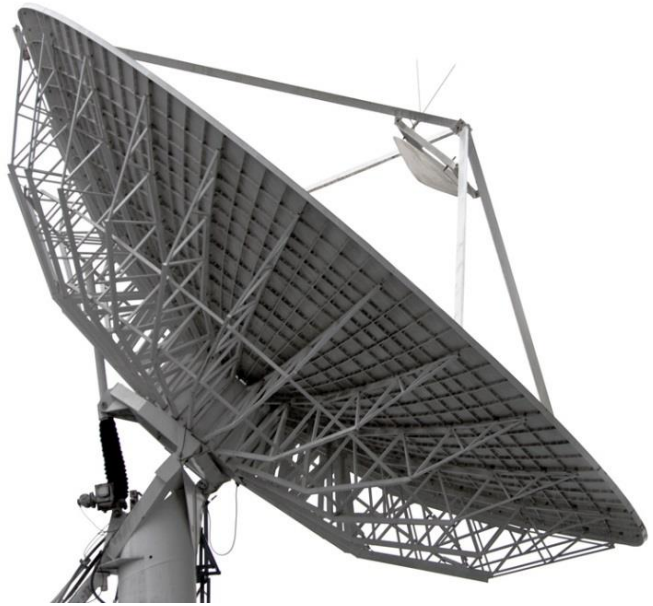
Signal Analysis Fundamental

January 2017



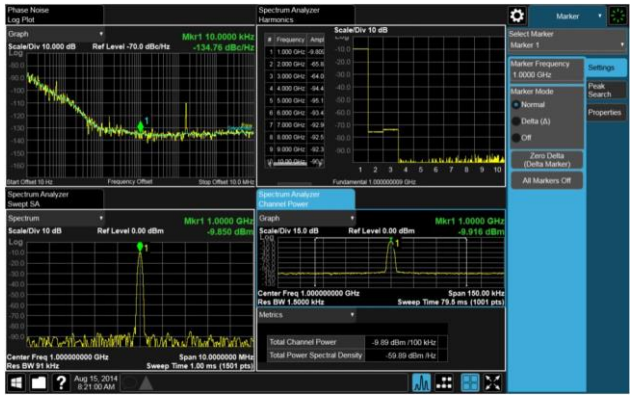
KEYSIGHT TECHNOLOGIES

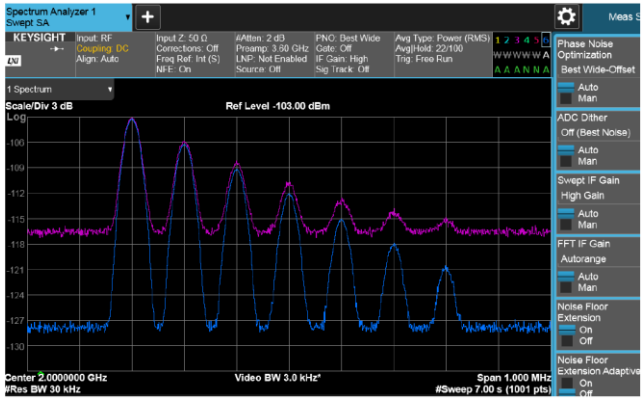
KEYSIGHT HOTSPOTS
Where Technologies and Experts Meet

Agenda

- Introduction
- **Overview:**
  - What is Spectrum and Signal Analysis?
  - What Measurements are available?
- Theory of Operation
- Specifications
- Modern Signal Analyzer Designs & Capabilities
  - Real Time Spectrum Analysis
  - Millimeter Wave Measurements
  - Wide Bandwidth Vector Measurements
- Wrap-up

Overview
What is Spectrum Analysis?

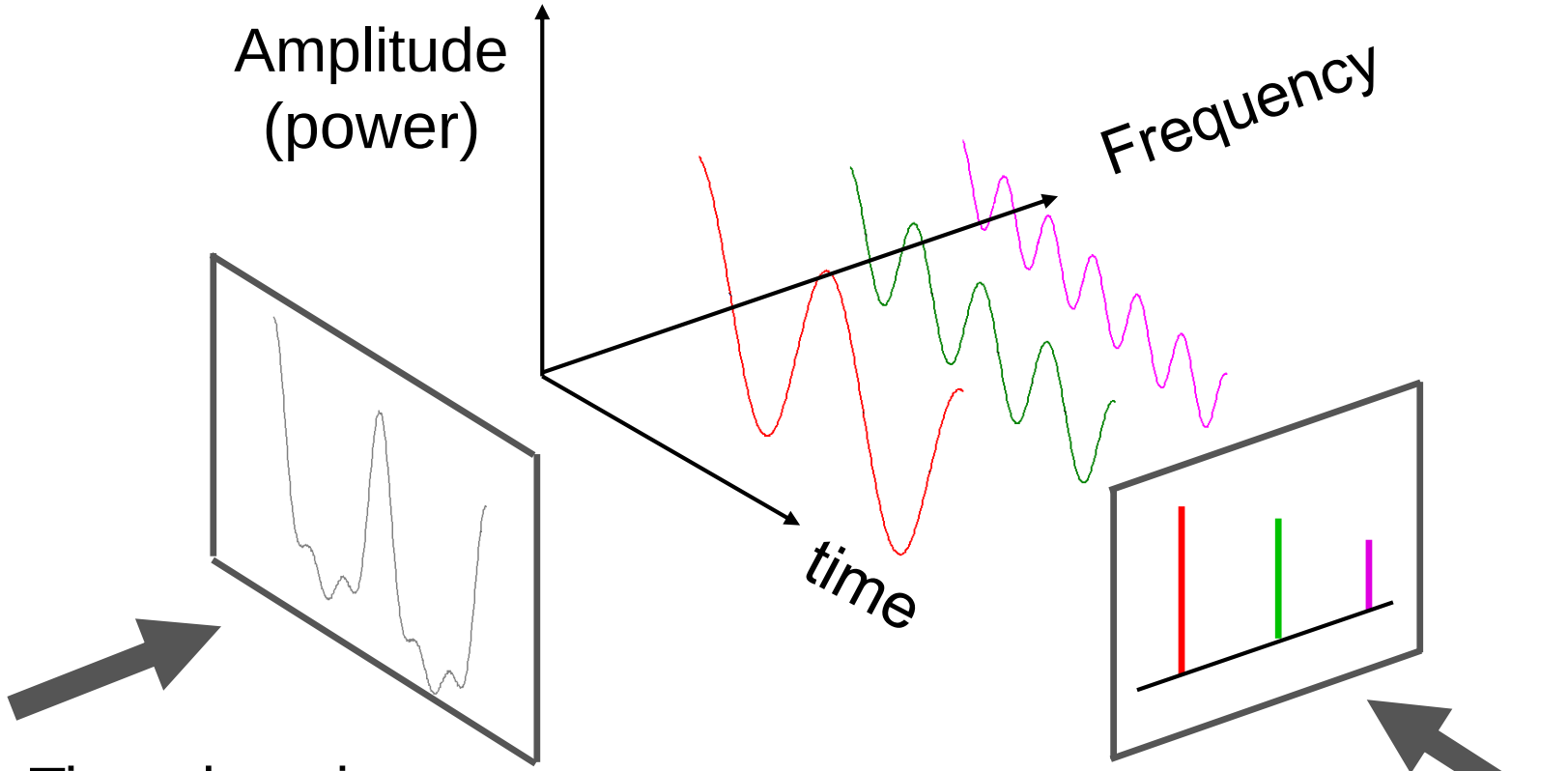




- Passive Receiver
- Display and measure amplitude versus frequency for RF & MW signals
- Separate or demodulate complex signals into their base components (sine waves)

Overview

Frequency versus Time Domain



Time domain
Measurements
(Oscilloscope)

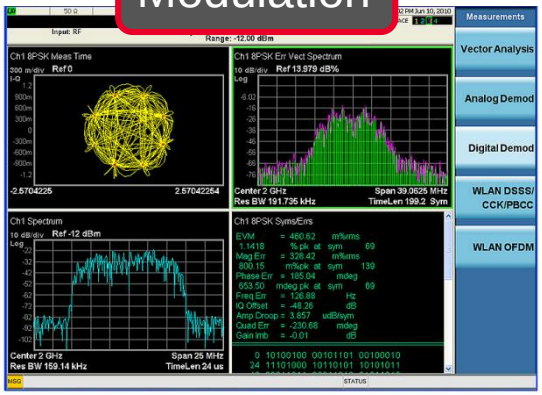
Frequency Domain
Measurements
(Spectrum Analyzer)

Overview

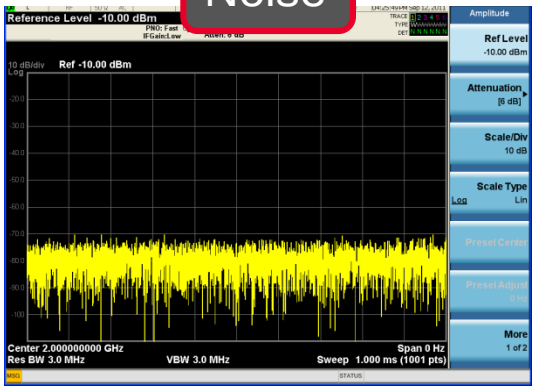
Types of Measurements Available

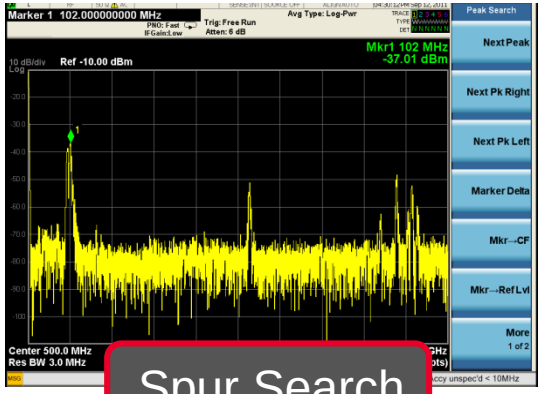
- **Frequency, power, modulation, distortion, and noise**
  - Spectrum monitoring
  - Spurious emissions
  - Scalar network analysis
  - Noise figure & phase noise
  - Harmonic & intermodulation distortion
  - Analog, digital, burst, & pulsed RF modulation
  - Wide bandwidth vector analysis
  - Electromagnetic interference
- **Measurement range:** -172 dBm to +30 dBm
- **Frequency range:** 3 Hz to 1.1 THz

Modulation

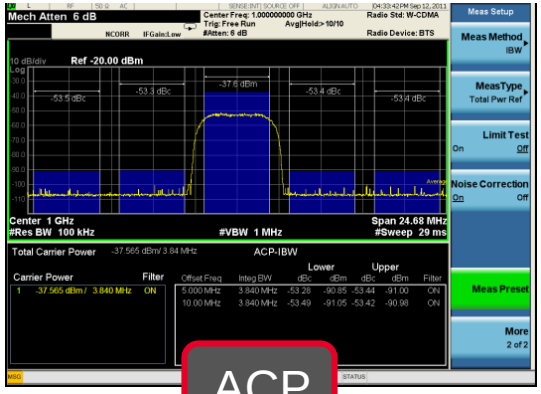


Noise





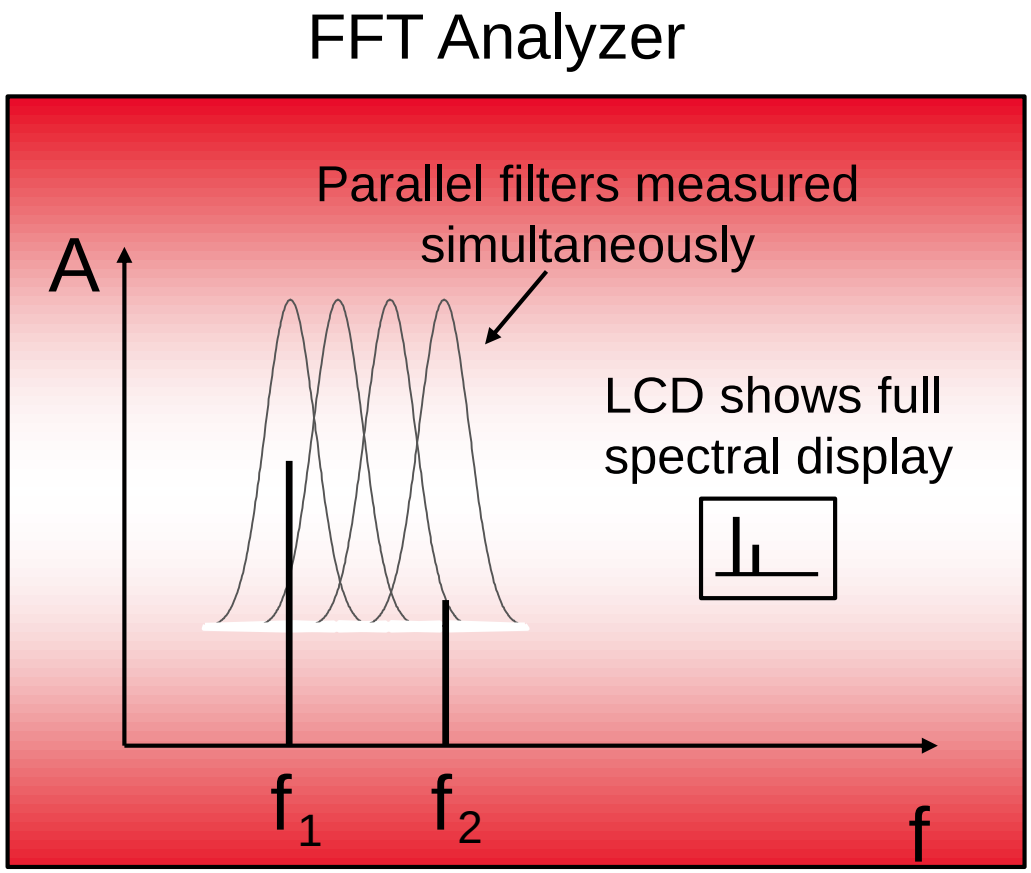
Spur Search



ACP

Overview

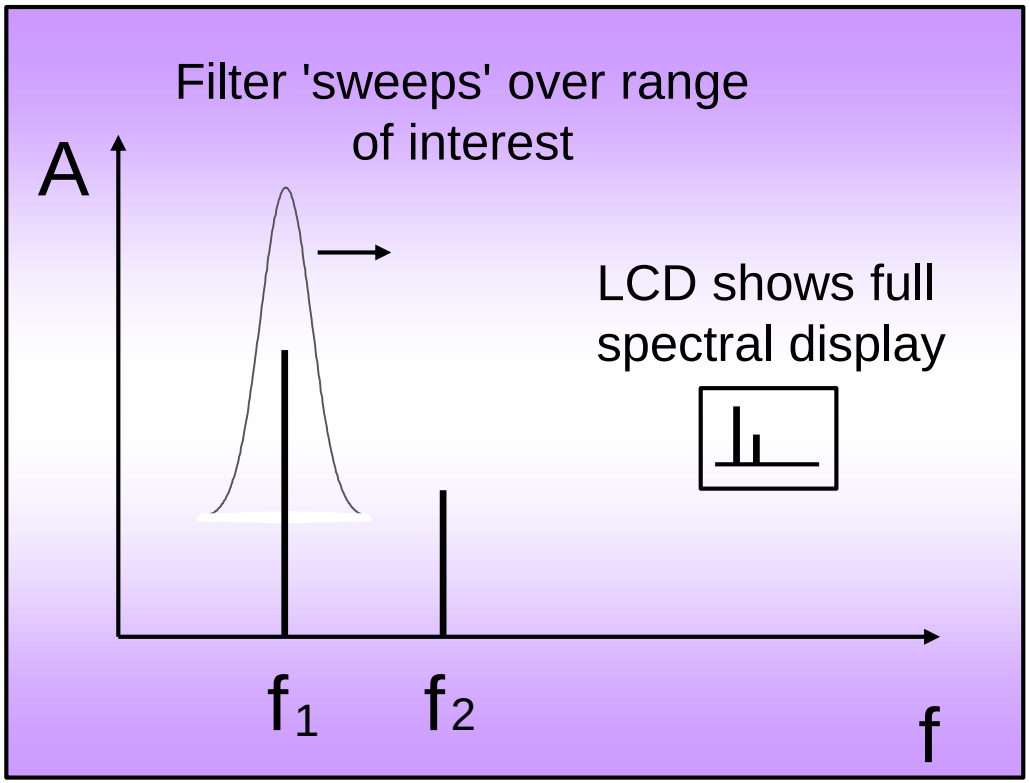
Different Types of Analyzers



Overview

Different Types of Analyzers

Swept Analyzer



Analyzer Definitions

Spectrum Analyzer: A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to display and measure Amplitude vs. Frequency of known and unknown RF and Microwave signals.

Analyzer Definitions

Vector Signal Analyzer: A vector signal analyzer measures the magnitude and phase of an input signal at a single frequency within the IF bandwidth of the instrument. The primary use is to make in-channel measurements, such as error vector magnitude, code domain power, and spectral flatness, on known signals.

Analyzer Definitions

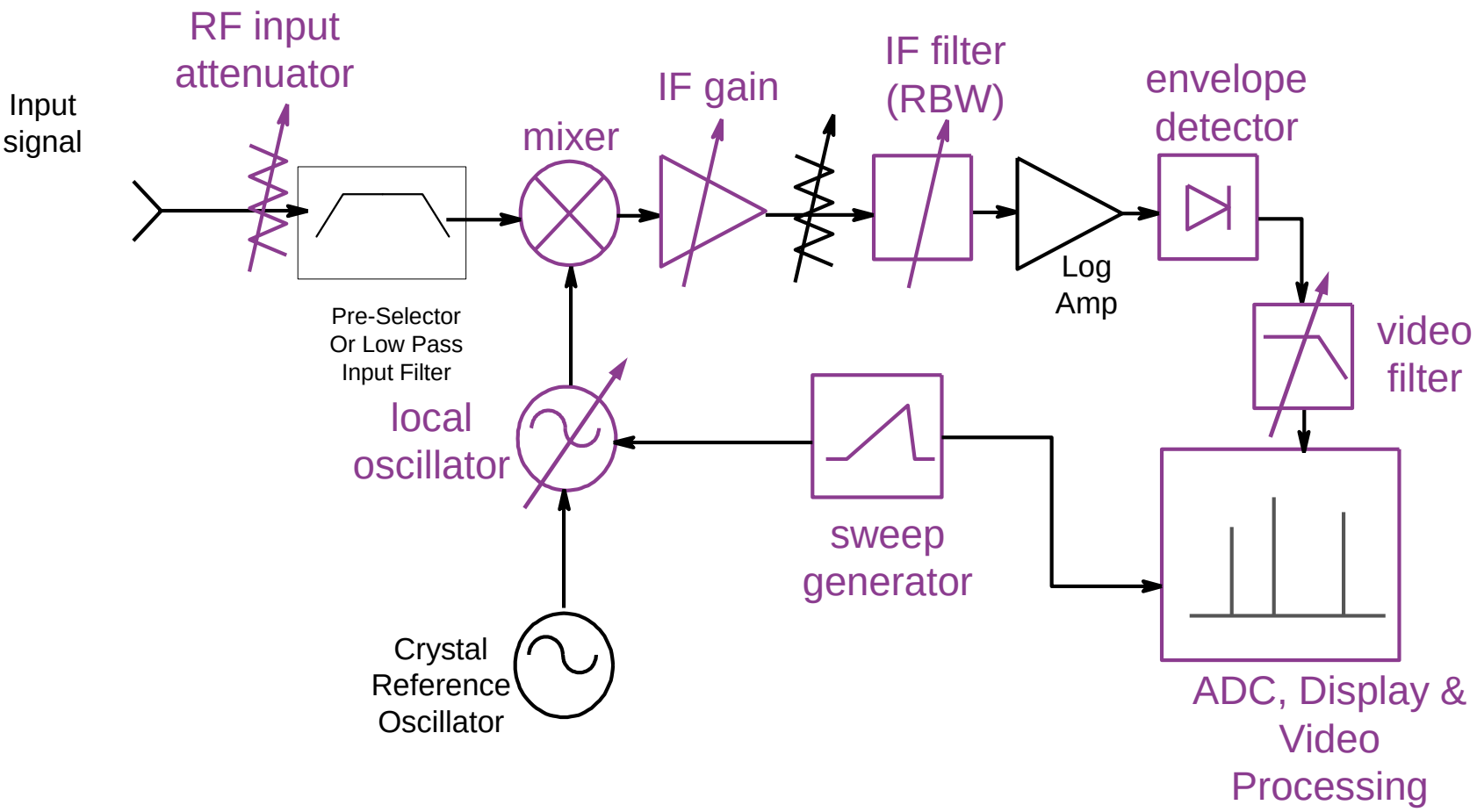
Signal Analyzer: A signal analyzer provides the functions of a spectrum analyzer and a vector signal analyzer.

Agenda

- Introduction
- Overview
- **Theory of Operation**
  - **Swept Spectrum Analyzer Hardware**
- Specifications
- Modern Signal Analyzer Designs & Capabilities
  - Real Time Spectrum Analysis
  - Millimeter Wave Measurements
  - Wide Bandwidth Vector Measurements
- Wrap-up

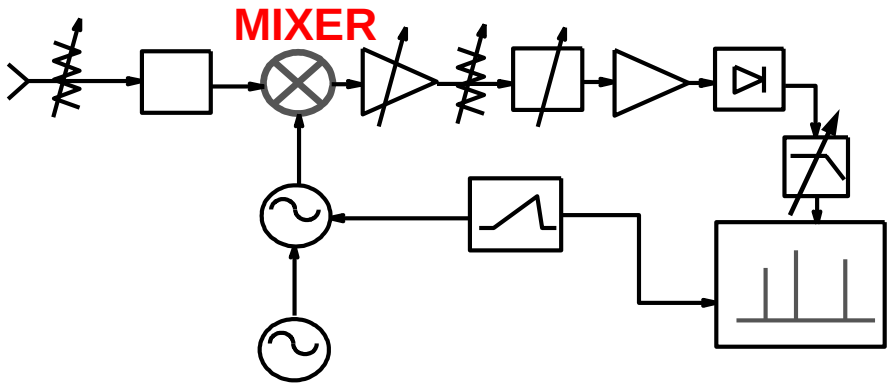
Theory of Operation

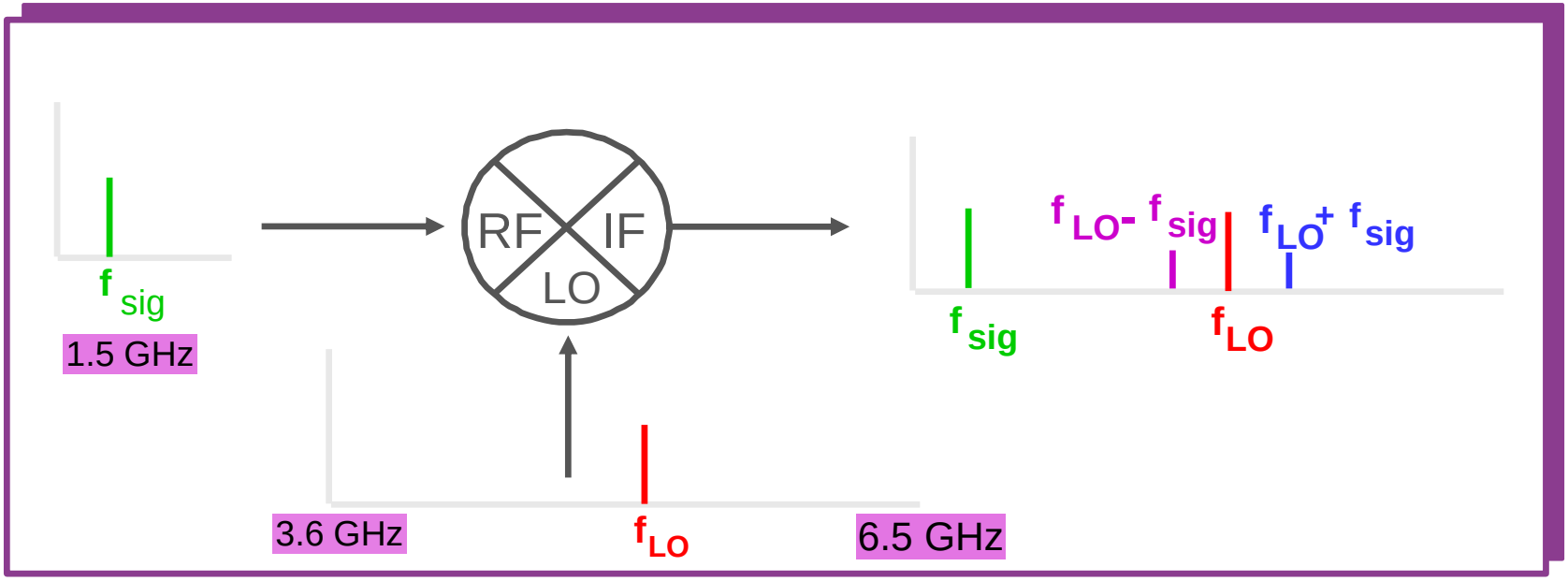
Swept Spectrum Analyzer Block Diagram



Theory of Operation

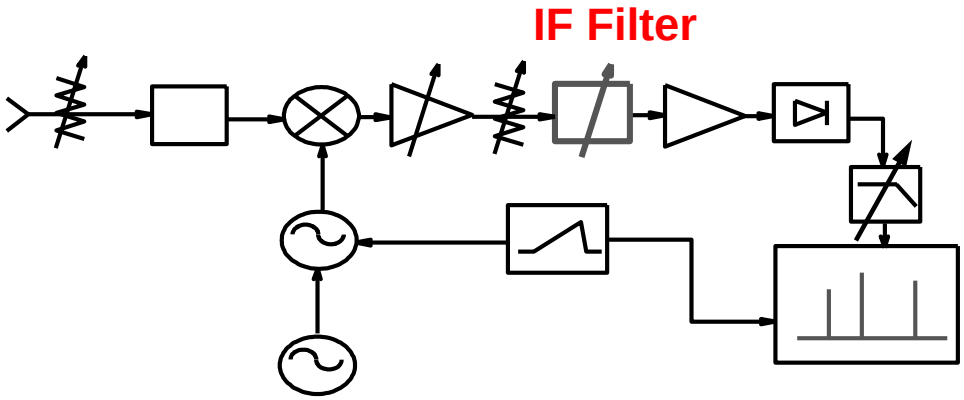
Mixer

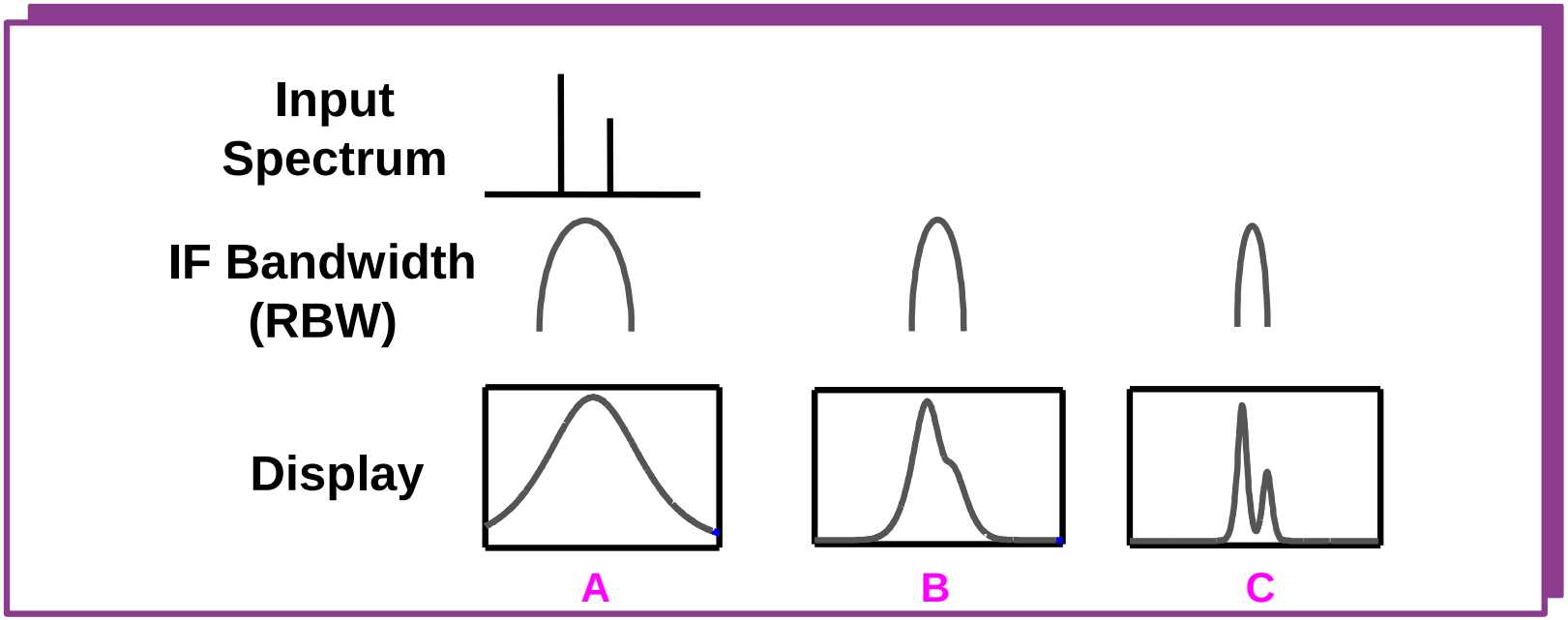




Theory of Operation

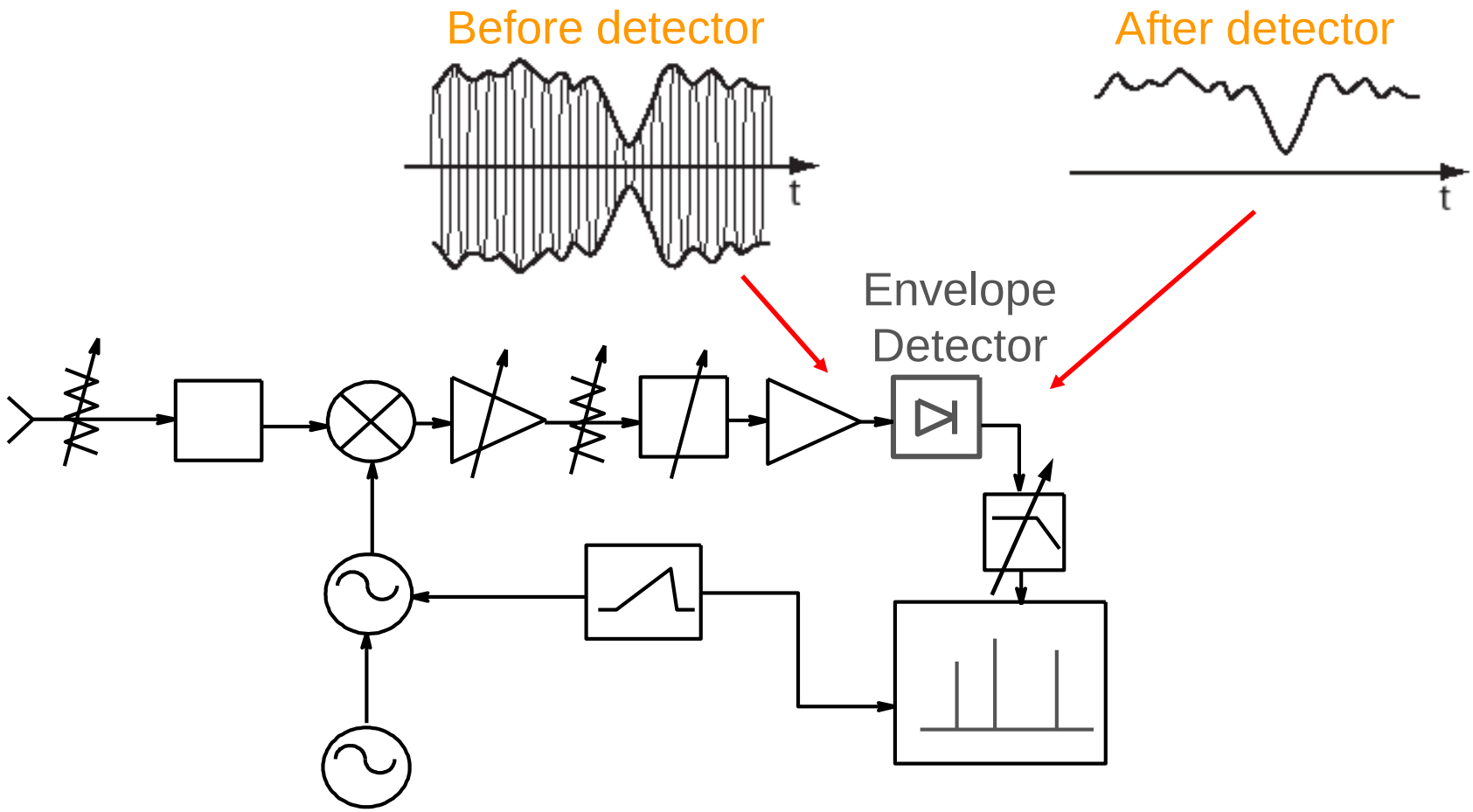
IF Filter (Resolution Bandwidth – RBW)





