Introduction to RF measurements and instrumentation

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Content

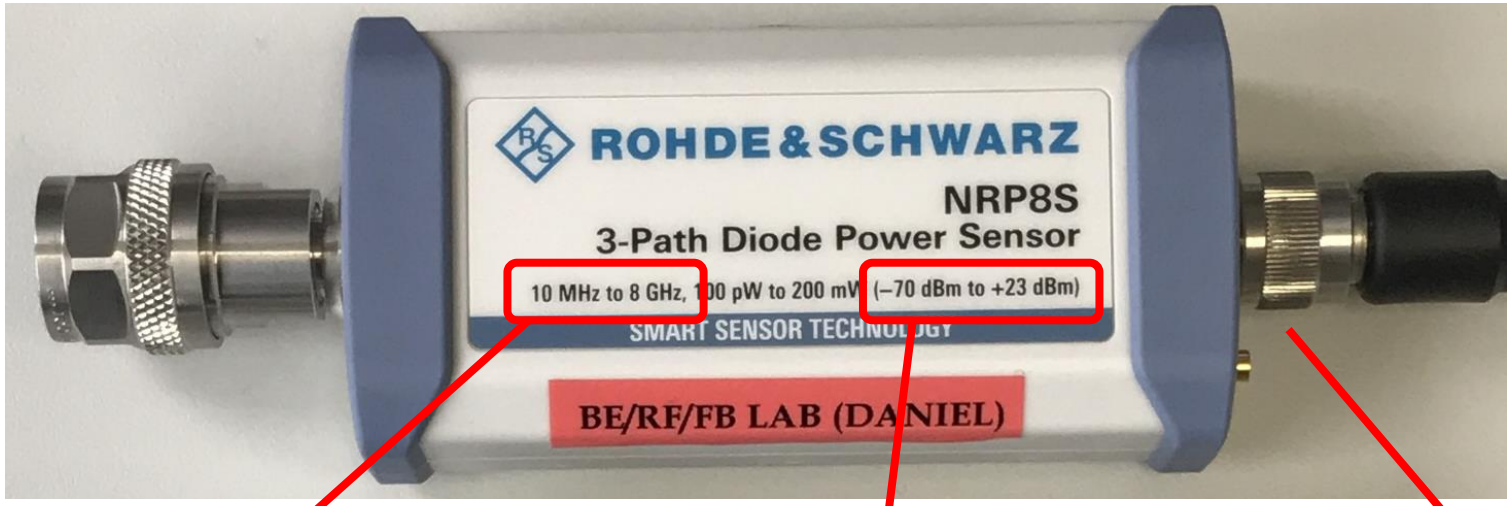
- RF power measurement
- Spectrum analyzers
- Vector network analyzers

RF power measurement

- Most popular methods to measure the RF power
  - **Diode envelope detection**: Most common, large dynamic range, suitable for constant signals
  - **Thermal**: Very accurate, limited dynamic range, ideal for complex modulated signals
  - **Electronic receivers**: Most complex, suitable for fast, pulsed signals

RF power measurement

- How to read specifications of a power sensor



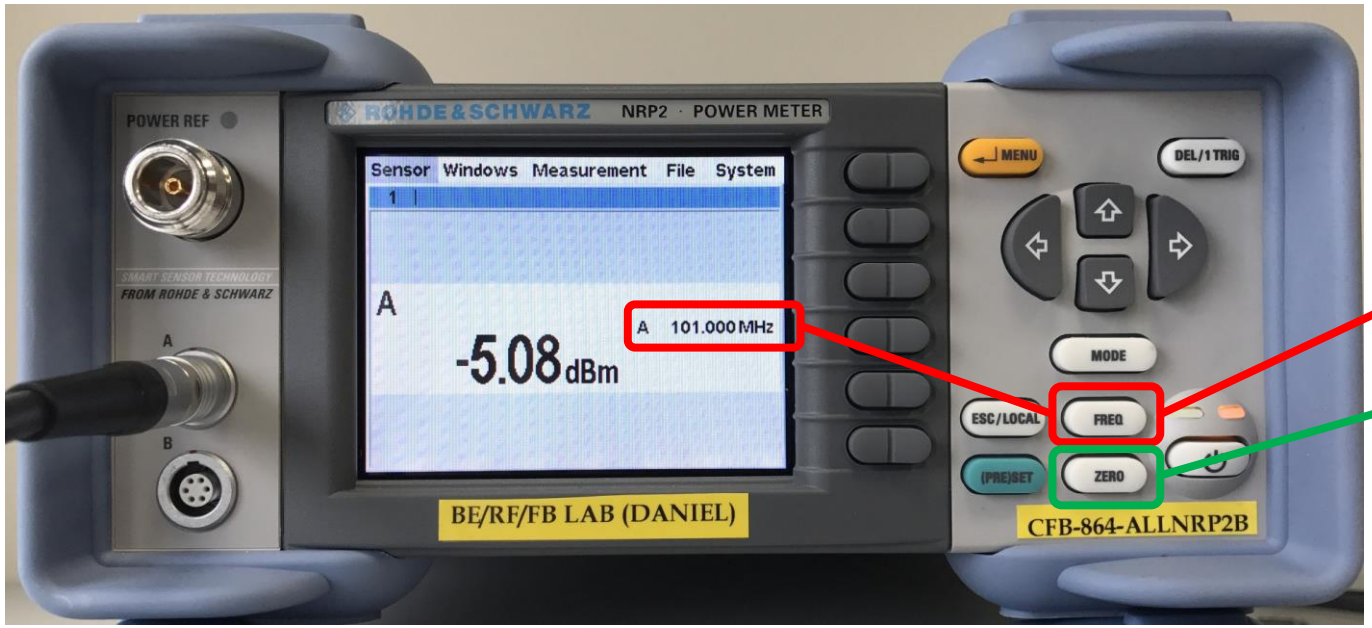
Frequency range:
Diode sensors ~10MHz
Thermal sensors DC
Pulsed sensors 50-100MHz

Power/dynamic range:
Minimum and maximum power for your application.
Values change typ. factor 1000+ between room temperature and superconducting state

External trigger and interface:
Synchronized acquisition, USB interface, ethernet…

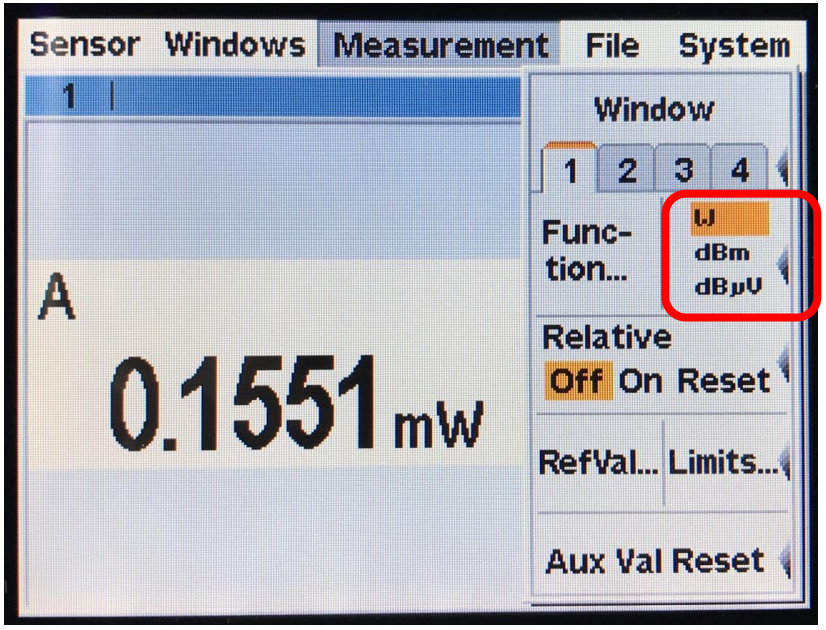
RF power measurement

- How to use a RF power meter

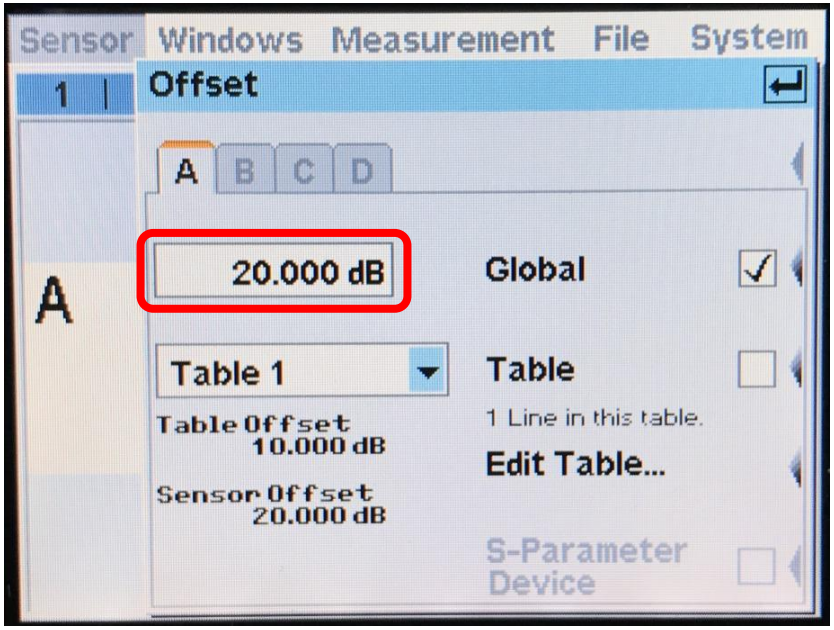


1. Set the frequency
2. Zero the offset
3. Connect sensor to the signal source

RF power measurement



Chose the desired measurement unit



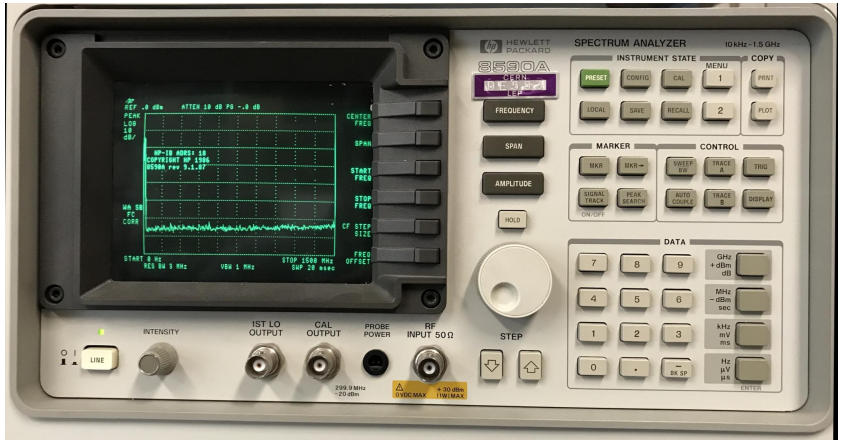
If measuring through couplers/ attenuators etc. set-up the offset for direct reading of the source power value, instead of measured power value

RF power measurement

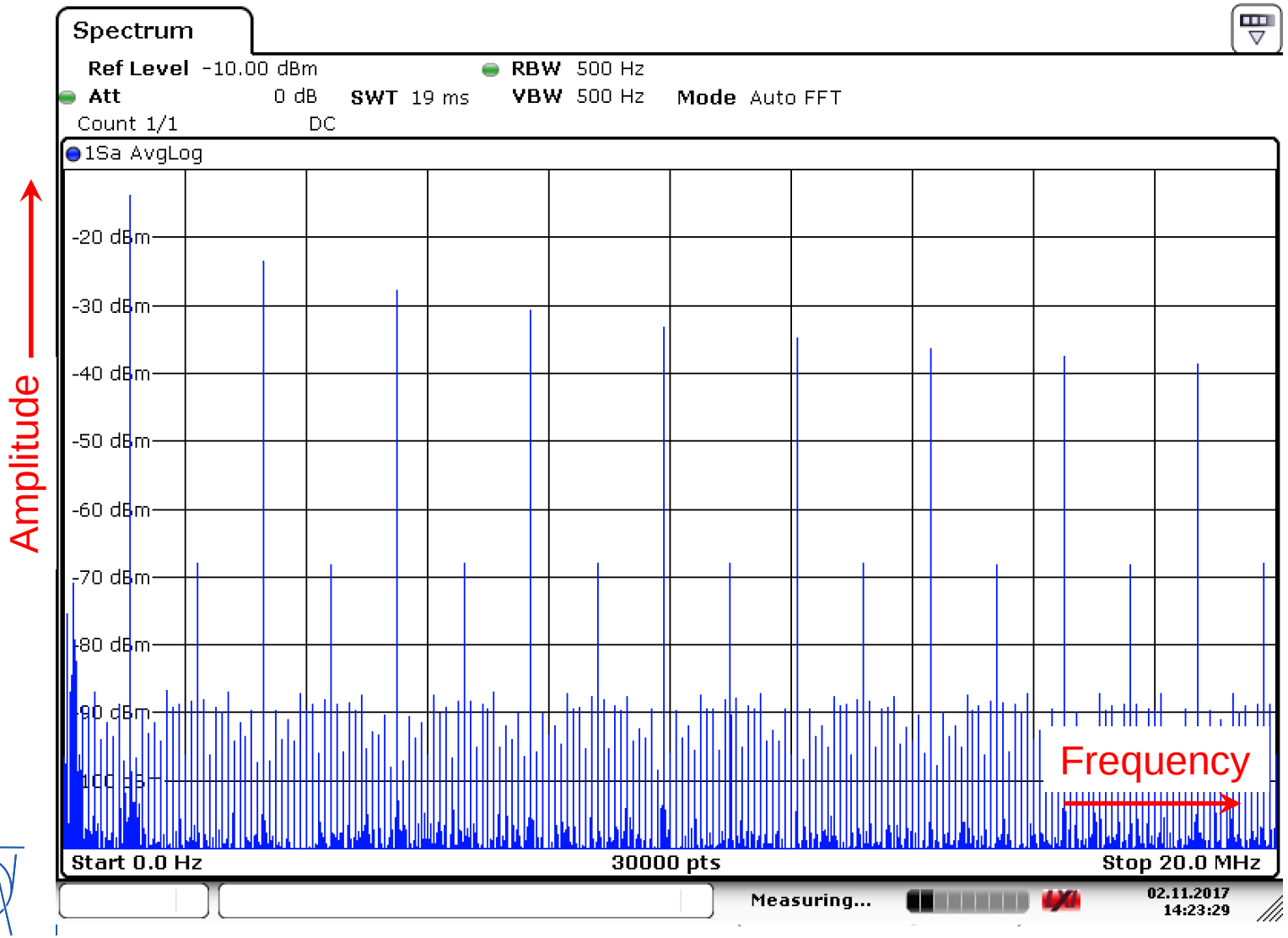
- Some comments:
  - The reading is noisier at the bottom of the dynamic range
  - ***The power sensor really burns when overloaded*** (very costly to repair)
  - Sensors have optimized dynamic range for type of measurements they do (very accurate, very fast, RMS…)
  - Sensors and instruments need certain time to measure a data point, be careful with automation
  - Decide what to buy based on how are you going to use the instrument: Table top, USB sensor, Ethernet sensor…

Spectrum analyzer

- Spectrum analyser is a device, which measures frequency content of a signal.



