Test Equipment and Applications for the Microwave Enthusiast

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75 Years of Driving Innovation

ROHDE&SCHWARZ

Introduction

- **Identify Different Categories of Test & Measurement Equipment**
- **Describe Field Applications**
- **Describe Lab Applications**

Different Categories of *Microwave* T&M Equipment

- **Power Sensors**
- **Signal Generators**
- **Spectrum Analyzers**
- **Vector Network Analyzers**

Power Sensors

- **"Traditional"/Surplus**
  - Consist of a separate Sensor and a Base Unit
    - HP 436 / HP8481

- **Modern**
  - Consists of Sensor Only (no base required)
    - USB Connectivity
    - PC or Instrument Control
      - R&S "NRP-Z" series

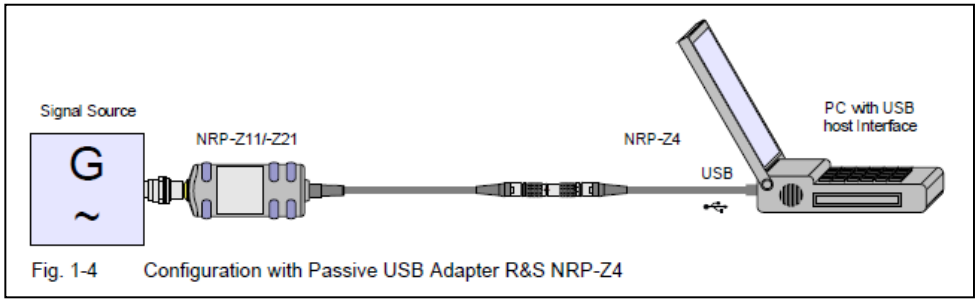


Fig. 1-4 Configuration with Passive USB Adapter R&S NRP-Z4


R&S®FSMR measuring receiver with the R&S®NRP-Z37 power sensor module

Power Sensors

- **Sensor Technology**
  - Thermal Sensor
    - Advantages
      - Highest Accuracy Available (Lowest VSWR)
      - Widest Frequency Range available
    - Disadvantages
      - Slow
      - Limited Dynamic Range (50 dB)
      - Easily Damaged by RF Overload

R&S®NRP-Z55 sensor

R&S®NRP-Z5x thermal power sensors

- Suitable for very demanding reference applications
- Industry-proven DC-coupled thermoelectric test cell
- DC to 18 GHz (R&S®NRP-Z51, R&S®NRP-Z52)
- DC to 40 GHz (R&S®NRP-Z55)
- Level range –30 dBm to +20 dBm
- Highly accurate continuous average power measurements
- Linearity uncertainty <0.02 dB

Recommendation:
Try before you buy

Power Sensors

Sensor Technology (Cont'd.)

- Diode Sensor
  - Advantages
    - Fast Measurements
    - 'Scope Mode'
    - Modulation Analysis
    - "Peak/RMS"
    - Wide Dynamic Range (90 dB)
  - Disadvantages
    - Internal Sampling Rate limits modulation analysis capabilities
    - Frequency Range limited to 18 GHz
    - Not as good a VSWR as Thermal Sensors
    - Easily Damaged by RF Overload

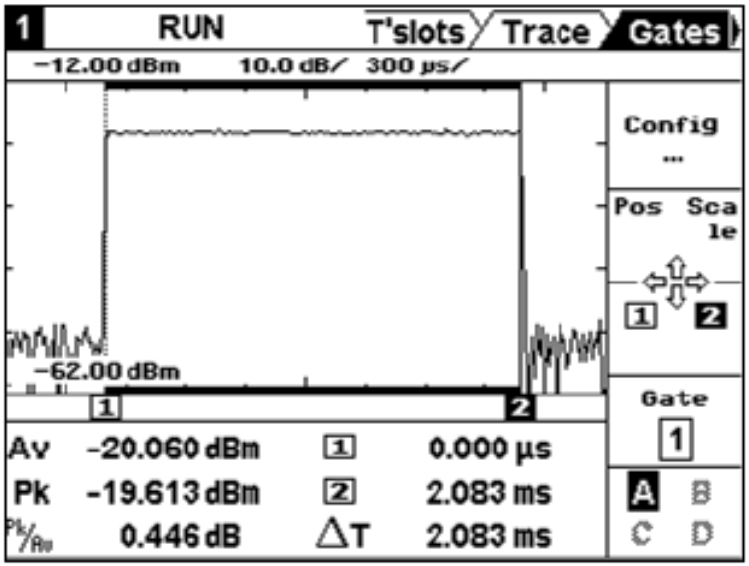
R&S®NRP-Z23 sensor

R&S®NRP-Z11/-Z2x universal power sensors

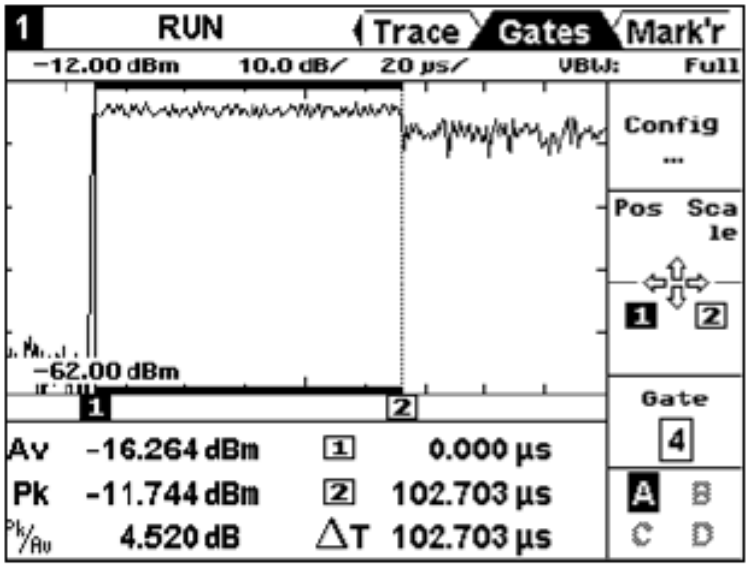
- True universal power sensors for a vast number of applications
- 10 MHz to 8 GHz (R&S®NRP-Z11)
- 10 MHz to 18 GHz (R&S®NRP-Z2x)
- Innovative three-path diode power sensor with enhanced inter-range performance
- 90 dB dynamic range for CW und modulated signals
- R&S®NRP-Z22/-Z23/-Z24 high-power sensors for measurements up to 30 W
- Continuous average, burst average, timeslot average, time gating and trace mode supported (video bandwidth 100 kHz)
- Automatic burst detection and acquisition
- Up to 1500 measurements/s (buffered mode)
- Low sensitivity to harmonics

Recommendation:
Try before you buy

Power Sensors



Measurement of the average power of a WLAN IEEE 802.11n signal using the R&S® NRP-Z21



Time gating for measuring the preamble power of a modulated WiMAX IEEE 802.16-2005 OFDMA signal using the R&S® NRP-Z81

