Signal Analyzer Fundamentals and New Applications

Microwave & Communications Division

Erik Diez
Senior Product Manager
March 13, 2013

Agenda

Introduction

Overview:

- What is Spectrum and Signal Analysis?
- What Measurements are available?

Theory of Operation

Specifications

Modern Signal Analyzer Designs & Capabilities

- Wide Bandwidth Vector Measurements

Wrap-up

Appendix

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 measure the power of the spectrum of known and unknown signals.”

Vector Signal Analyzer

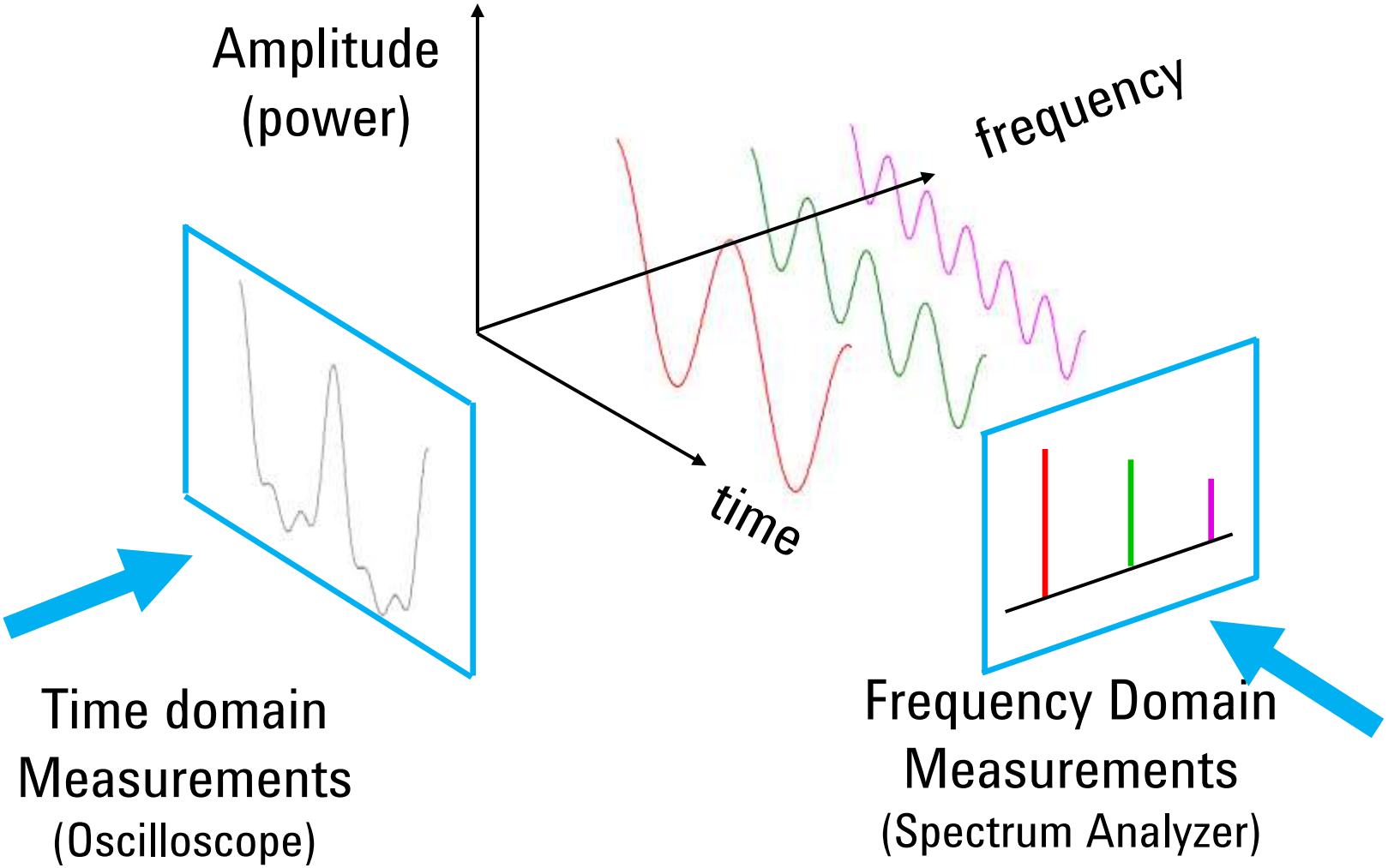
– “A vector signal analyzer measures the magnitude and phase of an input signal at a single frequency within the IF bandwidth of the instrument. The primary use is to make in-channel measurements, such as error vector magnitude, code domain power, and spectral flatness, on known signals.”

Signal Analyzer

– “A signal analyzer provides the functions of a spectrum analyzer and a vector signal analyzer.”