Spectrum analyser user interface



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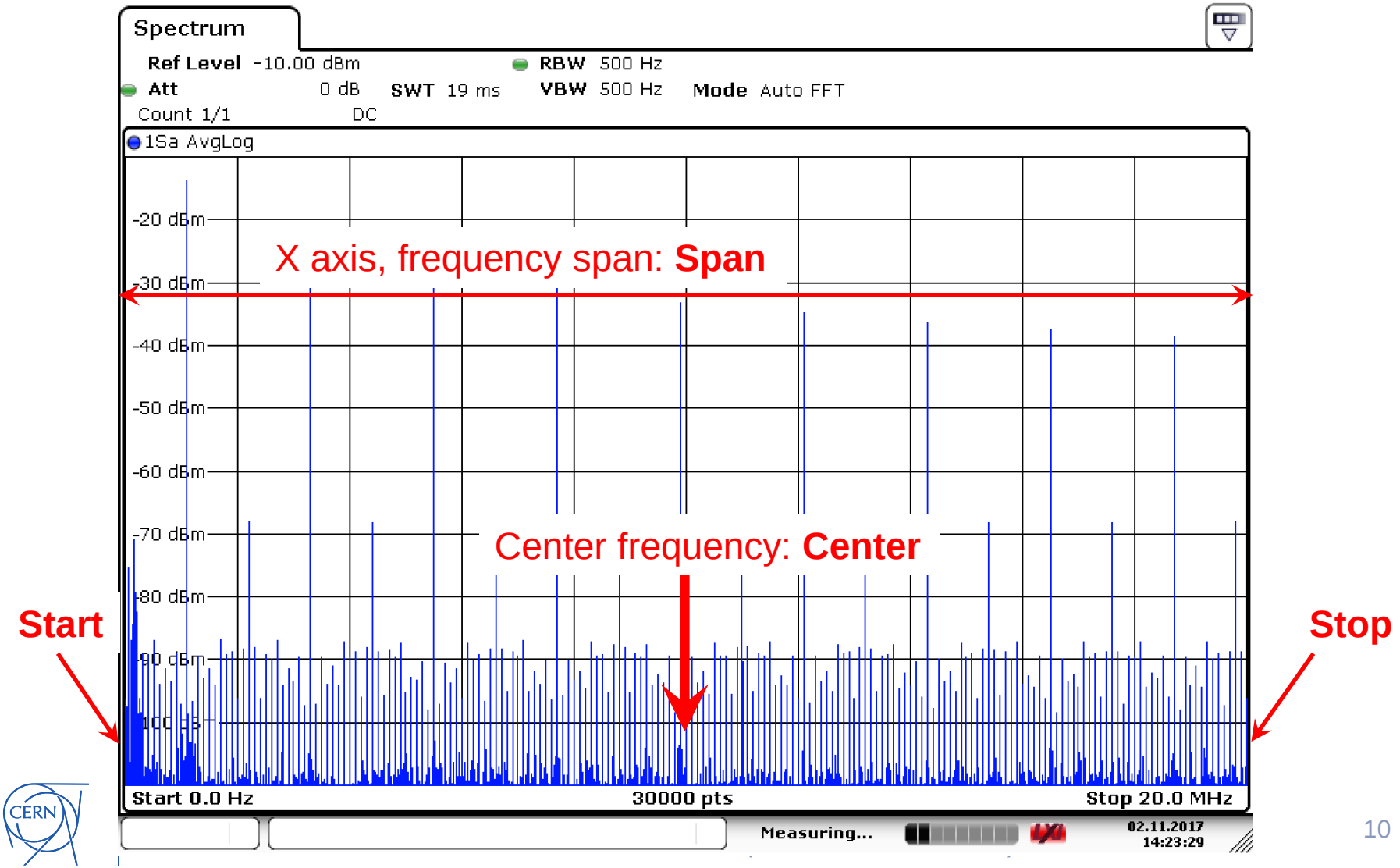

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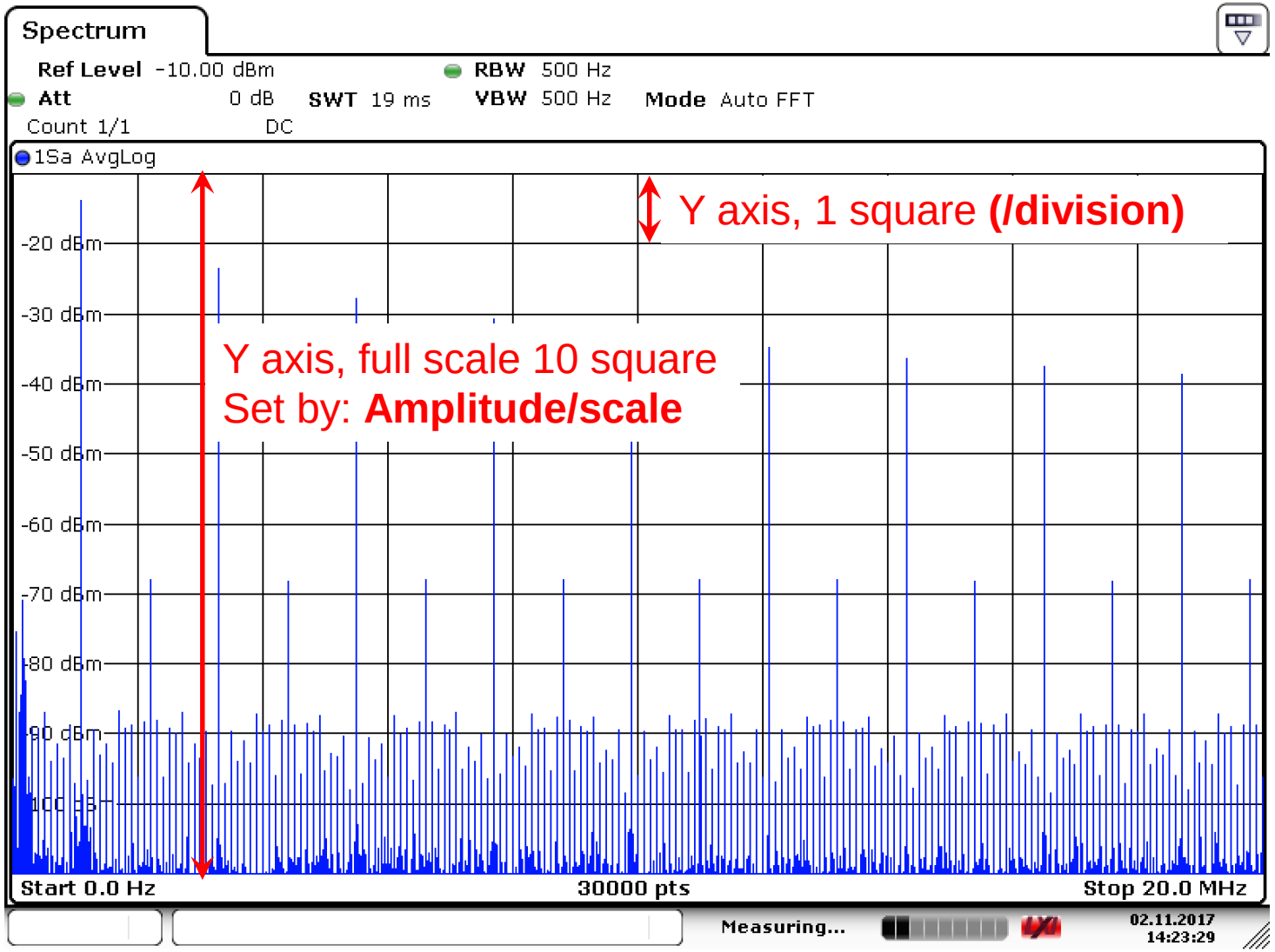

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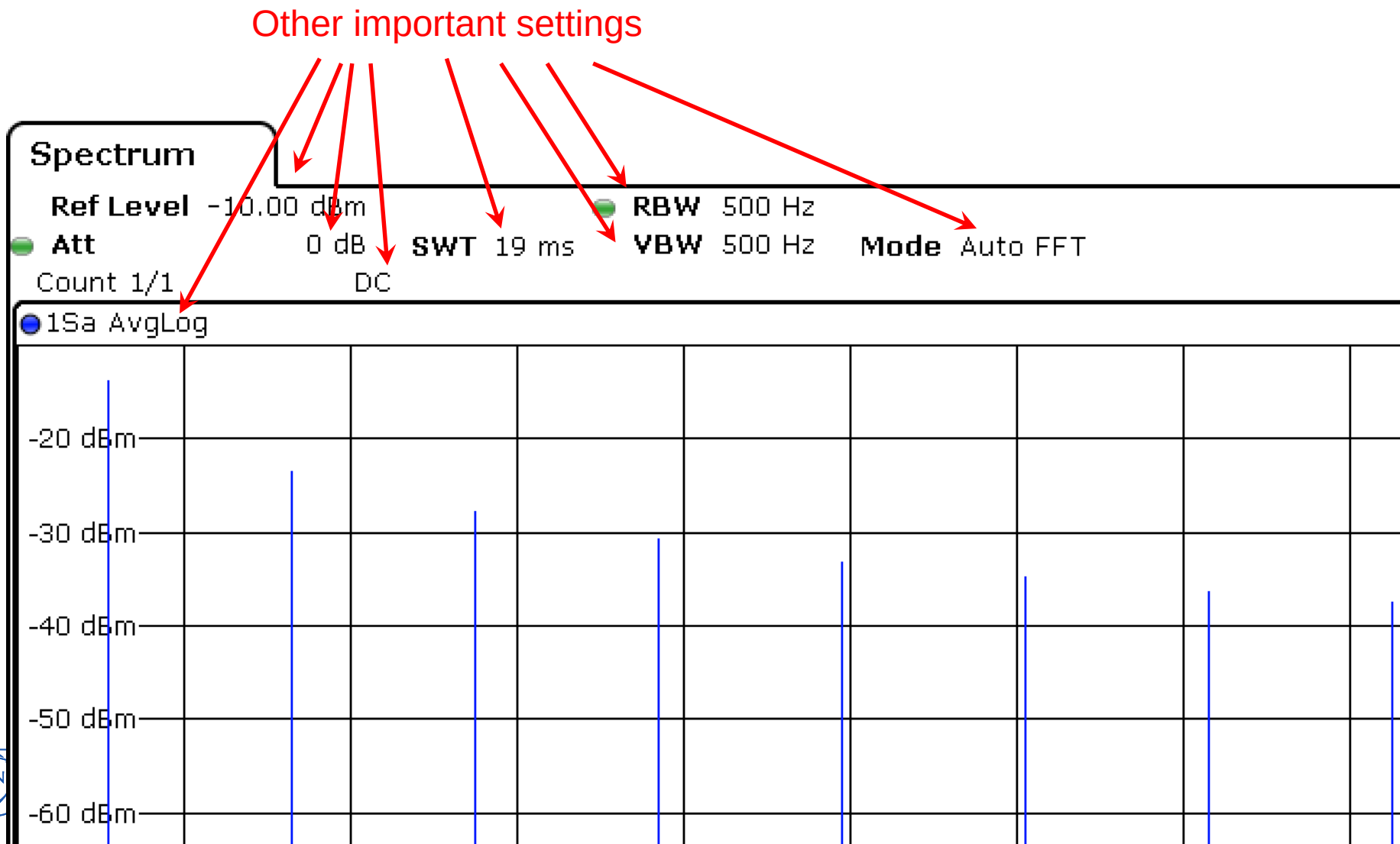

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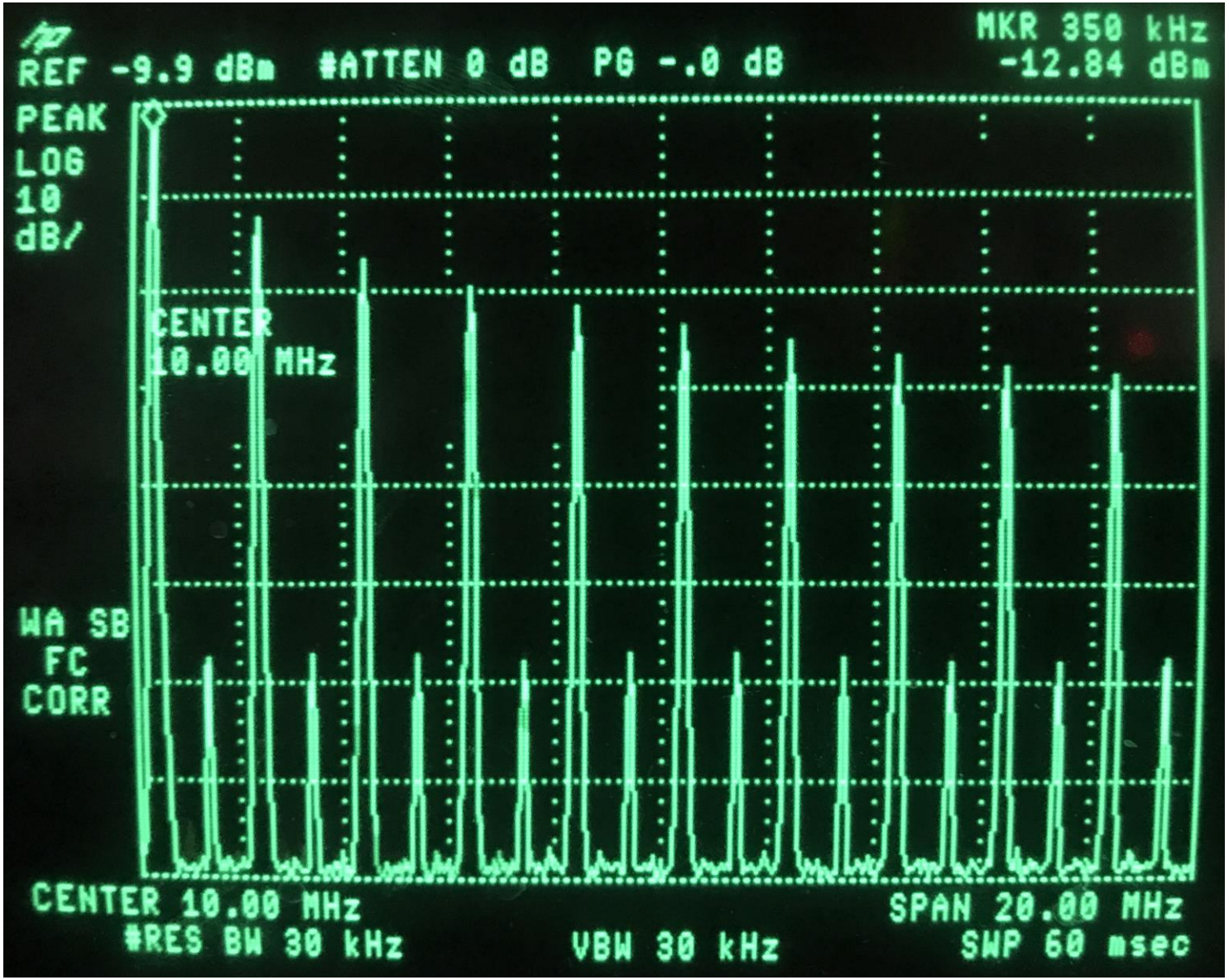