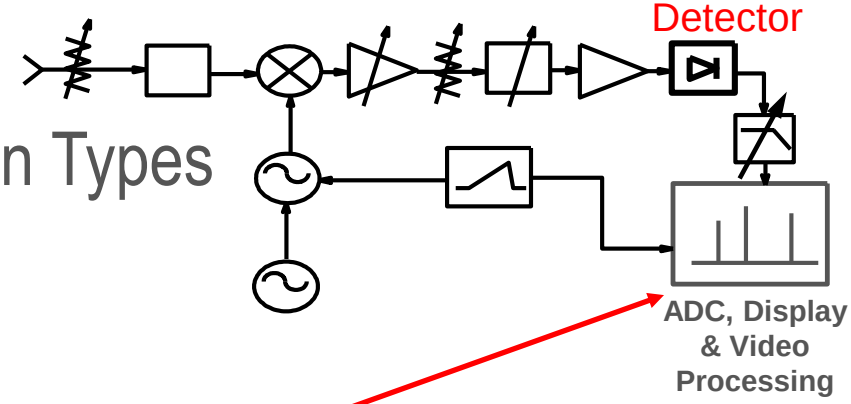
Theory of Operation

Envelope Detector

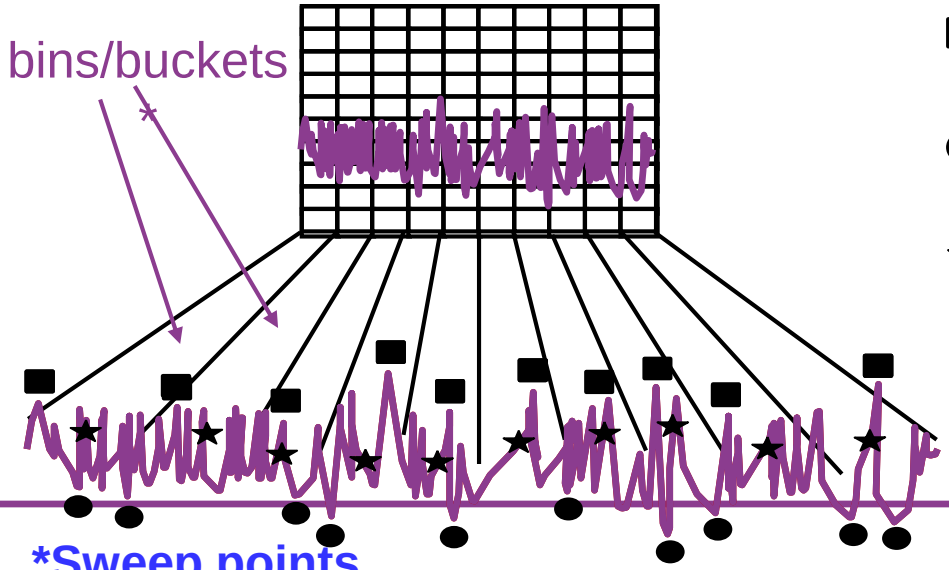


Theory of Operation

Envelope Detector and Detection Types



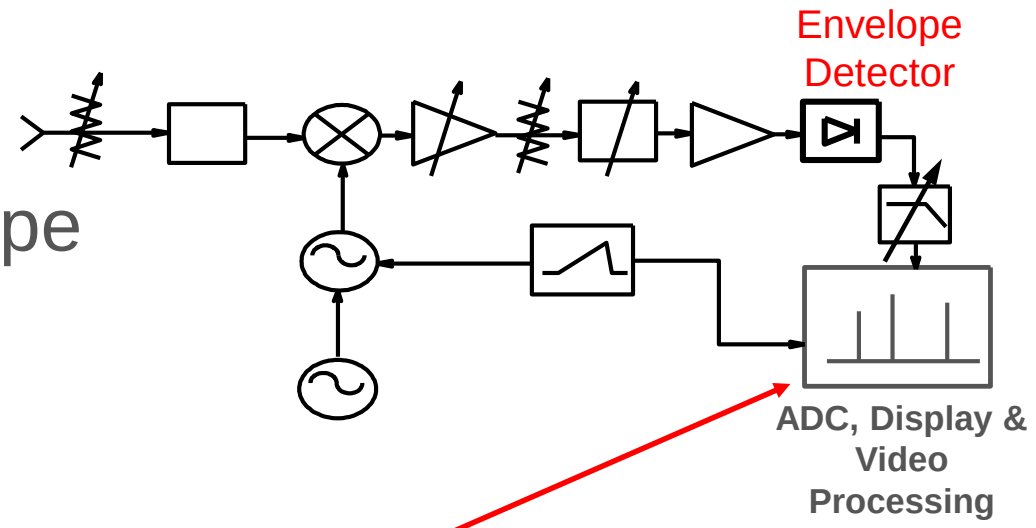
Digitally Implemented Detection Types

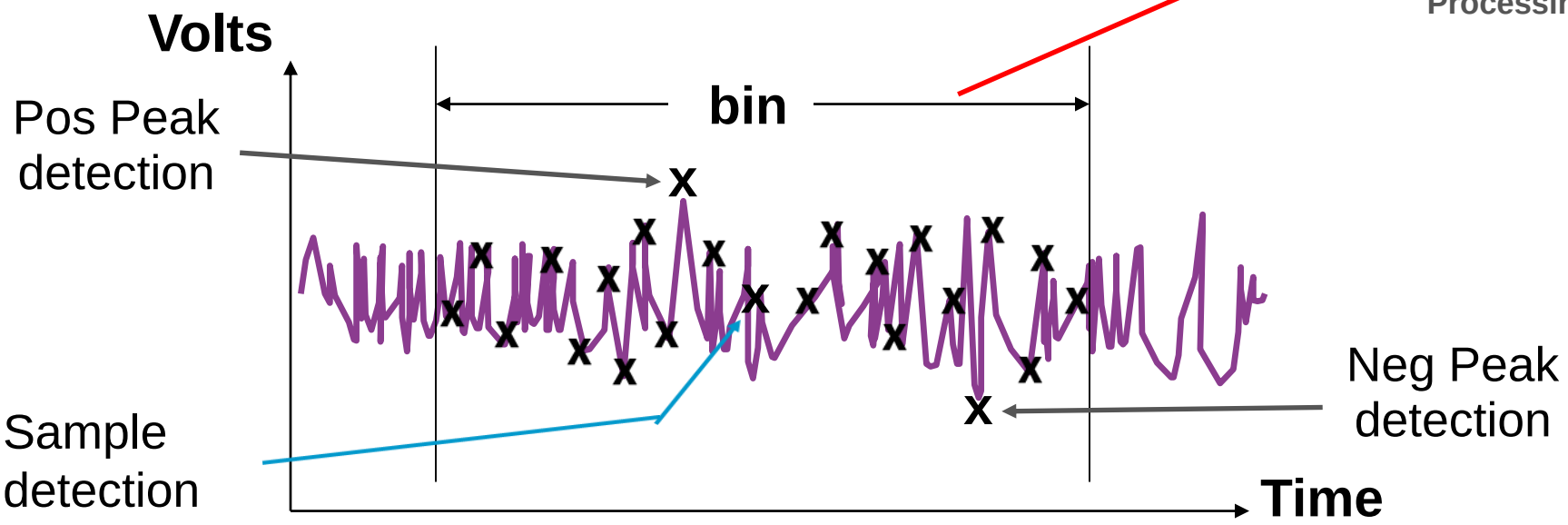


- ■ Positive detection: largest value in bin displayed
- ● Negative detection: smallest value in bin displayed
- ★ Sample detection: middle value in bin displayed

Other Detectors: Normal (Rosenfell), Average (RMS Power)

Theory of Operation
Average Detector Type

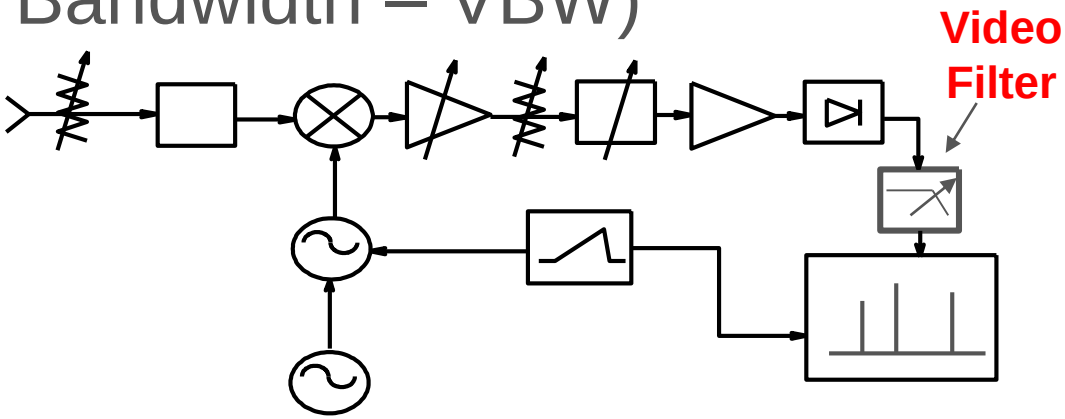


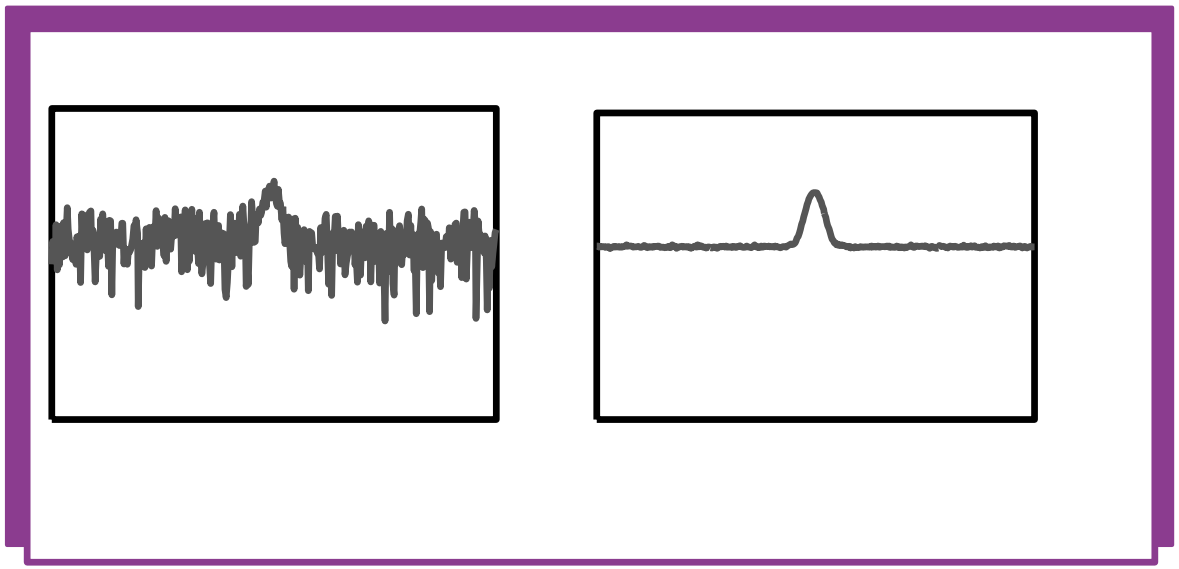


Power Average Detection (rms) = Square root of the sum of the squares of ALL of the voltage data values in the bin /50Ω

Theory of Operation

Video Filter (Video Bandwidth – VBW)

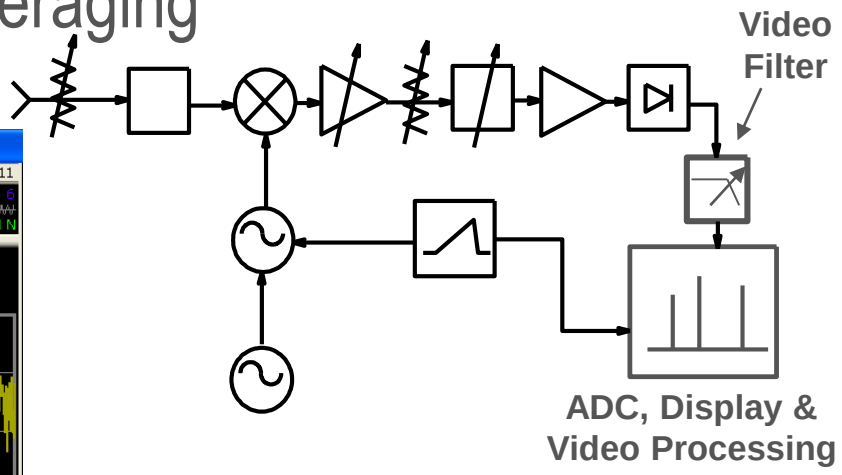




Theory of Operation

Video Filter vs. Trace/Video averaging

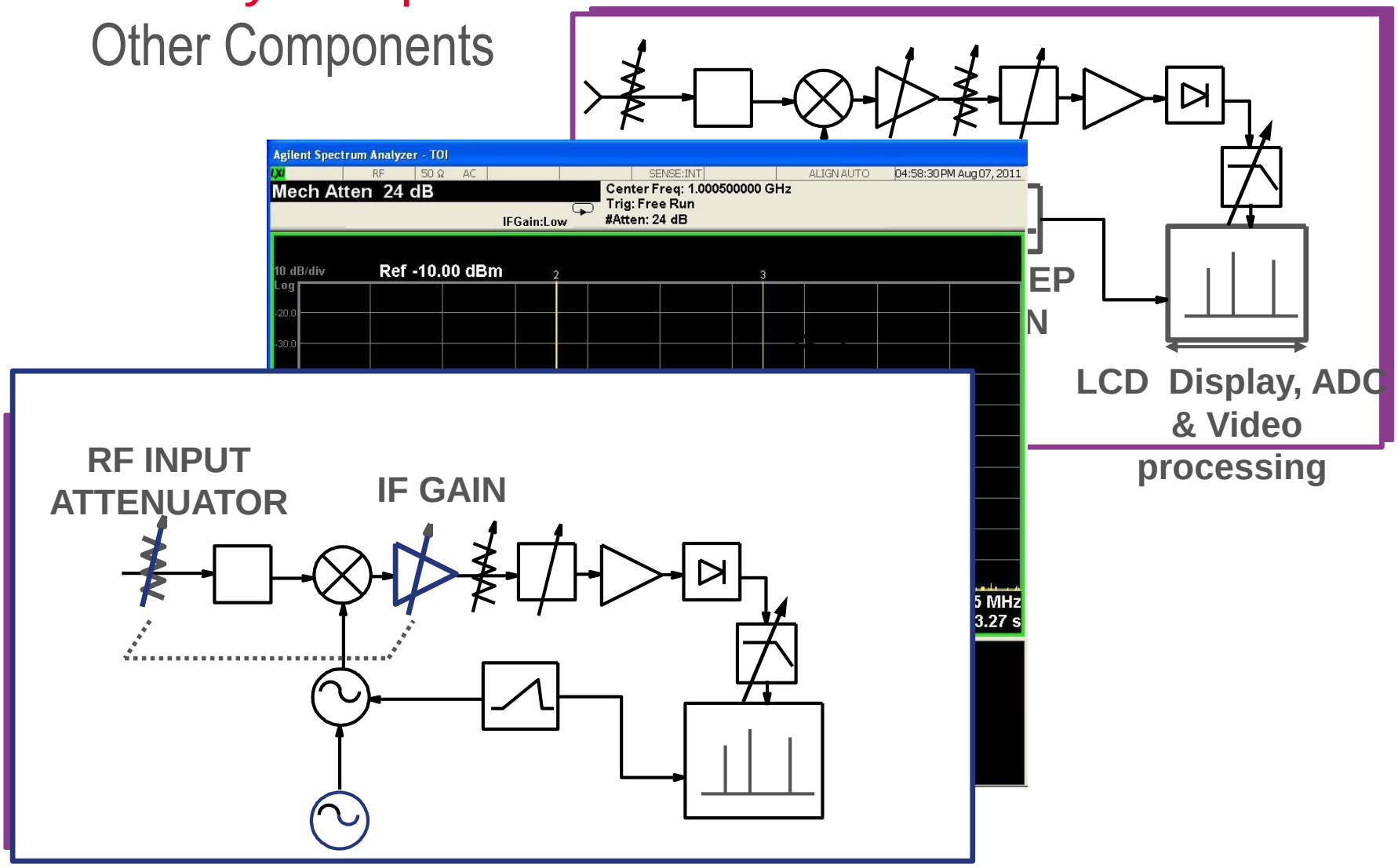
Trace averaging for 1, 5, 20, and 100 sweeps, top to bottom (trace position offset for each set of sweeps)



- Video Filter operates as the sweep progresses, sweep time may be required to slow down by the transient response of the VBW filter.
- Trace/Video Average takes multiple sweeps, sweep time for each sweep is not affected
- Many signals give the same results with either video filtering or trace averaging

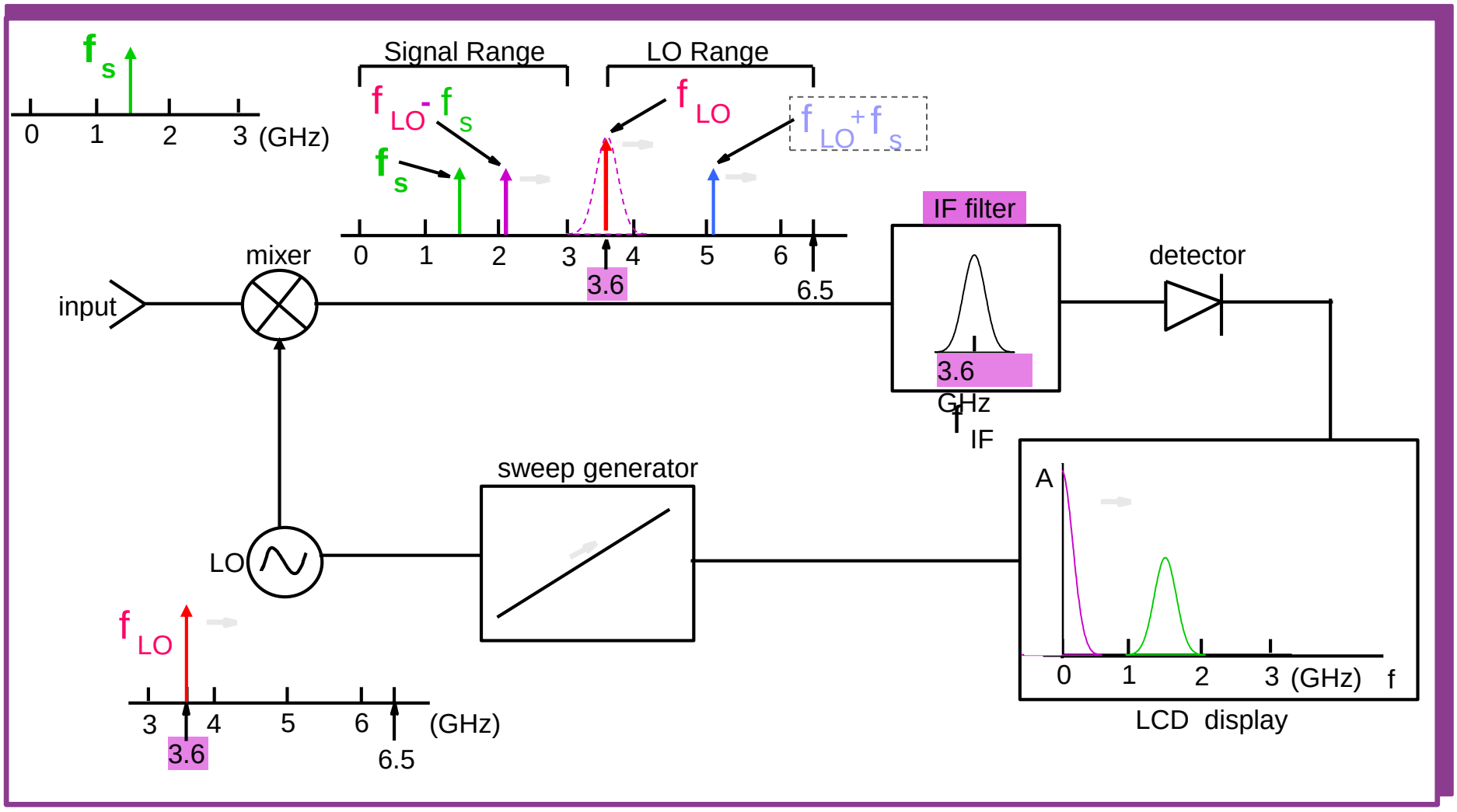
Theory of Operation

Other Components



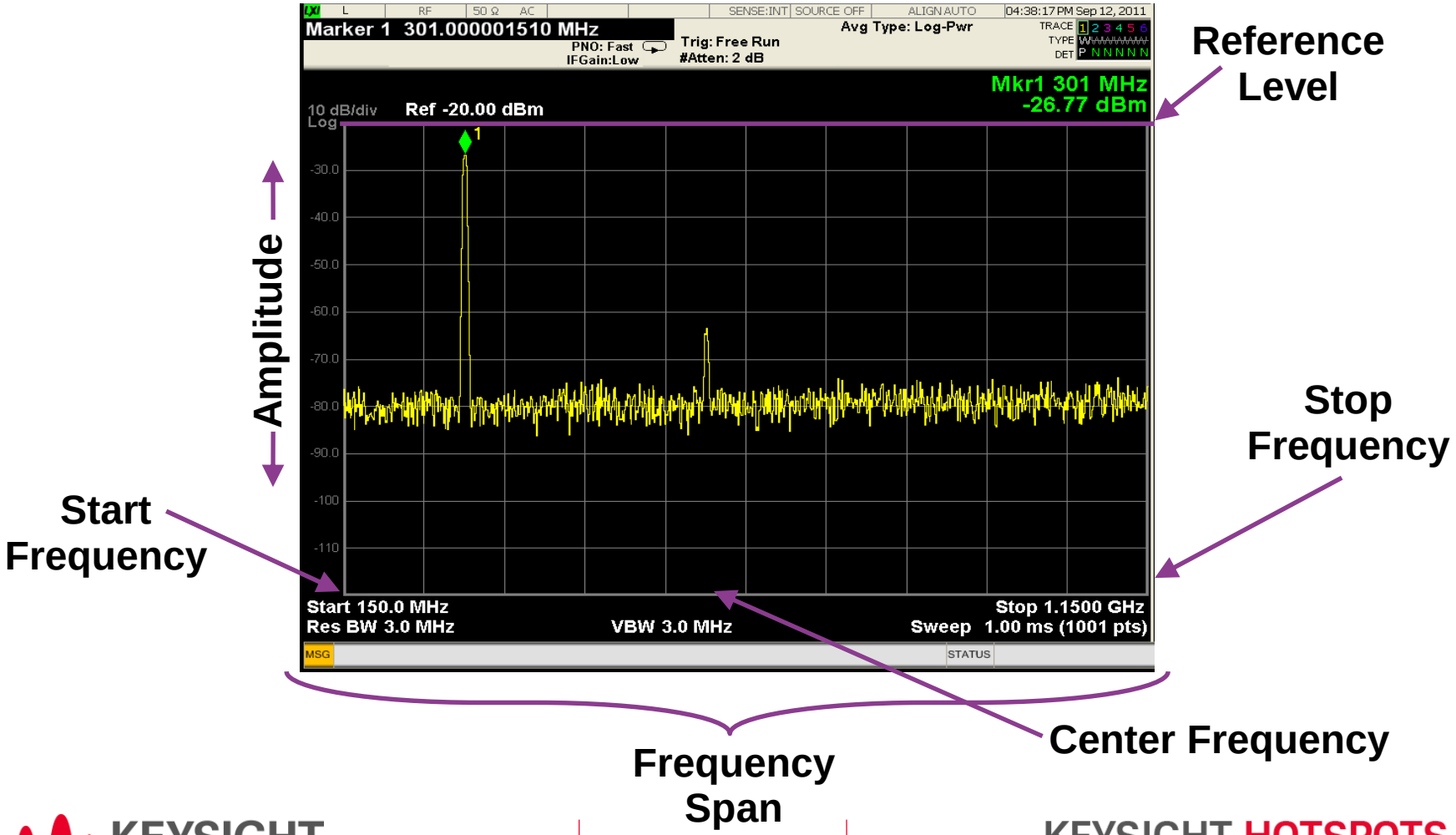
Theory of Operation

How it All Works Together - 3 GHz spectrum analyzer



Theory of Operation

Display Terminology



Agenda

- Overview
- Theory of Operation
- **Specifications:**
    - **Which are important and why?**
- Modern spectrum analyzer designs & capabilities
- Wrap-up
- Appendix

Key Specifications

- Safe spectrum analysis
- Frequency Range
- Accuracy: Frequency & Amplitude
- Resolution
- Sensitivity
- Distortion
- Dynamic Range

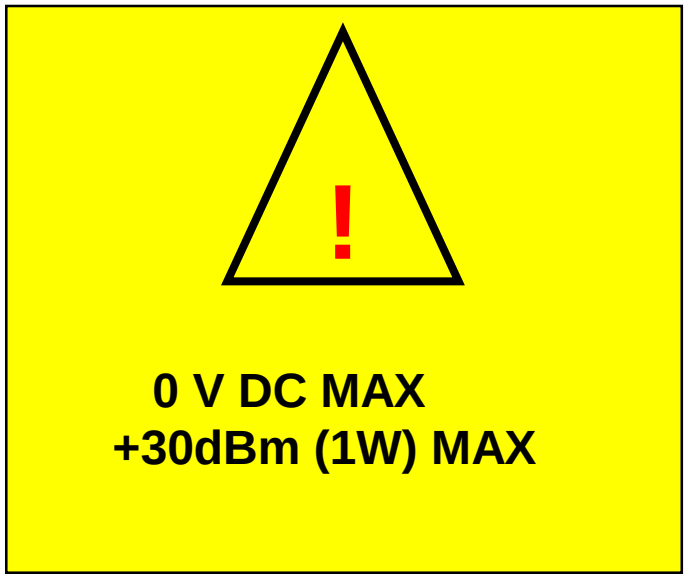
Specifications?
A Definition

- **Specifications** describe the performance of parameters covered by the product warranty (temperature = 0 to 55°C, unless otherwise noted).
- **Typical** values describe additional product performance information that is not covered by the product warranty. It is performance beyond specification that 80 % of the units exhibit with a 95 % confidence level over the temperature range 20 to 30° C. Typical performance does not include measurement uncertainty.
- **Nominal** values indicate expected performance, or describe product performance that is useful in the application of the product, but is not covered by the product warranty.

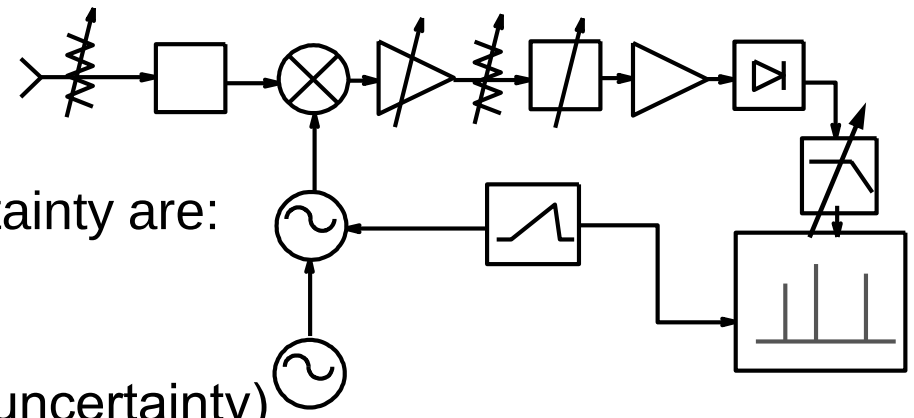
Specifications

Practicing safe spectrum analysis - *Safe* Hookups to RF Input

- Use best practices to eliminate static discharge to the RF input!
- Do not exceed the Damage Level on the RF Input!
- Do not input signals with DC bias exceeding what the analyzer can tolerate while DC coupled!