Power Sensors

- **Field/Portable Applications**
  - Advantages:
    - USB version SMALL
    - Covers MANY microwave bands
  - *Not* Recommended for Contests
    - *Unless a protective attenuator is welded on first!*
  - Other Portable Applications
    - Is power getting to my antenna?
    - How much?
    - Has it changed since last year?
    - Are my switches working?
    - *Is my amplifier working?*

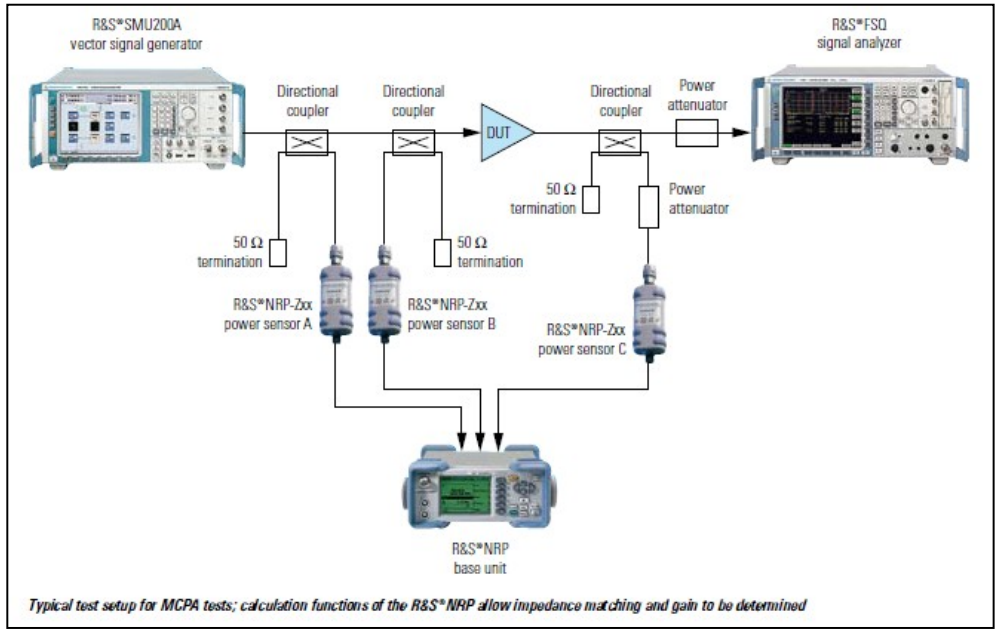
Think before you hook it up!

Power Sensors

- **Lab Applications**
  - Tweaking maximum performance from Oscilators/Amplifiers
    - Usually used ‘in addition to’ a Spectrum Analyzer
  - Impedance-Matching
  - Gain

Sensor	Windows	Measurement	File	System
1	Input Power			
A	1.960mW	A	3.400GHz	
2	Output Power			
C	0.137W	C	3.400GHz	
3	Input Match			
RC (A,B)	0.210	x̄ 2.096e-1 σ 6.903e-5		
4	Gain			
C/A	18.44dB	↑ 18.452dB ↓ 18.434dB		

Simultaneous display of up to four different measurement results; mathematical calculation of reflection coefficient and gain



*Typical test setup for MCPA tests; calculation functions of the R&S*NRP allow impedance matching and gain to be determined*

Signal Generators

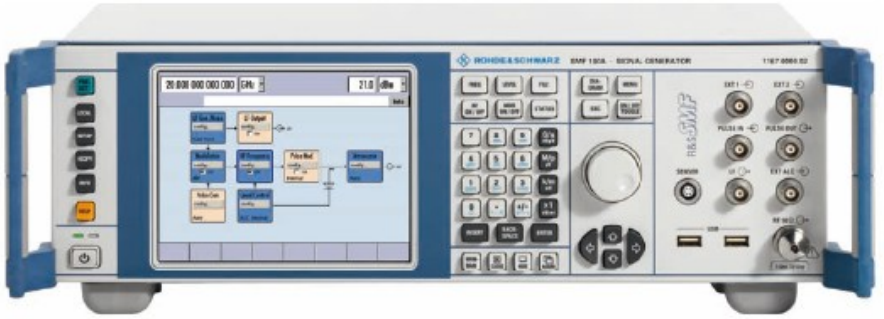
- **“Traditional”/Surplus**
  - Big
  - Heavy
  - Loud
  - Will outlive you and your children’s childen

  - Limited “Bells & Whistles”
    - Output levels
    - Modulation types

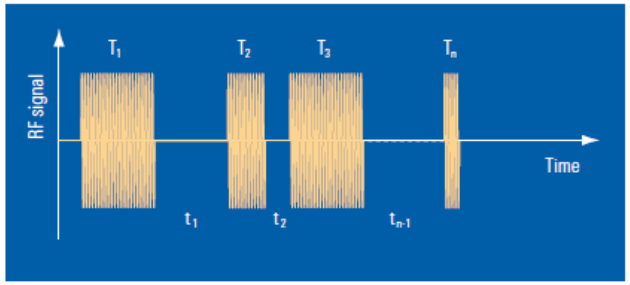
- **Modern**
  - Small & Lightweight
  - High Output levels / Wider Dynamic Range
    - -120 to +24 dBm Output
  - Many Modulation Formats
    - Analog (AM/FM)
    - Pulse Modulator
    - Digital (GSM, CDMA, WiMAX, LTE, etc.)

Signal Generators

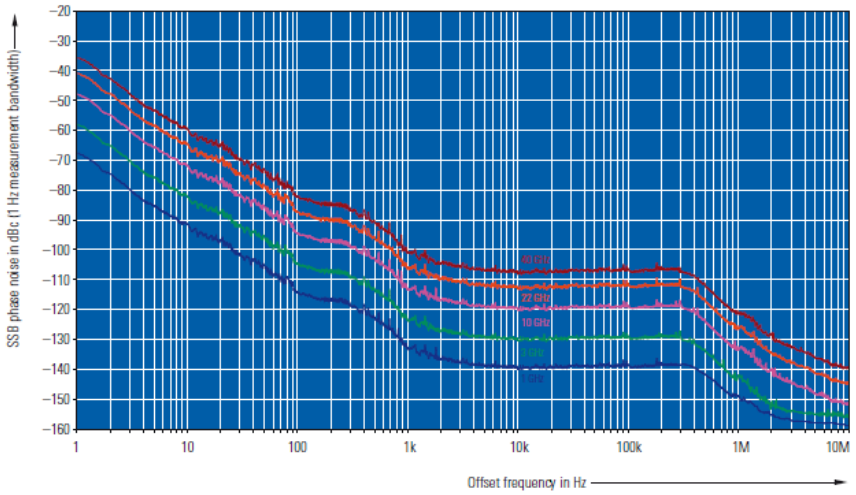
- **Technology**
  - Analog Signal Generators
    - – Advantages
      - Abundant
      - Many Different Types Available
      - Higher Frequency Capabilities
      - Best Phase-noise Performance



    - – Disadvantages
      - Limited Modulation Types (CW, AM, FM, Pulse)



Pulse train (with the R&S®SMF-K27 pulse train option)