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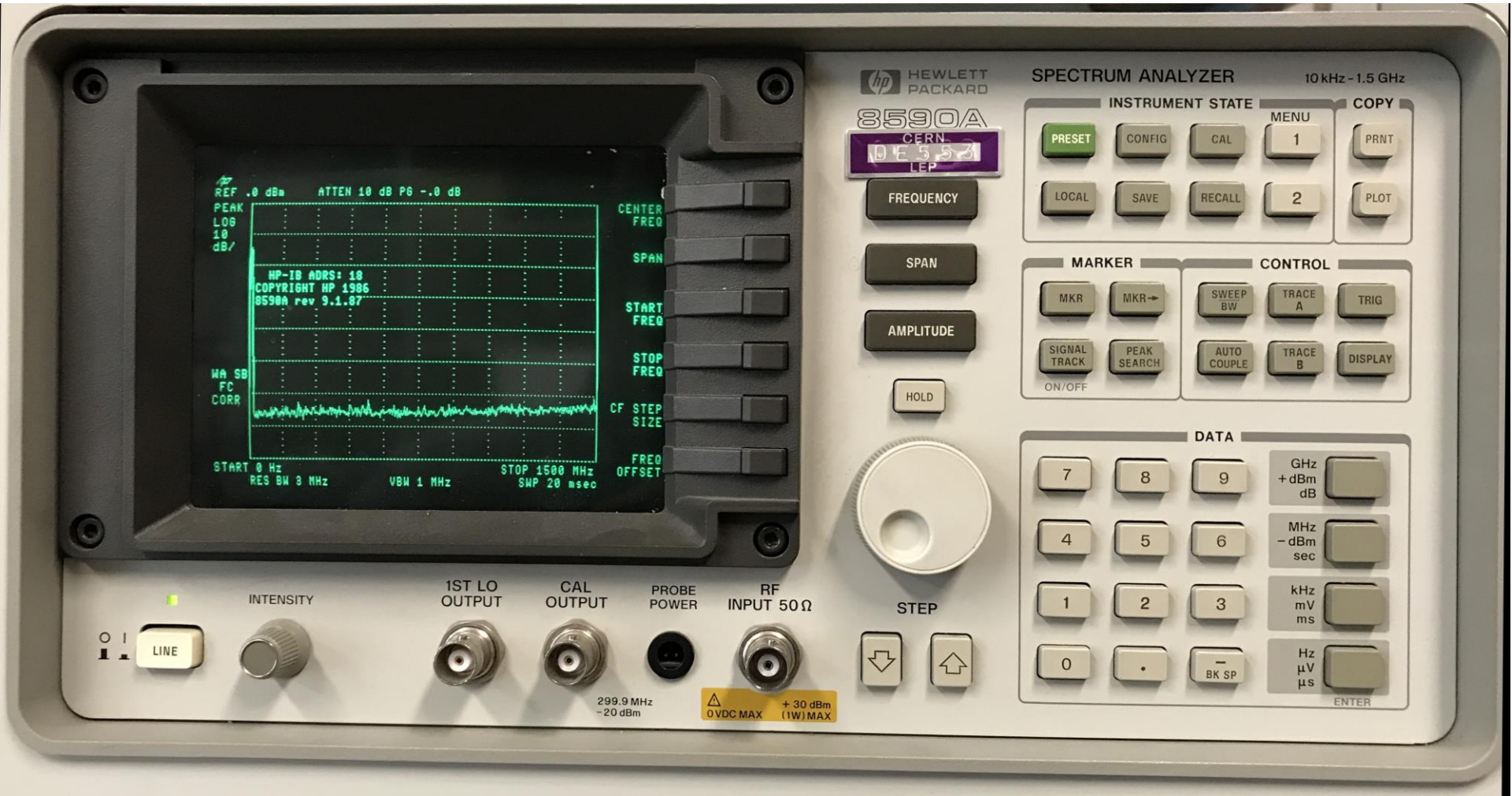

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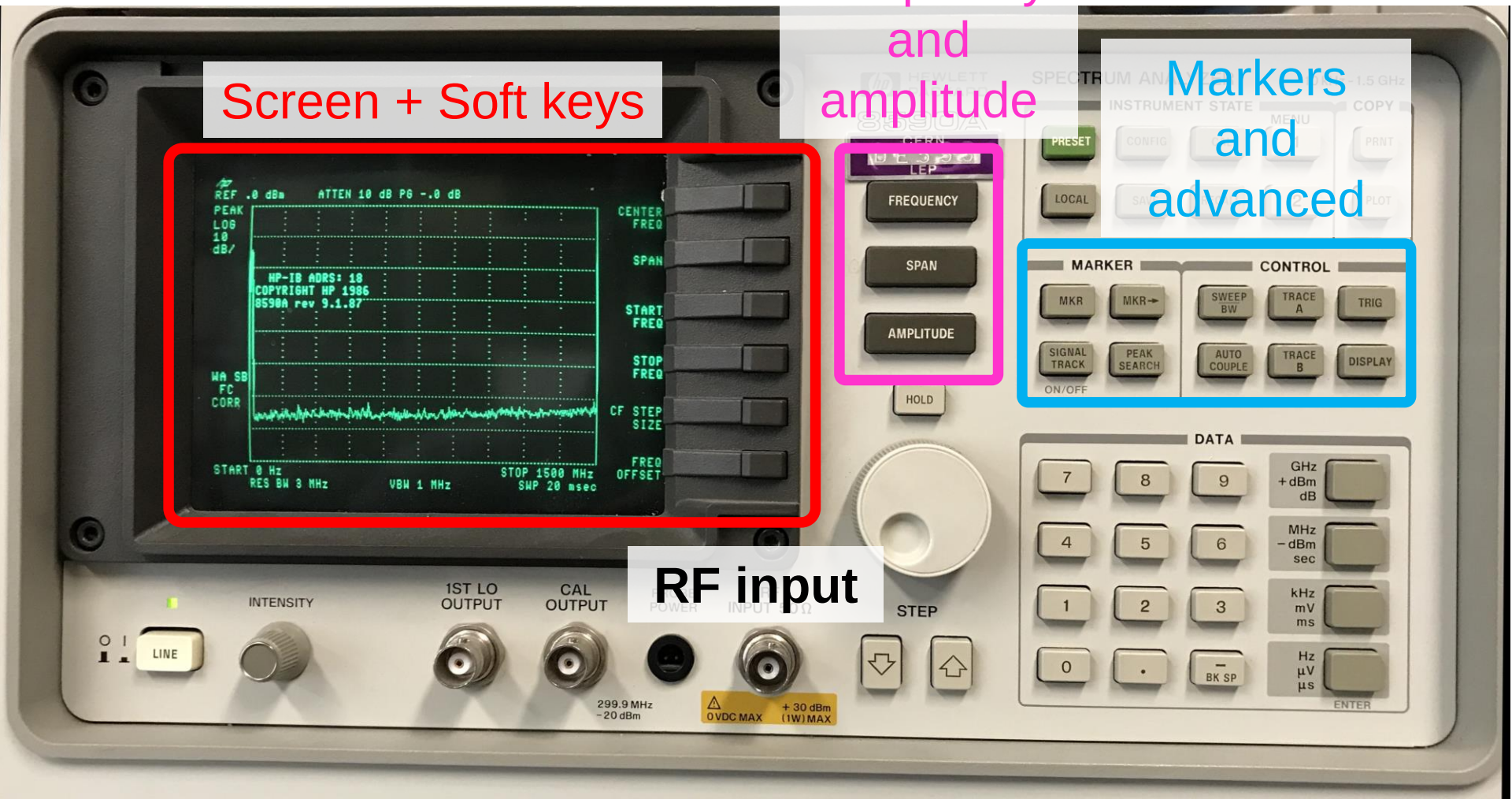

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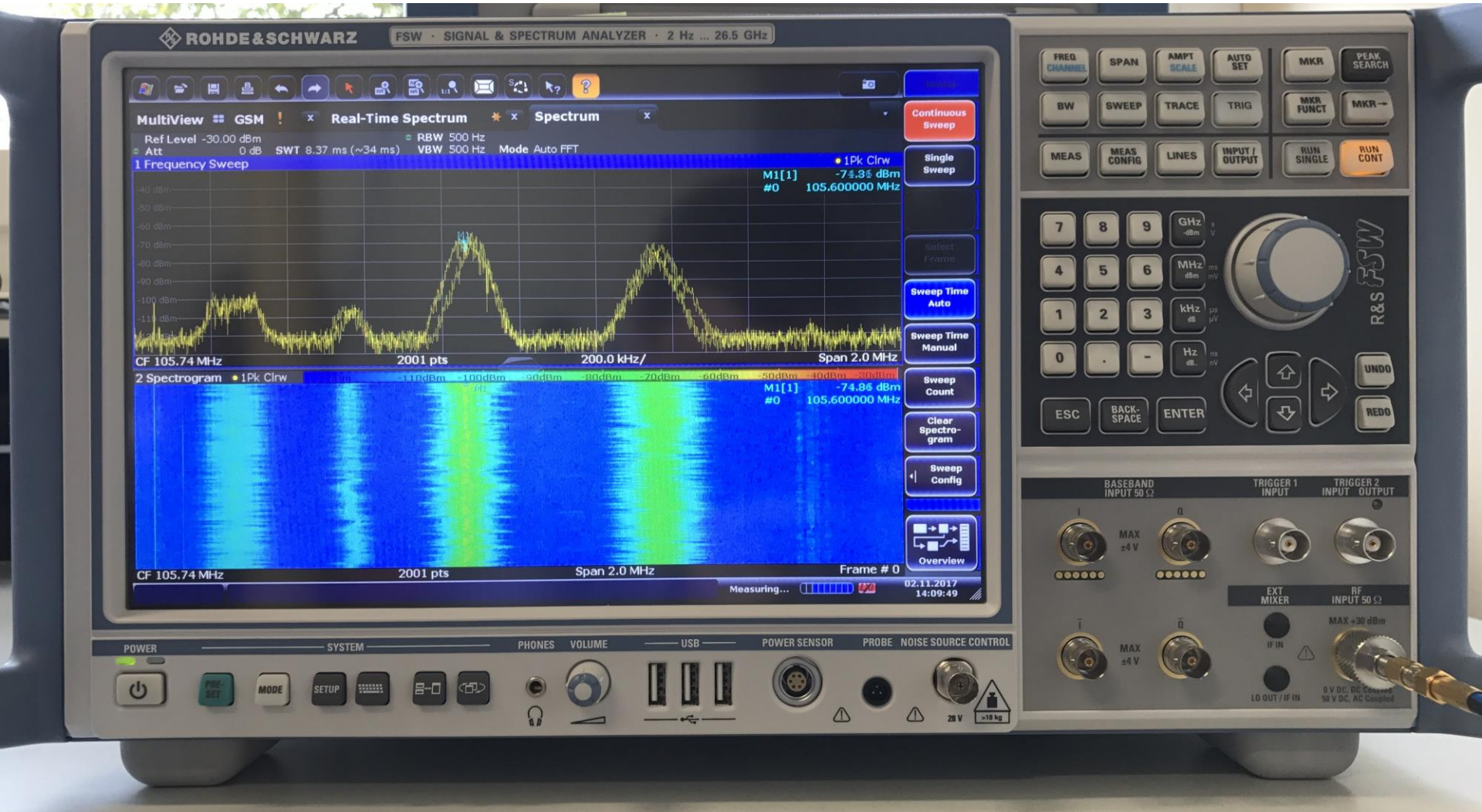
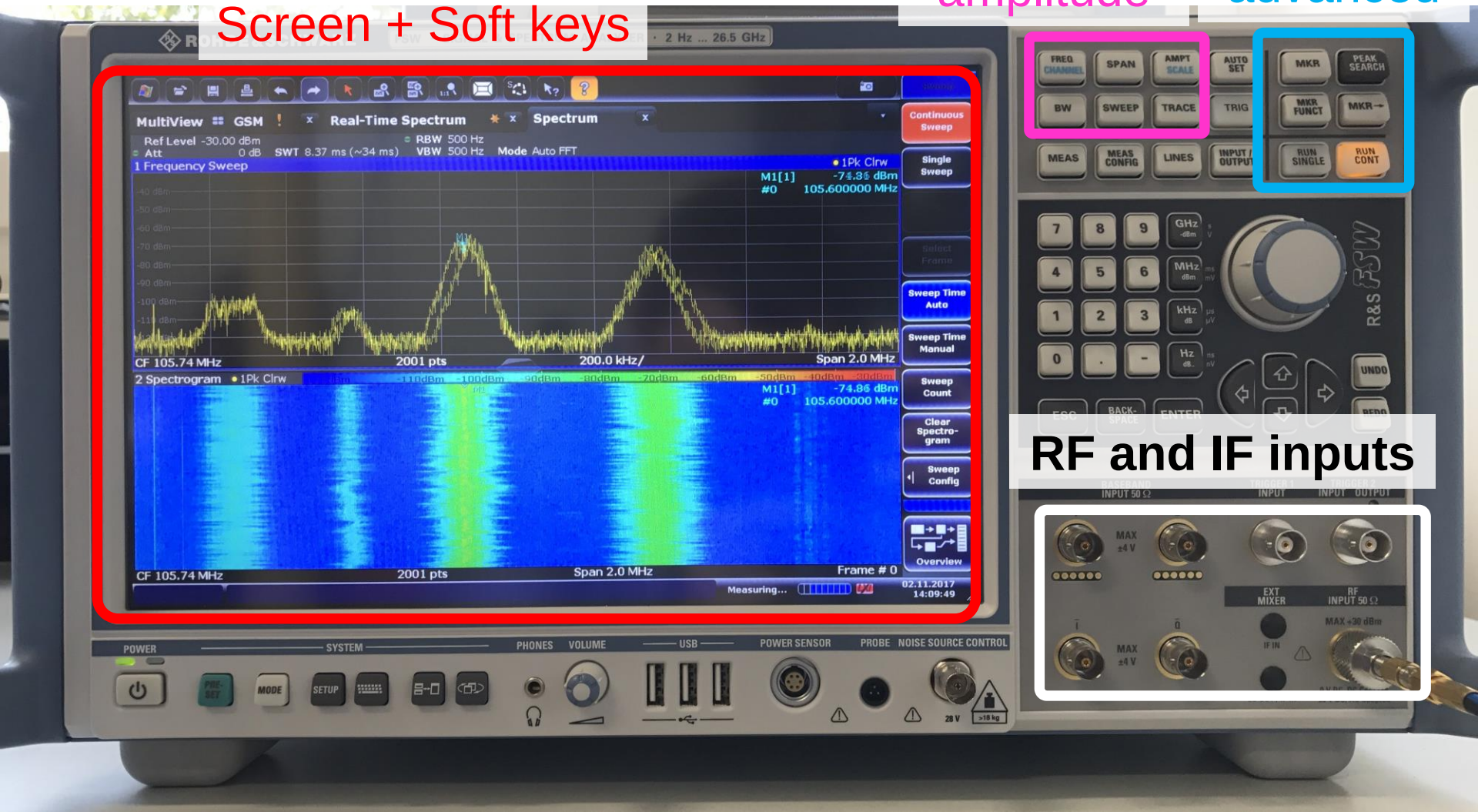