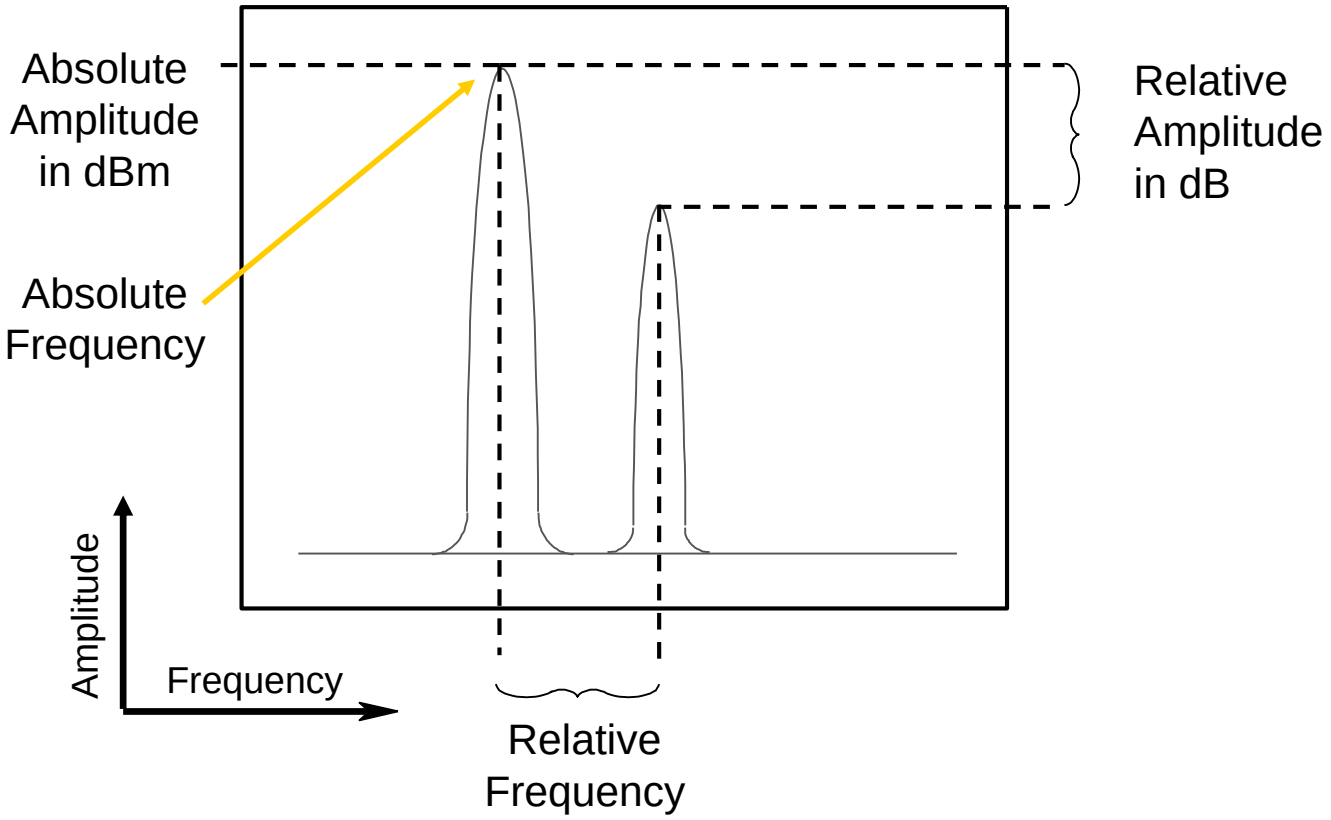
Specifications
Accuracy: Frequency & amplitude



Components which contribute to uncertainty are:

- Input mismatch (VSWR)
- RF Input attenuator (Atten. switching uncertainty)
- Mixer and input filter (frequency response)
- IF gain/attenuation (reference level accuracy)
- RBW filters (RBW switching uncertainty)
- Log amp (display scale fidelity)
- Reference oscillator (frequency accuracy)
- Calibrator (amplitude accuracy)

Specifications
Absolute and Relative Accuracy: Frequency & Amplitude



Note: Absolute accuracy is also “relative” to the calibrator reference point

Specifications
Accuracy: Frequency Readout Accuracy

Determined by Reference Accuracy

- From the PXA Data Sheet:

± (marker frequency x freq reference accuracy +
0.1%*span + 5% of RBW + 2Hz + 0.5 x Horiz. Res.*)

Span Accuracy

RBW Error
IF filter center frequency error

Residual Error

*Horizontal resolution is span/(sweep points – 1)

Specifications
Accuracy: Frequency Readout Accuracy Example

Frequency: 1 GHz
Span: 400 kHz
RBW: 3 kHz
Sweep points: 1000

Calculation: $(1x10^{9}Hz) \times (\pm 1.55x10^{-7}/Year\ ref.\ Error)$ **= 155Hz**
400kHz Span x 0.1% **= 400Hz**
3kHz RBW x 5% **= 150Hz**
2Hz + 0.5 x 400kHz/(1000-1) **= 202Hz**
Total uncertainty **= ±907Hz**

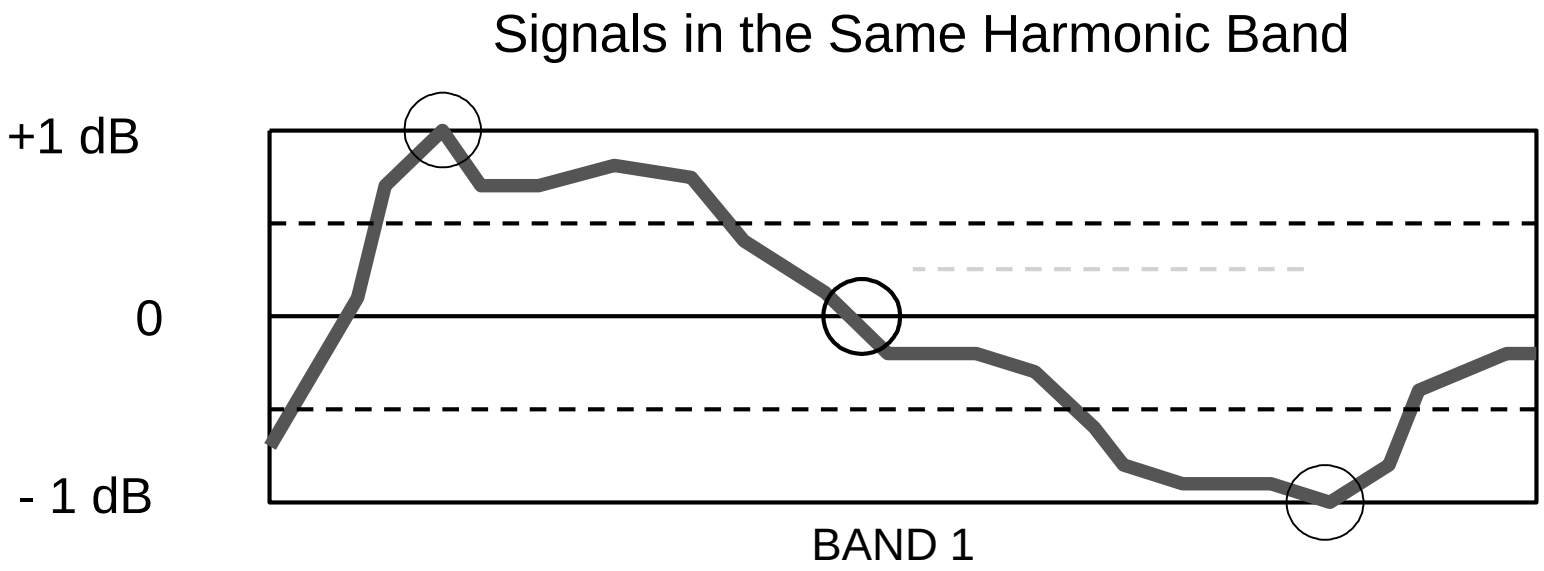
*Utilizing internal frequency counter improves accuracy to ±155Hz

**** The Maximum # of sweep points for the X-Series is 40,001 which helps to achieve the best frequency readout accuracy

Specifications
Accuracy: Key Amplitude Uncertainty Contributions

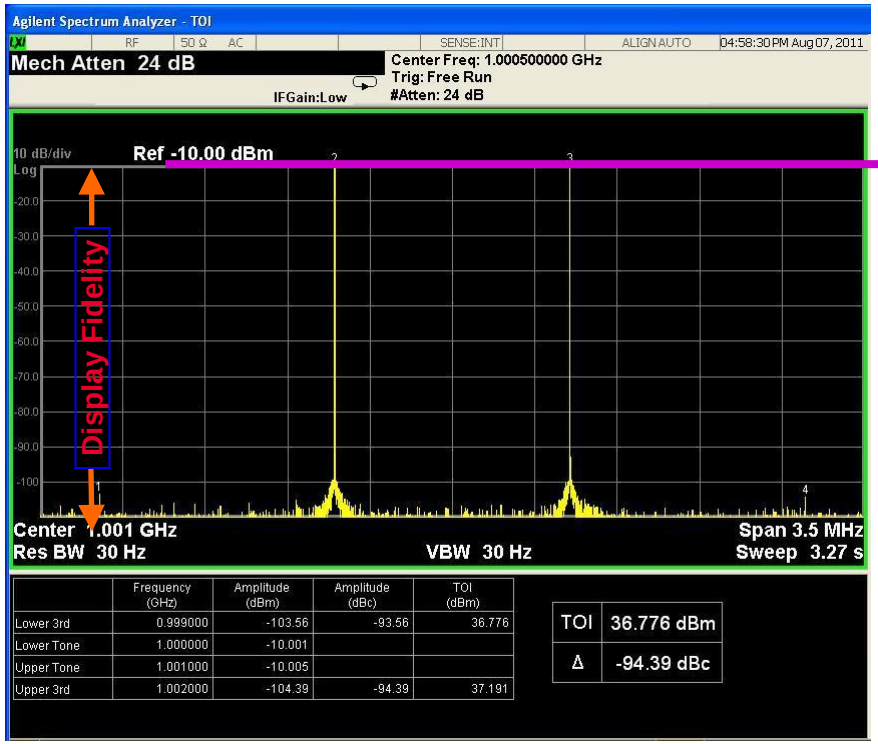
Relative and absolute: Uncertainties	PXA
• Input impedance mismatch	(±0.13 dB)
• Input attenuator switching uncertainty	(±0.14 dB)
• Frequency response	(±0.35 dB)
• Reference level accuracy	(0 dB)
• RBW switching uncertainty	(±0.03 dB)
• Display scale fidelity	(±0.07 dB)
Absolute only:	
• Calibrator accuracy	(±0.24 dB)

Specifications
Accuracy: Frequency Response



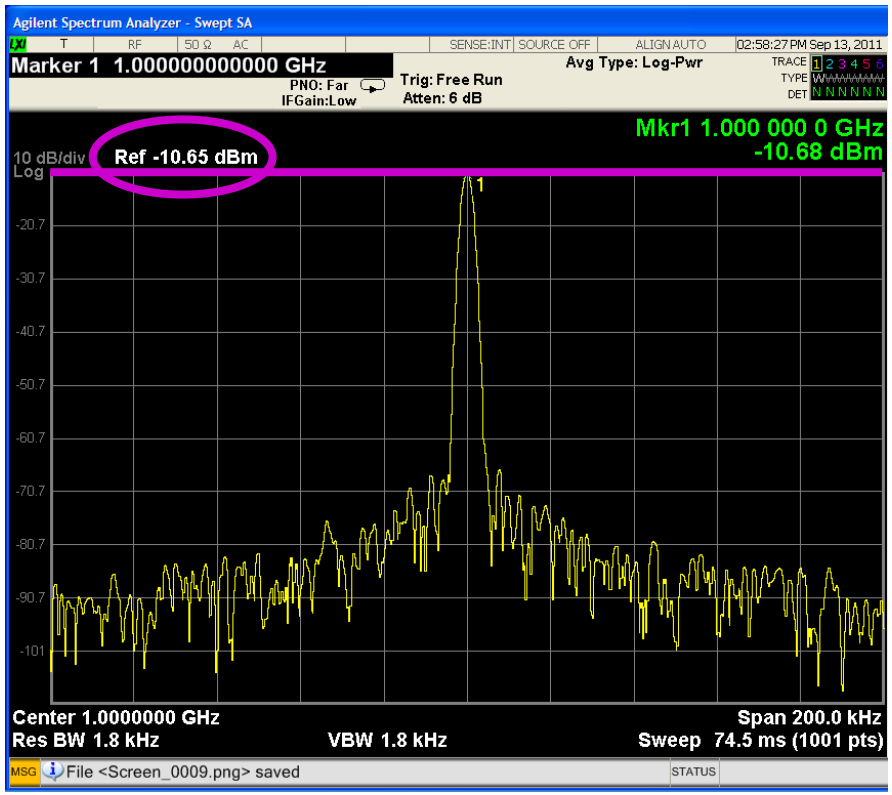
Absolute amplitude accuracy – Specification: ± 1 dB
Relative amplitude accuracy – Specification: ± 2 dB

Specifications
Accuracy: Display Fidelity



- Display Fidelity includes:
  - Log Amp Fidelity
  - Envelope Detector Linearity
  - Digitizing Circuit Linearity
- Display fidelity error applies when signals are not at the same reference level amplitude when measured
- In the past, technique for best accuracy was to move each measured signal to the reference line, eliminating display fidelity error.
- Display Scale Fidelity of analyzers with digital IF are superior to those with analog IF i.e. X-series analyzers have +/- 0.1 db vs. ESA, 856xEC +/- 1.0 db

Specifications
Amplitude Accuracy: Reference Level Switching



- Uncertainty applies when changing the Ref. Level
- Also called IF Gain Uncertainty
- Decision: Do I change the reference level or live with the display fidelity uncertainty in my measurements?
- However with today's X-series analyzers, provided the attenuation remains unchanged, the signal no longer needs to be at the reference level for the most accurate measurement.

Specifications
Amplitude Accuracy - Summary

Optimize measurement setup & techniques for best accuracy

- **Minimize changes to uncertainty contributors**
  - Or change contributor with least error impact
  - Or stay within the optimum accuracy envelope parameters that modern auto-alignment calibration techniques provide

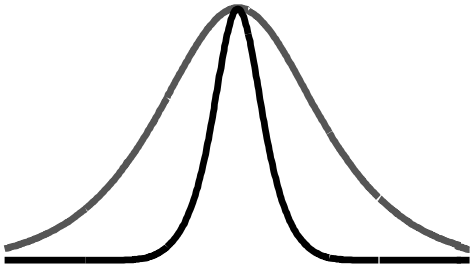
- **Traditionally, one technique for best accuracy was to move each measured signal to the reference line,** eliminating display fidelity error. However, in today's designs, display fidelity has improved to the point where there is generally less error just to leave the signals where they occur on the display.

- **Except for freq. response**, uncertainty contributors that impact both signals equally in a relative measurement can be ignored.

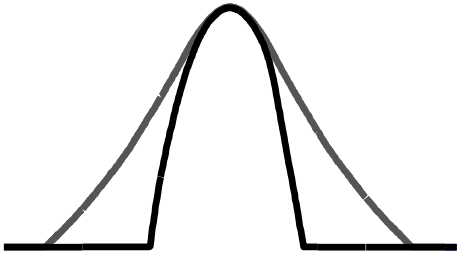
- **In the absence of specified relative freq. response**, the relative response uncertainty is assumed to be 2x specified absolute error.

Specifications
Resolution

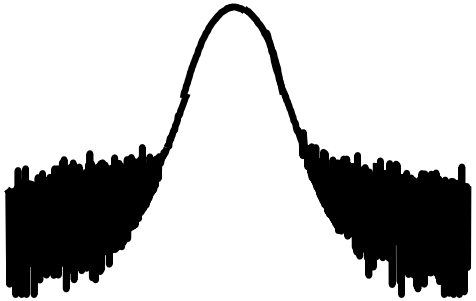
What Determines Resolution?



Resolution Bandwidth

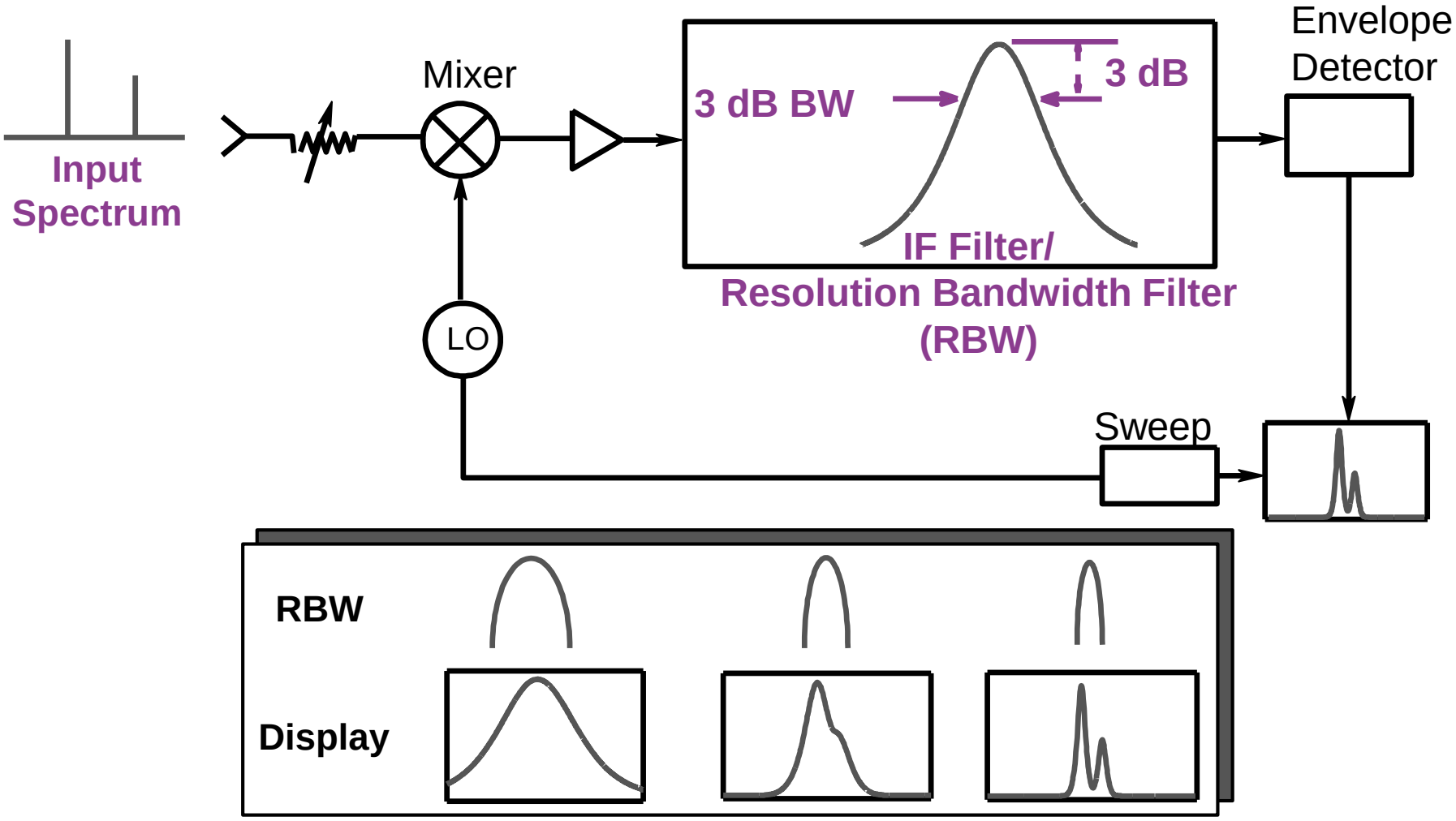


RBW Type and Selectivity

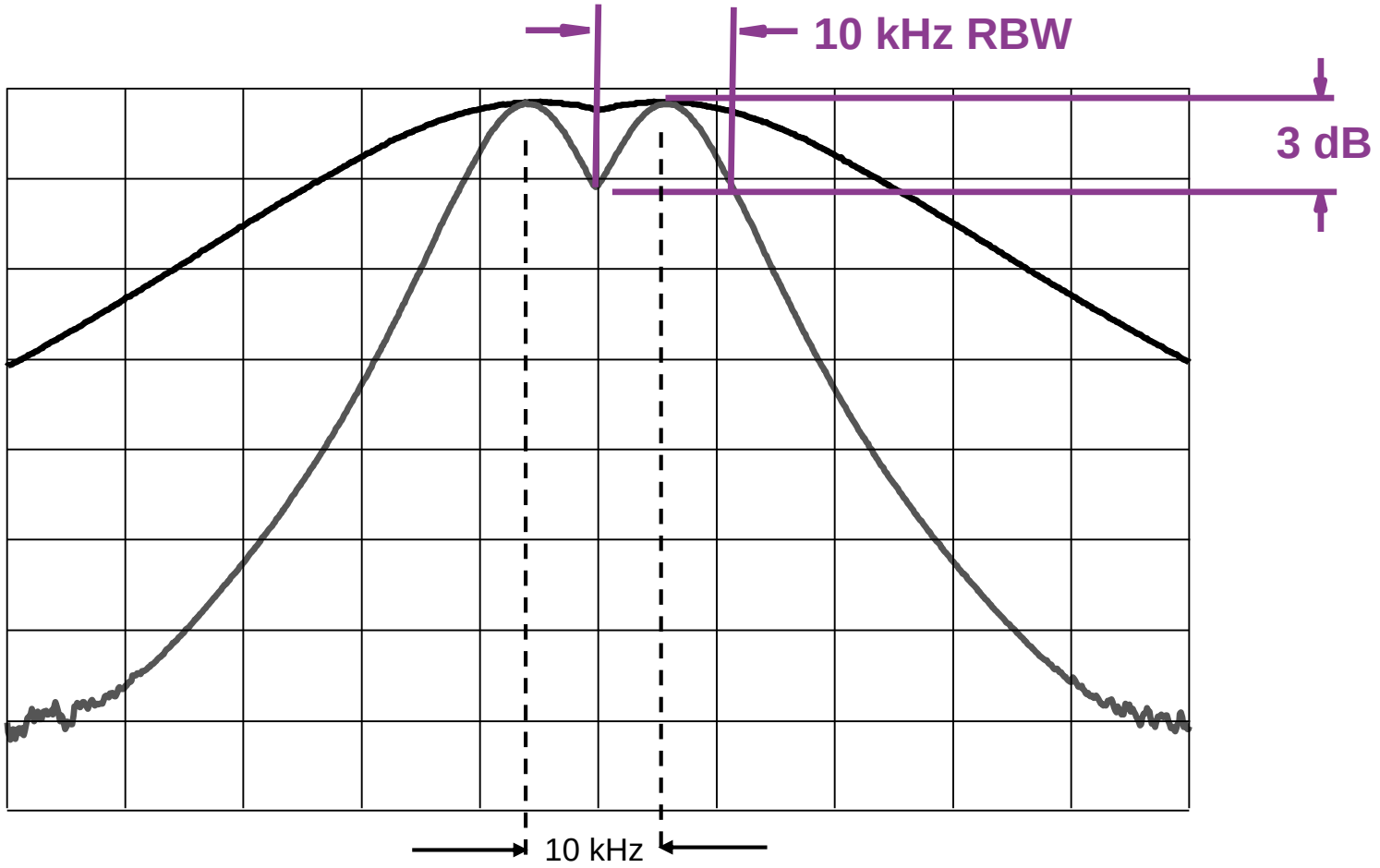


Noise Sidebands

Specifications
Resolution: Resolution Bandwidth

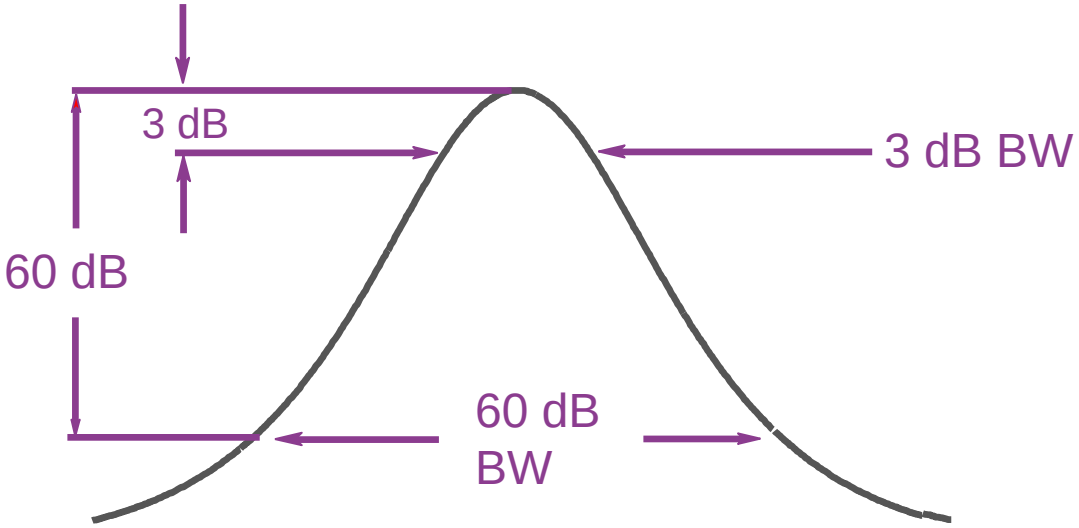


Specifications
Resolution: Resolution BW



Determines resolvability of equal amplitude signals

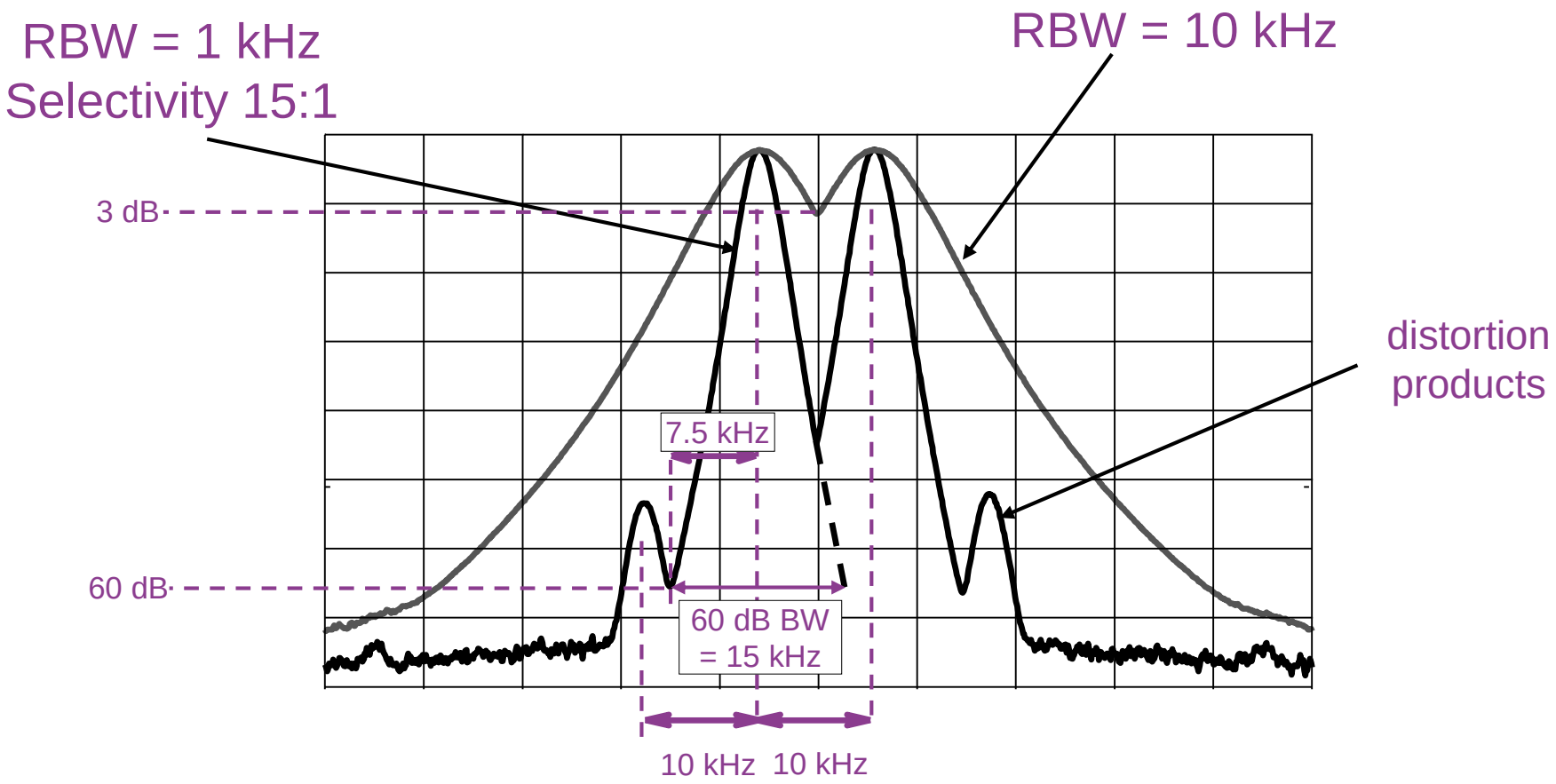
Specifications
Resolution BW Selectivity or Shape Factor



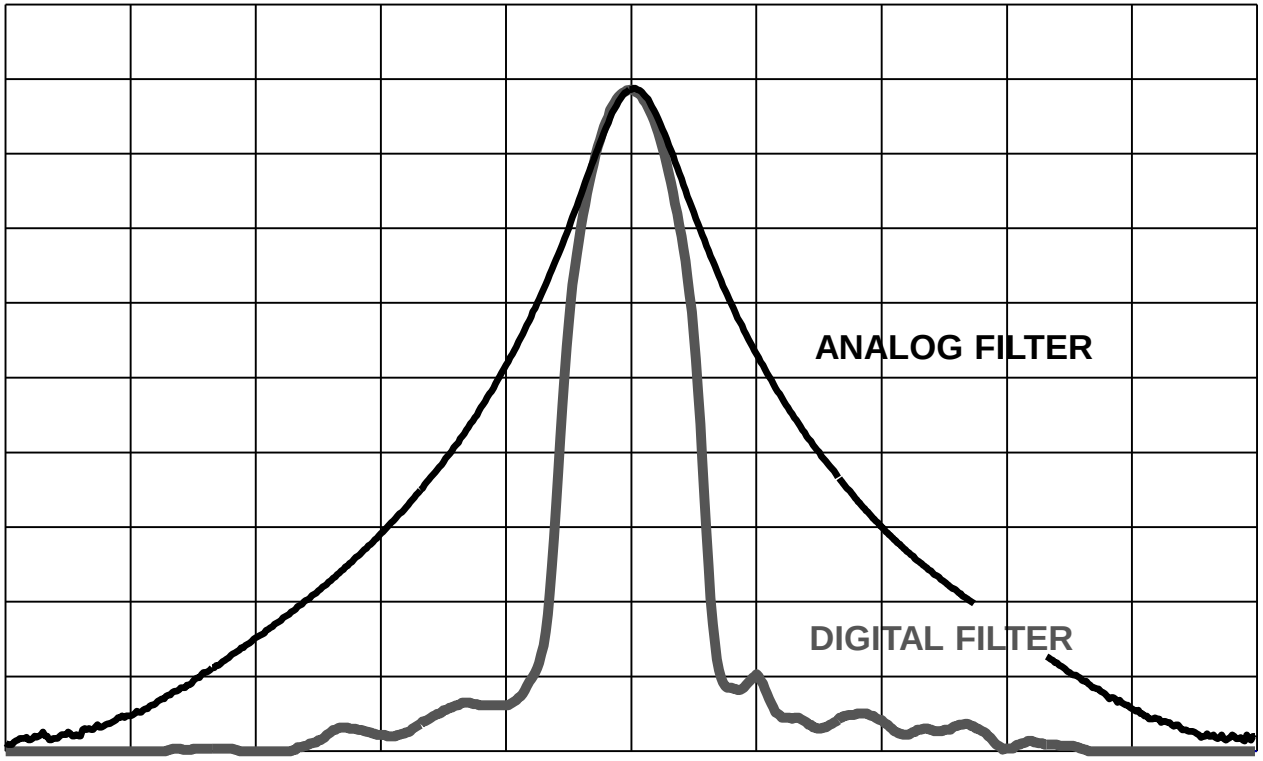
$$\text{Selectivity} = \frac{\text{60 dB BW}}{\text{3 dB BW}}$$

Determines resolvability of unequal amplitude signals

Specifications
Resolution BW Selectivity or Shape Factor



Specifications
Resolution: RBW Type and Selectivity



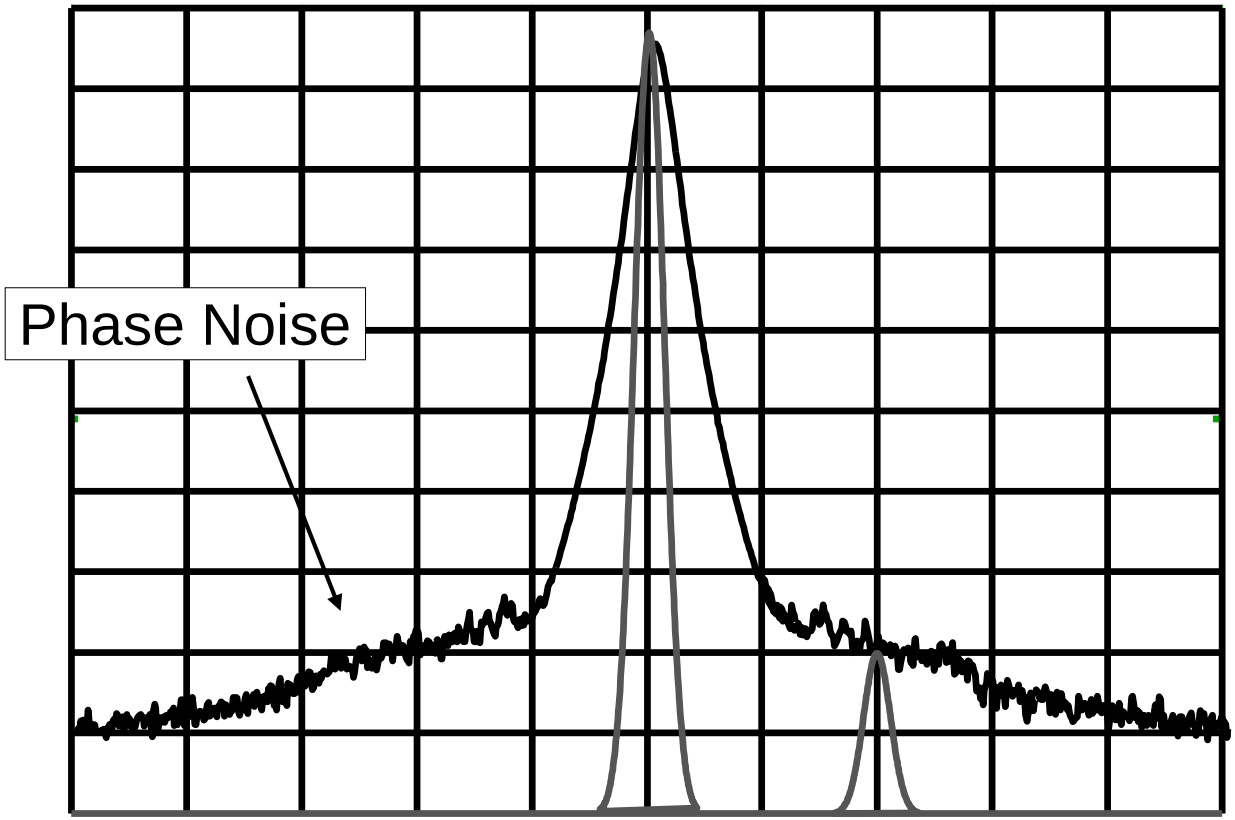
Typical Selectivity

Analog 15:1

Digital ≤5:1

*** The X-series RBW shape factor is 4.1:1**

Specifications
Resolution: Noise Sidebands



Noise Sidebands can prevent resolution of unequal signals

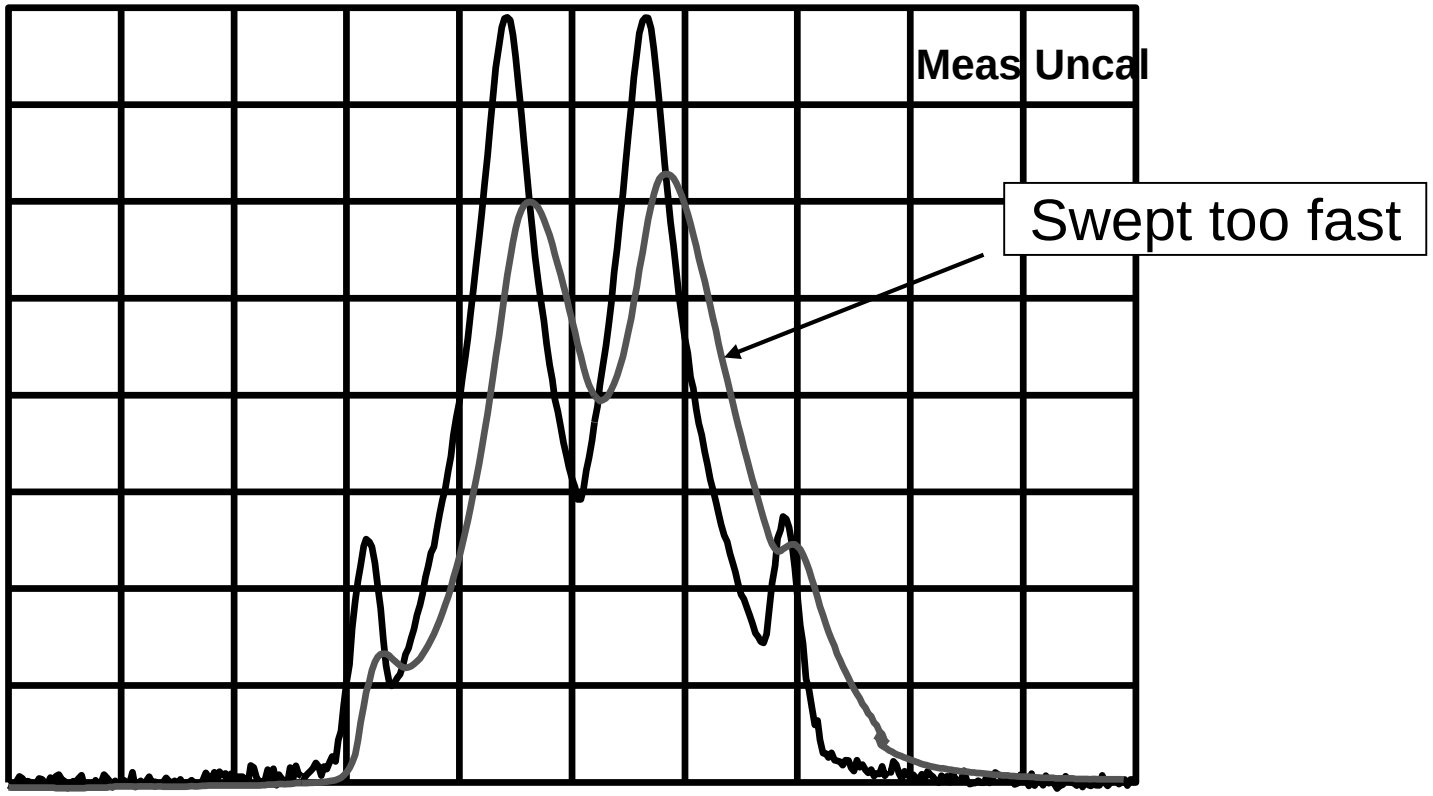
Question:

What is the minimum phase noise specification required to measure a signal 50 dB down from a 1 GHz carrier at a 10 kHz offset in a 1 kHz RBW?

