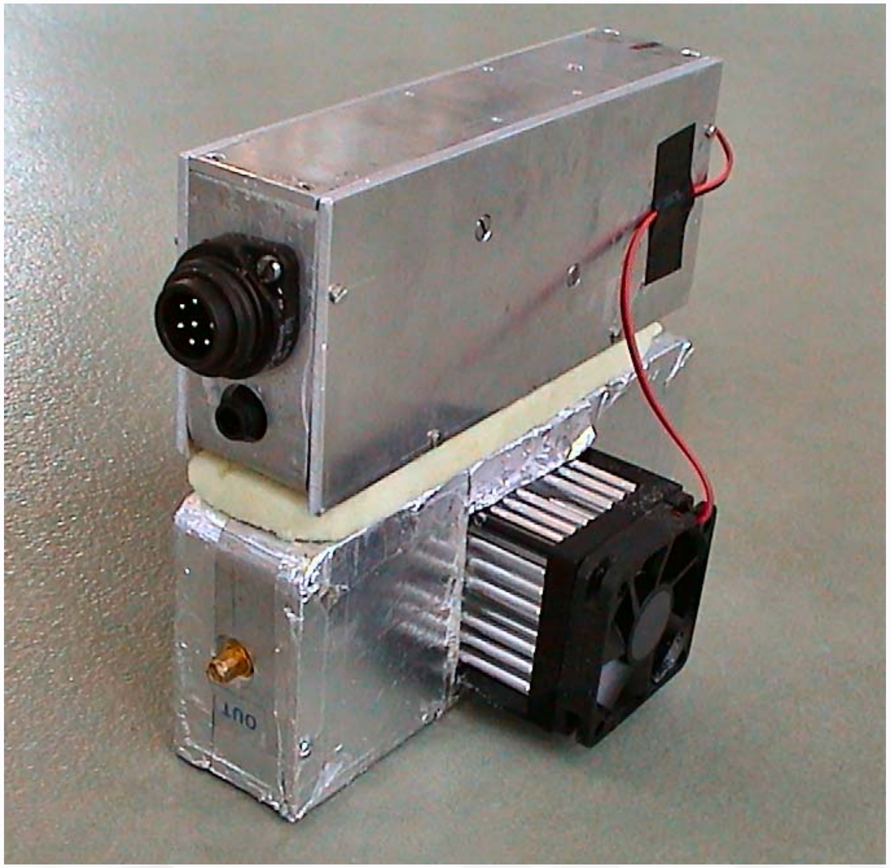
- FerroTec 3-stage Peltier element
  - Max. ΔT = 110 °C (Q_C = 0.1 W)
  - Max. ΔT = 90 °C (Q_C = 0.7 W)

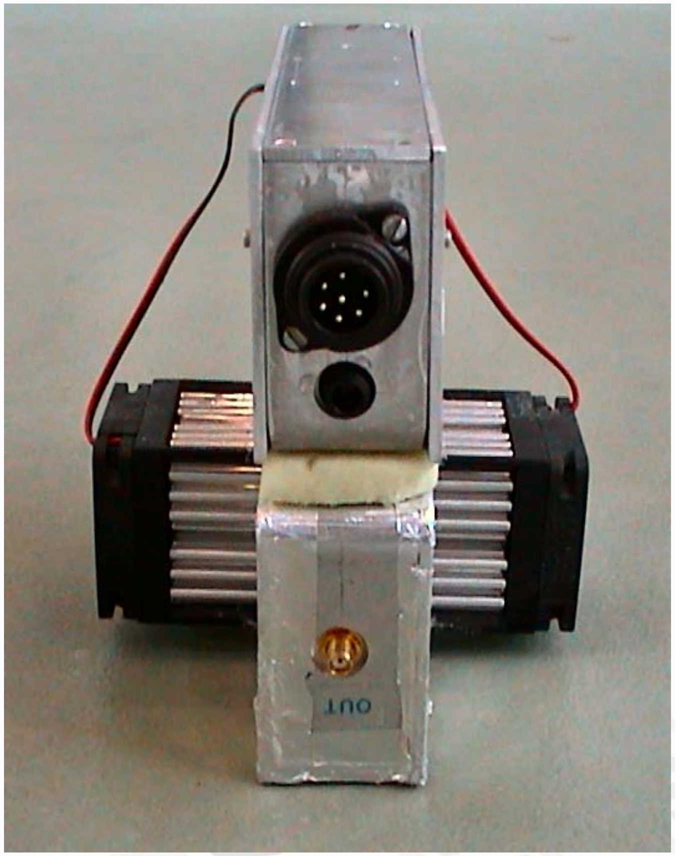


Cryogenic LNA – Module (I)