Spectrum analyser user interface

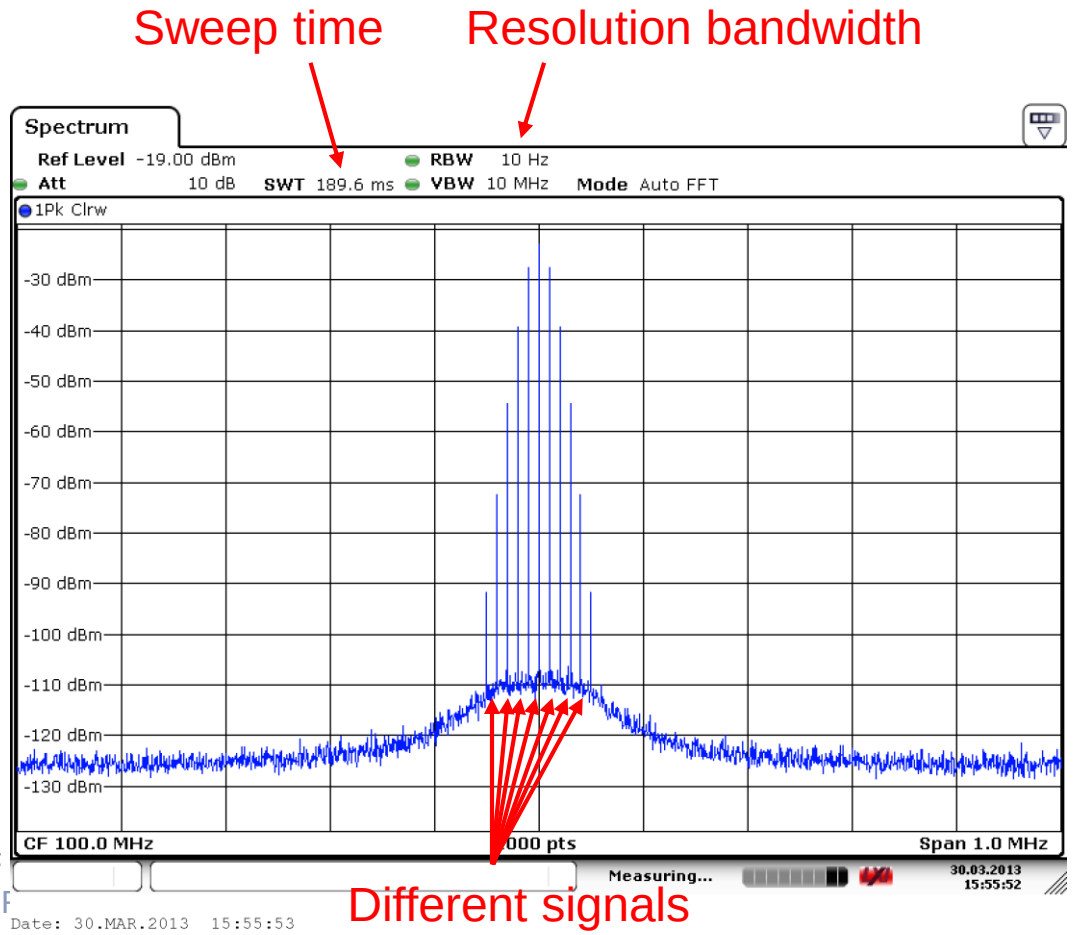
Frequency and amplitude

Markers and advanced



IF detector bandwidth – resolution bandwidth

- Receiver signal bandwidth prior the power detector
- IF/resolution bandwidth defines the measurement noise floor AND how close two different signals can be in order to still distinguish them



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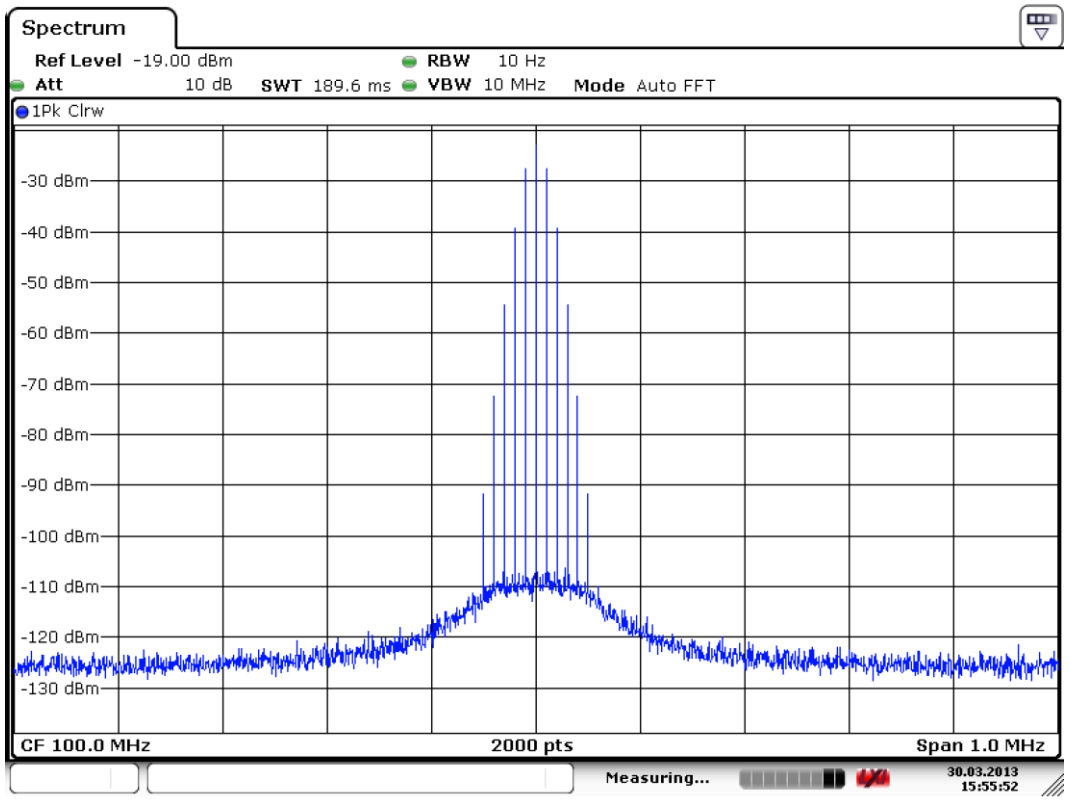
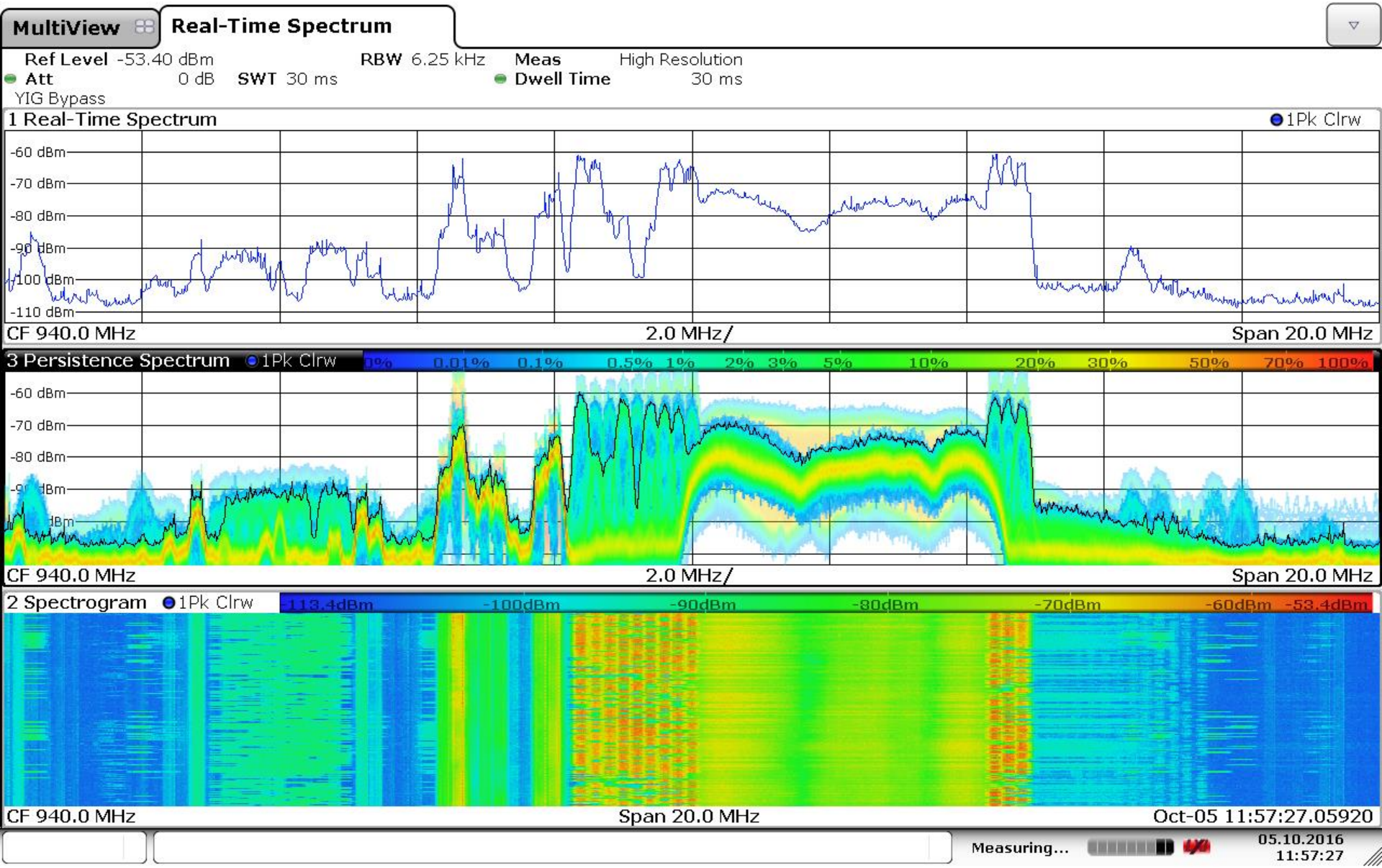
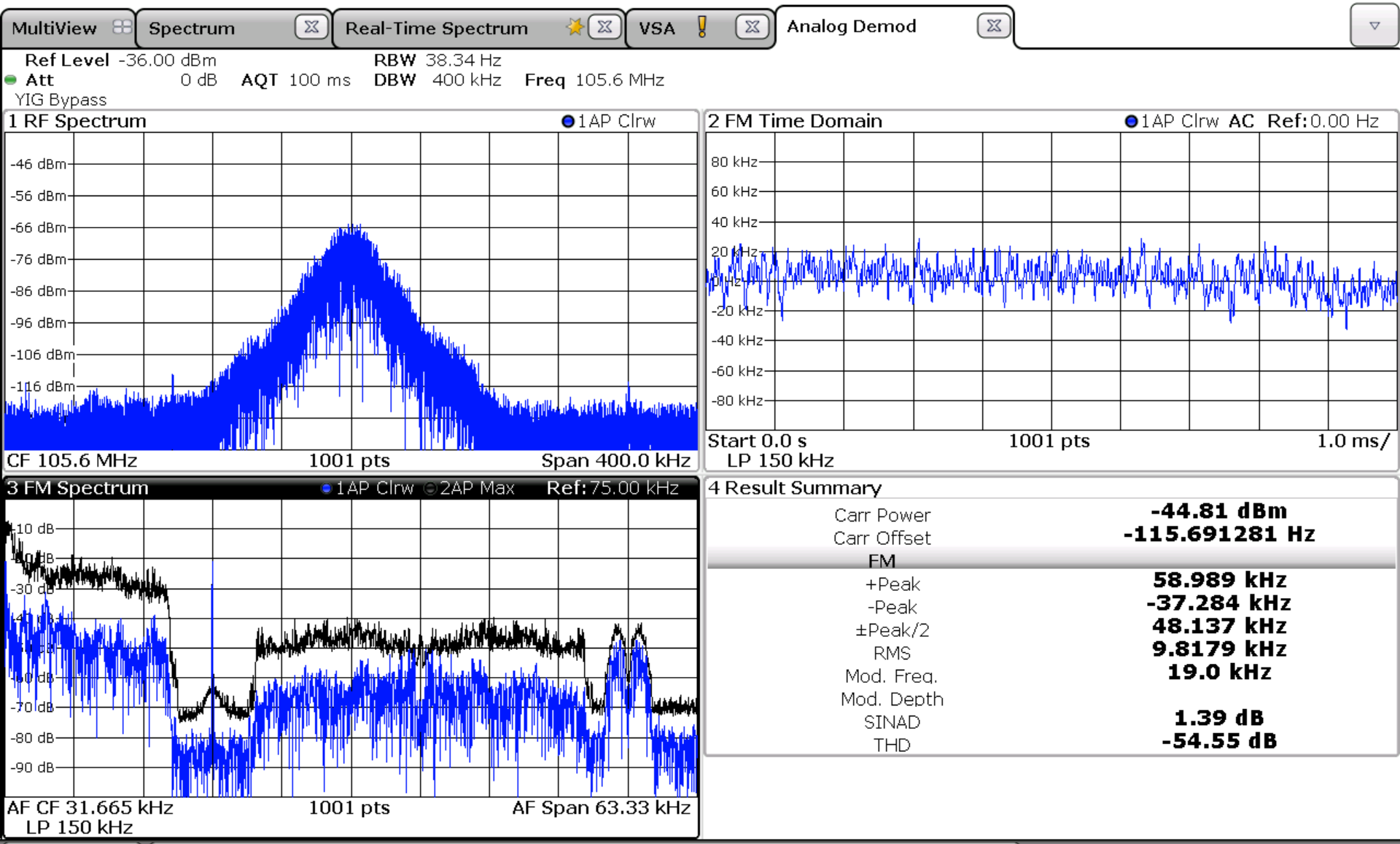