Answer:

50 dBc in a 1 kHz RBW can be normalized to a 1 Hz RBW using the following equation. (-50 dBc - [10*log(1kHz/1Hz)]) = (-50 - [30]) = **-80 dBc/Hz**

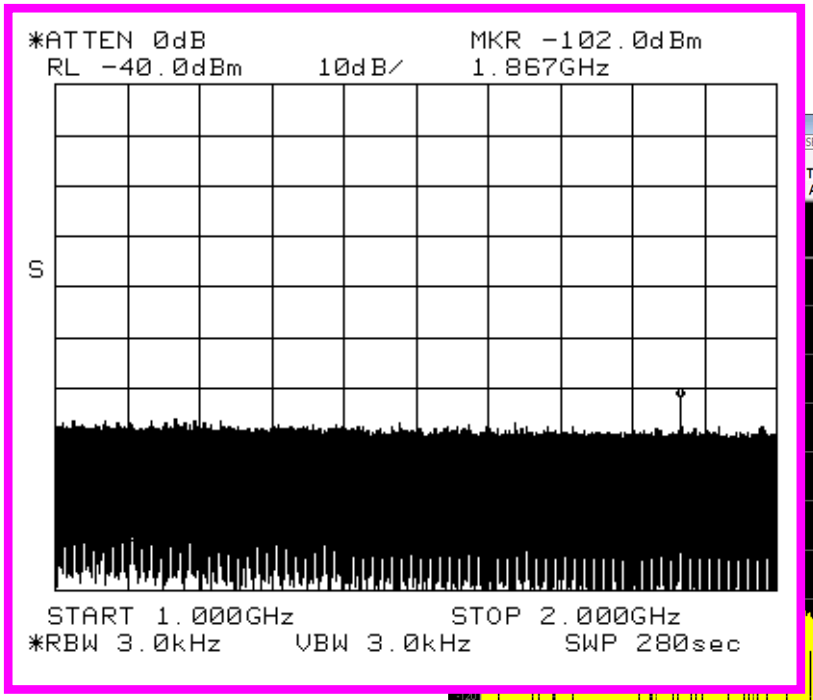
Specifications
Resolution: RBW Determines Sweep Time



Penalty For Sweeping Too Fast
Is An Uncalibrated Display

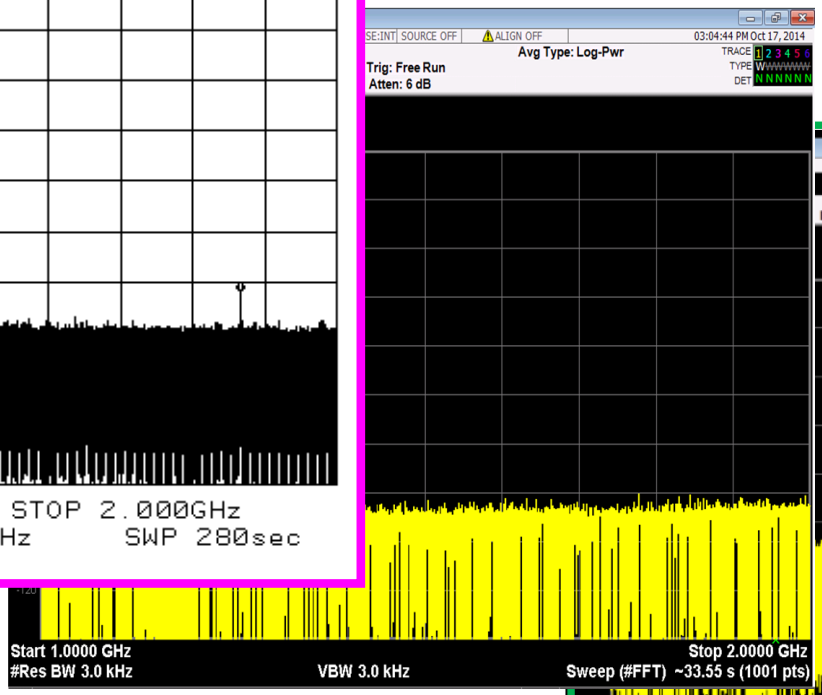
Specifications
Resolution: RBW Type Determines Sweep Time

8563E Analog RBW



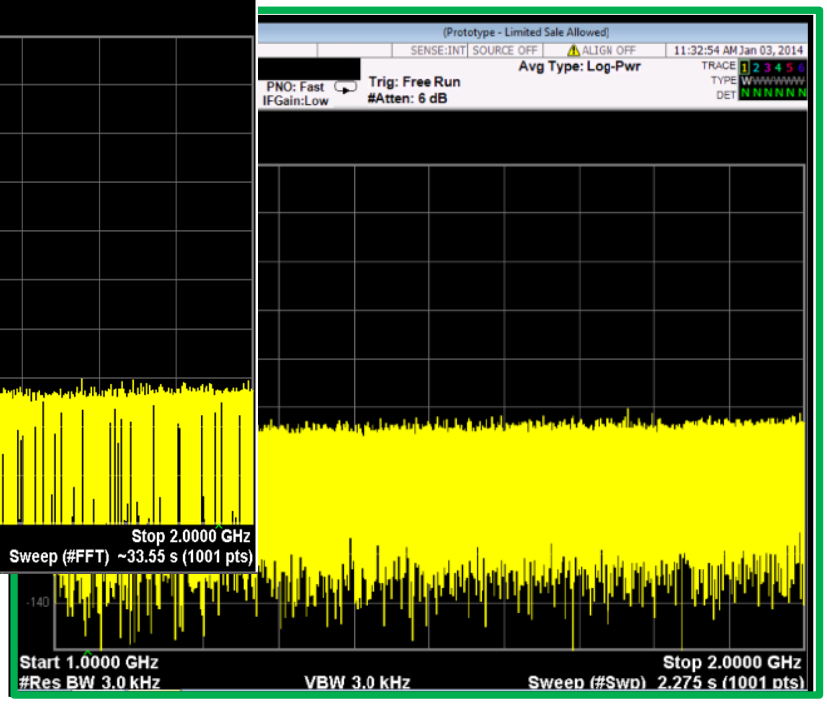
280 sec

MXA FFT RBW



33.55 sec

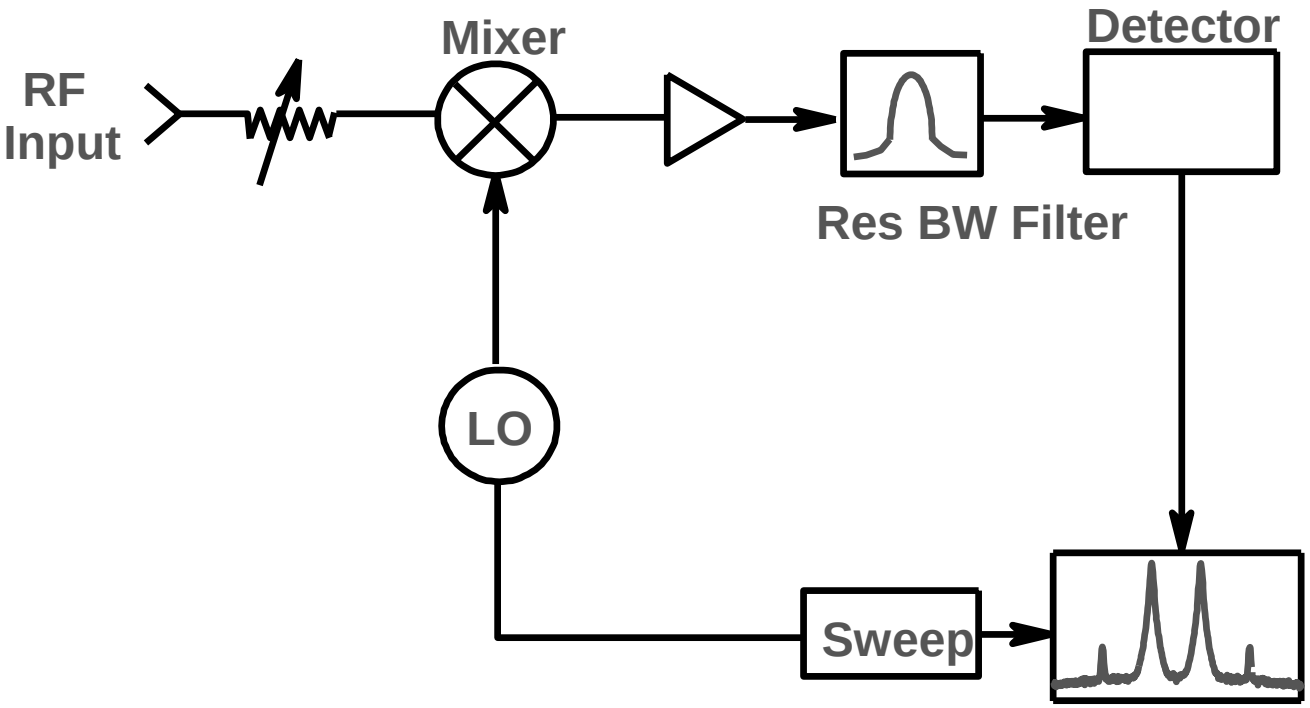
MXA Swept RBW (w/ FS1*)



1.9 sec

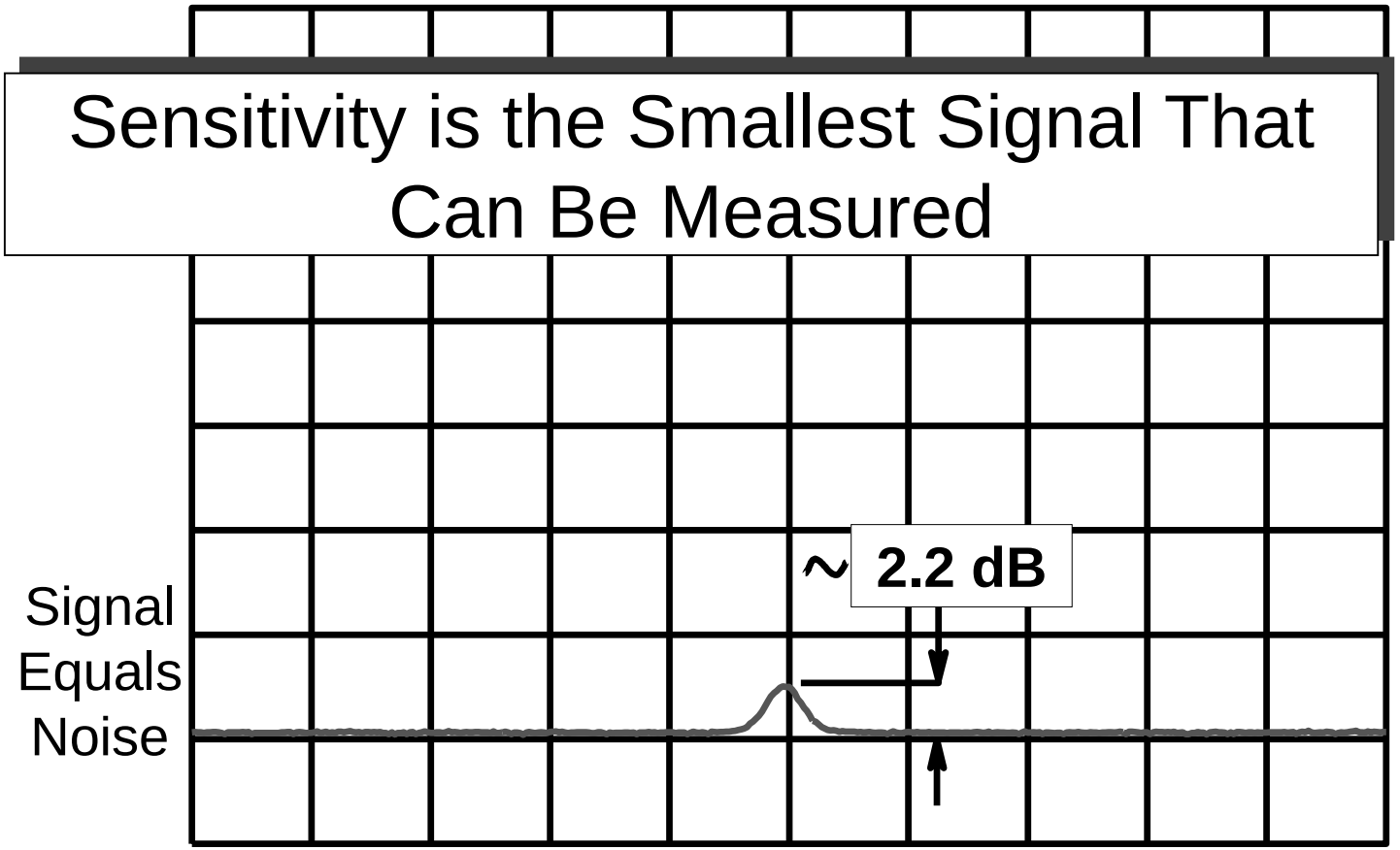
*: FS1 is “fast sweep capability” comes standard for MXA if the MXA has option DP2, MPB, or 40 MHz BW option and wider BW. It improves the sweep speed by ~50x

Specifications
Sensitivity/DANL

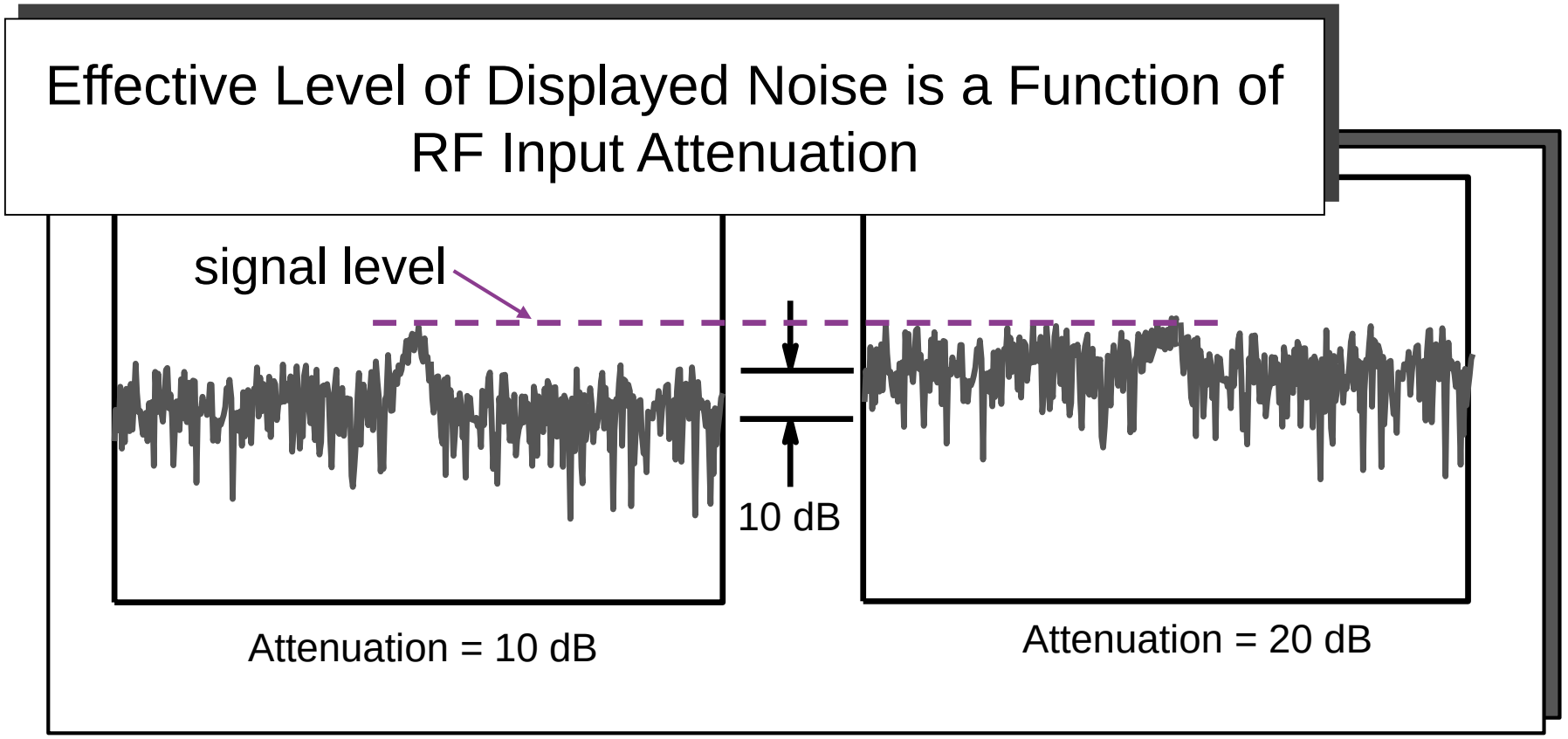


A Spectrum Analyzer Generates and Amplifies Noise Just Like Any Active Circuit

Specifications
Sensitivity/DANL

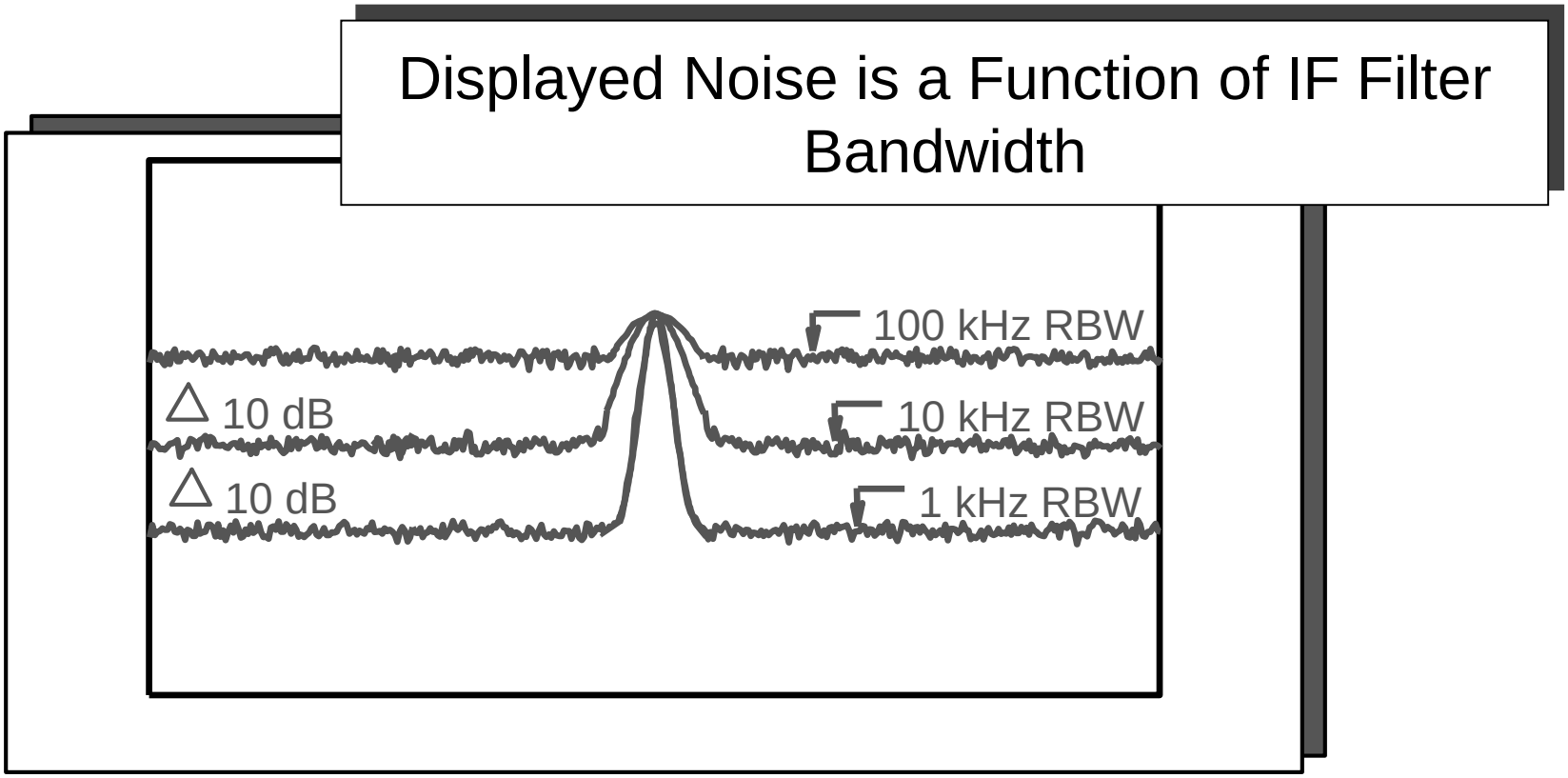


Specifications
Sensitivity/DANL



Signal To Noise Ratio Decreases as
RF Input Attenuation is Increased

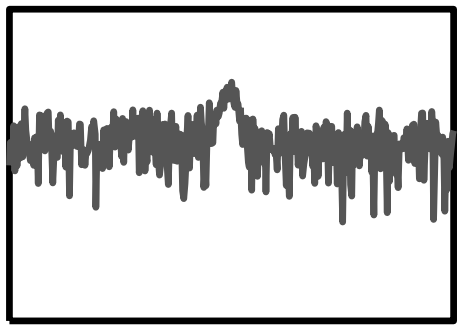
Specifications
Sensitivity/DANL: IF Filter(RBW)

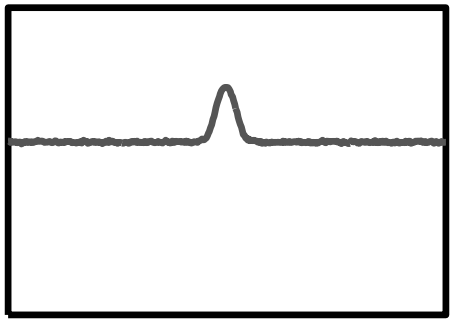


Decreased BW = Decreased Noise

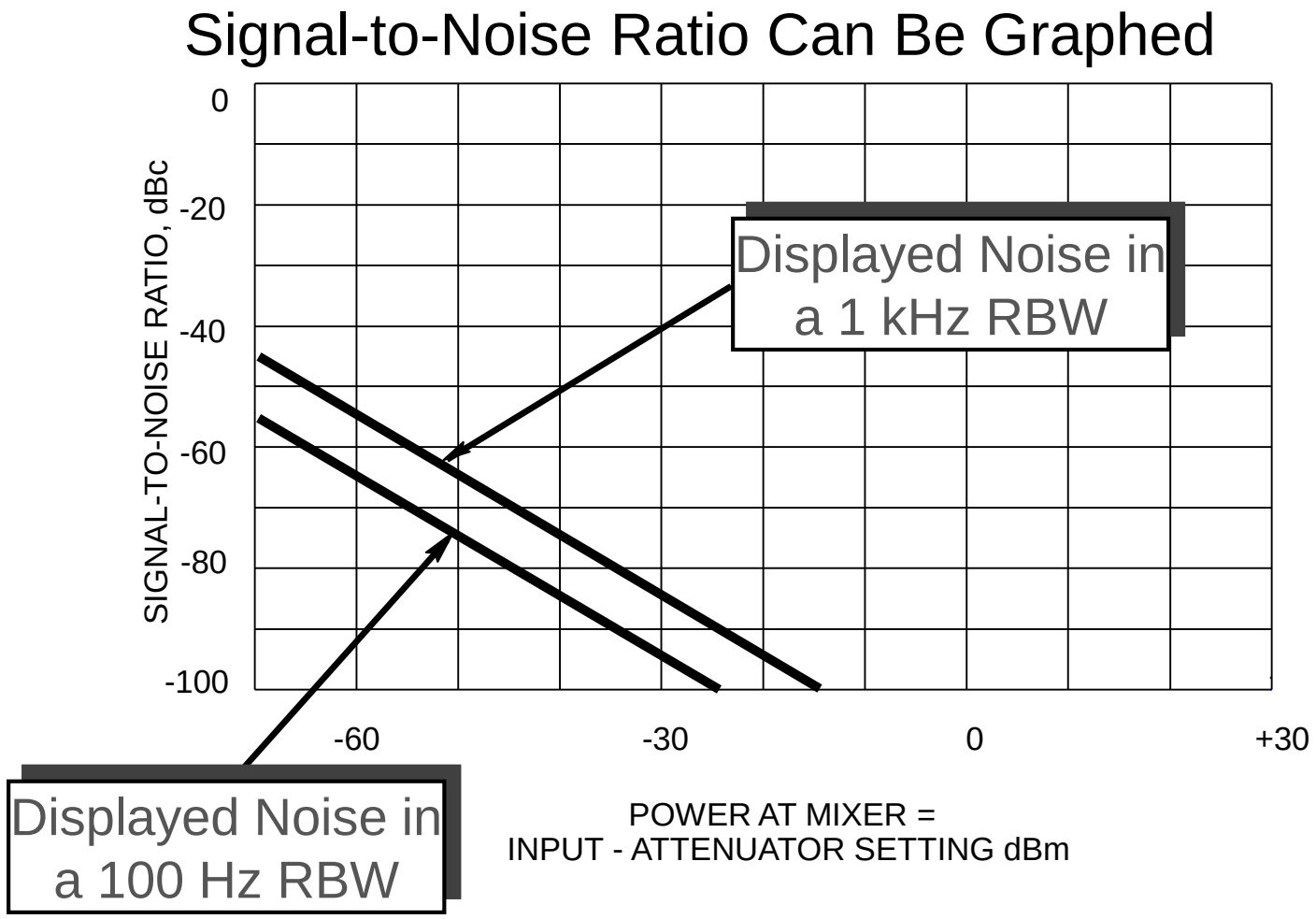
Specifications
Sensitivity/DANL: Video BW filter (or Trace Averaging)

Video BW or Trace Averaging Smoothes Noise for Easier Identification of Low Level Signals