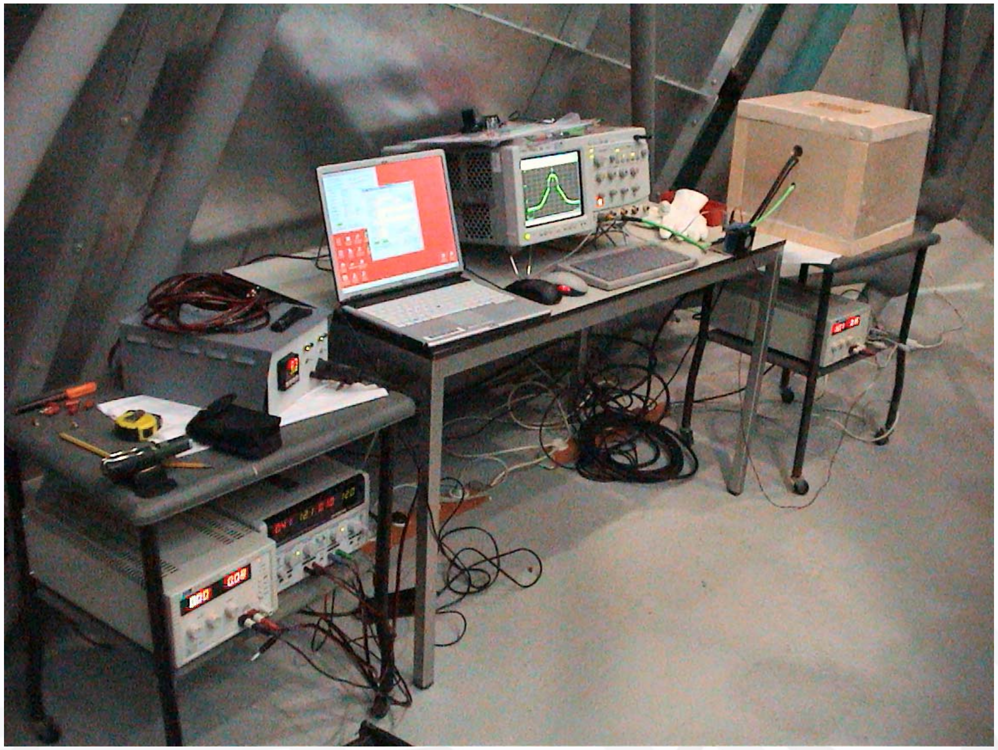
Cryogenic LNA – Module (2)