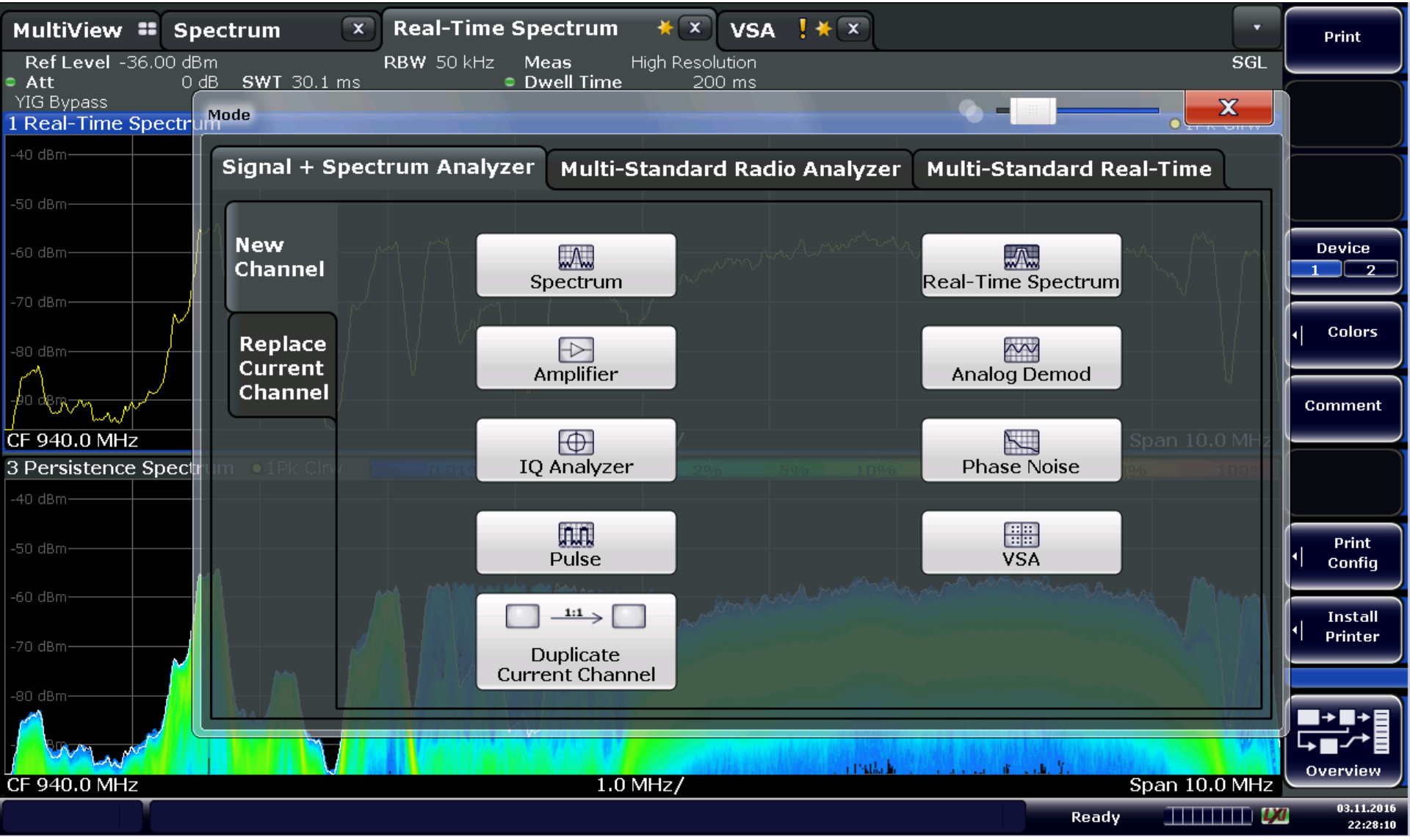
Real time spectrum analyzer



Signal demodulation by s.a.



Modern spectrum analysers



Vector network analyser

- Vector network analyser is a device, which excites a RF network and measures a response from its ports. All signals are measured as phasors.

If we know RFL and FWD we can calculate:

- VSWR
- S-parameters S_{11}, S_{12}
- Reflection coefficient Γ
- Impedance R+jX
- Admitance Y+jB
- Input matching

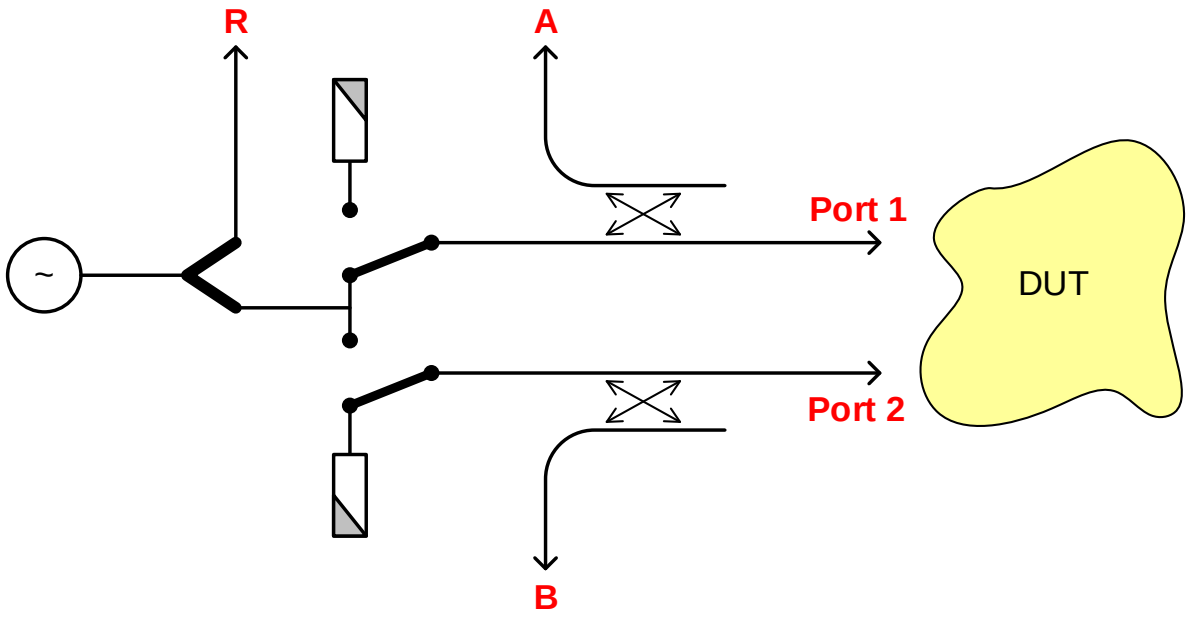
If we know TRN and FWD we can calculate:

- Gain, attenuation
- S-parameters S_{21}, S_{22}
- Transmission coefficient T
- Group delay
- Phase shift

Vector network analyser

Vector network analyser

- How does the VNA measure?
  - Send signal from port 1 and measure the response at port 1 and port 2



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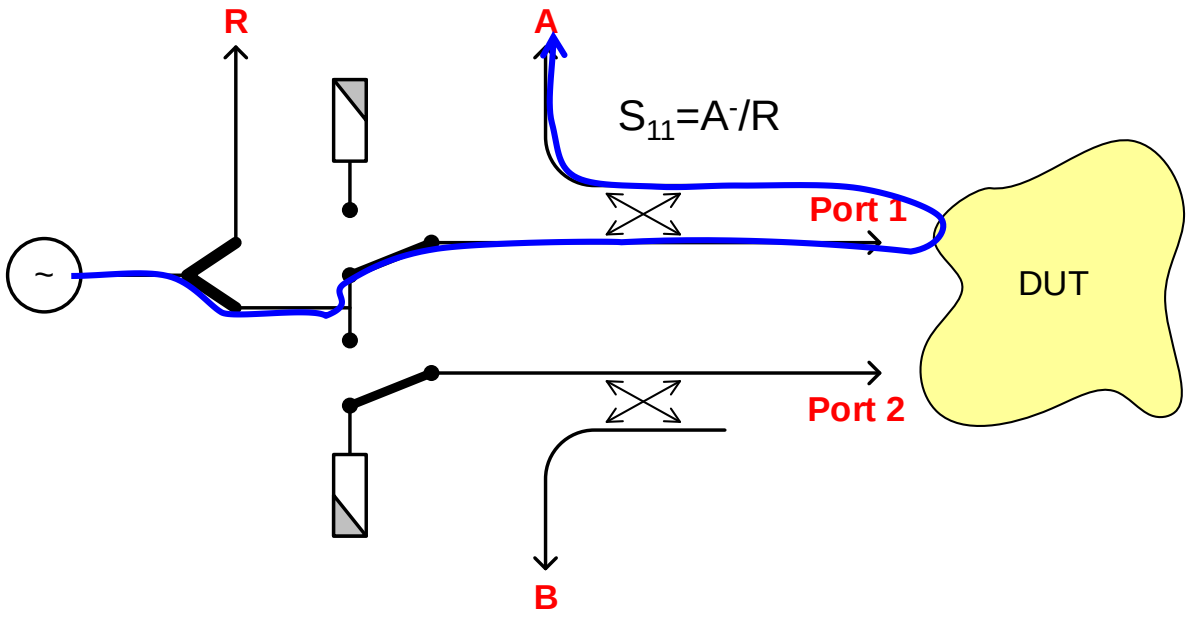

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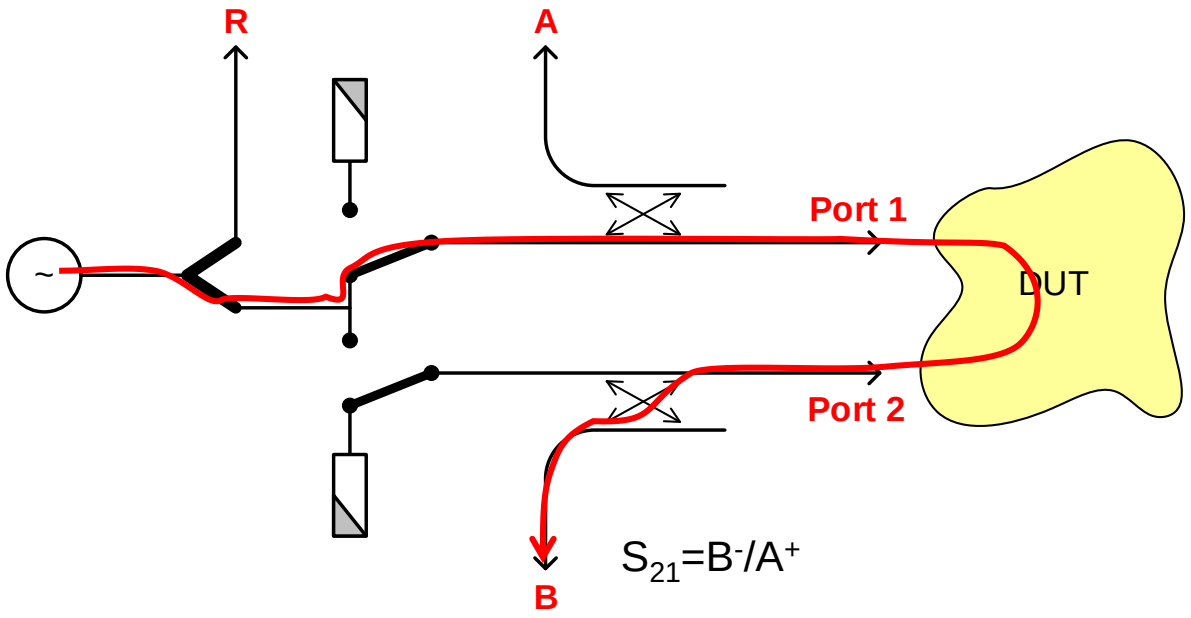
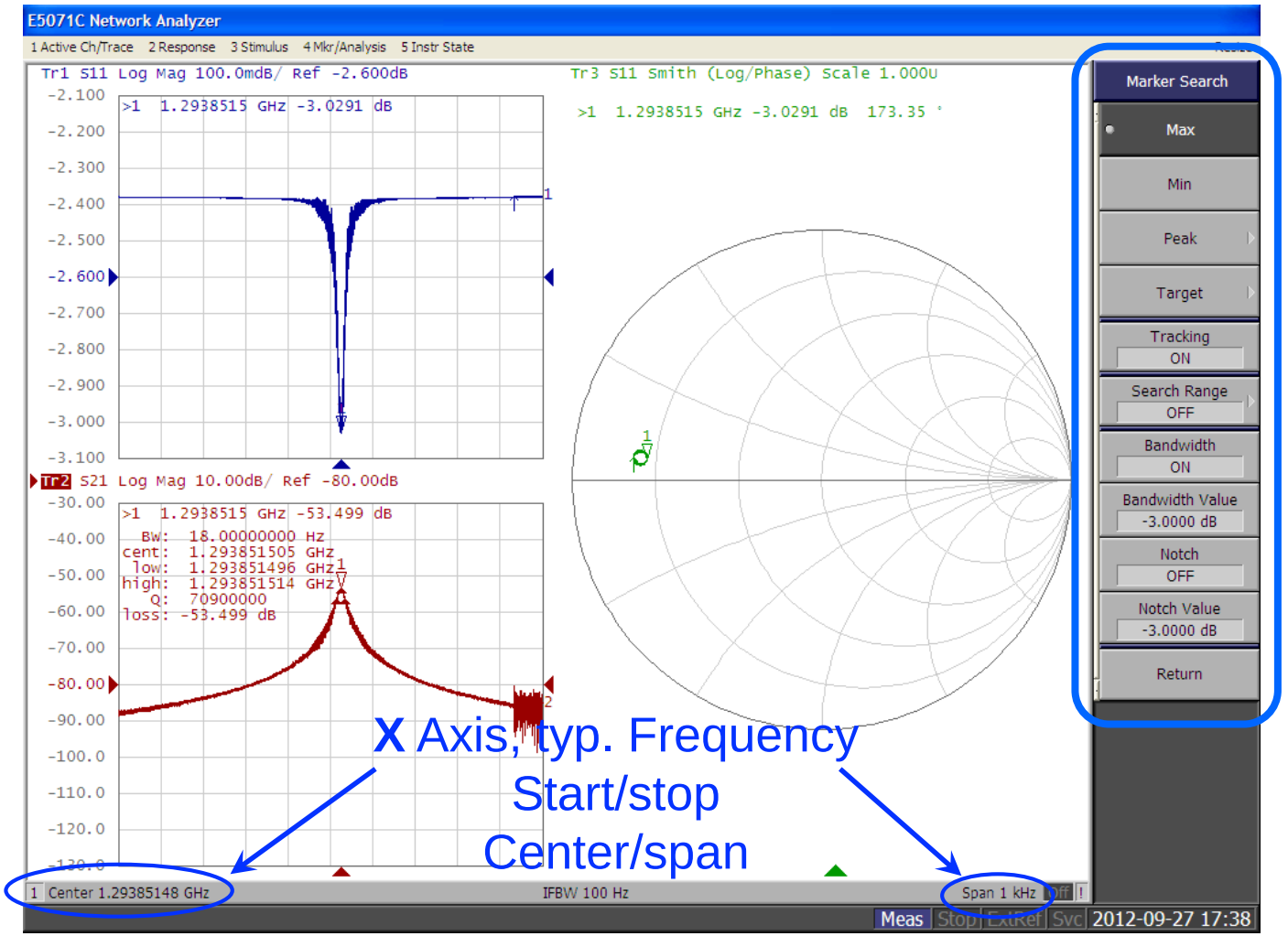