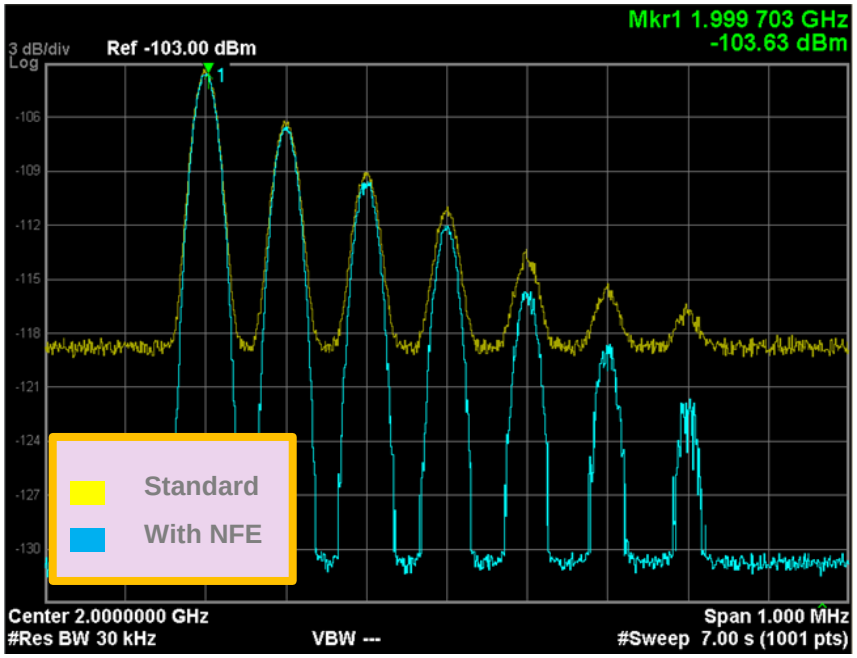


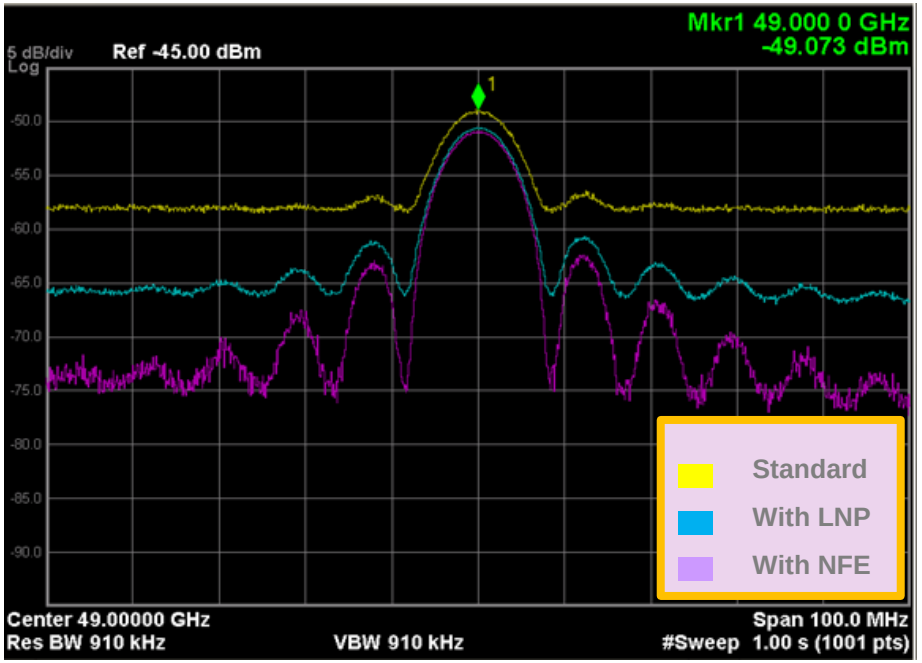


Specifications
Sensitivity/DANL:



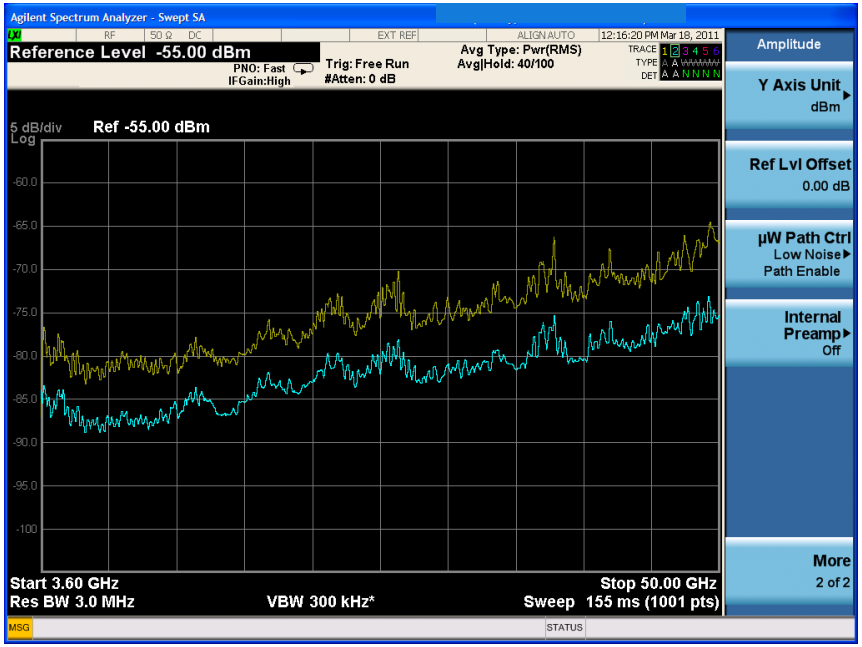
Standard feature that improves DANL for the PXA & UXA
Noise Floor Extension (optional on MXA and EXA)

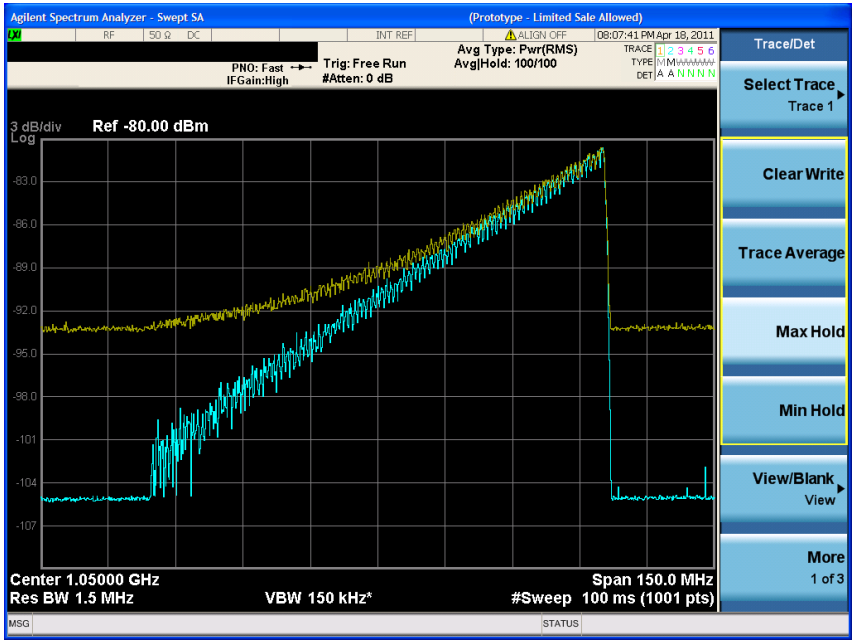




- The PXA and the UXA combines real-time measurement processing with an unprecedented characterization of the analyzer's own noise to allow that noise to be accurately removed from measurements.
- The improvement from *noise floor extension* varies from RF to millimeter wave. At RF, from about 3.5 dB for CW and pulsed signals to approximately 8 dB for noise-like signals, and up to 12 dB or more in some applications.
- DANL at 2 GHz is –161 dBm without a preamp and –172 dBm with the preamp.

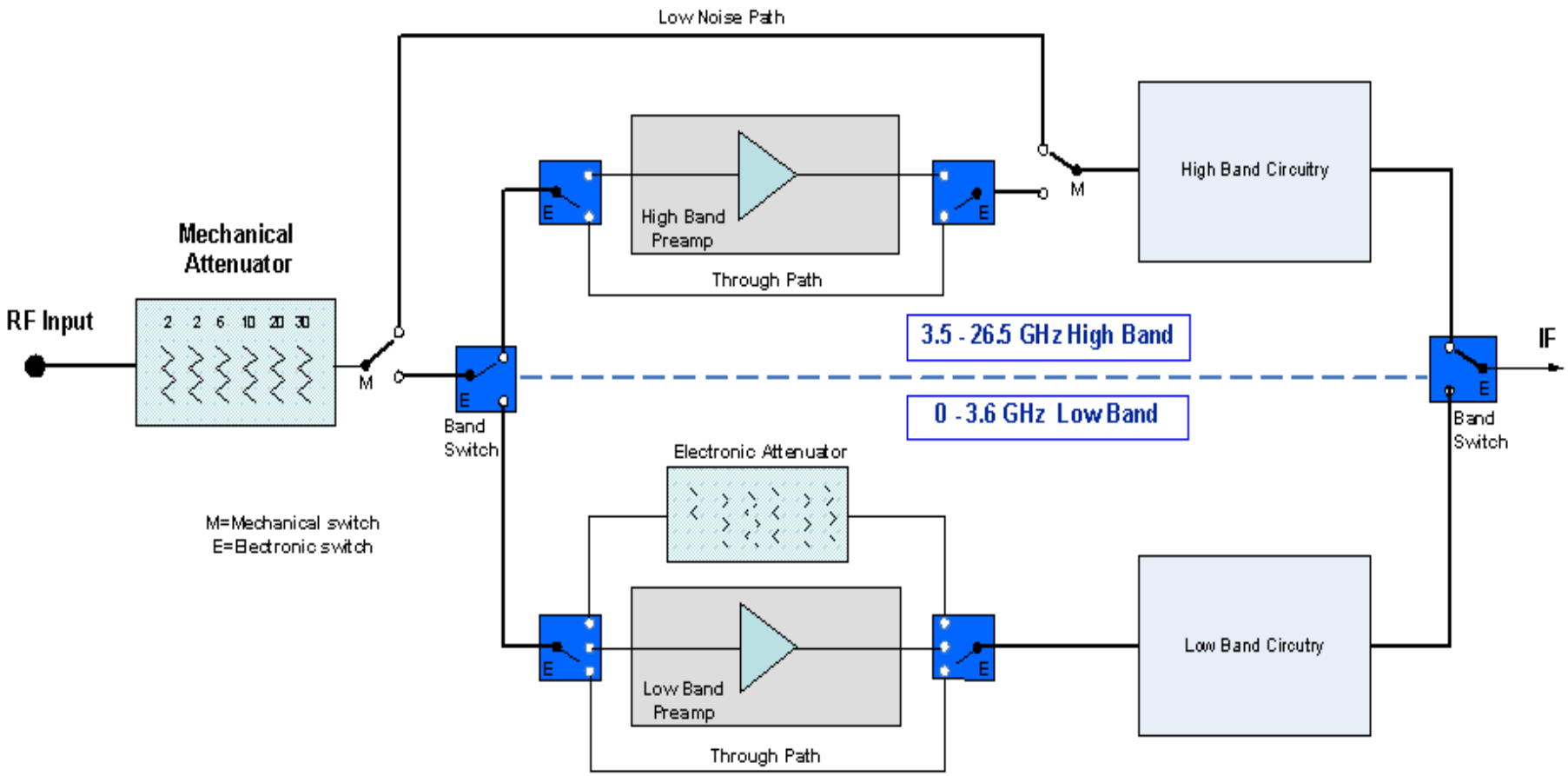
Hardware Option that improves DANL for the PXA & UXA Low Noise Path





- At microwave frequencies any sort of signal routing or switching results in signal path loss.
- Preamplifiers can compensate for this loss and improve signal/noise for small signals, but they can cause distortion in the presence of larger signals
- LNP allows the “lossy” elements normally found in the RF input chain to be completely bypassed for highest sensitivity without a preamplifier
- LNP allows measurements of small spurs w/o speed penalty imposed by narrow RBW that would otherwise be needed for adequate noise level

Low Noise Path Block Diagram (LNP)



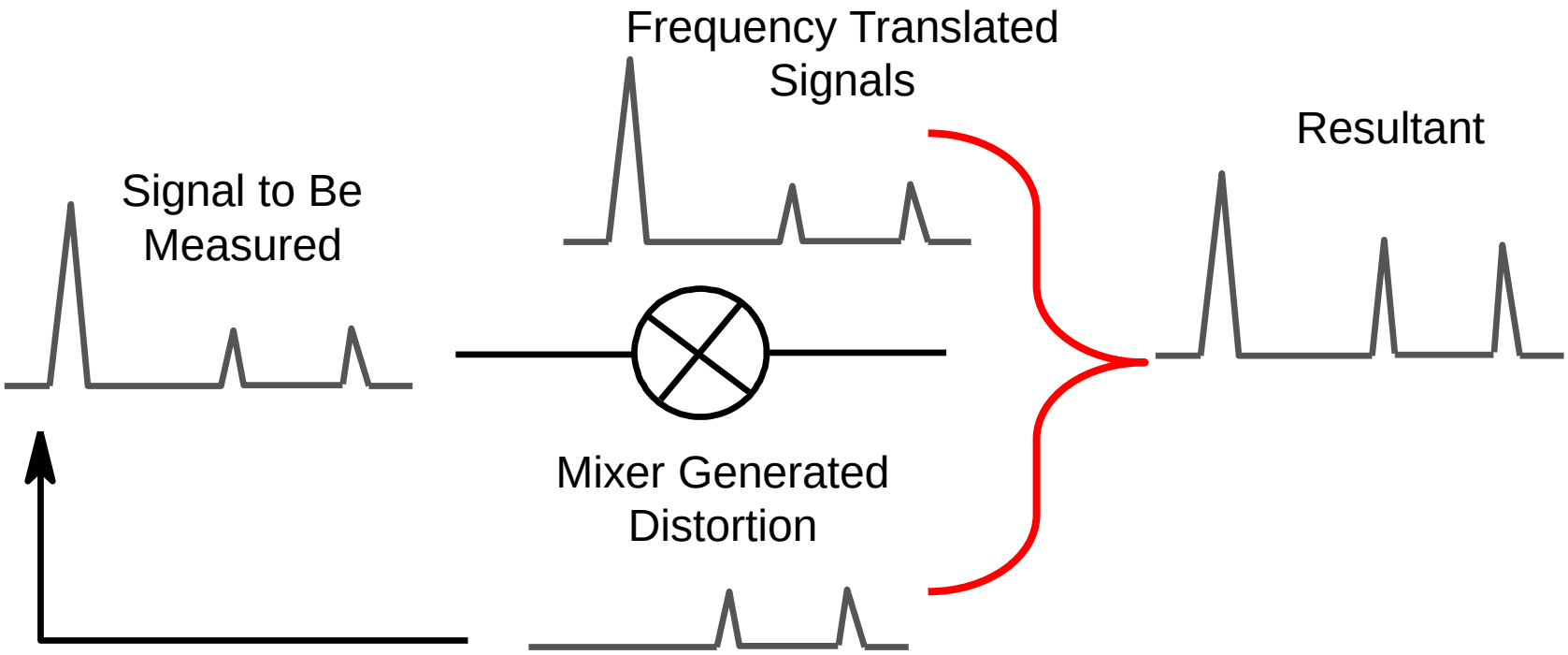
Specifications
Sensitivity/DANL: Summary

For Best Sensitivity Use:

- Narrowest Resolution BW
- Minimum RF Input Attenuation
- Sufficient Averaging (video or trace)
- Using the Preamp also improves sensitivity
- Low Noise Path (PXA/UXA only)
- Noise Floor Extension (UXA, PXA, MXA, EXA)

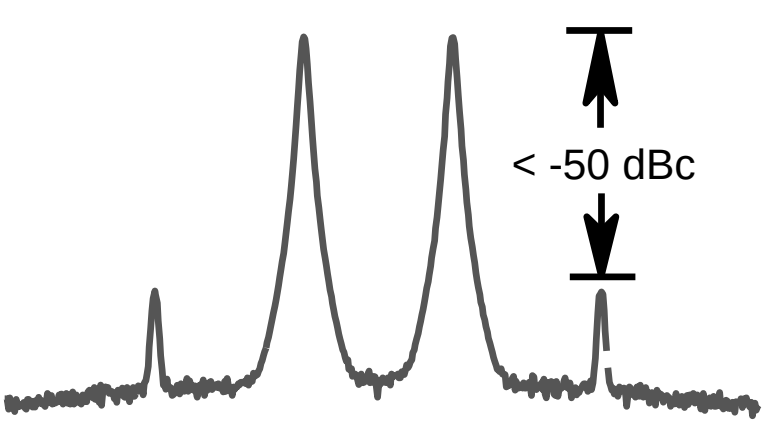
Specifications
Distortion

Mixers Generate Distortion

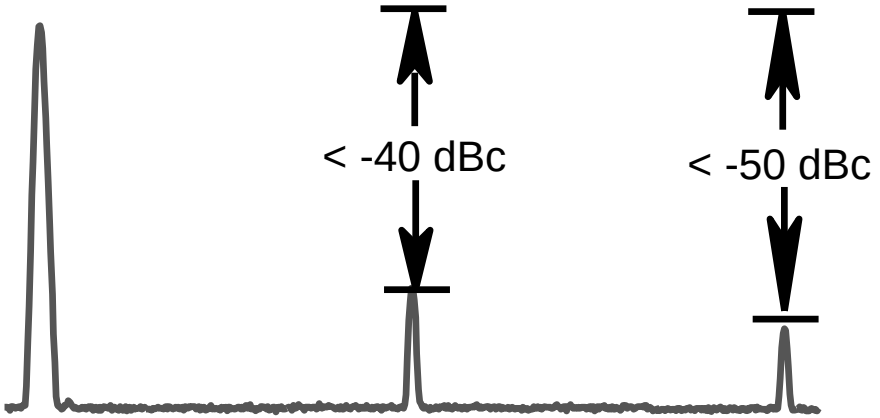


Specifications
Distortion

Most Influential Distortion is the Second and Third Order



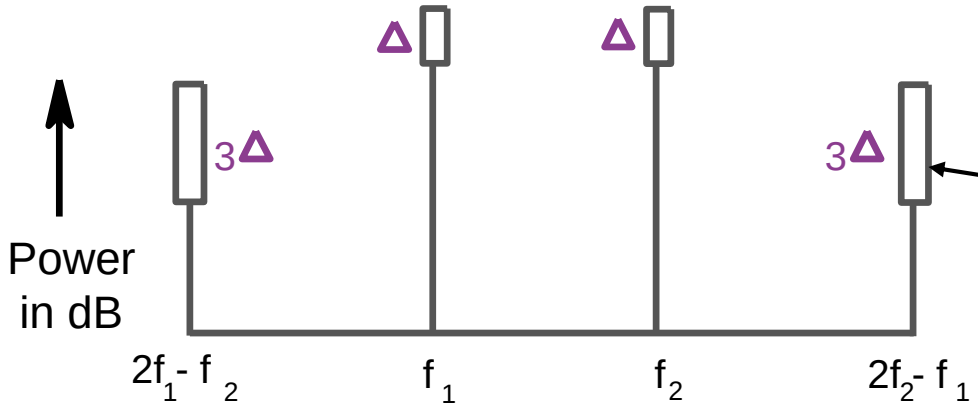
Two-Tone Intermod



Harmonic Distortion

Specifications
Distortion

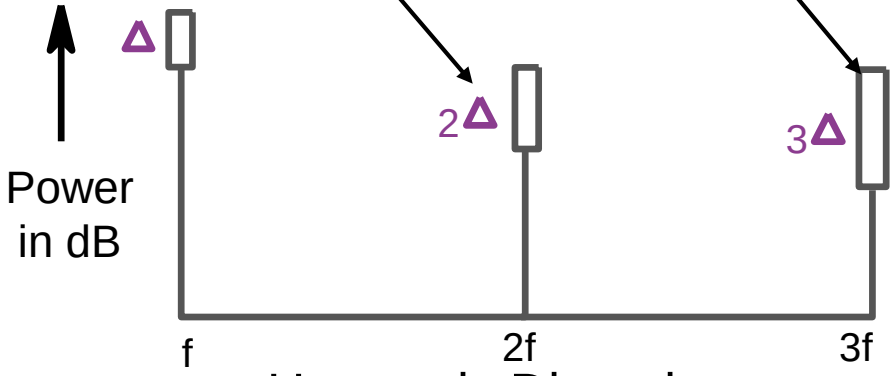
Distortion Products Increase as a Function of Fundamental's Power



Two-Tone Intermod

Third-order distortion

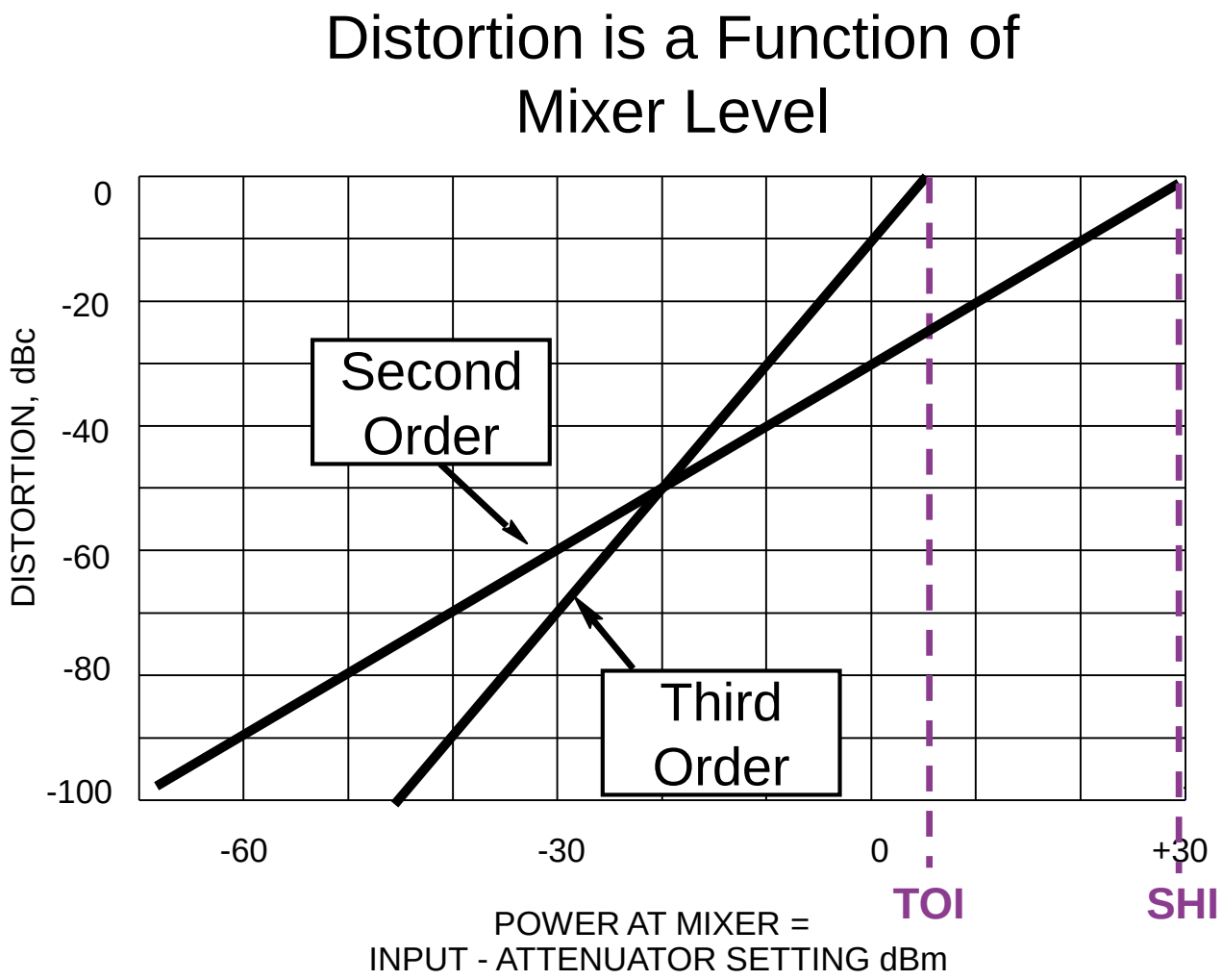
Second-order distortion



Harmonic Distortion

Third Order: Δ3 dB/dB of Fundamental
Second Order: Δ2 dB/dB of Fundamental

Specifications
Distortion



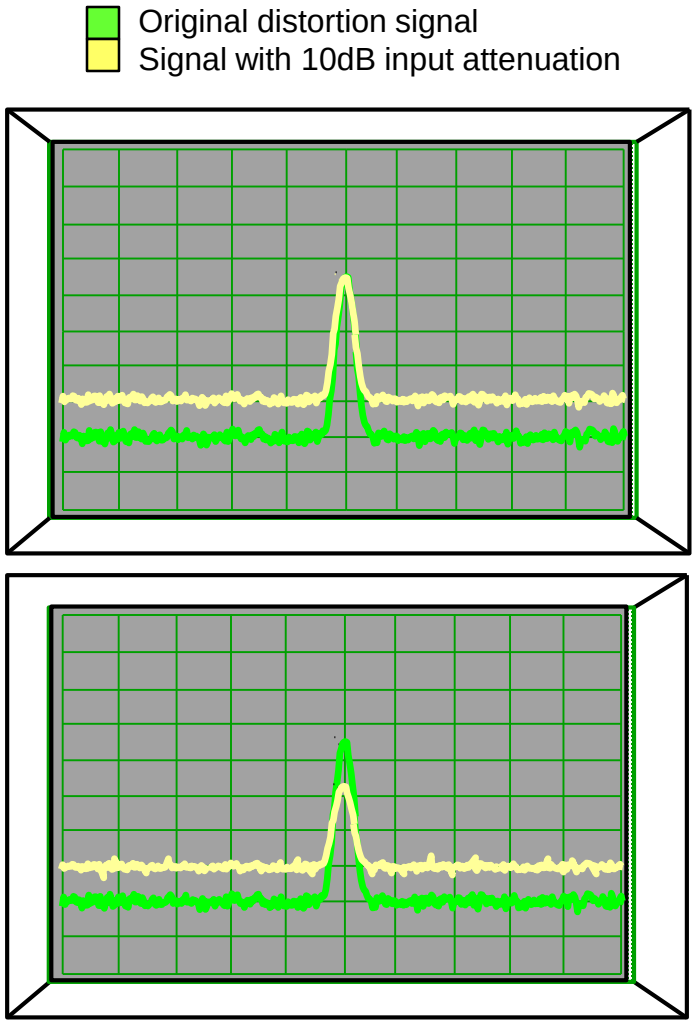
Specifications
Distortion – Internal or External?

Attenuator Test:
Change power to the mixer

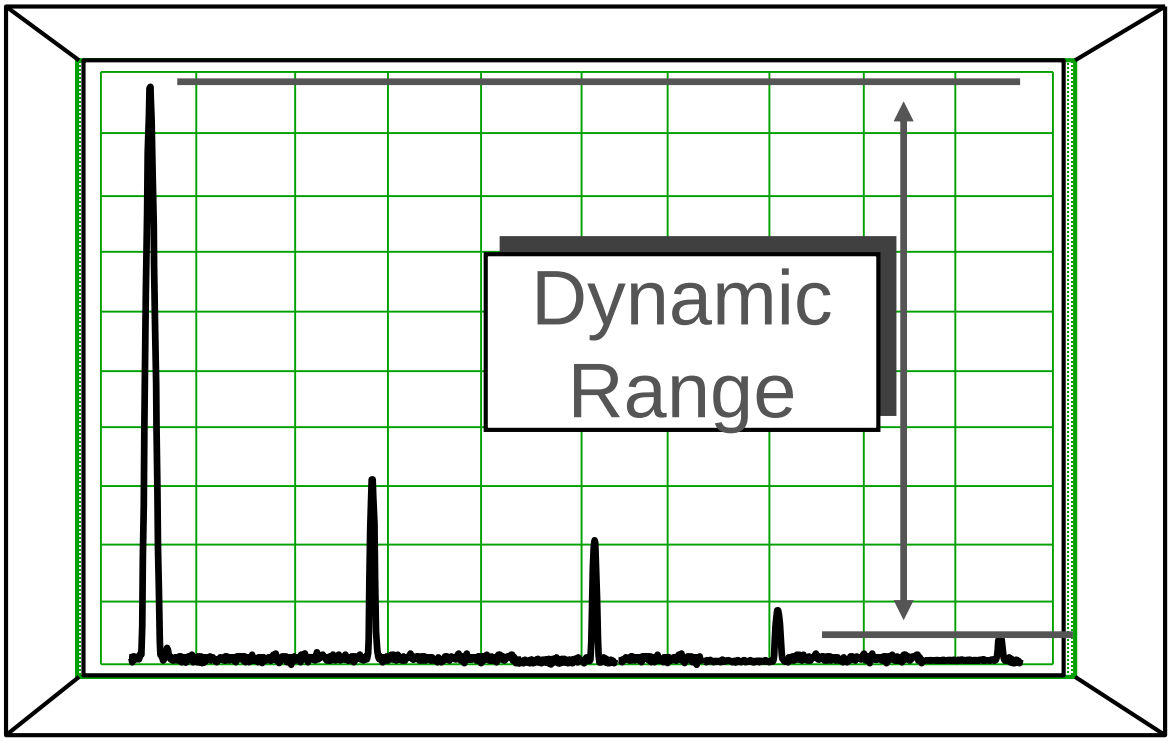
1. Change input attenuator by 10 dB
2. Watch distortion amplitude on screen

No change in amplitude:
distortion is part of input signal (external)

Change in amplitude:
at least some of the distortion is being generated inside the analyzer (internal)



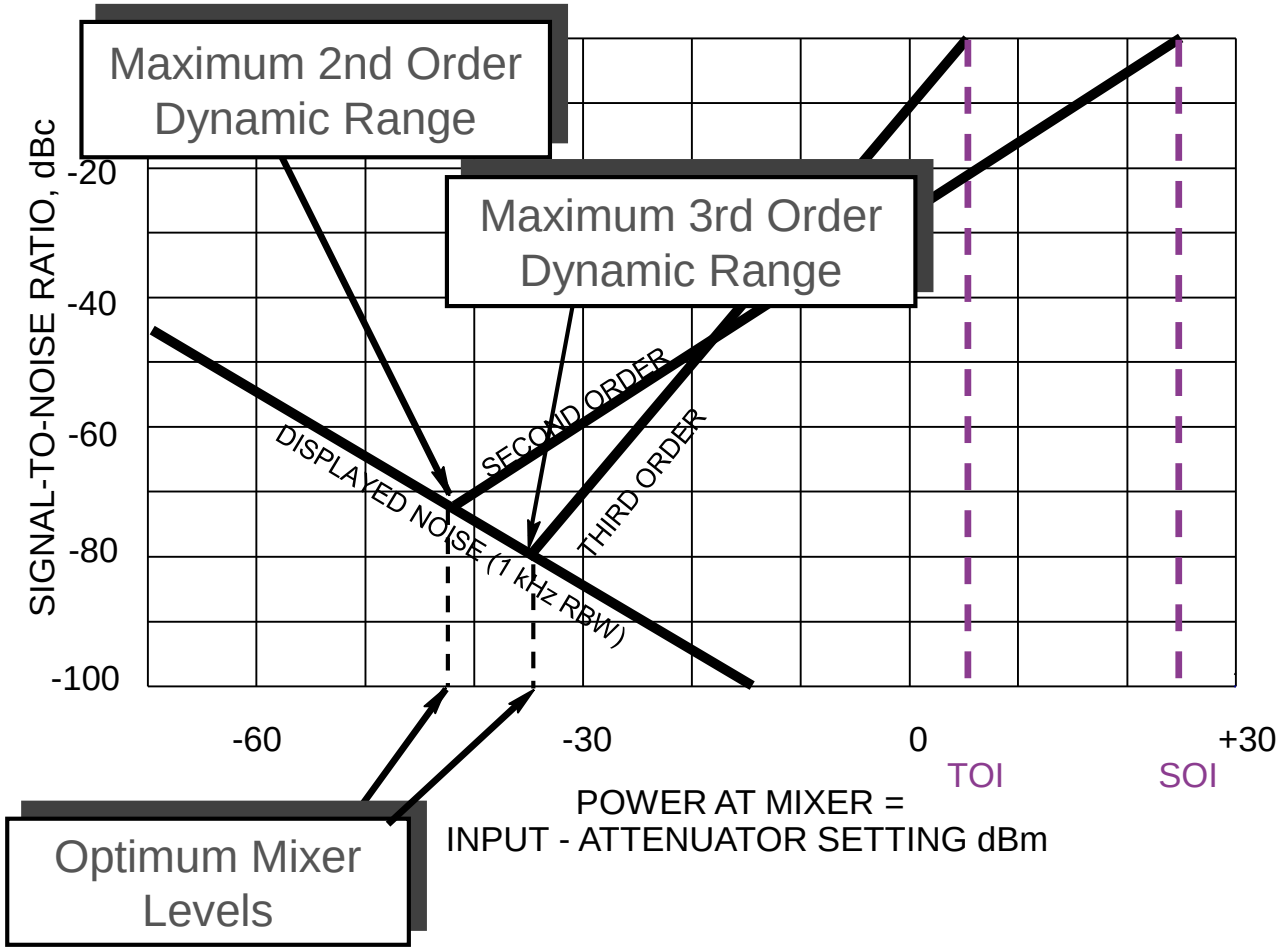
Specifications
Spectrum Analyzer Dynamic Range



The ratio, expressed in dB, of the largest to the smallest signals simultaneously present at the input of the spectrum analyzer that allows measurement of the smaller signal to a given degree of uncertainty.