Signal Generators

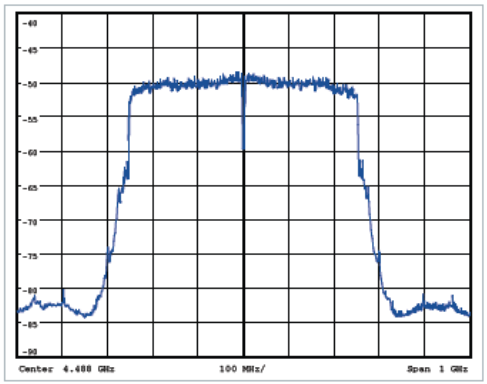
Technology

Vector Signal Generators

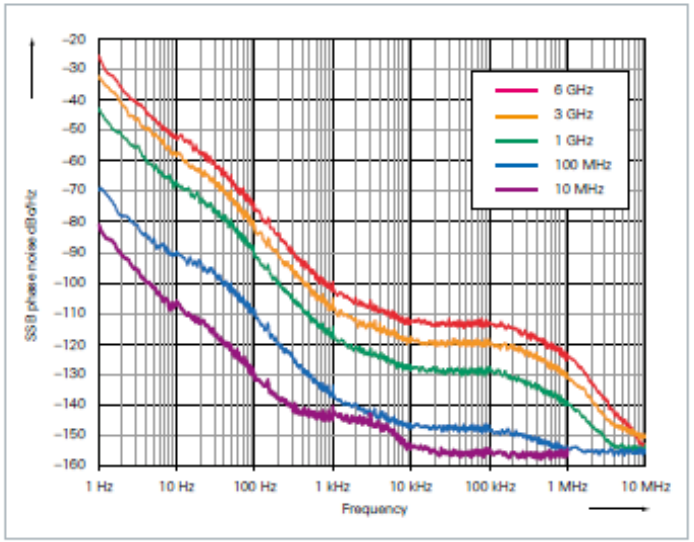
- Advantages
  - Support wide variety of modulation formats
  - On-air capture (Spectrum Analyzer) & Playback (Arbitrary Waveform Generator)
  - Wide-Modulation Bandwidths

- Disadvantages
  - More Expensive than Analog Generators
  - Limited Frequency Range (~ 6 GHz)
  - Lower RF Performance
    - Phase Noise

Frequency response of the I/Q modulator with bandwidth of over 500 MHz



Measured SSB phase noise with internal OCXO (R&S®SMBV-B1 option)



Signal Generators

- **Field/Portable Applications**
  - N/A
    - There are better approaches than stand-alone Signal Generators!

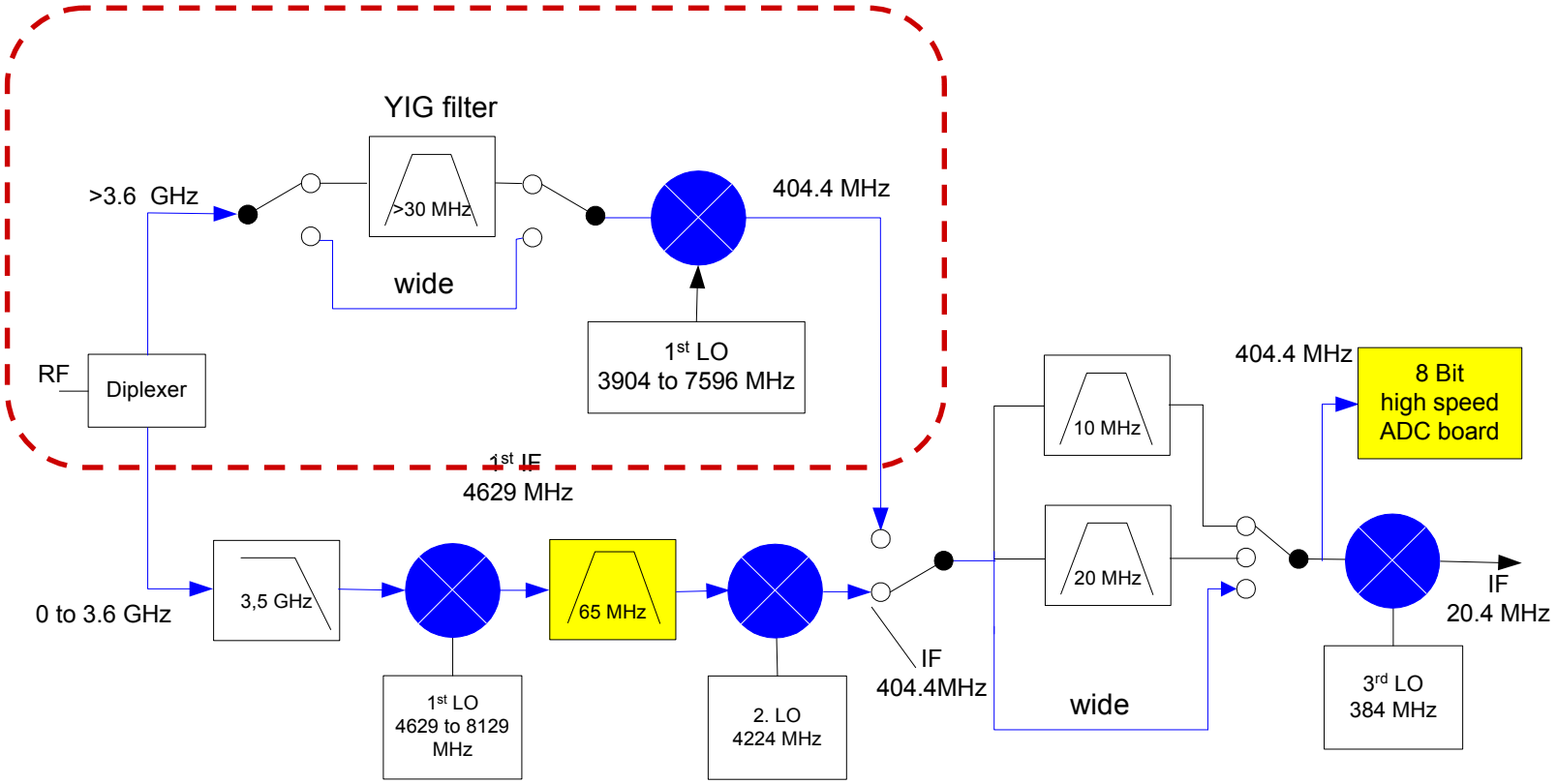
- **Lab Applications**
  - Receiver Tests
    - Amplitude
      - How sensitive is my Front End/Downconverter?
      - How do strong interferers affect me?
      - Has anything changed since last year's contest?
    - Frequency
      - How accurate is my frequency readout?
      - How stable is my oscillator (vs. power/temperature/vibration)?
  - Upconverter/Downconverter Development
    - Generate LO, IF, RF signals for mixers
      - What is the optimum LO amplitude to drive this Mixer?
      - What RF levels will compress this mixer?
      - What is the Third-order Intermod (IP3) of this mixer at this frequency?