VNA user interface



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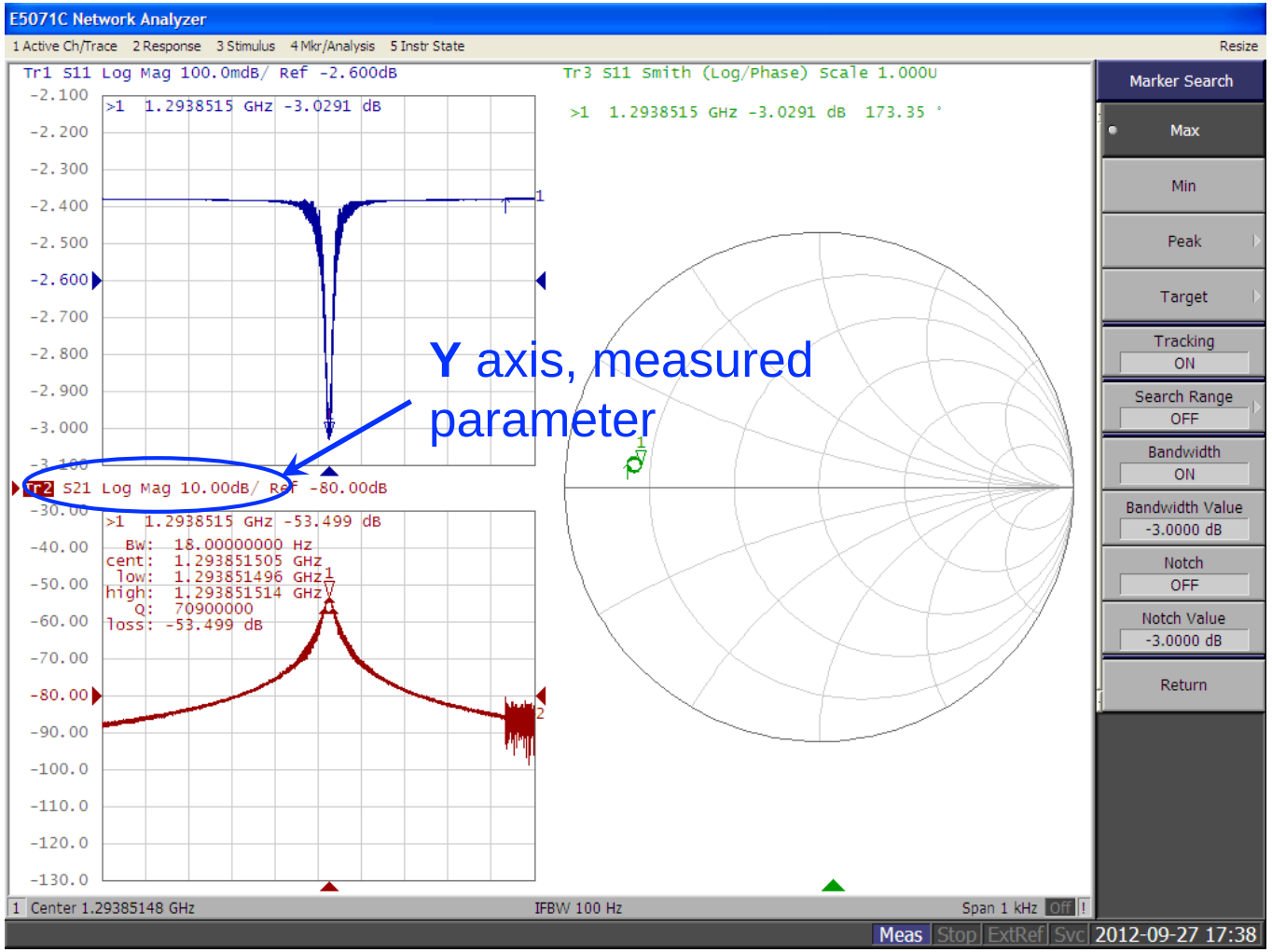

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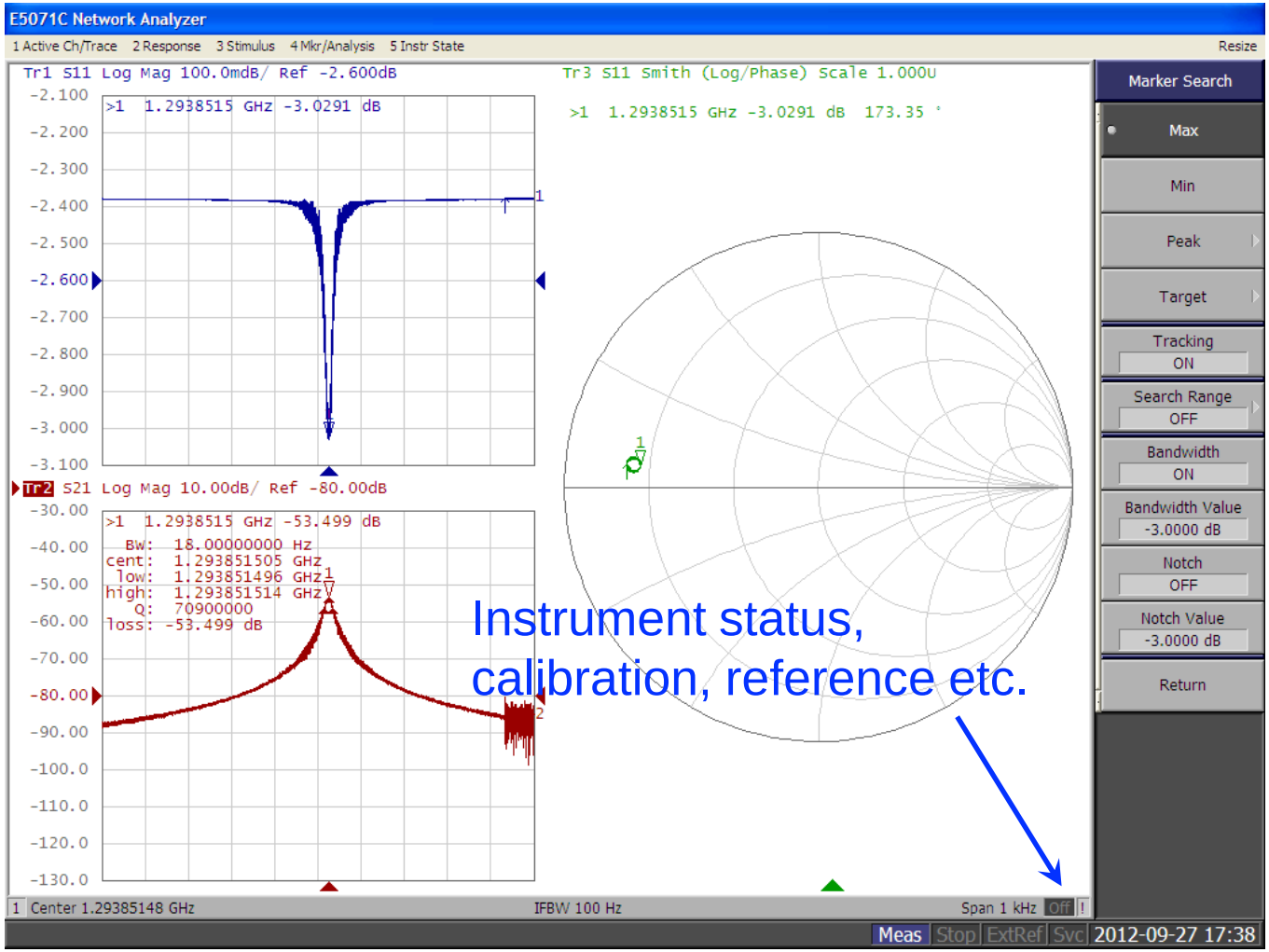

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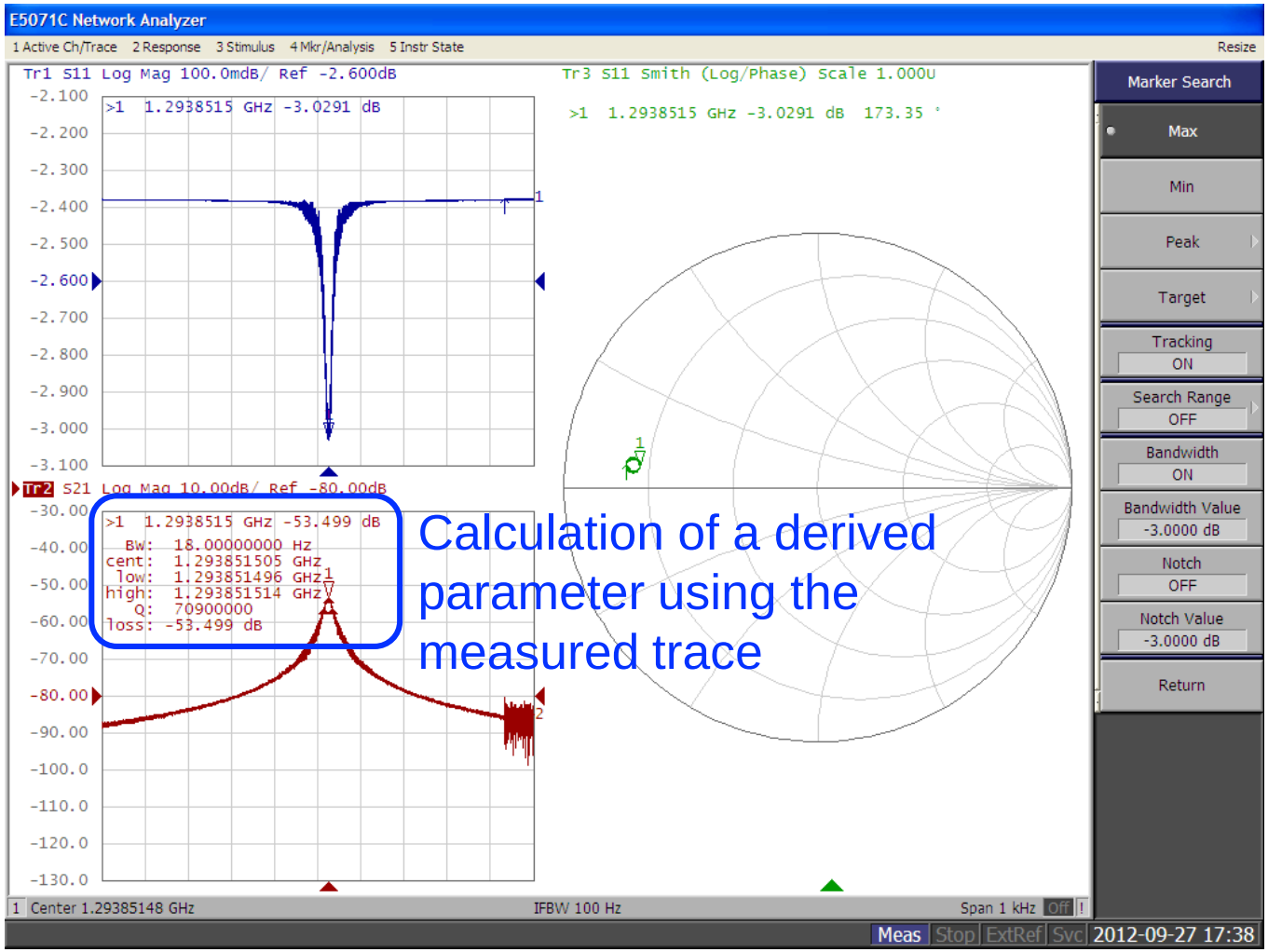