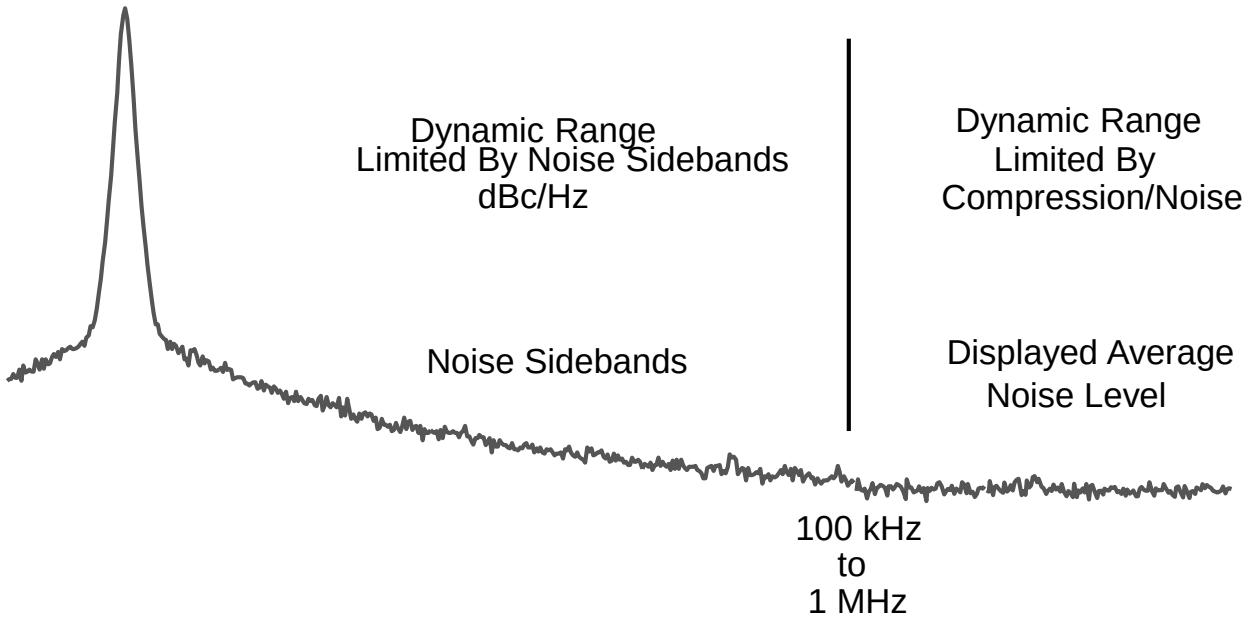
Specifications
Dynamic Range

Dynamic Range Can Be Presented Graphically



Specifications
Dynamic Range

Dynamic Range for Spur Search Depends on Closeness to Carrier



Specifications
Dynamic Range – Distortion, Noise Floor, LO phase noise

Dynamic Range is actually:

Maximum dynamic range calculation

Calculated from distortion products and sensitivity/DANL

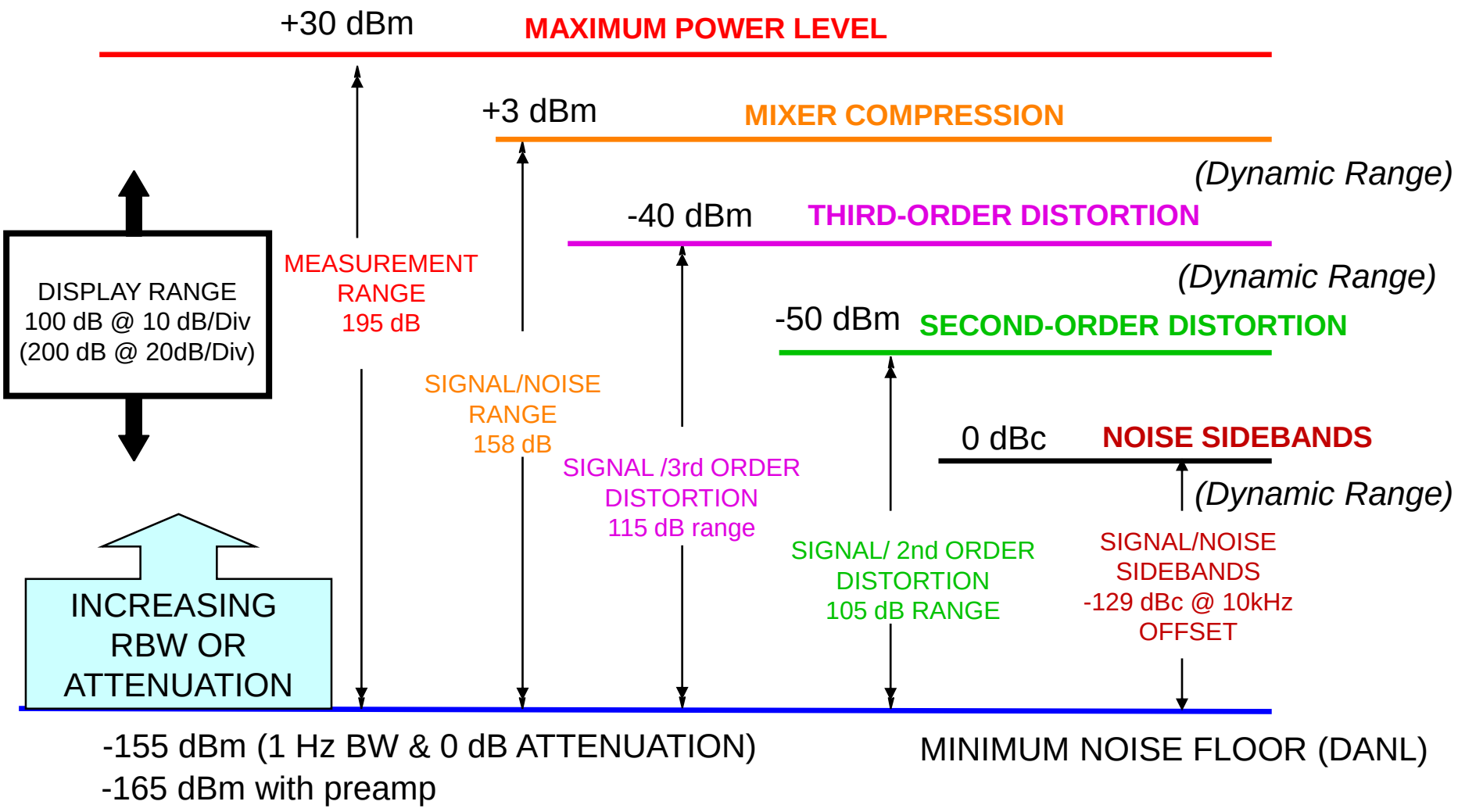
bounded by

-dBc/Hz Phase Noise sidebands @ close-in offset frequencies

Determined by the phase noise specifications of the SA

Specifications

Dynamic Range vs. Measurement Range



Specifications
Summary: Optimizing Dynamic Range

- What settings provide the best sensitivity?
  - Narrowest resolution bandwidth
  - Minimal input attenuation
  - Sufficient averaging

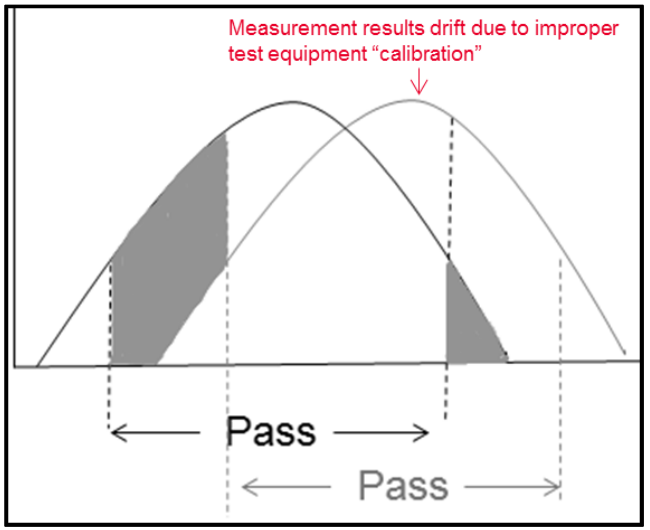
- How do you test for analyzer distortion?
  - Increase the input attenuation and look for signal amplitude changes
  - Then set the attenuator at the lowest setting without amplitude change

- What determines dynamic range?
  - Analyzer distortion, noise level, and sideband/phase noise

How do you maintain your signal analyzer's measurement integrity over time?

Why test equipment calibration matters

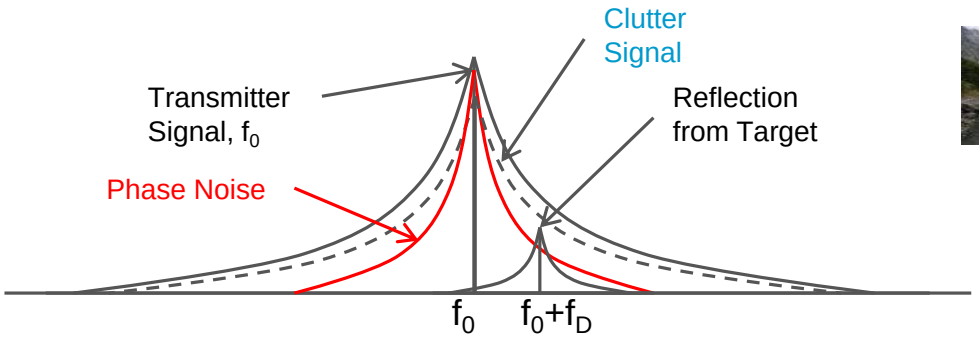
- As the components in the electronic test equipment age, its performance could drift.
- Sometimes test equipment could be in need of adjustment or even repair, possibly impacting the reliability of your measurement.

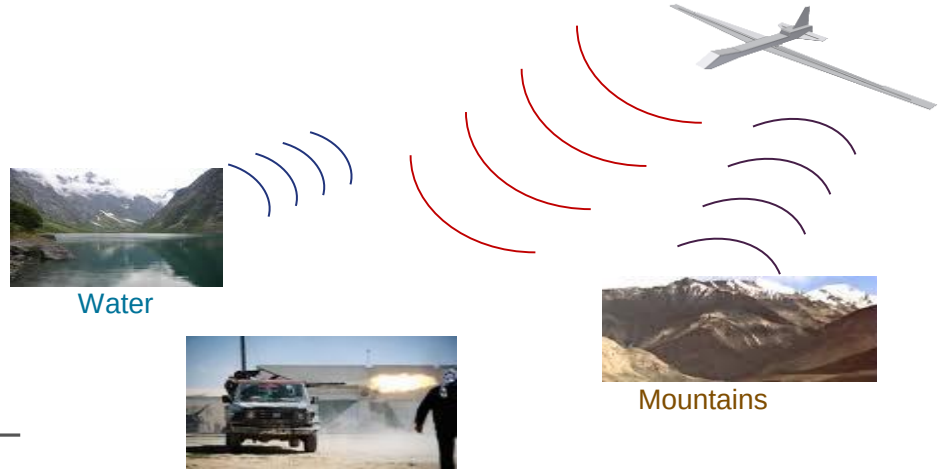


Periodic performance verification of the equipment can help catch any failures or failure trend in early stages and reduce your operational risk.

Keysight's One-Stop Calibration Services, for your Keysight and non-Keysight electronic instruments, as well as physical, dimensional and optical instruments, is designed to ensure you can rely on your test equipment's measurement integrity over time.

Example on Importance of Phase Noise Accuracy: Doppler Radar





Radar systems detect target velocity(speed and direction) by measuring Doppler shift in frequency

- ❑ Slow-moving targets exhibit very small frequency shift
- ❑ Return pulses are very low in amplitude & masked by clutter

CW Frequency = 1.00 GHz

Phase Noise Offset (kHz)	Measured Phase Noise (dBc/Hz)	Measurement Uncertainty (+/- dB)	Specification (dBc/Hz)	Result
0.10	-105	0.68	-107.00	FAIL
0.99	-129.85	0.35	-125.00	PASS
10.00	-138.20	0.35	-134.00	PASS
100.00	-142.89	0.61	-139.00	PASS
1,000.00	-148.50	0.61	-145.00	PASS
9,900.00	-156.31	0.61	-155.00	PASS

Excerpt from UXA signal analyzer calibration report

Choose the standard of test equipment calibration suitable for your measurement needs

Standards Compliance

Deliverables	Keysight Calibration	Keysight Cal + Uncertainties	Keysight Cal + Uncertainties + Guardbanding[3]	Accredited Calibration	Standards Lab Calibration
ANSI Z540.3-2006			✓		
ISO 17025:2005		✓	✓	✓	✓
ANSI Z540.1-1994		✓	✓		
ISO 9001:2015	✓	✓	✓	✓	✓

Europe / Middle East / Africa / India Calibration Service Selection Guide

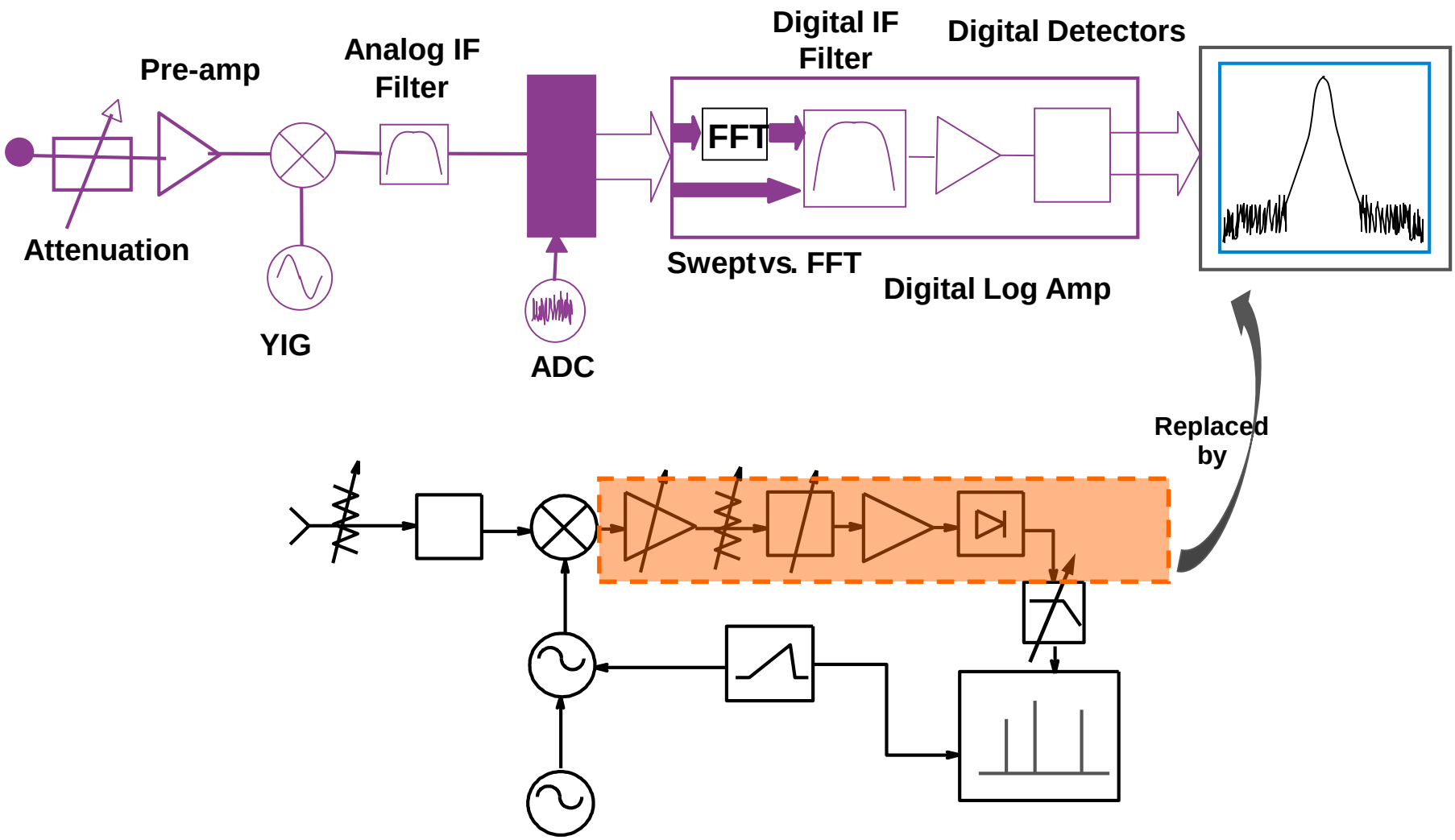
Deliverables	Keysight Calibration	Keysight Cal + Uncertainties	Keysight Cal + Uncertainties + Guardbanding[3]	Accredited Calibration	Standards Lab Calibration
Primary lab standards[1]					✓
Locally accredited				✓	✓
Measurement guardband			✓	✓	✓
Measurement uncertainties		✓	✓	✓	✓
Adjustments	✓	✓	✓	✓	✓
As received data report	✓	✓	✓	✓	✓
As completed data report[2]	✓	✓	✓	✓	✓
Calibration certificate	✓	✓	✓	✓	✓
Sample calibration certificates	PDF	PDF	PDF	PDF	PDF

1. Primary lab standards, such as a Josephson junction, used for lowest measurement uncertainty comparable to a National Measurement Institute.
2. Provided when adjustment(s) are made.
3. Guardbanding is not available / provided when the device has no associated specification, for example when characterizing power sensors for cal factor.

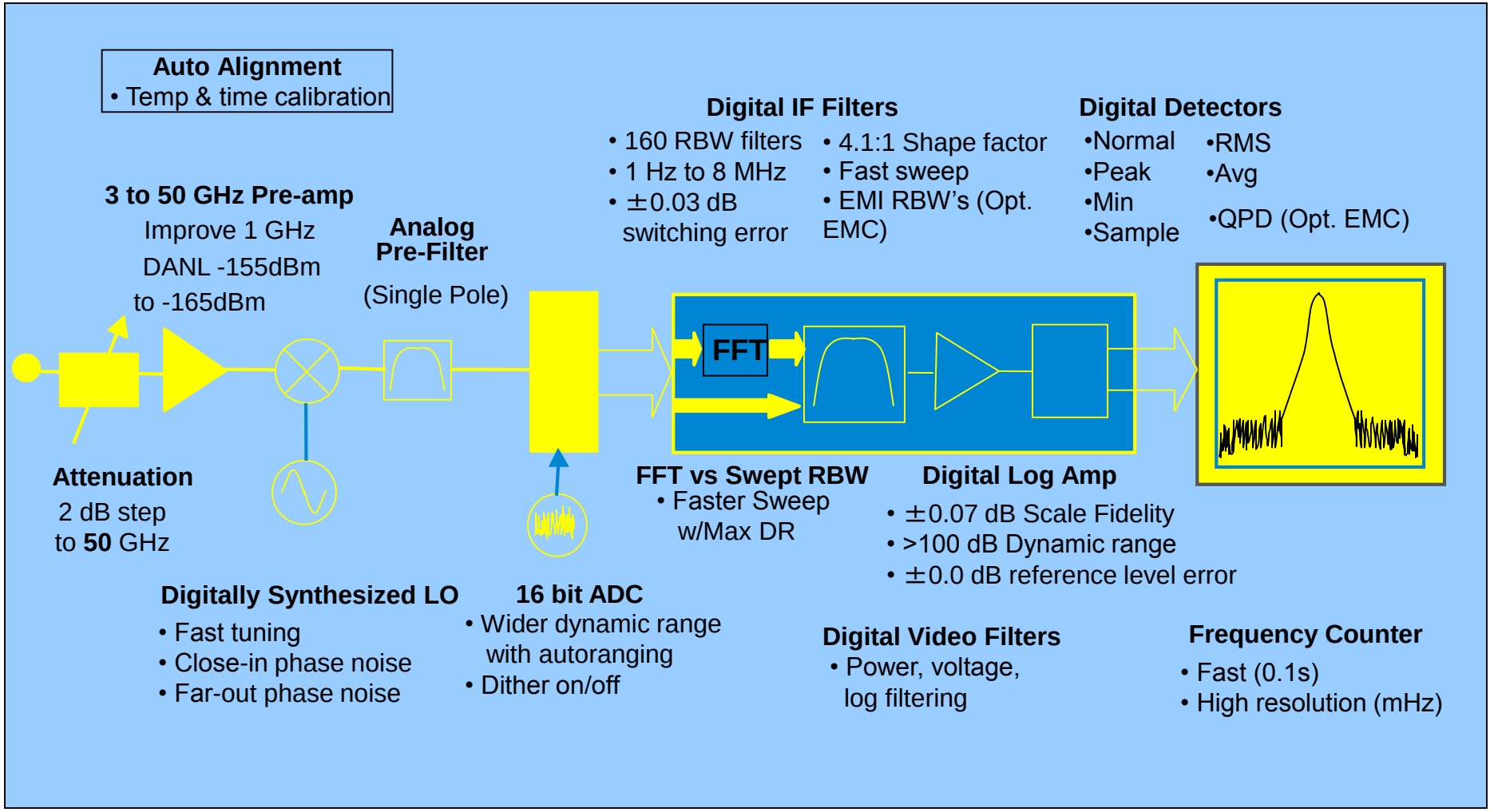
Agenda

- Introduction
- Overview**:**
  - What is Spectrum and Signal Analysis?
  - What Measurements are available?
- Theory of Operation
- Specifications
- **Modern Signal Analyzer Designs & Capabilities**
  - **Real Time Spectrum Analysis**
  - **Millimeter Wave Measurements**
  - **Wide Bandwidth Vector Measurements**
- Wrap-up

Modern Spectrum Analyzer Block Diagram



Modern Spectrum Analyzer Block Diagram



Modern Spectrum Analyzer - Specifications
Digital IF provides improved accuracy

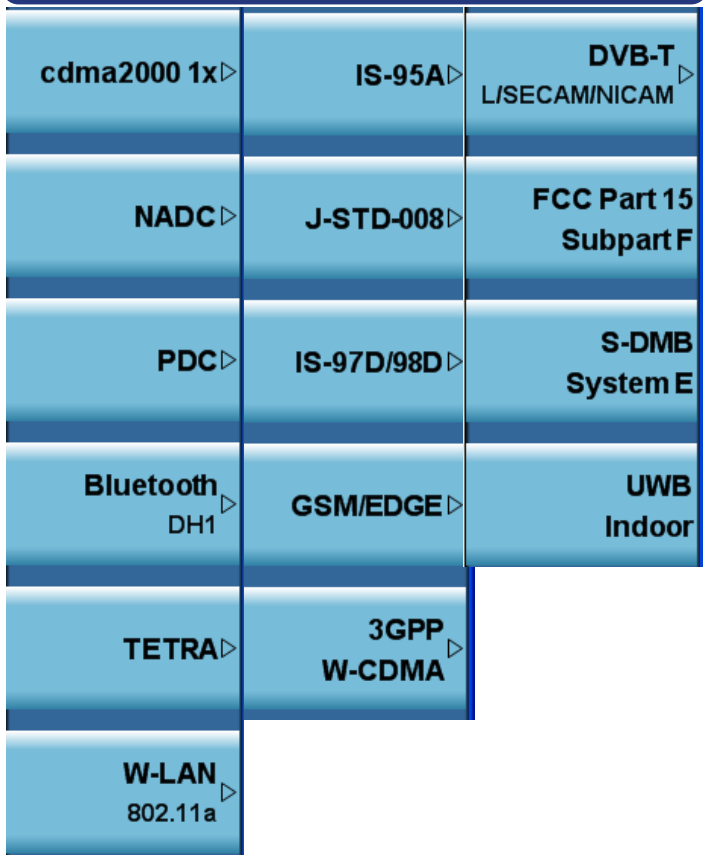
Parameter	PXA		Traditional
• Input impedance mismatch	±0.13	.v.	±0.29 dB
• Input attenuator switching uncertainty	±0.14	.v.	±0.6 dB
• Frequency response	±0.35	.v.	±1.8 dB
• Reference level accuracy	±0.0	.v.	±1.8 dB
• RBW switching uncertainty	±0.03	.v.	±0.5 dB
• Display scale fidelity	±0.07	.v.	±0.85 dB
• Calibrator accuracy	±0.24	.v.	±0.34 dB
Total accuracy (up to 3 GHz)	±0.59 dB	.v.	±1.8 dB
95% Confidence	±0.19 dB		

Modern Spectrum Analyzer Features
Built-in One-Button Power Measurements

Power Measurements:

- Occupied Bandwidth
- Channel Power
- ACP
- Multi-carrier ACP
- CCDF
- Harmonic Distortion
- Burst Power
- TOI
- Spurious Emissions
- Spectral Emissions Mask

Format Setups include:



Modern Spectrum Analyzer Features

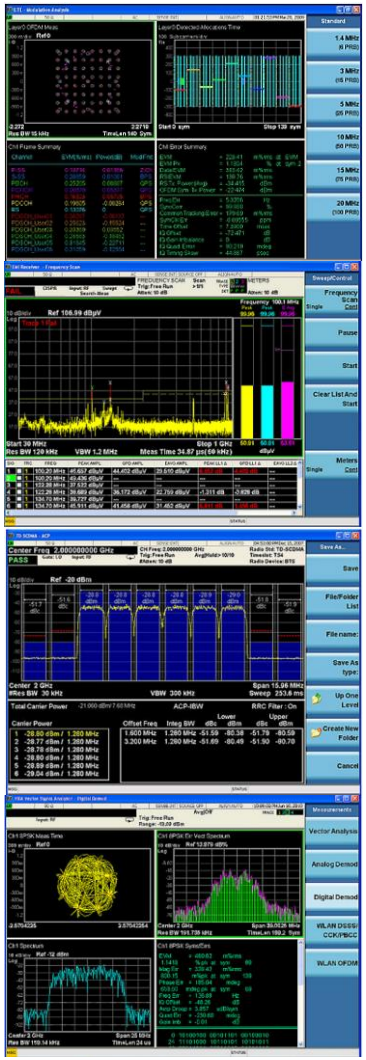
Application Focused Internal Software (one-button measurements)

General purpose applications

Flexible digital modulation analysis

Power & digital modulation measurements for wireless comms formats

Phase noise	ACPR, Multi-carrier Power
Ext. source control	Occupied Bandwidth (OBW)
Noise figure	Spectral Emissions Mask
Code compatibility suite	Phase and Freq. (PFER)
EMI pre-compliance	Mod Accuracy (Rho)
Analog demod	Code Domain Power
Flexible demod	ORFS (GSM/EDGE)
LTE FDD, TDD	Spurious Emissions
W-CDMA/HSPA/HSPA+	Power vs Time
GSM/EDGE/EDGE Evo	Channel power
cdma2000 & 1xEV-DO	IM distortion
cdmaOne	CCDF
DVB-T/H/C/T2	ACPR
TD-SCDMA/HSPA	EVM
WLAN (802.11a/b/g/p/j)	SEM
802.16 OFDMA	
Bluetooth	



X-Series Measurement Applications

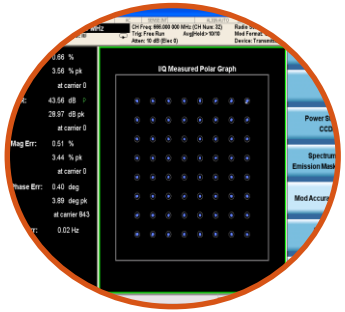
… unravel more signals with the industry's broadest set of applications and demodulation capabilities

Broad application coverage

…over 25 measurement apps

UXA/PXA/MXA/EXA/CXA shares common algorithms, programming commands and applications library:

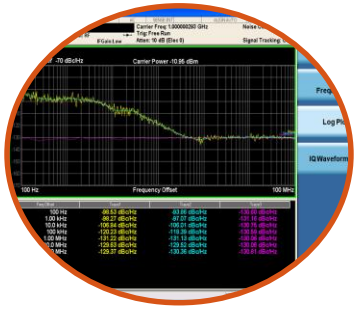
- General purpose
- Cellular communications
- Wireless connectivity
- Digital video



Fast, easy-to-use

… one-button embedded apps

- One-button test with standard based pass/fail limit
- Hardkey/softkey manual user interface
- Ready for automation with SCPI programming
- Built-in context sensitive help



Flexible licensing

…choice of fixed or transportable

- Fixed license – application fixed to a specific instrument
- Transportable license* - share applications between UXA,PXA,MXA and EXA
- License pre-installed with initial HW purchase or purchased as a stand-alone upgrade item
- 30-day free trial license!

…plus run 89600 VSA and MATLAB inside X-Series Analyzers!

89600B Vector Signal Analysis Software

Premier frequency, time & modulation analysis for Wireless R&D

Over 75 signal standards and modulation types, including

– Cellular communications:
LTE- Advanced, LTE, W-CDMA HSPA+, GSM/EDGE Evolution, cdma2000®, TD-SCDMA

– Wireless connectivity:
WLAN 802.11ac, 802.11n, 802.11a/b/g, WiMAX™, *Bluetooth*®, ZigBee, RFID

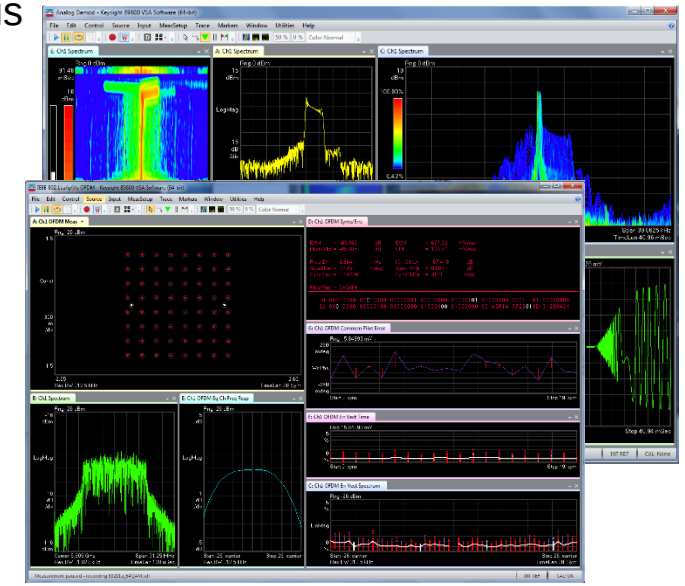
– Aerospace, defense and satellite:
AM, FM, PM, BPSK, QPSK, QAM, APSK, FSK, VSB, SOQPSK, APCO 25

– Custom modulation:
Evaluate your non-standard or proprietary OFDM and APSK signals

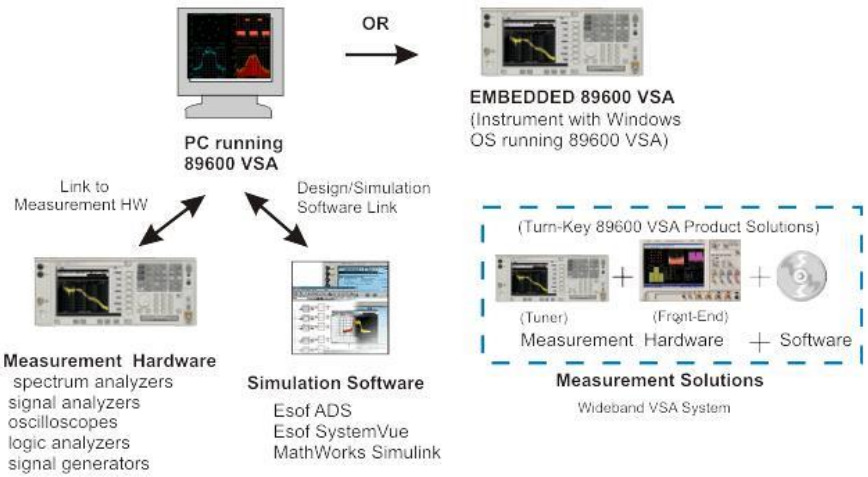
– Also supports up to 8 channels for MIMO and multi-channel

Keysight Vector Signal Analysis Software

- FFT-based spectrum, time-domain & bit-level modulation analysis
- Support for more than 75 signal standards and modulation types
- Unlimited trace/marker capability and arbitrary window arrangement
- Digital persistence and cumulative history displays
- Wireless networking: 802.11a/b/g/n, 802.16 OFDMA, WiMAX, 802.11ac, DOCSIS 3.1
- Cellular: LTE (FDD/TDD), W-CDMA HSPA+, LTE Advanced
- Custom OFDM modulation analysis for proprietary signals



- Links to over 40 hardware platforms including: *X-series signal analyzers, 16800 logic analyzers, 90000 X-series scopes, Infiniium scopes, PXI, N7109A Multi Channel Signal Analyzer*
- Runs on external PC linked to hardware or embedded operation on instruments with Windows



MATLAB with Keysight Signal Generation and Analysis Hardware

Signal Generation Hardware

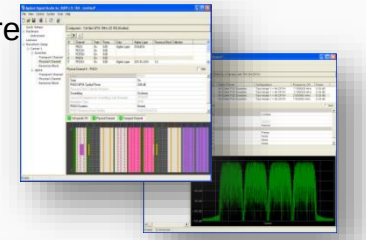
- RF/MW signal generators
- Arbitrary waveform generators

Signal Analysis Hardware

- RF/MW signal analyzers
- Oscilloscopes

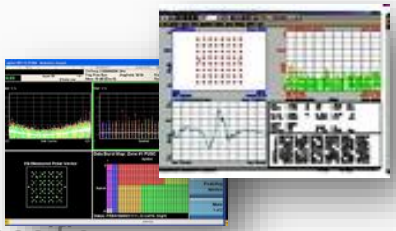
Signal Generation Software

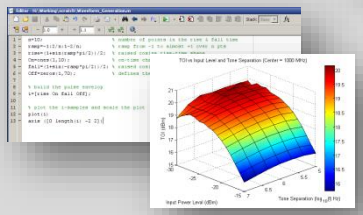
- Embedded software (firmware)
- Signal Studio software
  - Standard-specific
  - Pulse Building, etc.