Spectrum Analyzers

- **“Traditional”/Surplus**
  - Big
  - Heavy
  - Limited Bandwidths
  - Slow Sweeps
  - Will outlive you (except for CRT)

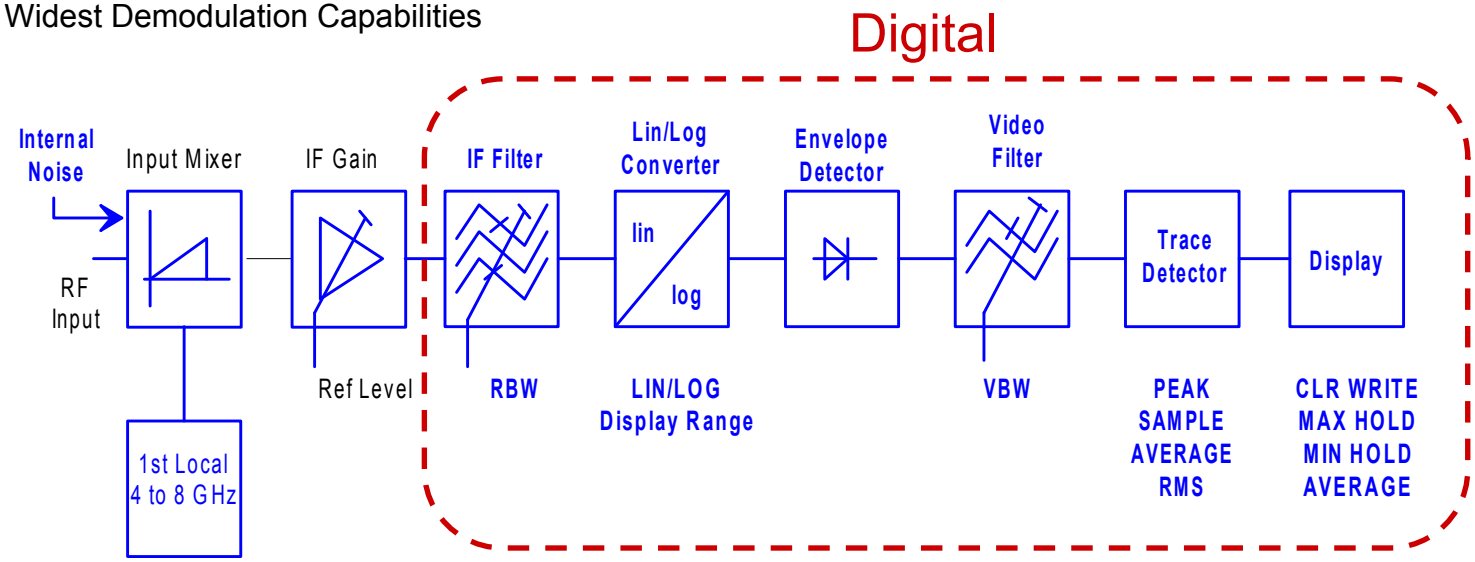
- **Modern**
  - Small & Lightweight
  - Combination Digital/Analog or “Pure Digital IF”
  - Conventional “Analog” Sweeps as well as FFT sweeps
    - Fast
  - Wide Dynamic Range*
  - Lots of Built-in Measurement Functions
    - IP3, Harmonics, Spurs, Phase Noise
  - Many “Extra Modes”
    - Tests and Demodulation optimized for Modern Digital Formats (WiMAX, WLAN, LTE, Bluetooth)

Spectrum Analyzer (> 7 GHz)

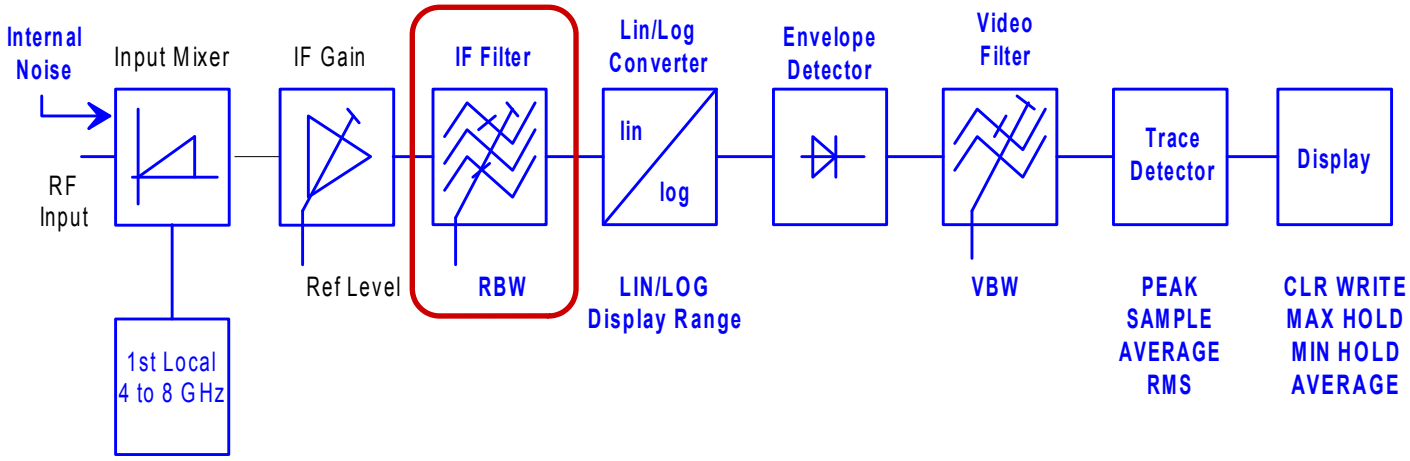


Spectrum Analyzer (< 7 GHz)

- **Technology**
  - Digital/Analog Hybrid
    - – Advantages
      - Widest Dynamic Range (similar to Pure-Analog)
  - “Pure-Digital” IF
    - – Advantages
      - Fastest Sweeps
      - Widest Demodulation Capabilities