Setting up process…

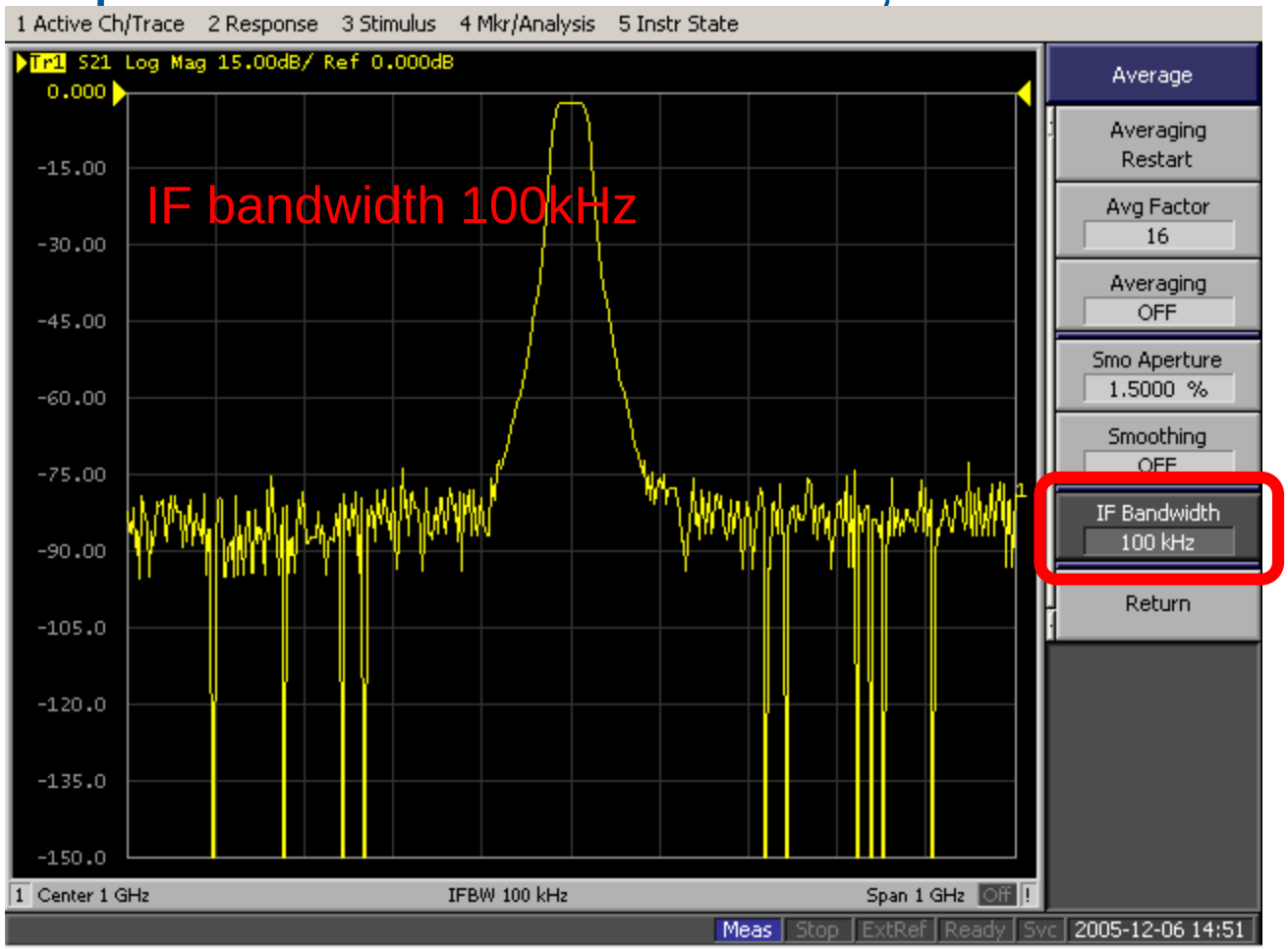
Few notes on IF bandwidth

- VNA uses a super-heterodyne receivers to measure the RF signals

- Same noise handling procedures as for the spectrum analyser apply

IF (detector) bandwidth

- Bandpass filter measurement, fc=1GHz



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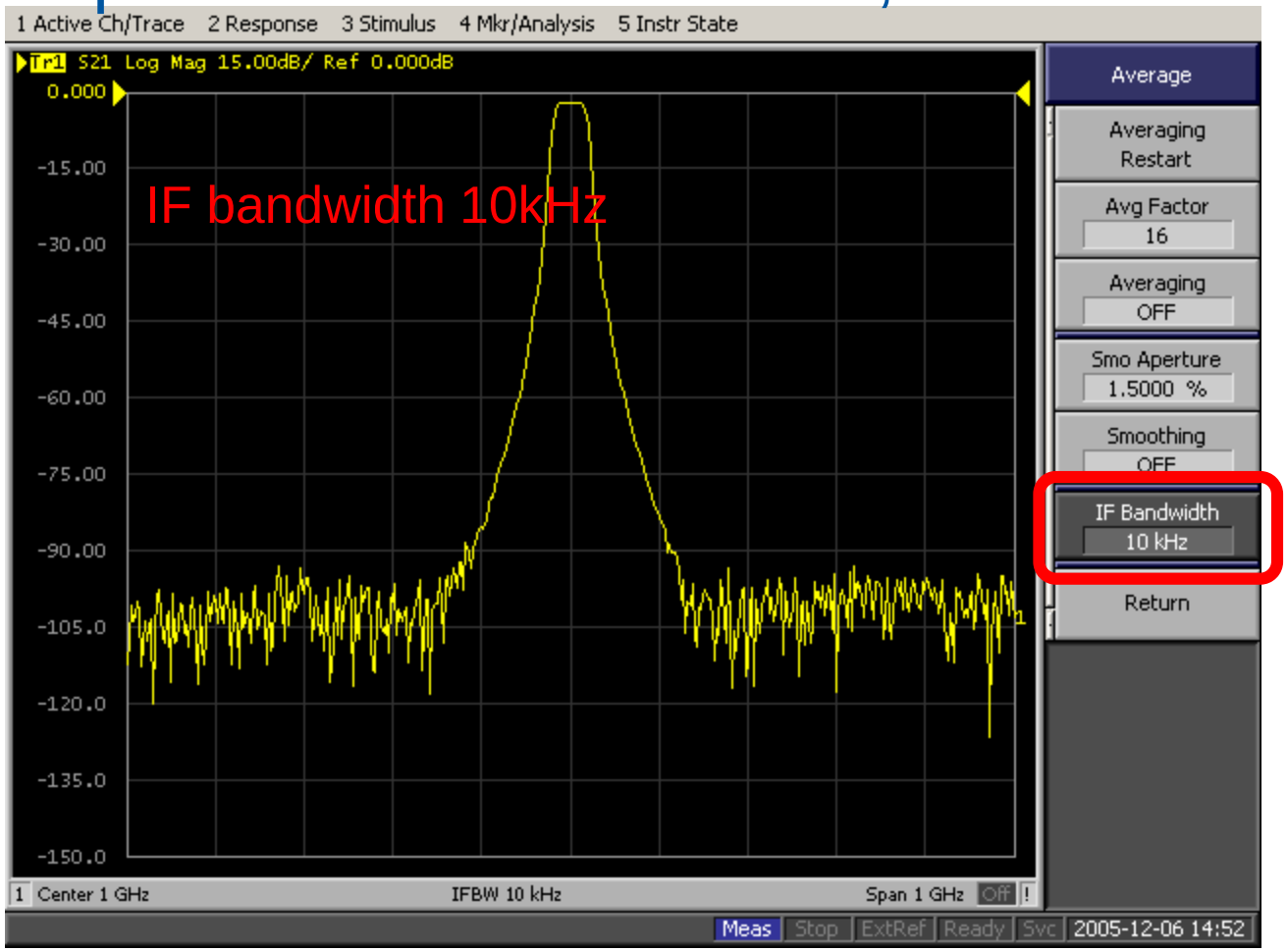

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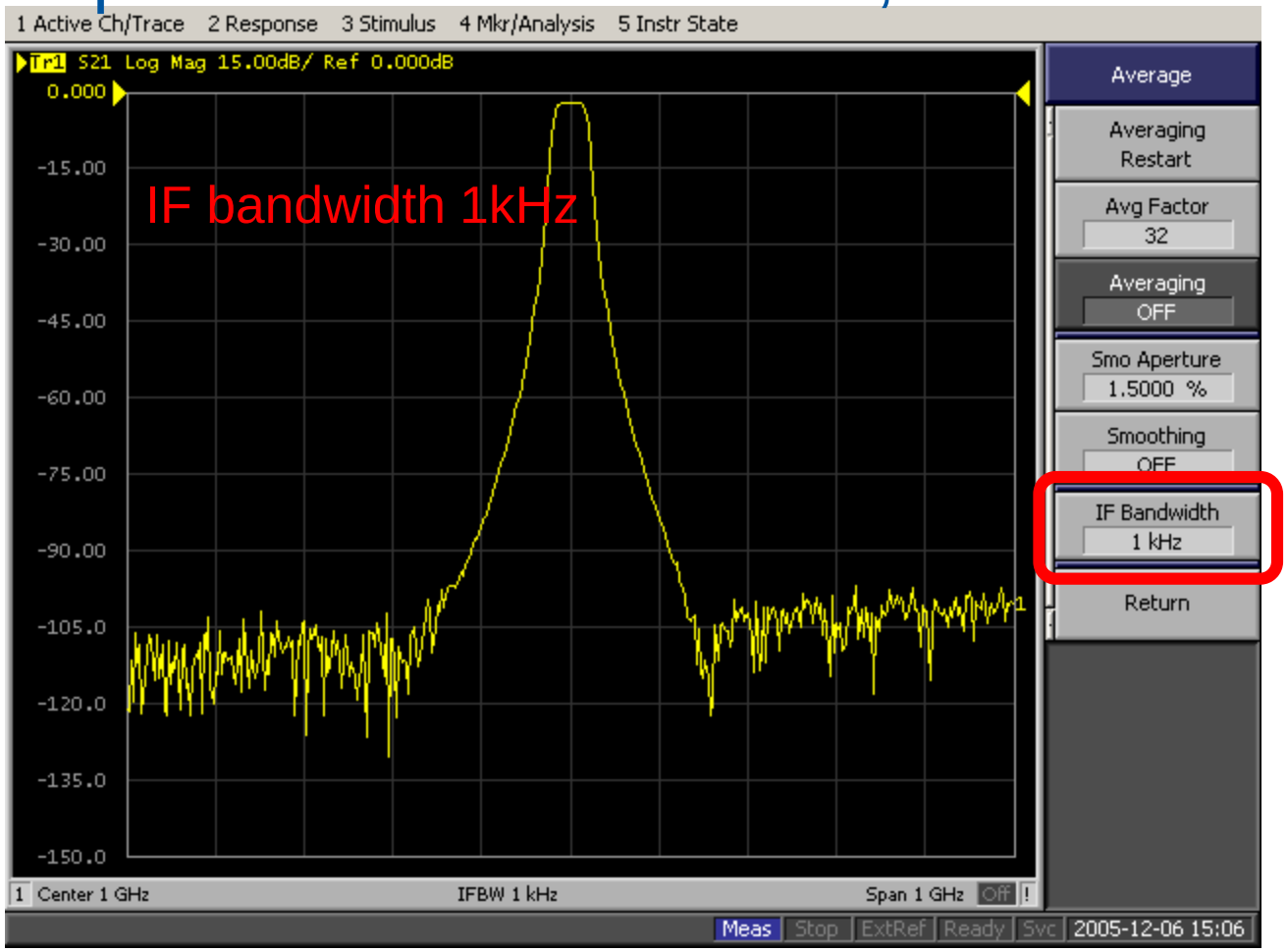

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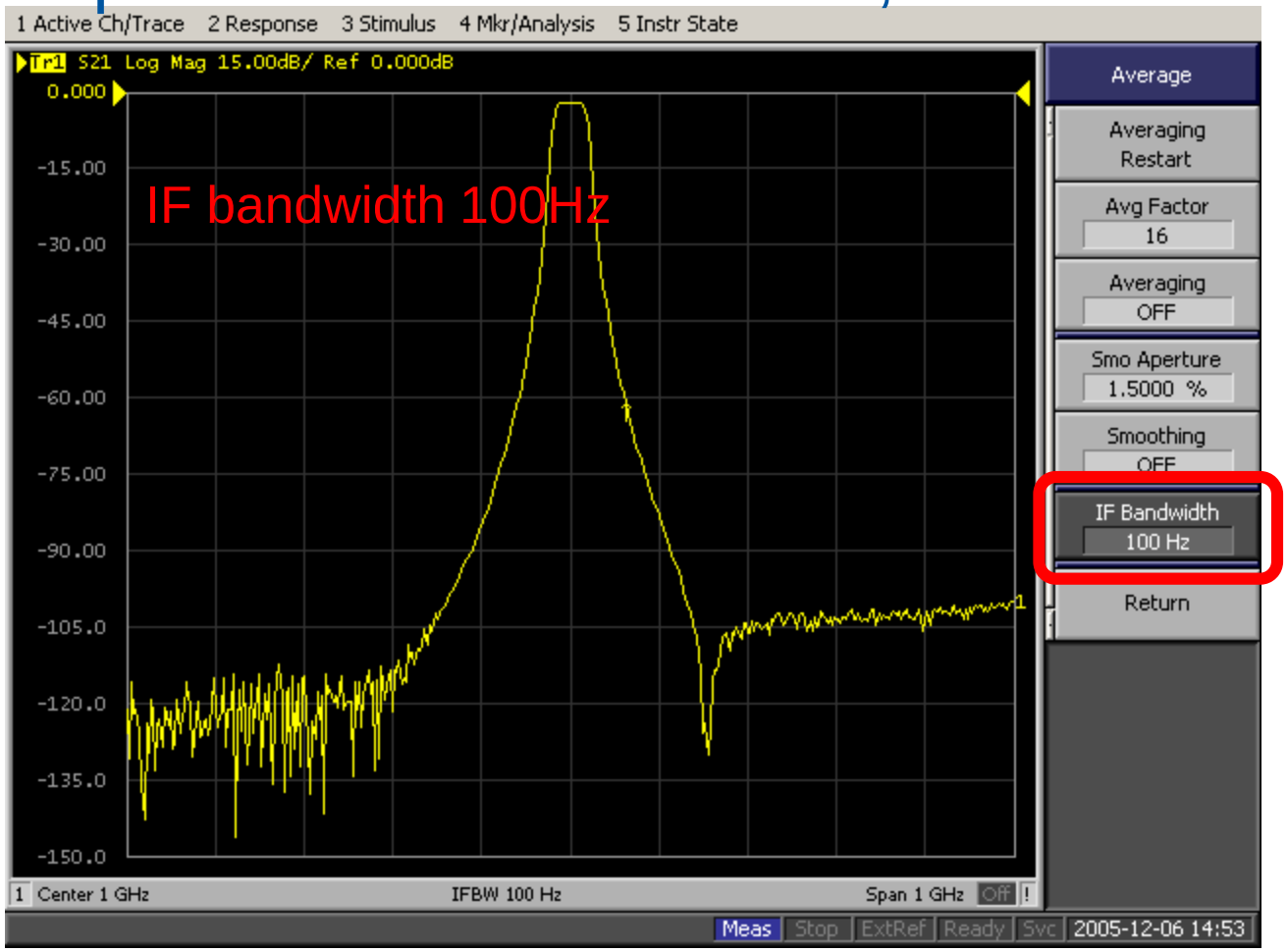

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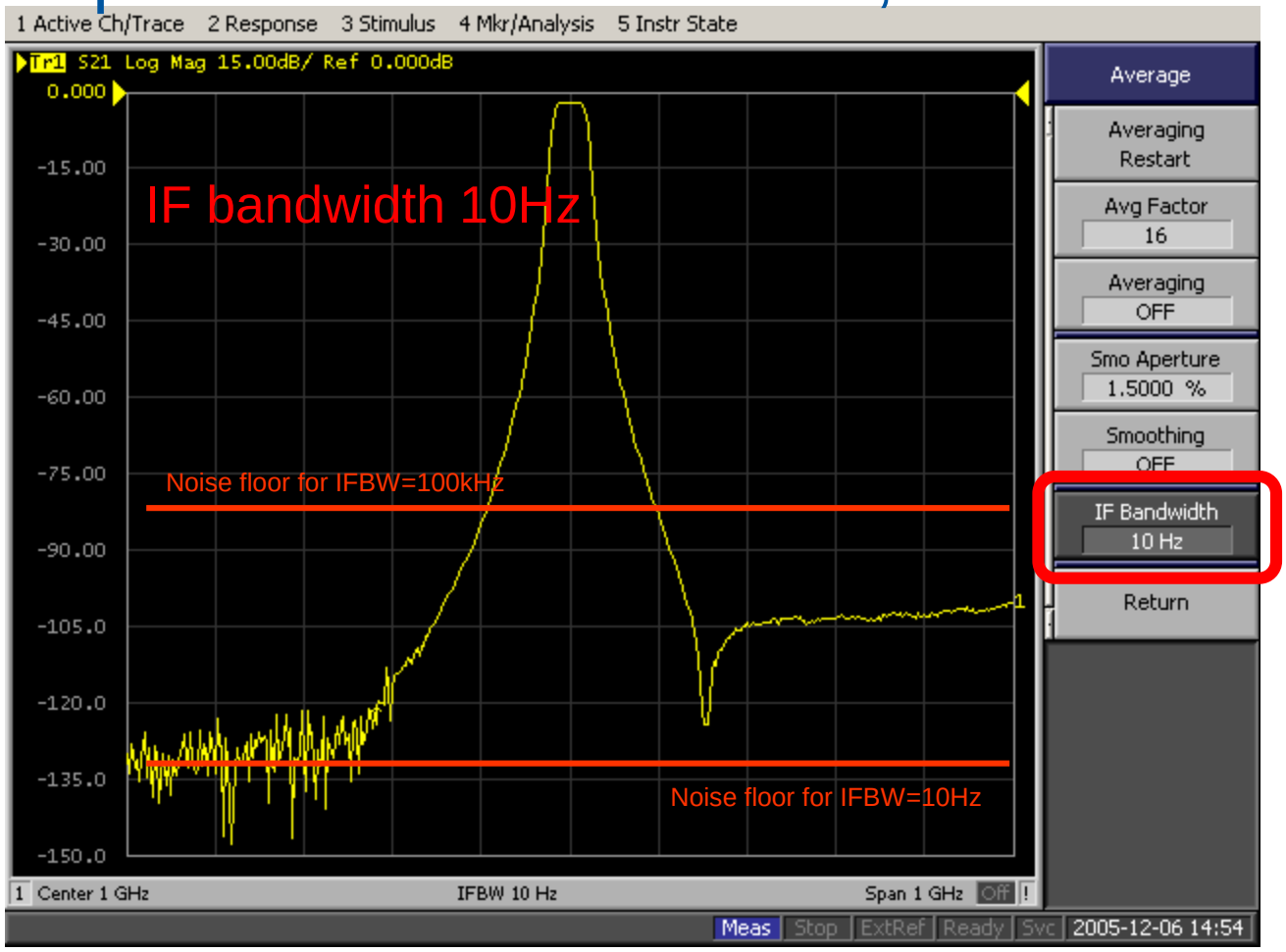