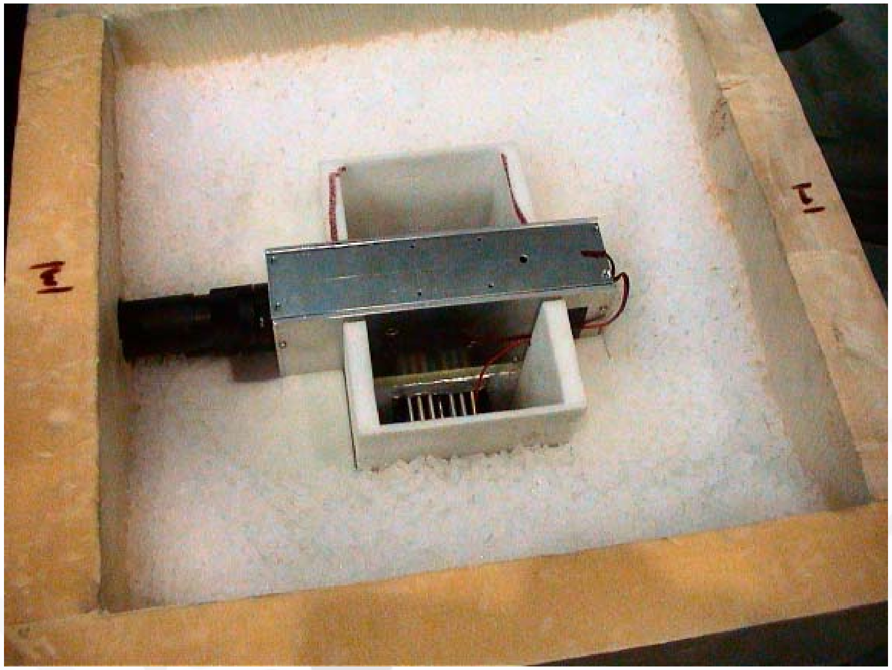




Measurement setup I

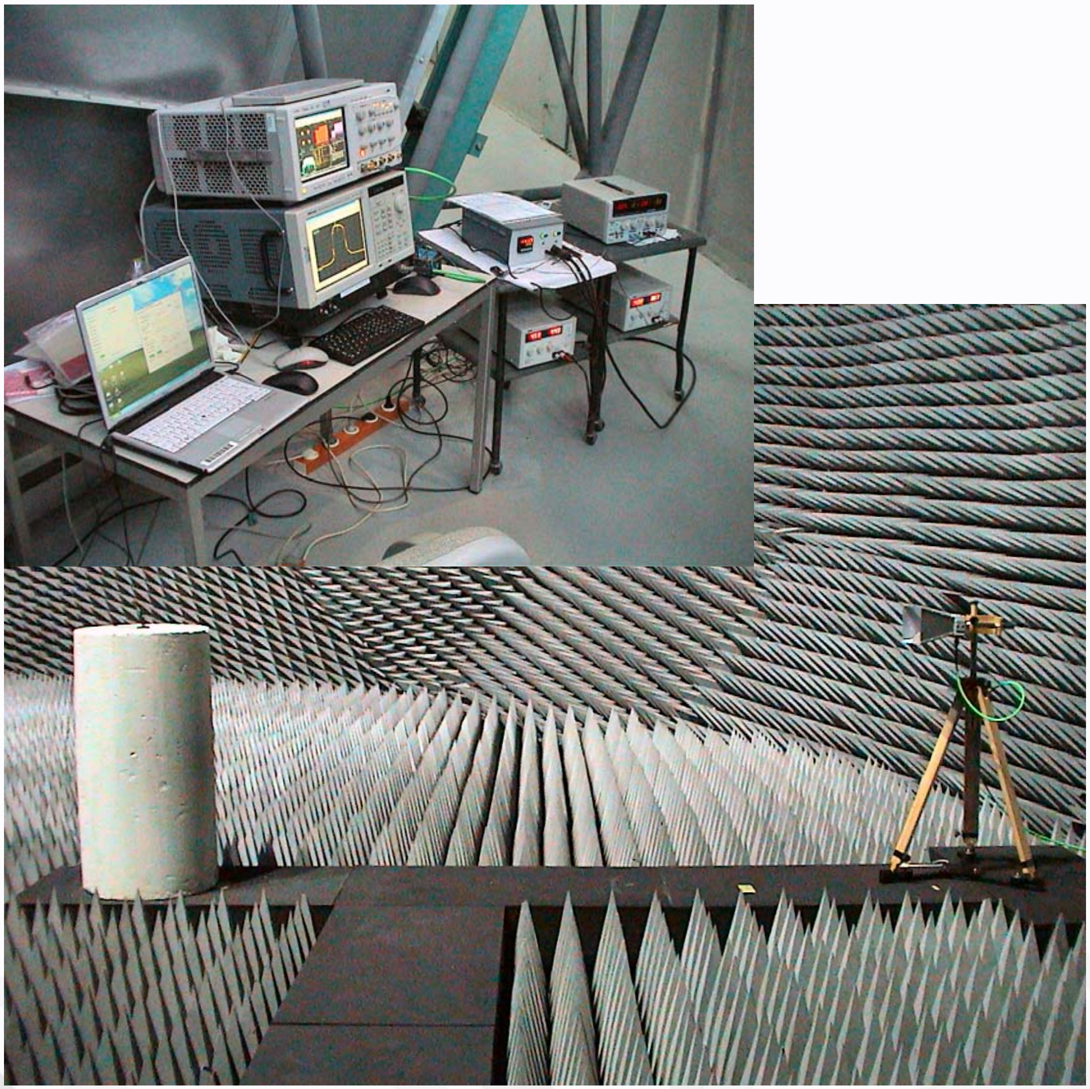
- First & second run
  - Peltier cooling only: -40 °C
  - Peltier + CO_2 cooling: -87.8 °C