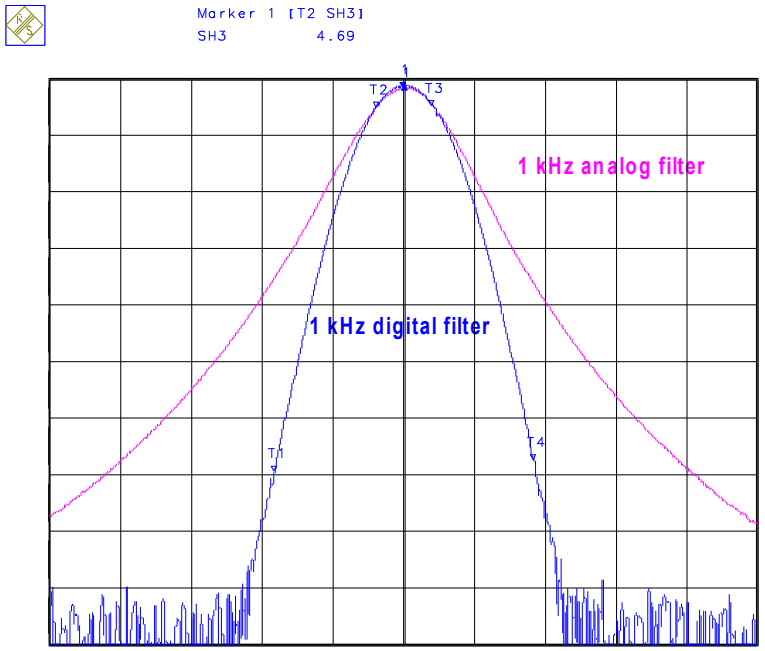


Spectrum Analyzer Filters

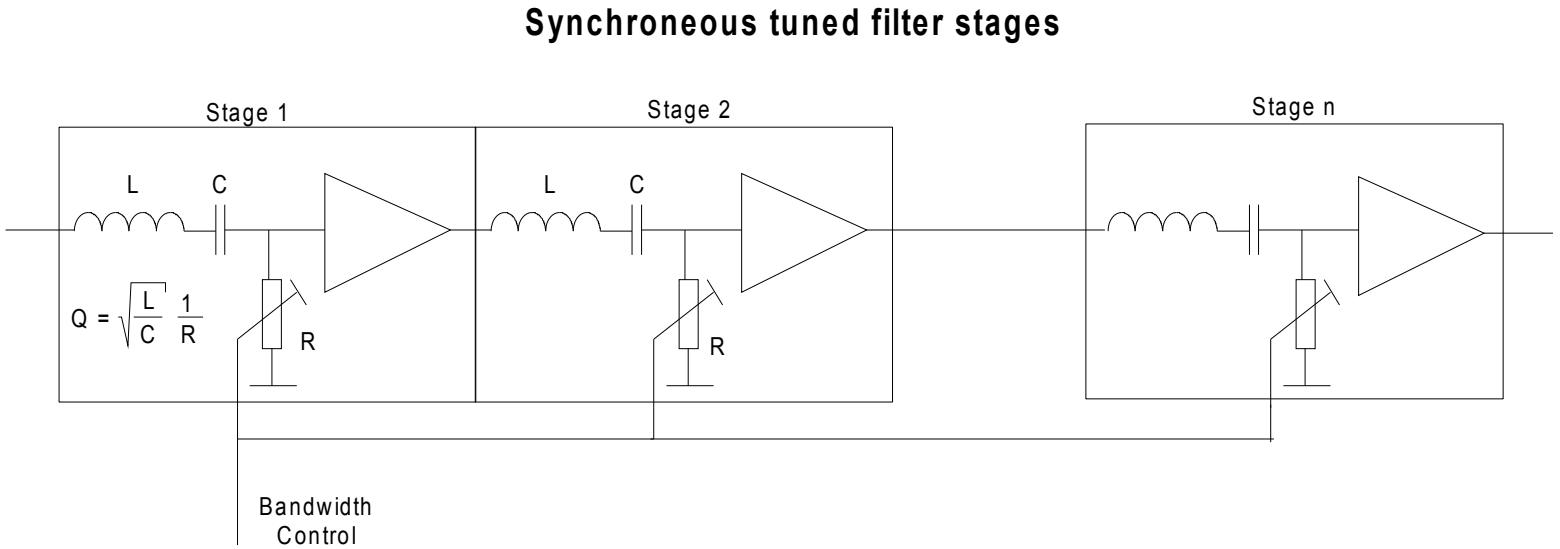


IF Filter - Characteristics

- Determines the Resolution Bandwidth (RBW)
- Determines the selectivity
- Limits the sensitivity (Noise Floor)
- Limits minimum sweeptime

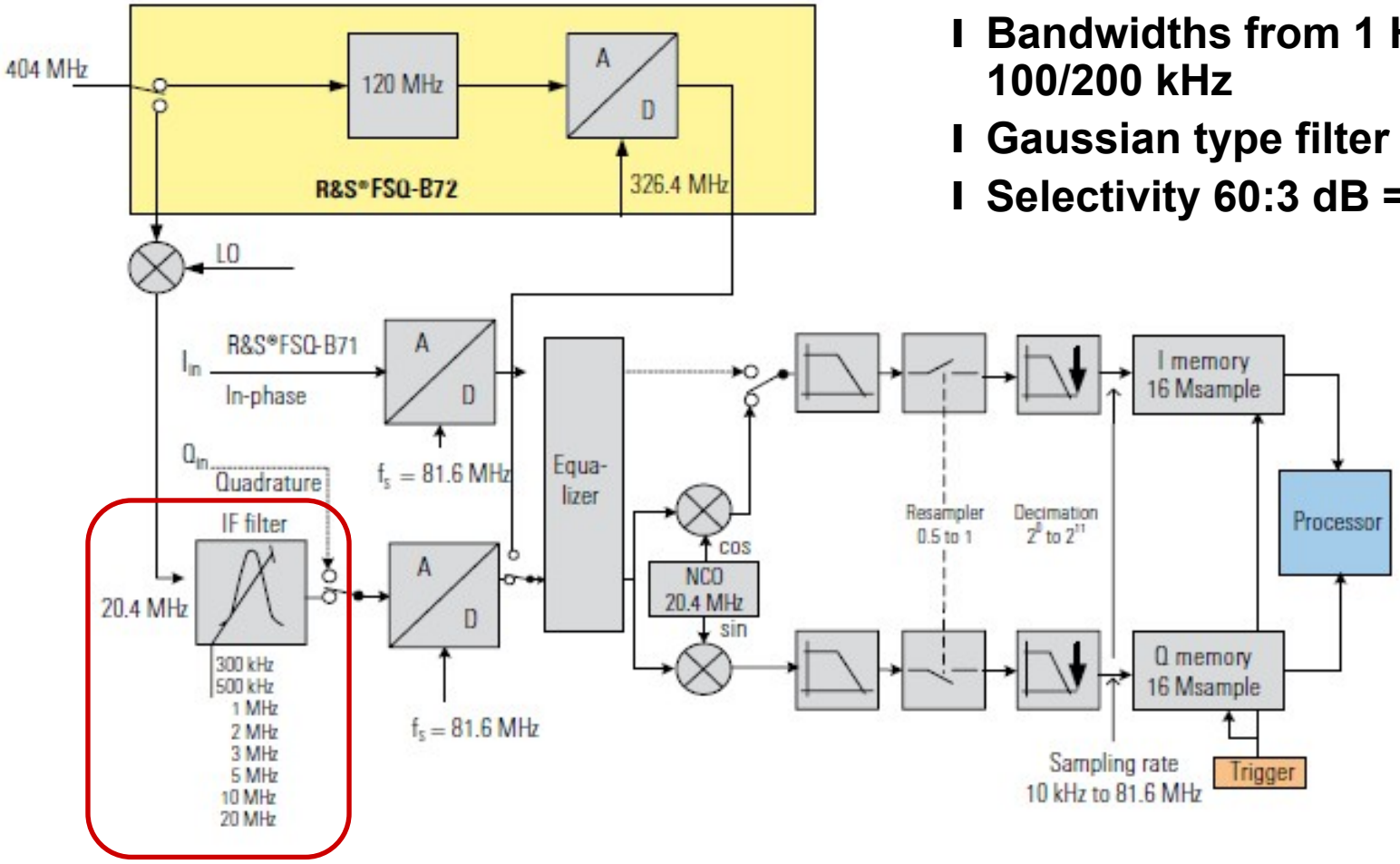


IF Filter Technology - Analog



- **Bandwidth for example tunable from 1 kHz to 5 MHz**
- **Selectivity determined by No. of stages**
  - 4 stages (poles), shape factor 60 / 3 dB ~ 12
  - 5 stages (poles), shape factor 60 / 3 dB ~ 9
- **Remark: GSM specs are based on 5-pole filter selectivity**