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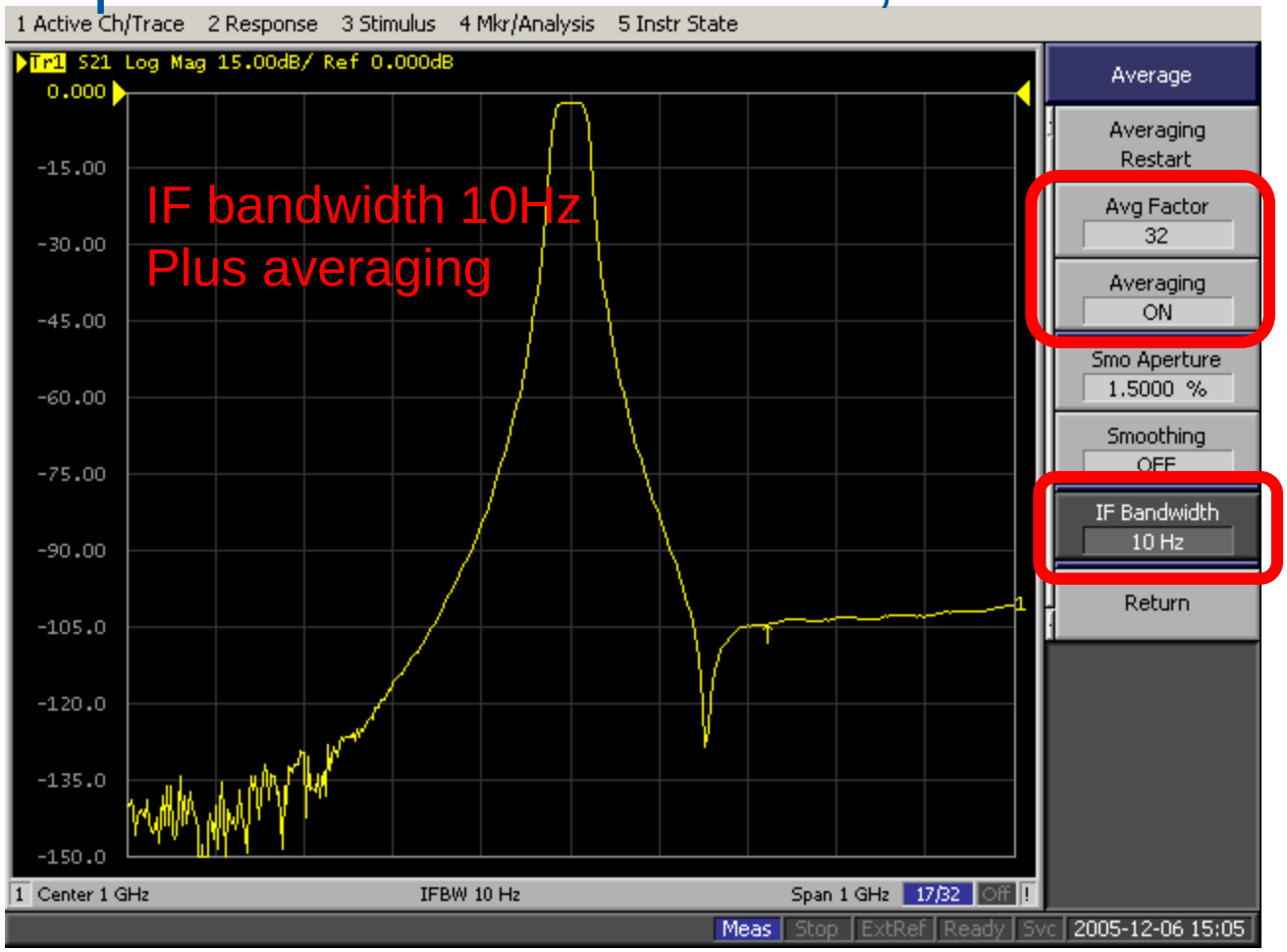
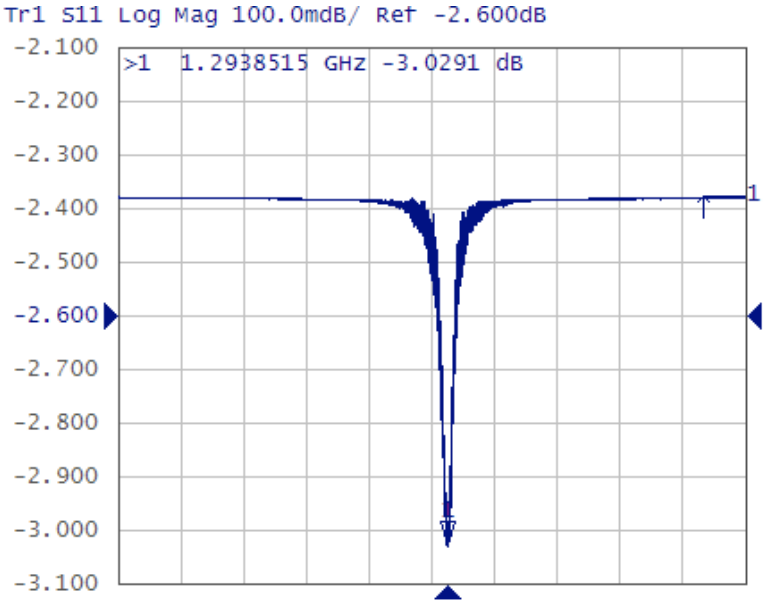


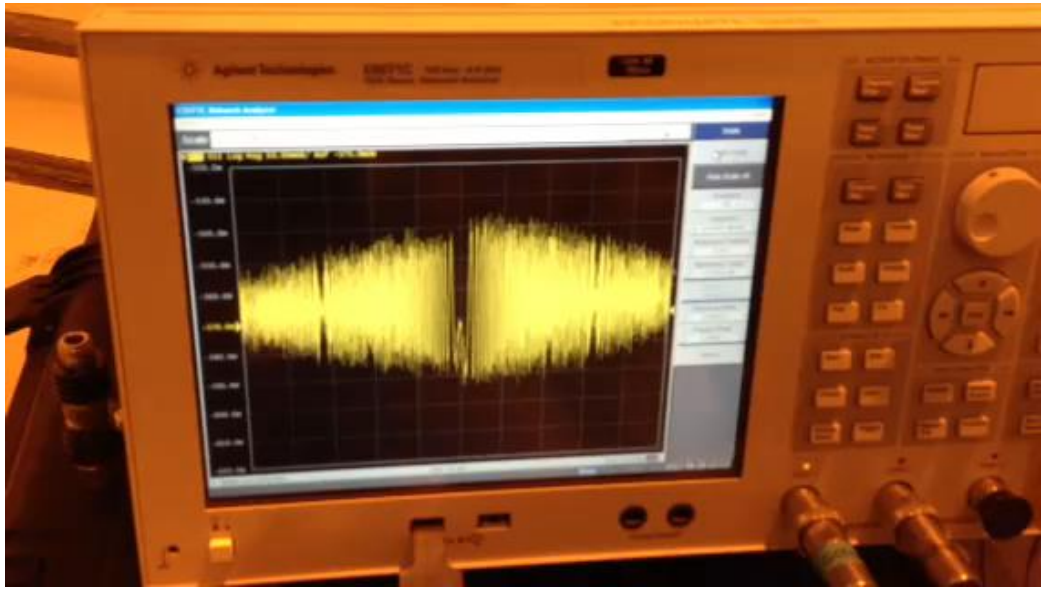
Measurement errors and calibration

- The instrument always shows some curves…
- …but in 99% cases this is not what you want to measure

Measurement errors and calibration

- *"Hello Daniel, this is Nikolai. We are trying to measure the 1.3GHz superconducting cavity but the instrument shows something strange…"*





Measurement errors and calibration

- We work in the RF domain
- The instrument measures our DUT
- …but also everything around (cables, connectors, adapters, spurious reflections etc.)
- …and the instrument is sensitive to temporal alignment of the signals as well
- …finally the instrument also measures himself

Measurement errors and calibration

- All networks which connect DUT to the instrument introduce static systematic errors
- We can measure them and mathematically de-embed them from the measurement
- This process is called **Calibration**

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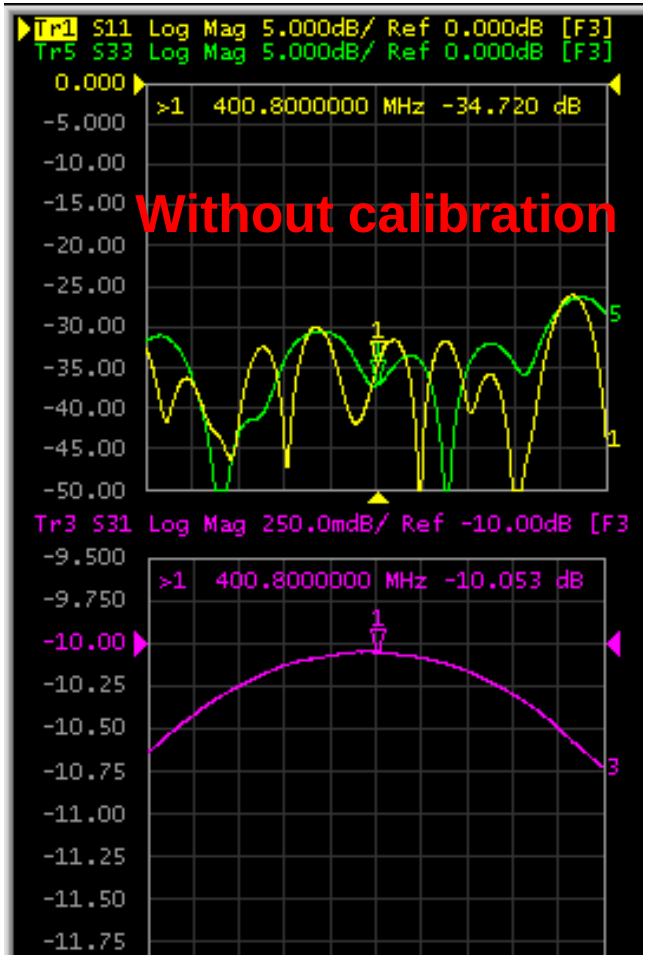
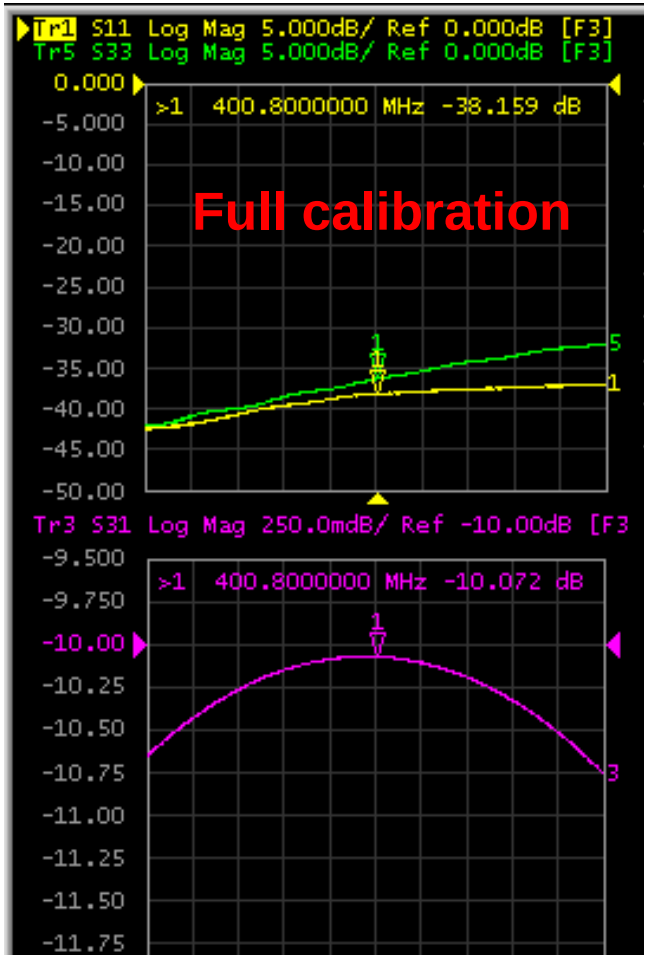
Measurement errors and calibration

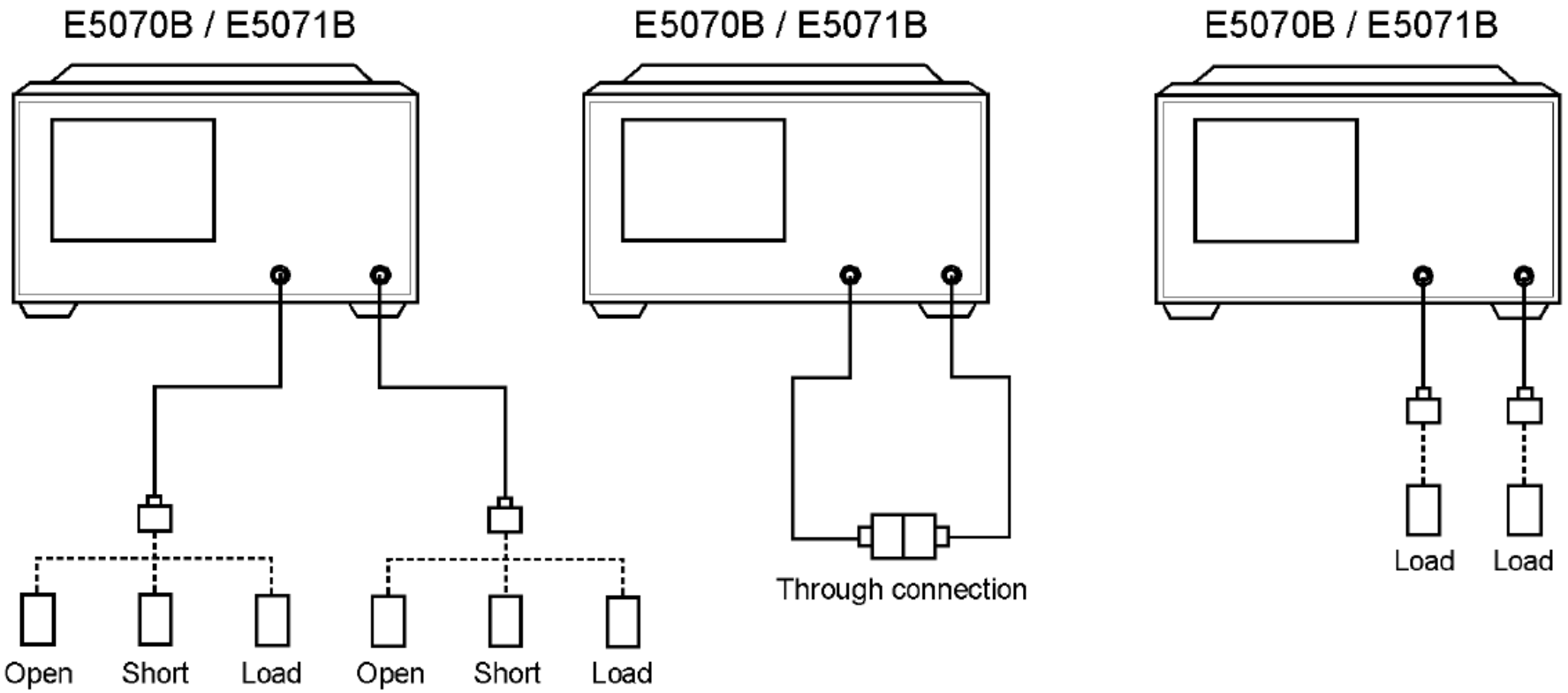
- Directional coupler measurement without and with full calibration





Calibration process

- 3 standards: Open, Short, Load + Thru



Thank you for your attention

After the break: hands on part