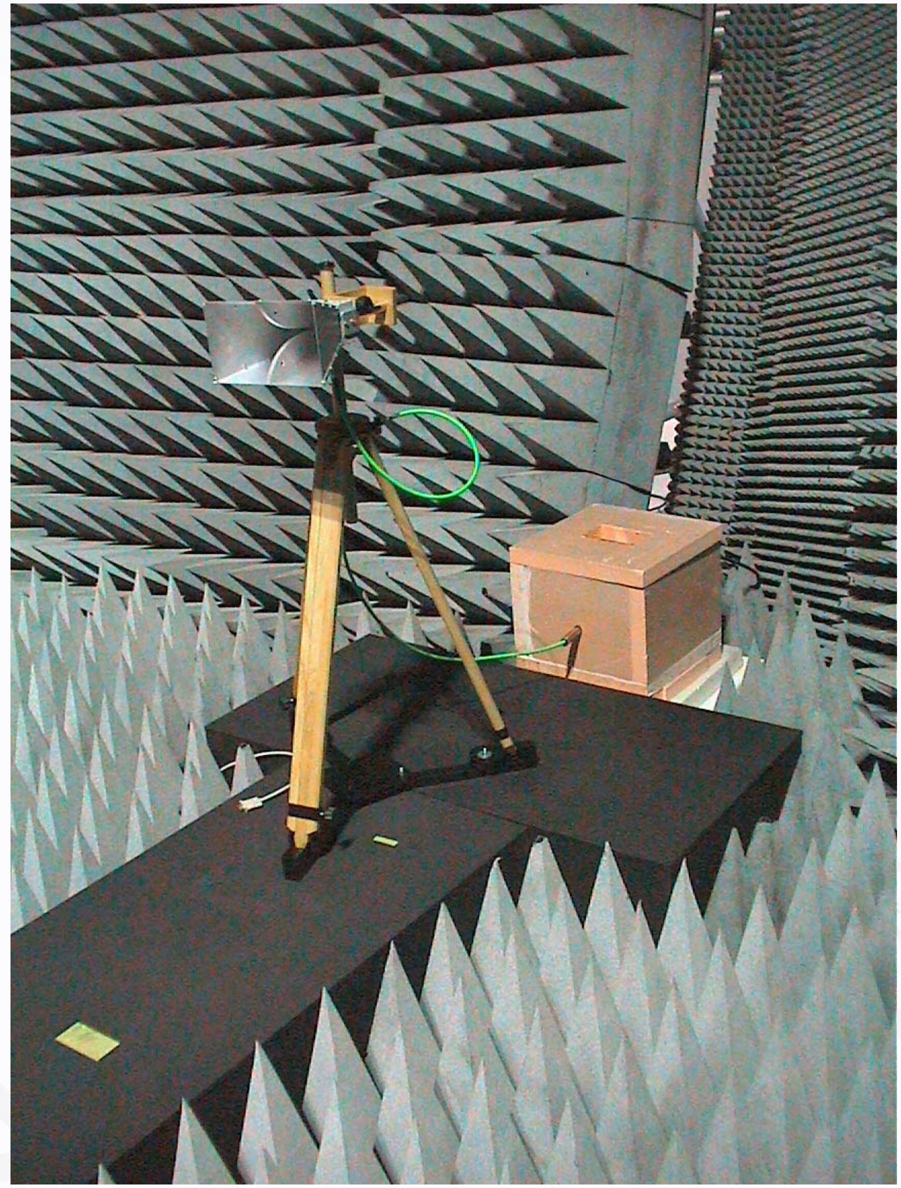




Measurement setup 2

- Third run





Conclusion

- Cooling the LNA only improves SNR but not significantly
  - Gain is 1.6 dB at 20K, 1.2 dB at 77K and 0.8 dB at 190K
- Using higher gain antennas could improve SNR but … Gain ~ size ~ Far field distance
- Reducing measurement distance could provide improvements in SNR but again the Far field condition has to be observed
- The simplest way would be to increase UWB Tx power

Contacts

Coordinator	Presenter
Franck Le Gall (inno)	Detlef Fuehrer
Contact@walter-uwb.eu	detlef.fuehrer@jrc.ec.europa.eu
+334 923 884 18	+39 0332 783056

http://www.walter-uwb.eu