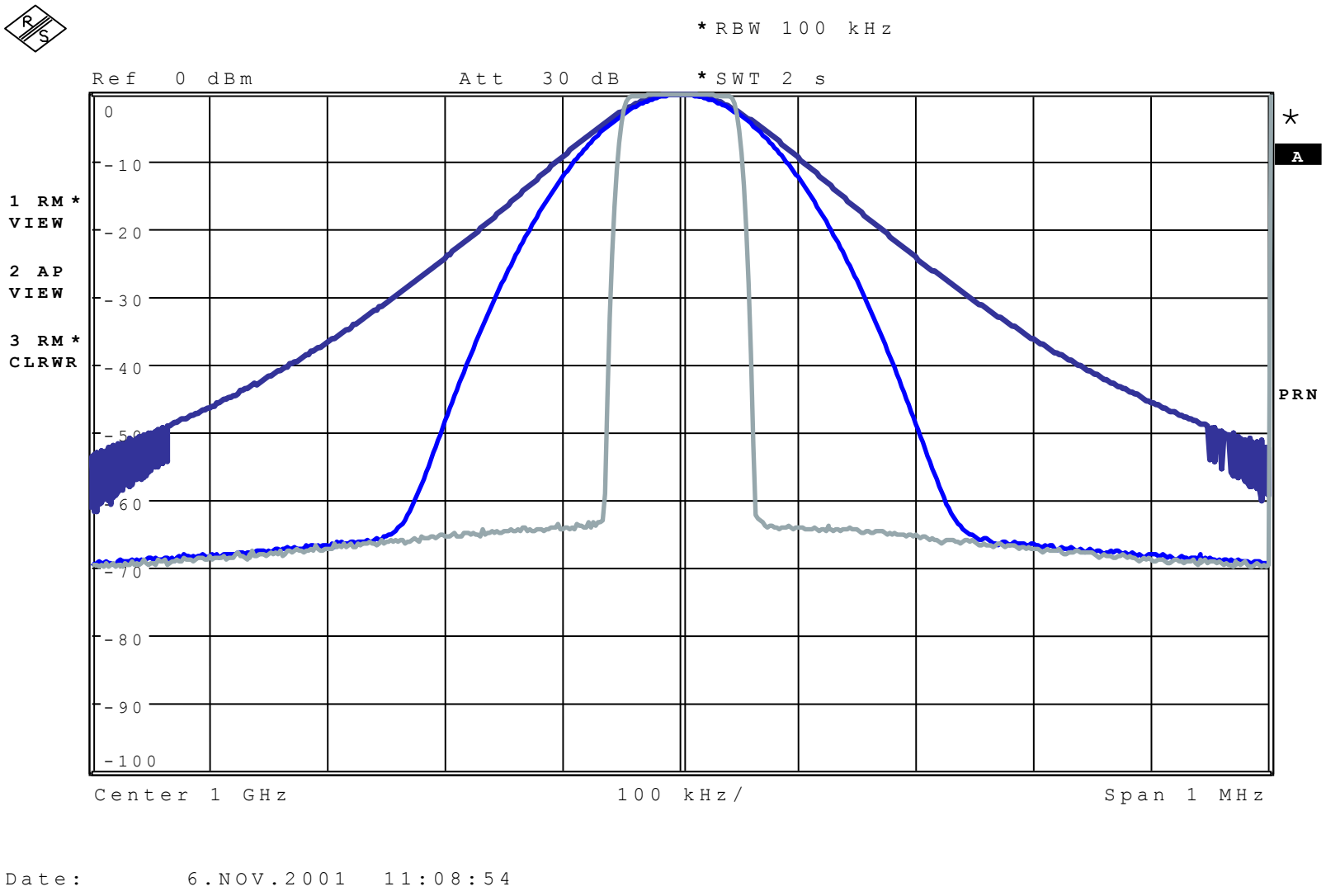
IF Filter Technology - Digital



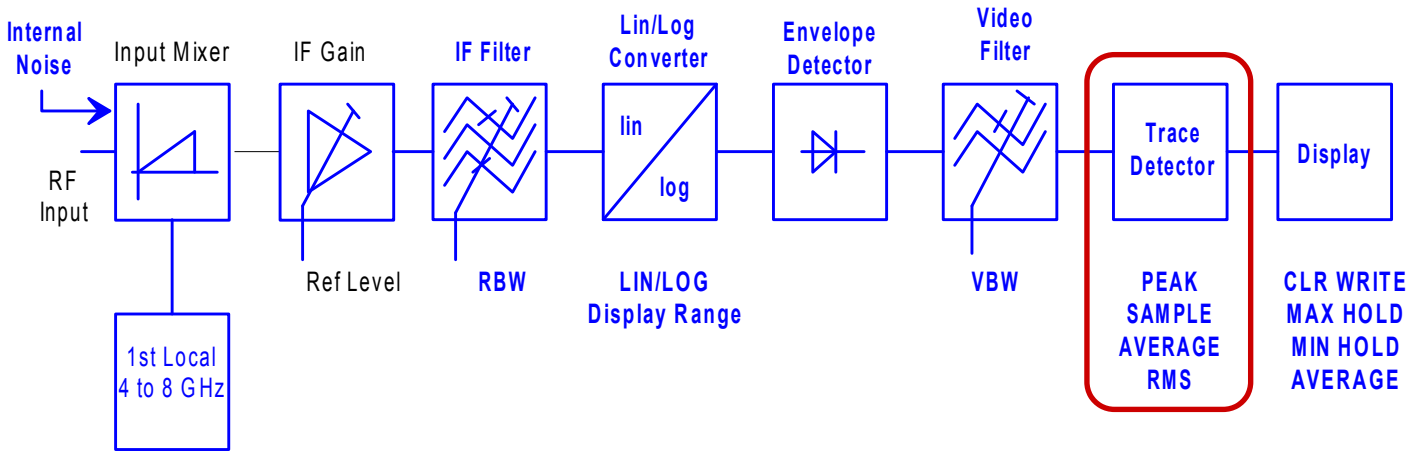
Block diagram of vector signal analysis section in the R&S®FSQ.