Signal Analysis Software

- 89601B VSA
- Measurement Apps
  - VXA
  - Standard-/task-specific

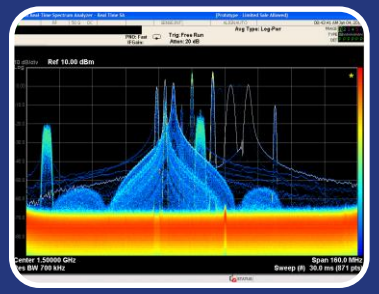




N6171A MATLAB - from Keysight

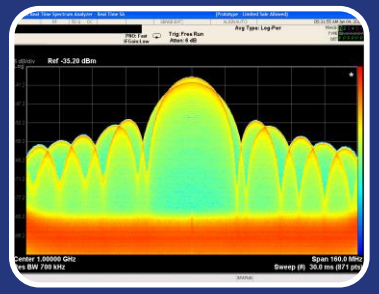
- Works with signal generation and analysis hardware
  - Extends the capabilities of Keysight instruments
  - Enables customized measurement and analysis routines
  - Option includes modifiable application examples

What is Real Time Spectrum Analysis? (RTSA)



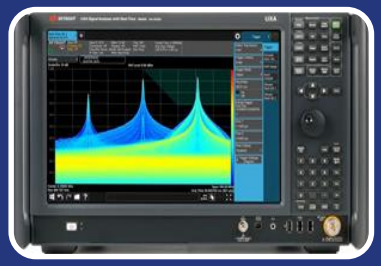
General Definition of Real-Time

- Measurement Operations where **all** signal samples are used in calculating measurement results of some kind (usually spectrum)



Real-Time Bandwidth (RTBW)

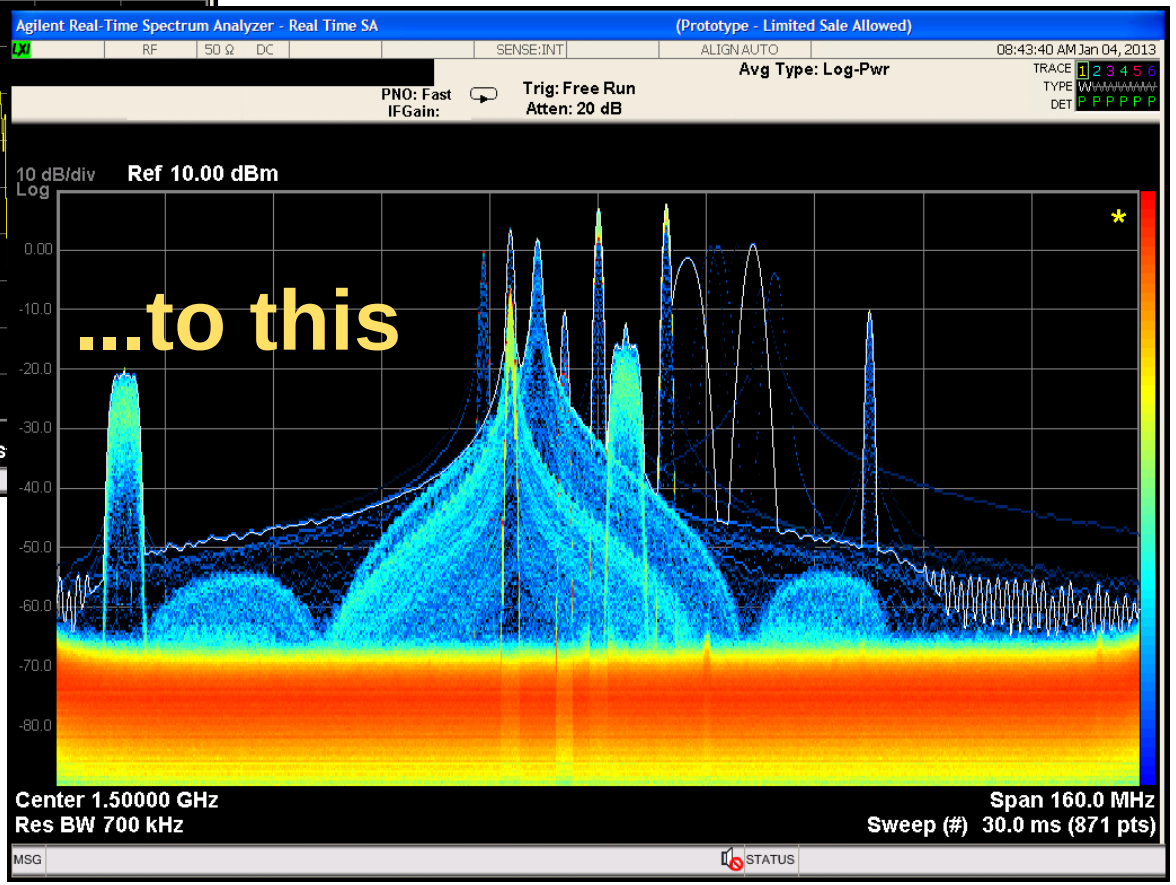
- The widest analysis bandwidth where an analyzer can maintain real time operation
- Duration of maintaining real time operation is not specified; it may be may be assumed to be short term or long term or unlimited



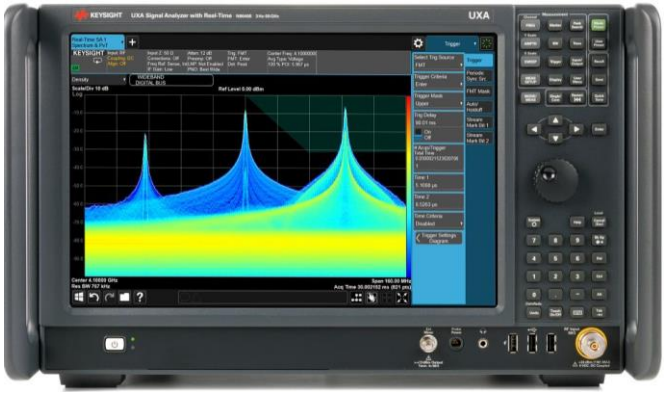
Current usage for Signal Analyzers

- A spectrum or FFT analyzer having a signal processing path where most or all of the samples, even at wide bandwidths, are used to create a spectral display **or** to trigger signal measurement or acquisition (sometimes both)

Swept vs. Real Time Spectrum Analysis

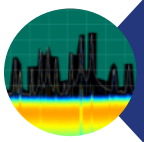


Real-time Spectrum Analysis with the Keysight X-series



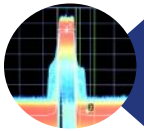
Best-in class RTSA and Dynamic Range

Scan 510 MHz Real Time BW and up to 75dB (PXA)/72 dB (MXA) Spur Free Dynamic Range



Frequency Mask Trigger

Combine FMT and low noise floor to detect signals as short as 3.57µs with 100% POI



Analysis of Complex signals

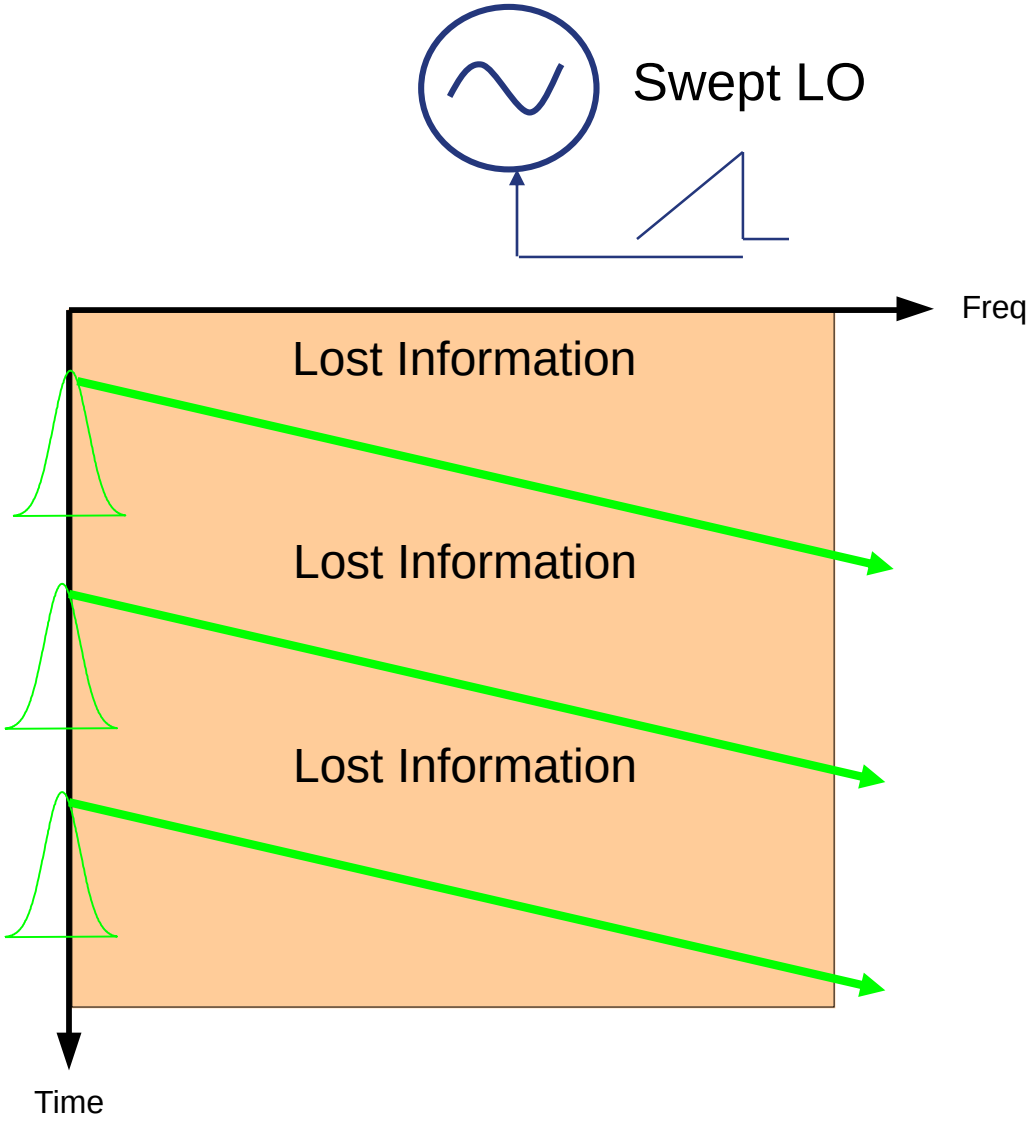
Seamless integration with 89600 VSA software

Retain Full Swept-Tuned Performance

Eliminate the need for dedicated instrument, PXA/MXA license key upgradable

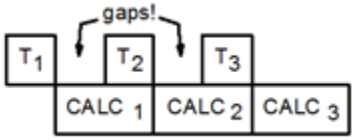
The Swept Analysis Mode

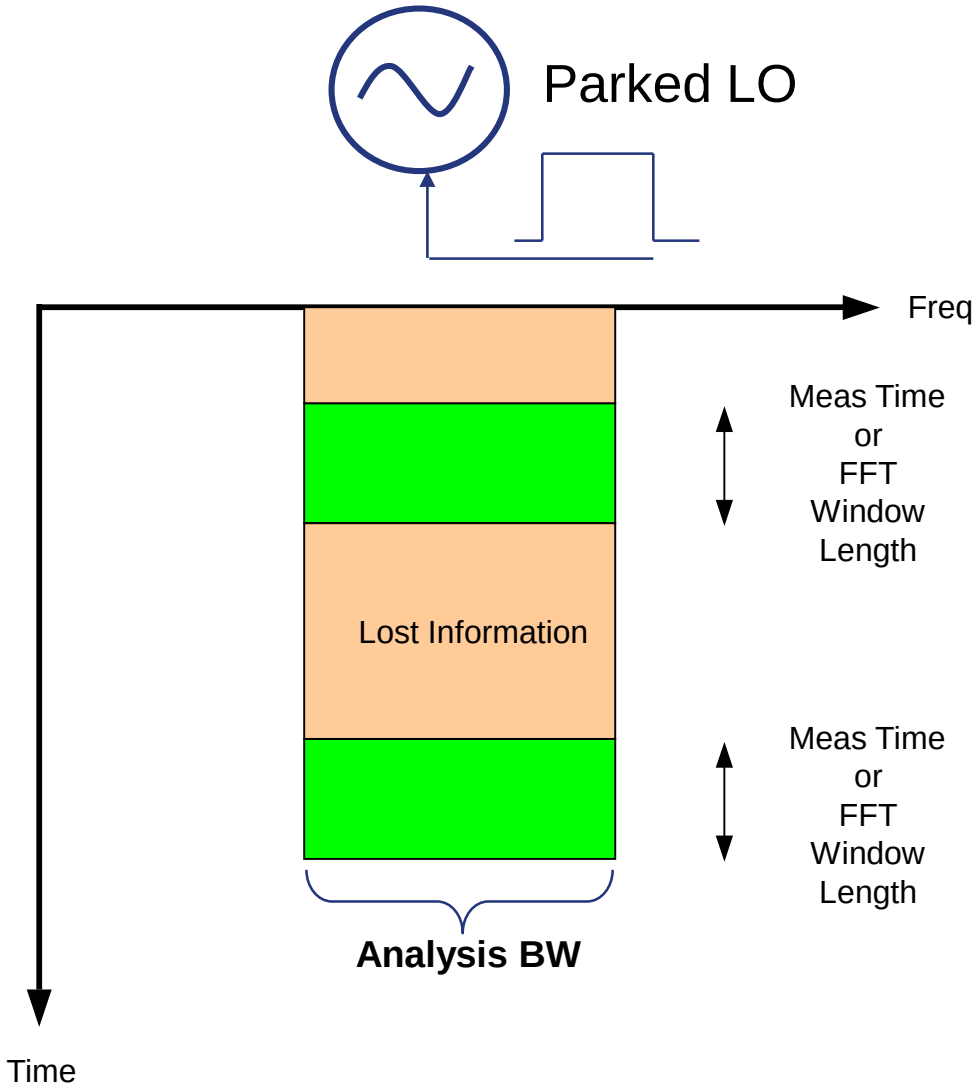
- A swept LO w/ an assigned RBW.
- Covers much wider span.
- Good for events that are stable in the freq domain.
- Magnitude ONLY, no phase information (scalar info).
- Captures only events that occur at right time and right frequency point.
- Data (info) loss when LO is “not there”.



IQ Analyzer (Basic) Mode – Complex Spectrum and Waveform Measurements

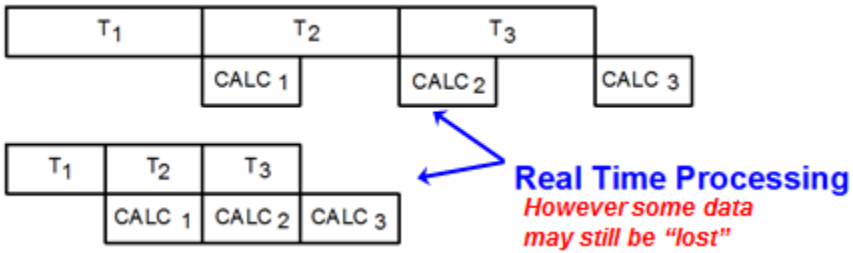
- A parked LO w/ a given IF BW
- Collects IQ data over an interval of time.
- Performs FFT for time-freq-domain conversion
- Captures both magnitude and phase information (vector info).
- Data is collected in bursts with data loss between acquisitions.

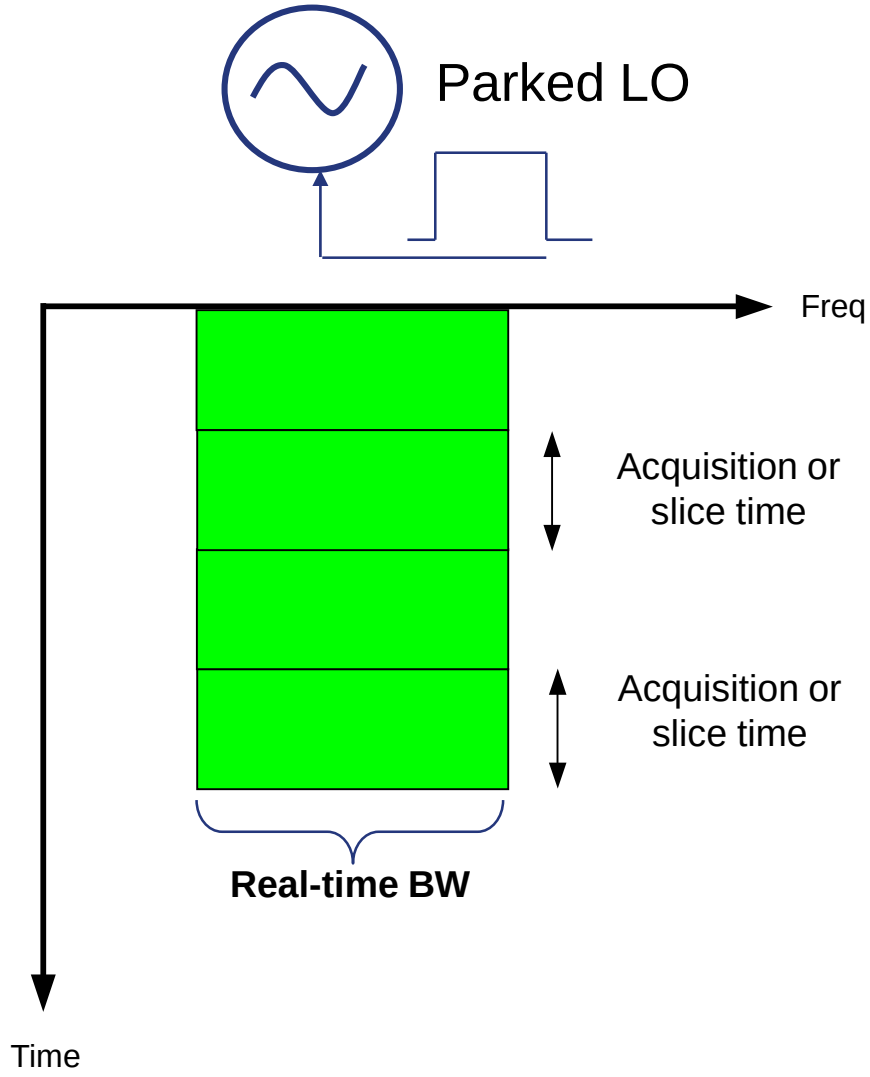




Real–Time Spectrum Analysis

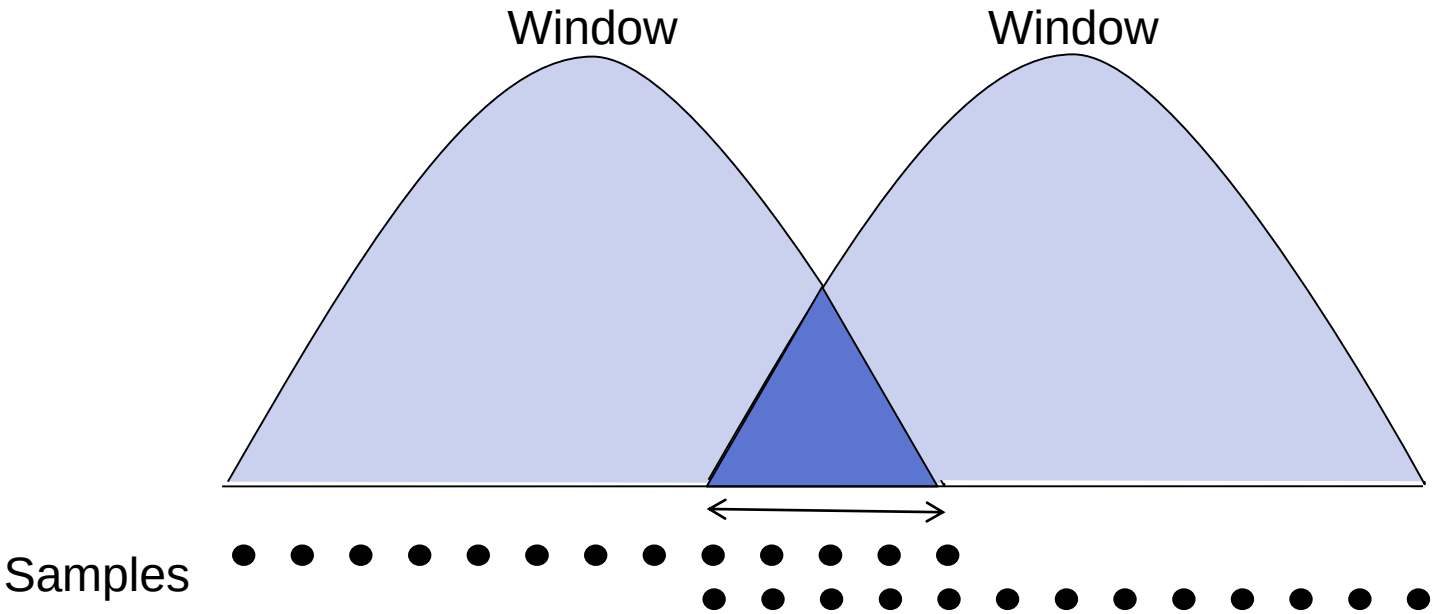
- A parked LO w/ a given IF BW
- Collects IQ data over an interval of time.
- Data is corrected and FFT'd in parallel
- Vector information is lost
- Advanced displays for large amounts of FFT's

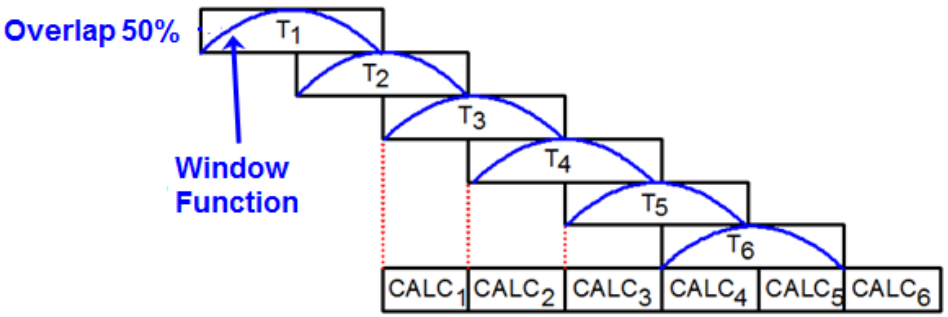




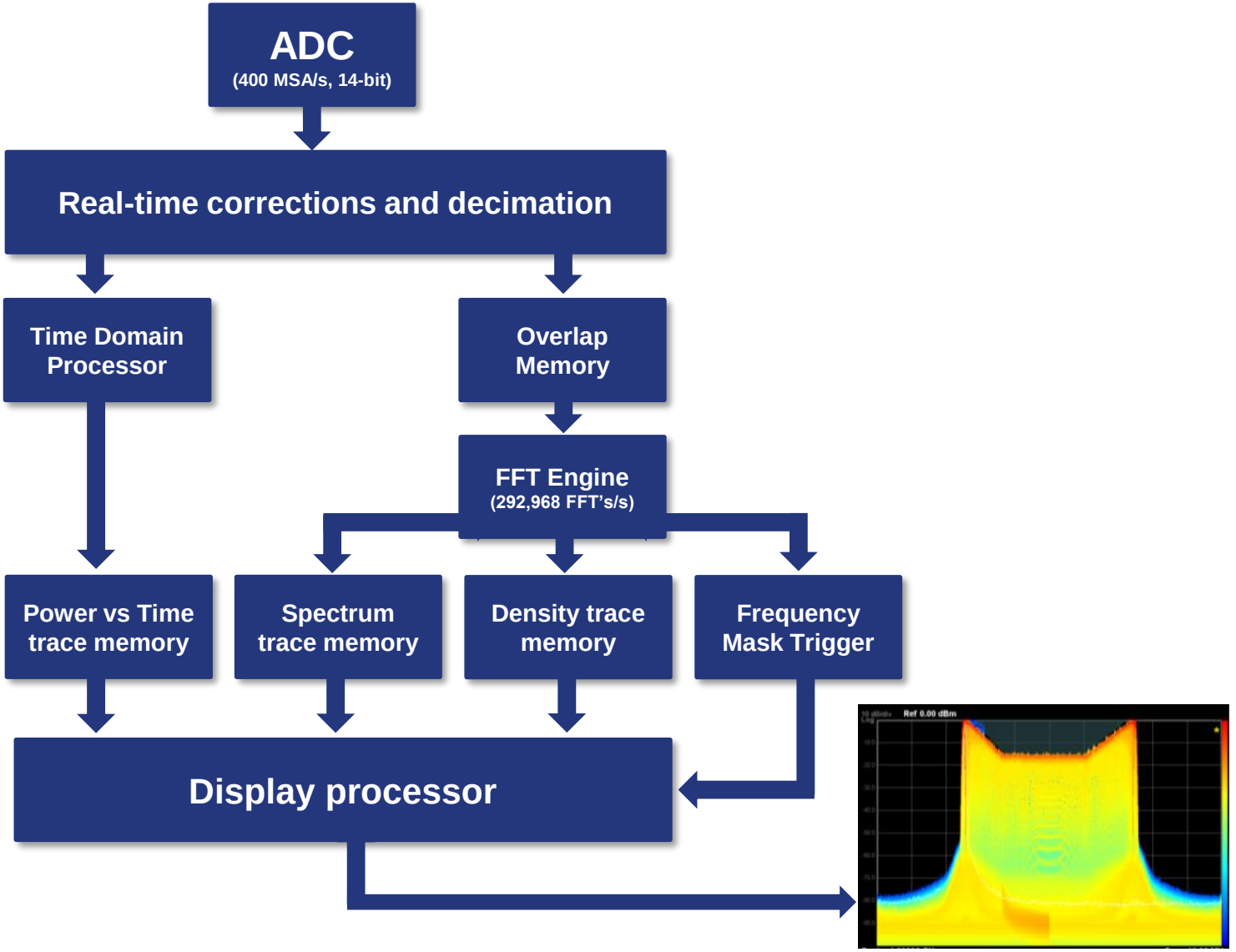
The FFT

At first glance

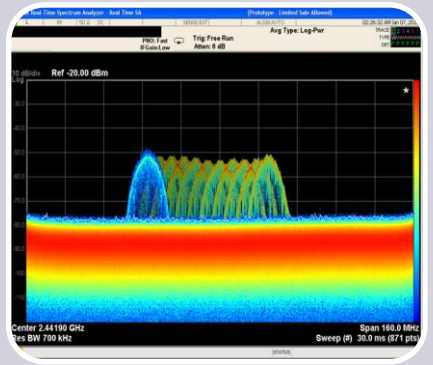


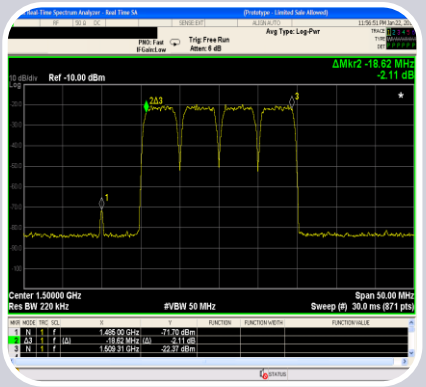


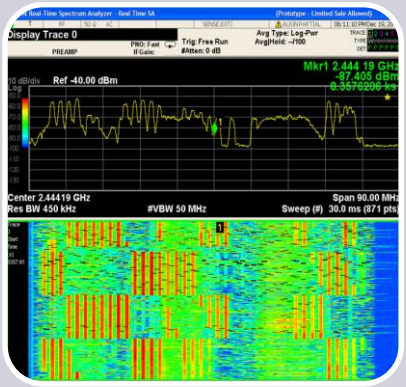
Simplified Block Diagram of Real-Time system

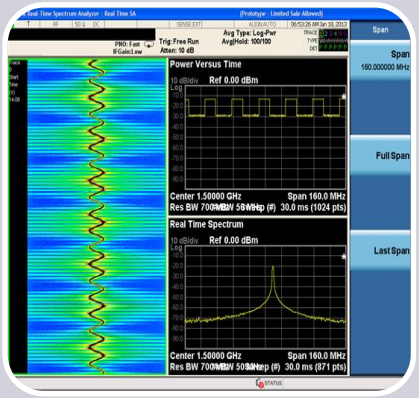


Real-Time Displays Type









Density

- Also know as Histogram Persistence
- Color indicates number of hits
- Screen typically updates every 30ms
- Persistence can be manual or infinite

Spectrum

- Accumulate all FFT's to a single trace
- Apply detector
- Superimposed on the density display
- Used for marker operations

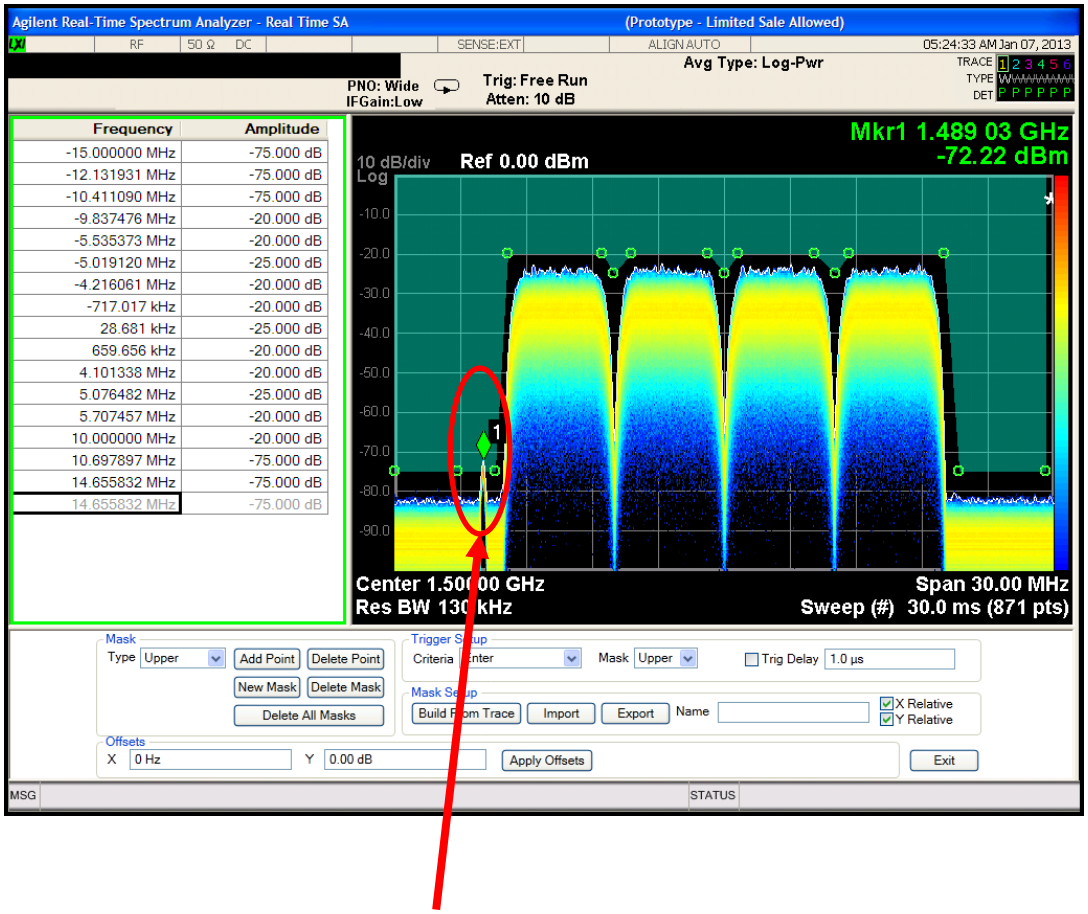
Spectrogram

- Real Time Spectrum slices – no gaps
- 10,000 spectrogram traces available
- Scroll through stored traces
- Use markers on and between traces

Power vs Time

- PvT over configurable range
- Gapless time data transformed to frequency domain
- Different displays available
- Level based trigger available

Frequency Mask Trigger (FMT) What is it?



Frequency Mask Violation

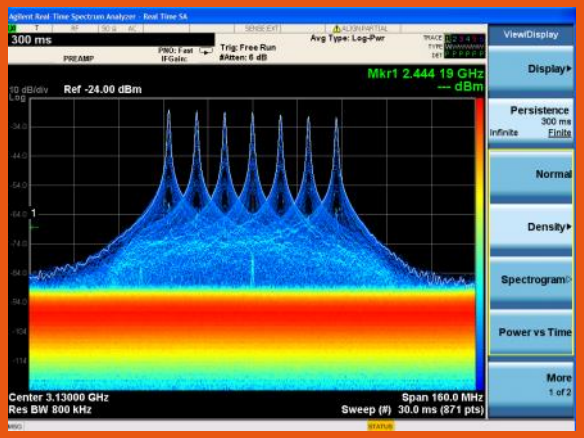
- Build Mask from trace and add offsets if required
- Edit table or use mouse to drag the mask points to the desired location
- Various criteria for Trigger: Enter, Leave, Inside, Outside, Enter → Leave, Leave → Enter
- Upper, Lower or Both masks available
- Import or Export masks as required
- FMT Combined with 89600B VSA software for further analysis

Probability of Intercept

Detect Low Level Signals With Precision

CHALLENGE

- Short burst comms, LPI radar systems make it very difficult to analyze jamming & interference
- Communication jamming needs to be done very quickly for adaptive threats



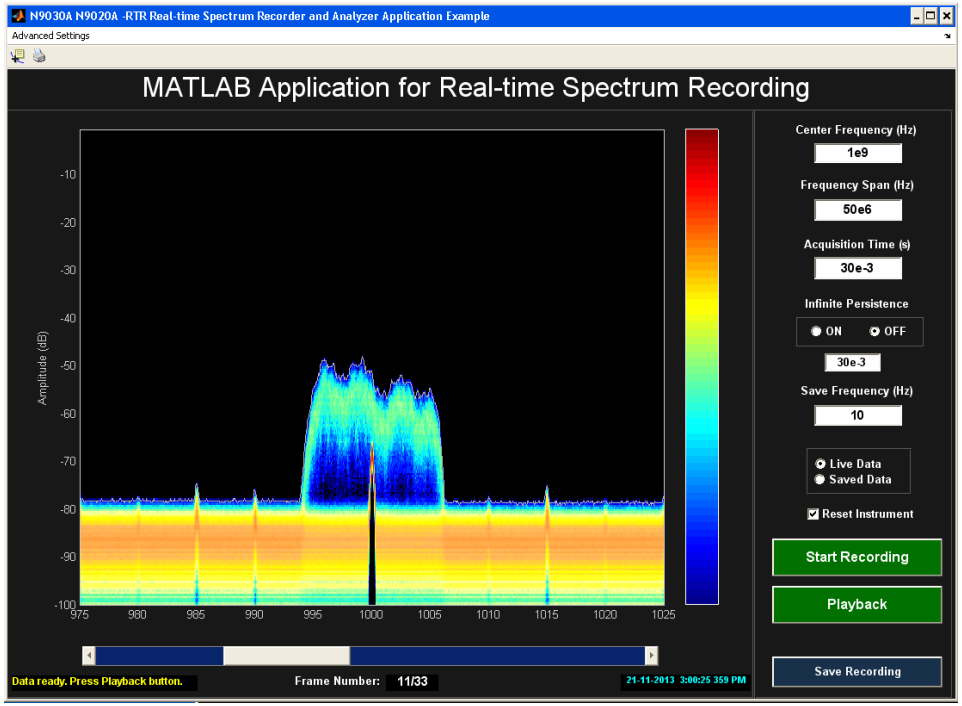
KEYSIGHT SOLUTION

- POI of 3.57μs for 100% POI with full amplitude accuracy to catch the most elusive signals
- Excellent noise performance at X-band further improves POI

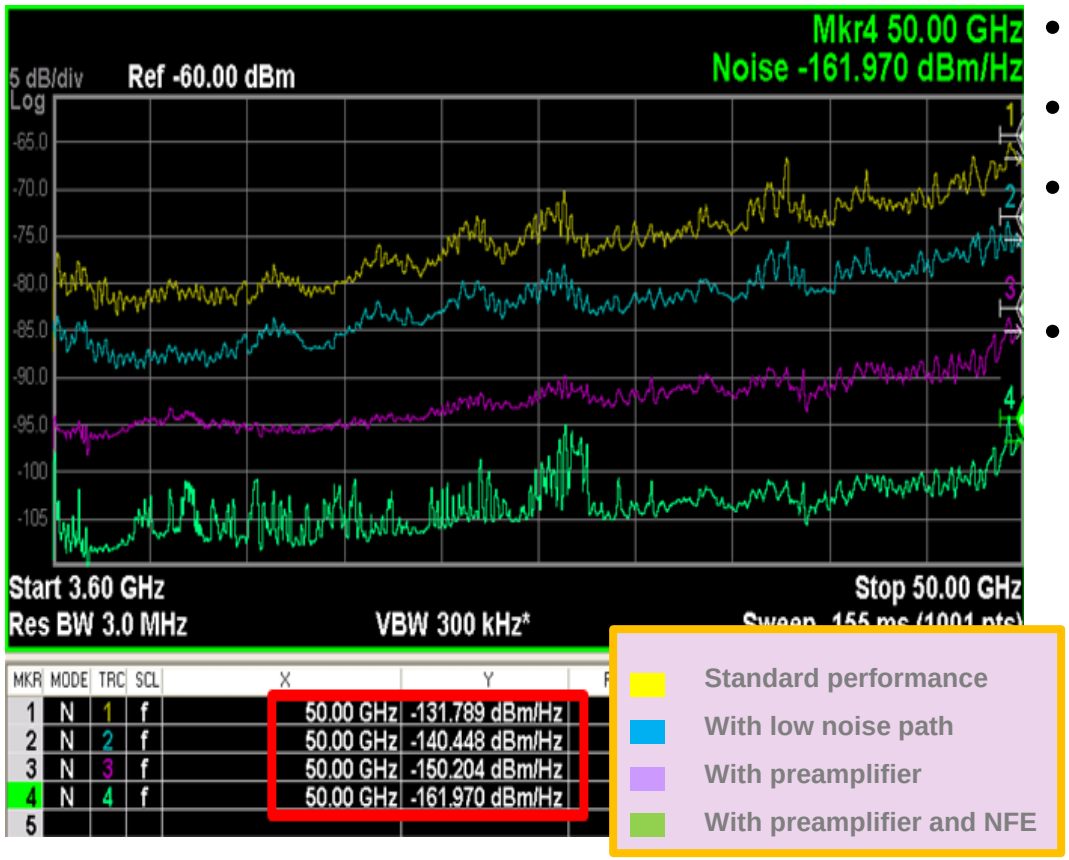
N9040B, N9030A & N9020A -RTR Real-time Spectrum Recorder and Analyzer Application Example

Option Overview

- An advanced application example for Keysight's real-time spectrum analyzers (RTSA), including its PXA and MXA series analyzers upgraded for RTSA capability (-RT1 or –RT2).
- Record, analyze, and visualize spectrum density data in order for you detect and analyze signal anomalies.
- Scroll through the evolution of spectrum density data.
- Identify the highest power signal received during a period interest by you placing density and density envelope cursors.
- Record the acquired density data for later analysis in MATLAB directly on the instrument or on a remote PC.



Millimeter-wave Signal Analysis



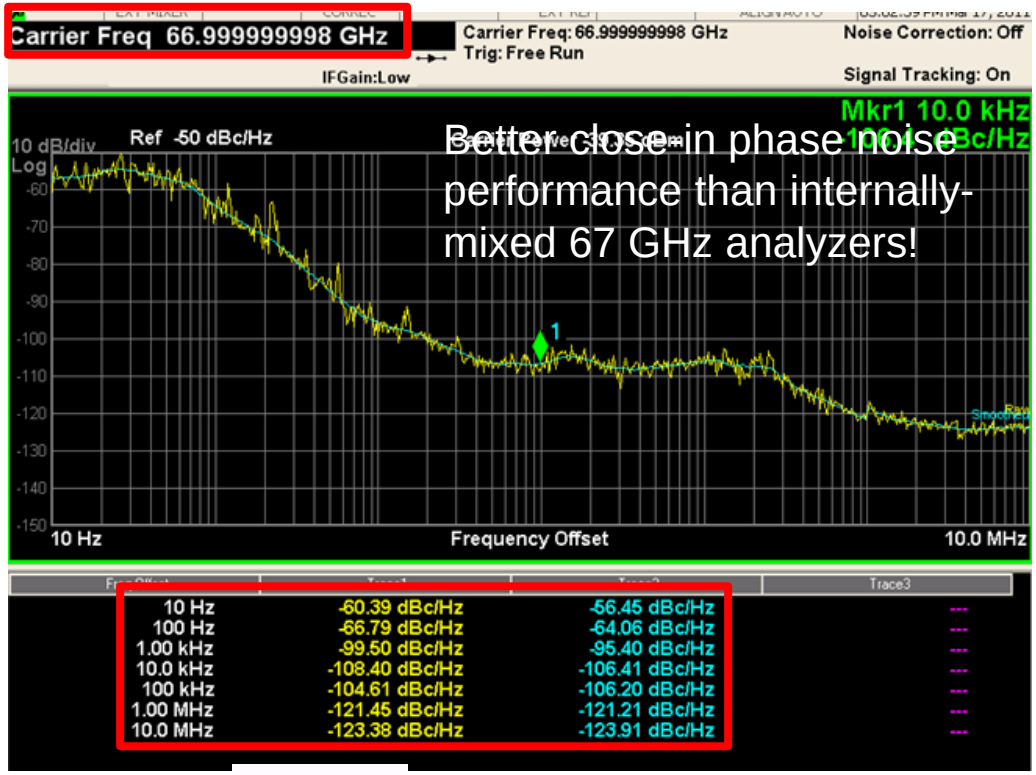
Unprecedented signal insight

- Unmatched sensitivity to 50 GHz
- Highest third-order dynamic range
- Superior close-in phase noise performance
- The industry's most accurate analyzer

Ideally suited for

- Advanced radar
- Satellite communications
- Surveillance
- Military communications

Extend Unmatched Performance with External Mixing to up to 1.1 THz



- Supported measurements
  - Spectrum analysis
  - PowerSuite one-button power measurements
  - N9068A phase noise measurement application
  - 89600A VSA
- Supported external mixers
  - M1970V/E/W
  - 11970 Series
  - OML Inc.
  - VDI

M1970 Series Waveguide Harmonic Mixers

New mixer family

- M1970V Option 001 (50 to 75 GHz)
- M1970V Option 002 band (50 to 80 GHz)
- M1971E (55/60 to 90 GHz) (2GHz BW)
- M1970E (60 to 90 GHz)
- M1970W (75 to 110 GHz)

Mixer smart features

- **Automatic amplitude correction** and **transfer of conversion loss data** through USB plug and play features
- **Automatic LO amplitude adjustment** to compensate the cable loss (up to 3 m or 10 dB loss)
- **Auto detect mixer model/serial number** when used with X-series SA
- **Automatic setting** of default frequency range and LO harmonic numbers
- **Automatic LO alignment** at start up
- **Automatic run calibration** when time and temperature changes

Improved DANL and TOI

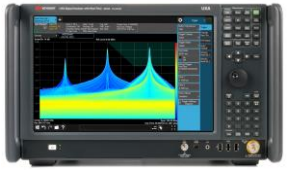
- **Excellent conversion loss** of **27 dB maximum** and **excellent amplitude calibration accuracy** of **2.2 dB**

X-Series Signal Analyzers

New capability to help design, test and deliver your next breakthrough

X-Series applications

Phase noise, noise figure, analog demodulation
Pulse
LTE/LTE-Advanced FDD & TDD
W-CDMA/HSPA+
Etc…



UXA

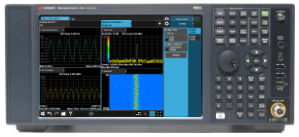
Wide-open performance
3 Hz to 50 GHz, 1 GHz BW
3 Hz to 110 GHz, 1GHz BW
(5GHz with Scope)
Real-time spectrum analysis
255 MHz real-time streaming

PXA

Benchmark for demanding apps
3 Hz to 50 GHz, 510 MHz BW
Real-time spectrum analysis
255 MHz real-time streaming
Enhanced phase noise (DDS LO)

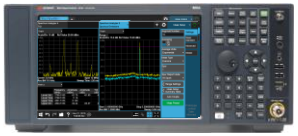
MXA

Optimum choice for wireless
10 Hz to 26.5 GHz, 160 MHz BW
Real-time spectrum analysis



EXA

Maximum value up to mmWave
10 Hz to 44 GHz, 40 MHz BW
Enhanced phase noise



CXA

Leading low-cost tool
9 kHz to 26.5 GHz, 25 MHz BW
Enhanced phase noise

NFA

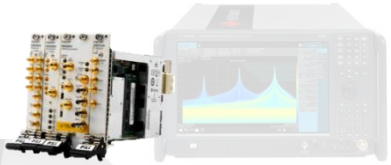
Up to 40 GHz

Keysight Modular Signal Analyzer Portfolio

Performance

Price

M9393A VSA
Mm-wave in PXI
3.6 kHz to 50 GHz, 160 MHz BW
Speed & Performance



UXA
See the real performance
3 Hz to 26.5 GHz, 510 MHz BW
Real-time spectrum analysis

M9393A VSA
The performance edge in PXI
9 kHz to 27 GHz, 160 MHz BW

PXA
Drive your evolution
3 Hz to 50 GHz, 160 MHz BW
Real-time spectrum analysis

M9391A VSA
Optimized for speed
10 Hz to 6G GHz, 160 MHz

MXA
Accelerate in wireless
10 Hz to 26.5 GHz, 160 MHz BW
Real-time spectrum analysis

EXA
Balance the challenges
10 Hz to 44 GHz, 40 MHz BW

M9420A VXT
Dedicated to wireless mfg
60 MHz to 6G GHz, 160 MHz BW
Measurement continuity

M9290A CXA-m SA
Smaller foot-print
10 Hz to 26.5 GHz, 25 MHz BW

CXA
Master the essentials
9 kHz to 26.5 GHz, 25 MHz BW

Platform Positioning

Benchtop and Modular

Benchtop Instruments "Optimized for Analysis"

PXI/AXIe Modules "Optimized for Test"

Integrated CPU Power Supply & Display

Upgradable

Flexible

Extensive Specs

Front-panel Operation

Compact Footprint

Multi-channel

Optimized For R&D

Portable

Optimized for ATE Solutions Development

Migration Opportunities

PXA
X-Series
High-performance
3 Hz to 50 GHz

PSA
Market leading performance
3 Hz to 50 GHz

MXA
X-Series
Mid-performance
10 Hz to 26.5 GHz

8560EC
Mid- performance

EXA
X-Series
Economy-class
10 Hz to 44 GHz

ESA
World's most popular
100 Hz to 26 GHz

CXA
Low-cost
9 kHz to 26.5 GHz

CSA
Low cost portable
100 Hz to 7 GHz

X-Series Code Compatible

- ✓ Backward CC with legacy
- ✓ Inherent X-Series CC

FieldFox Analyzer Portfolio

RF and microwave combination analyzers

Base: Cable and antenna analyzer

Key options:
- Spectrum analyzer
- Vector network analyzer
- Built-in power meter
- Pulse measurements

RF and microwave vector network analyzers

Base: Transmission/reflection vector network analyzer

Key options:
- Cable and antenna analyzer
- Vector voltmeter
- Built-in power meter
- Pulse measurements

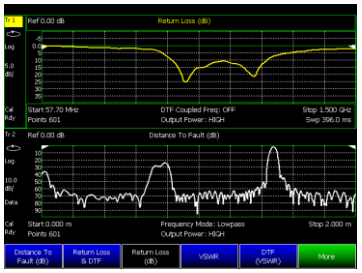
Microwave spectrum analyzers

Base: Spectrum analyzer

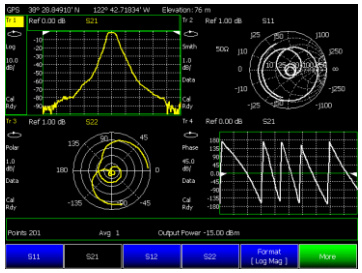
Key options:
- Full-band tracking generator
- Full-band preamplifier
- Built-in power meter
- Pulse measurements

Most Comprehensive Measurement Capabilties

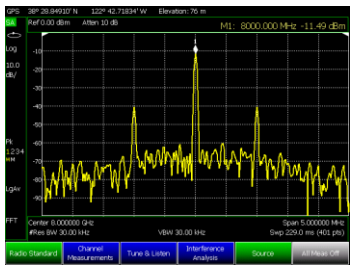
Field upgradeable, software enabled



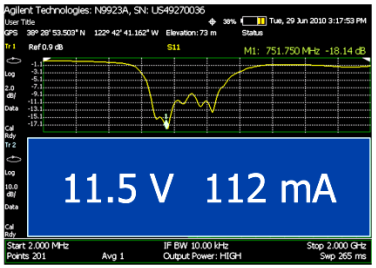
Cable and antenna analysis



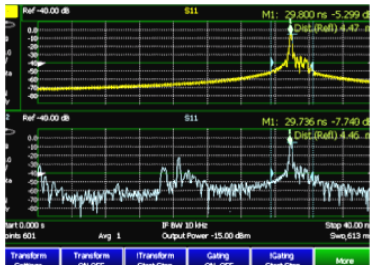
Vector network analysis



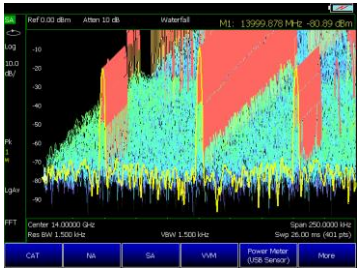
Spectrum analysis



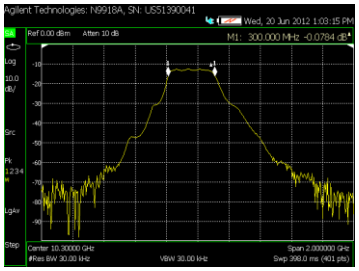
DC source & current monitor



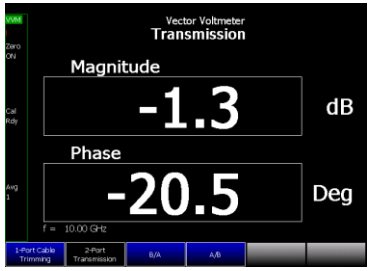
Time domain



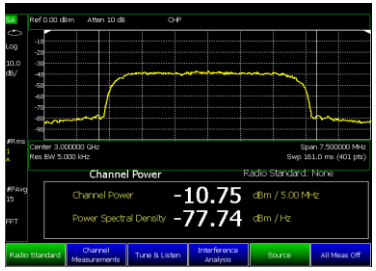
Interference analysis



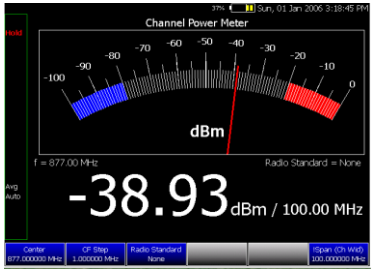
Full-band tracking generator



Vector voltmeter



Channel power measurement



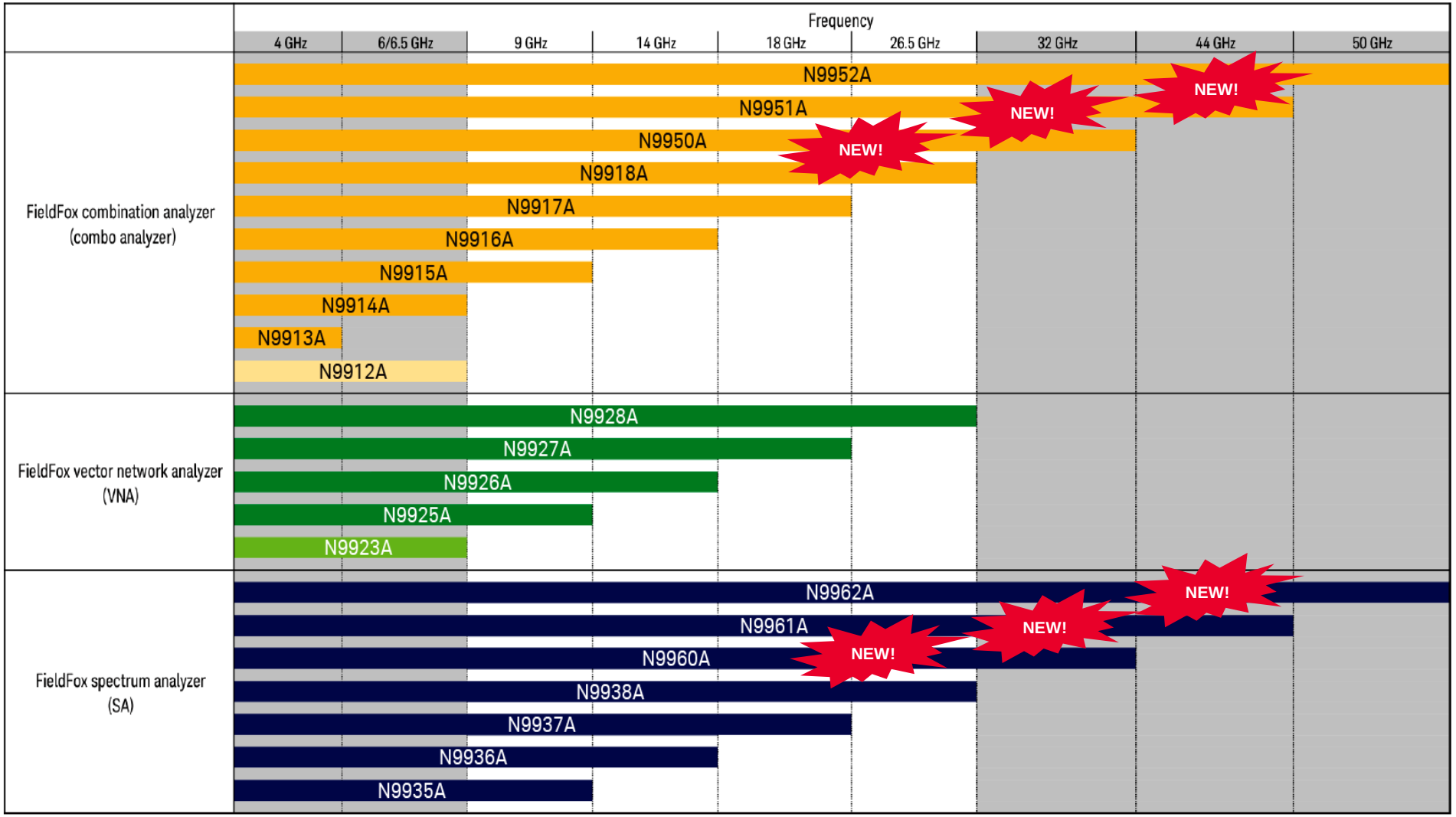
Built-in power meter

FieldFox Real-Time Spectrum Analysis (RTSA)

The world's only handheld RTSA that goes up to 50 GHz

Features	Specifications
Minimum signal duration with 100% POI	12us
Minimum detectable signal	< 1us
Real time bandwidth	10MHz
Amplitude accuracy	0.8dB to 1.4dB at center frequency
SPAN:RBW	20 to 280
Record and playback	Trace
Display modes	Real time trace, spectrogram, density spectrum
Number of points	561

Find the FieldFox that Meets Your Needs



Keysight Spectrum Analyzer Families (Handhelds)

N9344C Handheld Spectrum Analyzer

- Handheld SA -- 100 kHz to 20 GHz
- Fastest sweep – minimum sweep time < 2ms
- –144 dBm displayed average noise level (DANL) typical
- +15 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

N9343C Handheld Spectrum Analyzer

- Handheld SA -- 100 kHz to 13.6 GHz
- 10 ms non-zero span sweep time
- –144 dBm displayed average noise level (DANL) with pre-amplifier
- +15 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

Keysight Spectrum Analyzer Families (Handhelds)

N9342C Handheld Spectrum Analyzer

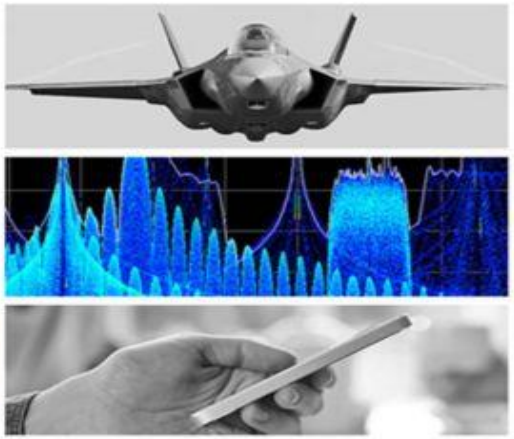
- Handheld SA -- 100 kHz to 7.0 GHz
- Fastest sweep – minimum sweep time < 2ms
- –152 dBm displayed average noise level (DANL) typical
- +10 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

N9340B Handheld Spectrum Analyzer

- Handheld SA -- 100 kHz to 3.0 GHz
- 10 ms non-zero span sweep time
- –144 dBm displayed average noise level (DANL) with pre-amplifier
- +10 dBm third order intercept (TOI)
- Built-in GPS receiver and GPS antenna
- Built-in tracking generator
- Light weight, rugged and portable
- four hours battery life

Keysight Technologies Training Services

Build new skills. Extract more value

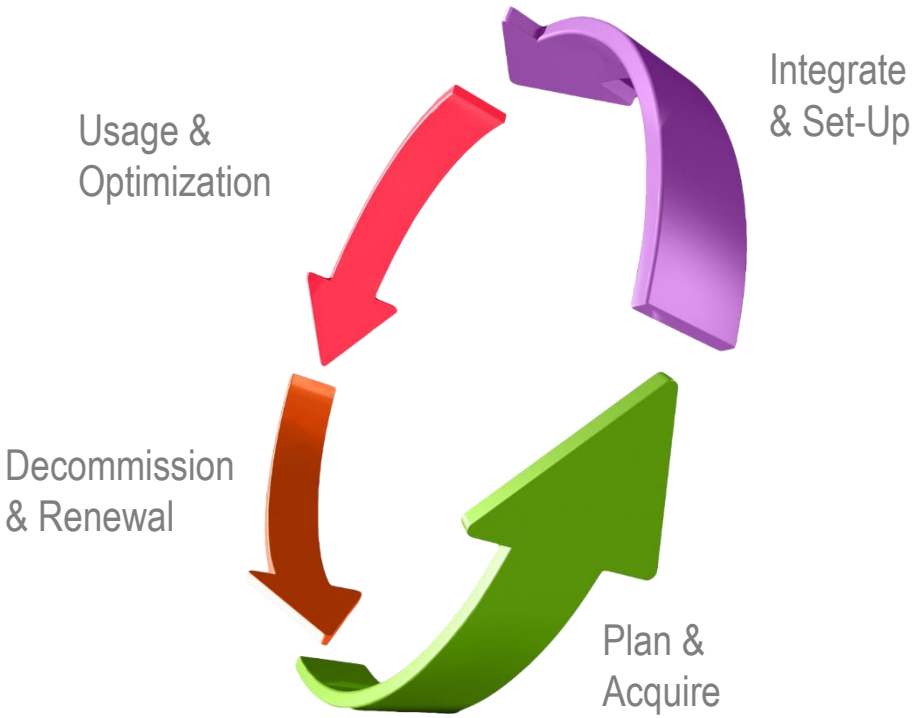


- Enable your teams to achieve the mastery necessary to optimize the use of your Signal Analyzers and use them to their fullest potential
- Access a comprehensive portfolio of technical training courses
- Utilize modular materials that focus on developing expertise in specific instruments, technologies or processes

www.keysight.com/find/Training

Keysight Technology Refresh

Minimize capital and operating expenses



Product Purchase Alternatives: Lower cost and flexible financing at Keysight quality

- Keysight Premium Used
- Keysight Instant Buy[1]
- Keysight Store on eBay

Consulting Services: Solve tough problems by leveraging our expertise

- Start-Up Assistance
- Test process analysis consulting

Asset Management: Stay ahead of required maintenance and regulatory audits with automated notifications

Technology Refresh Service: Extend, upgrade or migrate your existing test systems

[1]Available in US, Canada, Germany, UK & France

Keysight Technology Refresh

Migrate to the new Multi-Touch X-Series Signal Analyzers

Extend the value of your current assets

Upgrade your X-Series signal analyzers

Add a multi-touch UI to your N90x0A X-Series analyzer to streamline your measurement setup

Trade-in program

Lower your costs – up to 50% credit

- Use Keysight Trade-in when performance or feature set needs make it the right time to affordably migrate to newer test technology
- Get 50% Trade-in credit with a time limited introductory offer when migrating from the N90x0A to a new N90x0B X-Series with multi-touch

Premium Used

Cost savings alternatives to stretch your budget – at least 25% off

- Get 100% Keysight quality and performance for less money
- Same standard 3-year warranty as new models, extendable to 10 years, with optional 3,5,7,or 10-year calibration plans

Reasons to migrate

- Simplify measurement setup and customize views with the new multi-touch user interface
- Increase performance: phase noise, dynamic range, bandwidth, real-time streaming, and more
- Save money with a limited time 50% trade-in credit

Basic Spectrum Analyzer Application & Product Notes

- A.N. 150 – Spectrum Analysis Basics :5952-0292EN
- A.N. 150-15 - Vector Signal Analysis Basics :5990-7451EN
- Spectrum Analyzer & Signal Analyzer Selection Guide :5968-3413EN
- Real Time Spectrum Analyzer Technical Overview :5991-1748EN
- N9040B UXA X-Series Signal Analyzer – Brochure :5992-0089EN
- N9030A PXA Brochure :5990-3951EN
- N9020A MXA Brochure :5989-5047EN
- N9010A EXA Brochure :5989-6527EN
- N9000A CXA Brochure :5990-3927EN
- 89600B VSA Brochure :5990-6553EN
- N9342,43,44C Brochure :5990-8024EN
- N9935,36,37,38A Brochure :5990-9779EN

www.keysight.com/find/sa

Thank You

Any Questions?

KEYSIGHT TECHNOLOGIES

KEYSIGHT HOTSPOTS
Where Technologies and Experts Meet