- **Bandwidths from 1 Hz to 100/200 kHz**
- **Gaussian type filter (FIR)**
- **Selectivity 60:3 dB = 4.6**

Different Filter Types

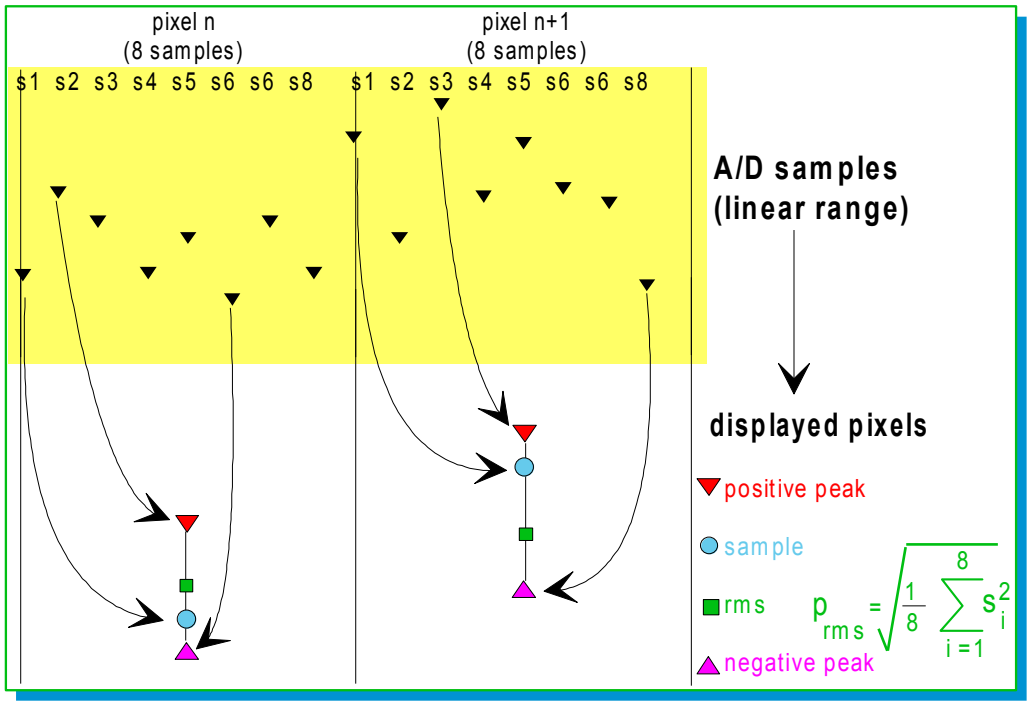


Spectrum Analyzer Detectors



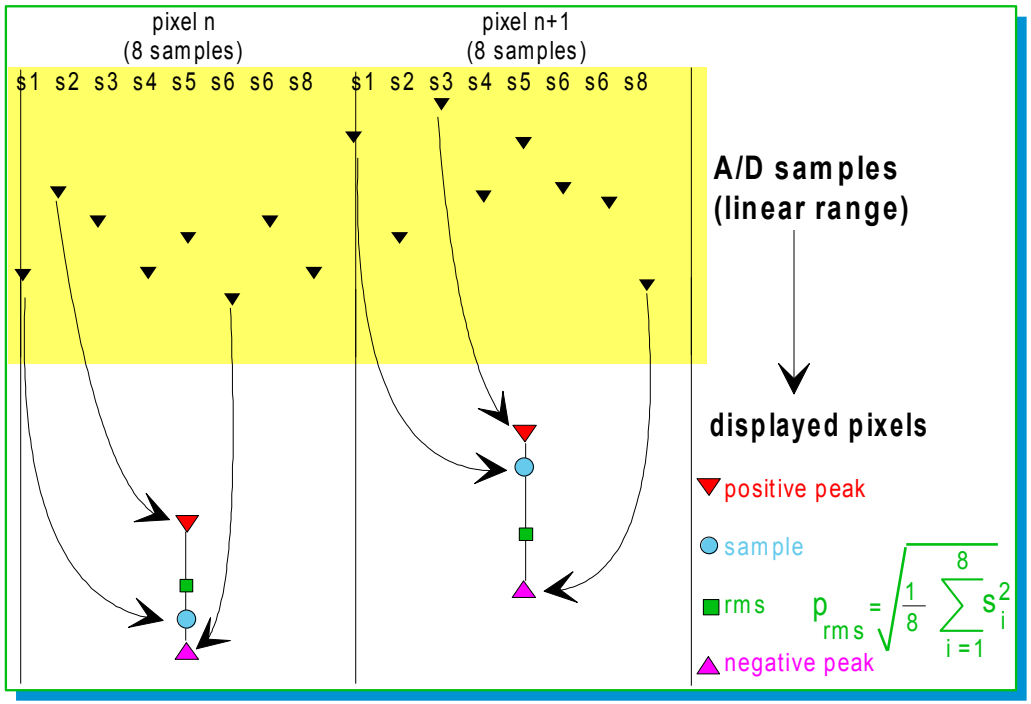
SA Technology - Detector Types

- **Max Peak Detector**:
  - Captures the Max video voltage for each pixel on screen
- **Min Peak Detector**:
  - Captures the Min video voltage for each pixel on screen
- **Auto Peak Detector**:
  - Captures the Max and Min video voltage for each pixel on screen
- **Sample Detector**:
  - Captures an arbitrary sample for display



SA Technology - Detector Types (cont'd.)

- **RMS Detector:**
  - Each pixel displays power of signal represented by the pixel
- **Symbolic graph with only 8 bins:**
  - number of data power-integrated to one pixel depends on sweep time
  - 32 MHz internal sample rate => 1 sample/31.25 ns
  - 500 pixels on-screen
  - 1 s sweep time results in 51,200 measured events per pixel

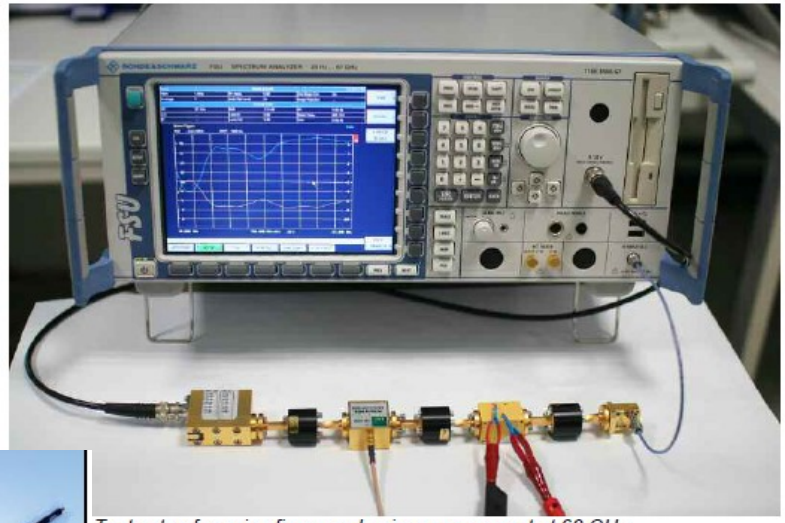


Spectrum Analyzers

- **Field/Portable Applications**
  - Spectrum Measurements
    - What Density and Amplitude of (Interfering or Intermod) signals are on top of this mountain?
    - Locate an intermittant interferer (repeater)
    - Radiolocation: Which direction has the most activity?
    - Propagation: How are signal levels changing vs. time?
    - Am I missing an opening on another frequency/band?

Spectrum Analyzers

- **Lab Applications**
  - Transmitters/Upconverters/Amplifiers
    - Output Power
    - Modulation Spectrum
    - Spurs
    - Harmonics
    - Intermodulation (IP3)
    - Phase Noise
    - Frequency Accuracy
      - Frequency Markers
    - Noise Figure
      - NF option & external Noise Source
    - Scalar Network Analyzer
      - Gain vs. Frequency
    - Signal Tracing
      - Coaxial probe



Test setup for noise figure and gain measurement at 60 GHz

R&S®FSH with near-field probe set and DUT

Vector Network Analyzers

- **"Traditional"/Surplus**
  - Big
  - Heavy
  - Multiple "Boxes"
    - Test Set
    - Generator
    - Display Unit
  - Will outlive you (except for CRT)
  - No "Bells & Whistles"
  - Limited DR Performance
    - Limited Output Power (-5 dBm)
  - Slow
  - Limited data display & export capabilities

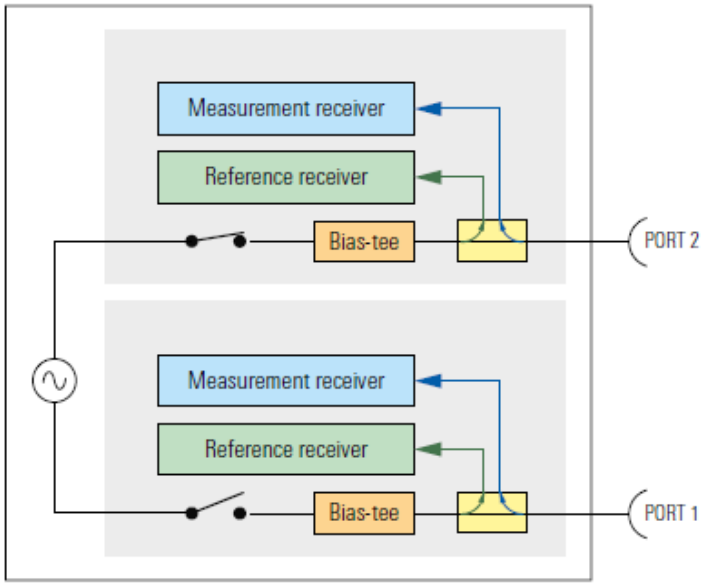
Fig. 3 Wiltron 310 Network Analyzer

Fig. 5 HP 8410 Network Analyzer

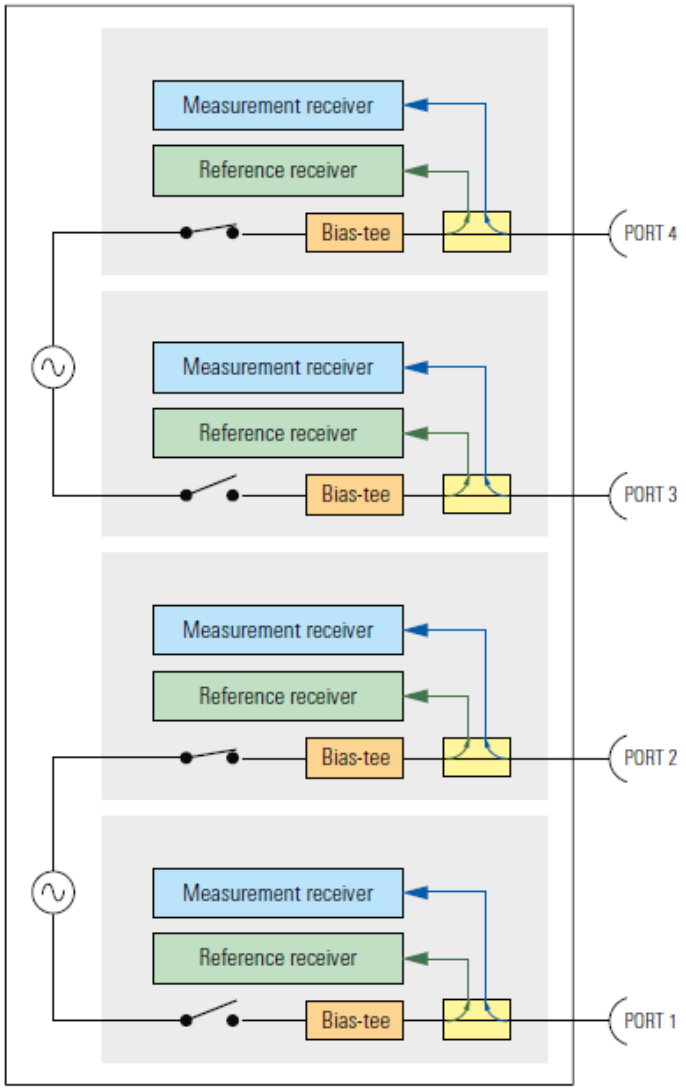
- **Modern**
  - "Heavy & Large" to "Compact & Lightweight"
  - Single-box solution
    - Wide "Single-box" Frequency Coverage
    - Frequency Extender boxes available to 325 GHz +
    - Wide Dynamic Range (to 150 dB)
      - High Output Power (+15 dBm)
  - Many "Bells & Whistles"
    - Gain, Power, Match, IP3, Hot-S22, Pulse, Mixer Msmts

Vector Network Analyzers

- **Technology**
  - Multiple Receivers
    - Amplitude and Phase
      - Ratio Measurements (S-parameters)
      - "Wave Quantities"



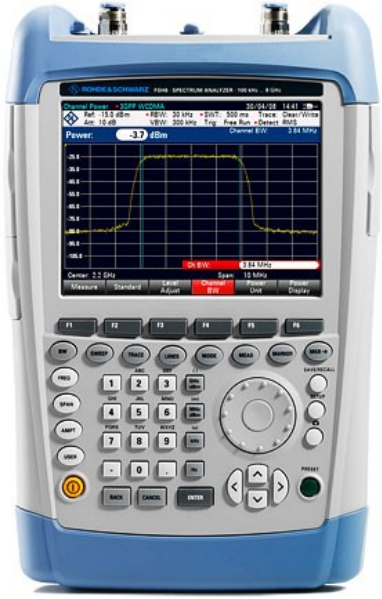
Block diagram of the R&S®ZVA two-port model



Block diagram of the R&S®ZVA four-port model

Vector Network Analyzers

- **Field/Portable Applications**
  - New Technology makes this practical
    - What is the length of my cable? (DTF)
    - Where is the break in my cable? (DTF)
    - What is my antenna feedpoint impedance?
    - Is my gamma match working?



Vector Network Analyzers

- **Lab Applications**
  - New Technology makes measurements fast and easy
    - How can I tweak this filter to the ham bands?
    - What is this Amplifier/ Upconverter/ Downconverter's Gain?
    - How do I improve the match of this device?
    - Does this mixer work? Over what frequency range?
    - What is my antenna's pattern?

Thank You!