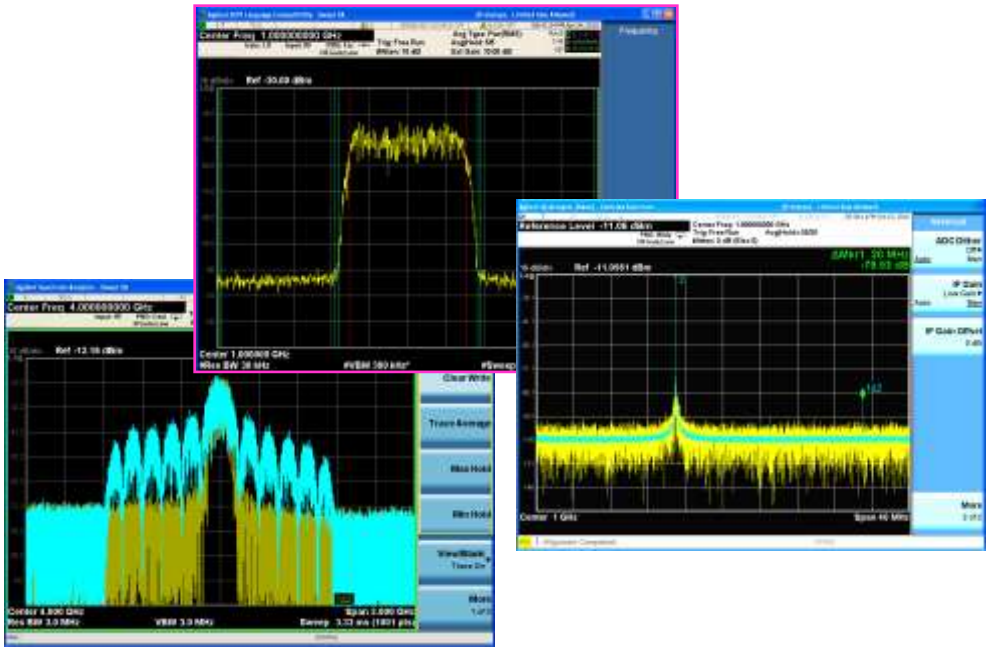
Overview

Frequency versus Time Domain



Overview

What is Spectrum Analysis?

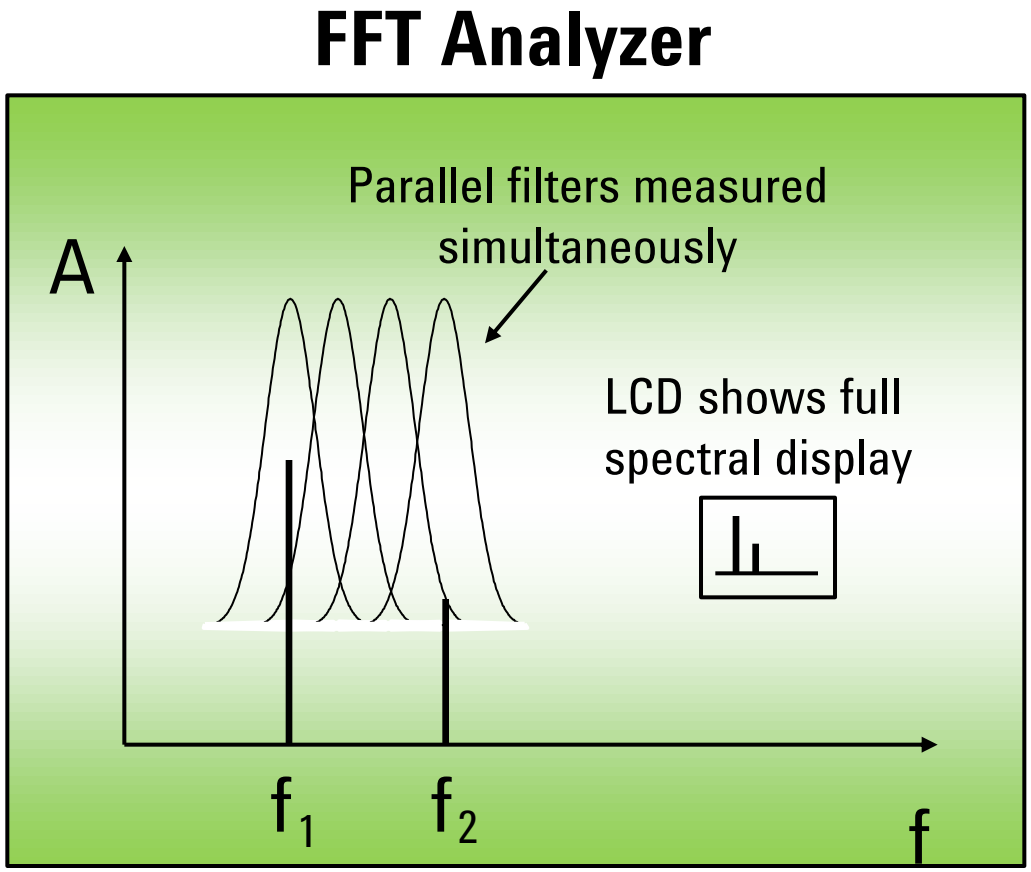


Spectrum Analysis

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

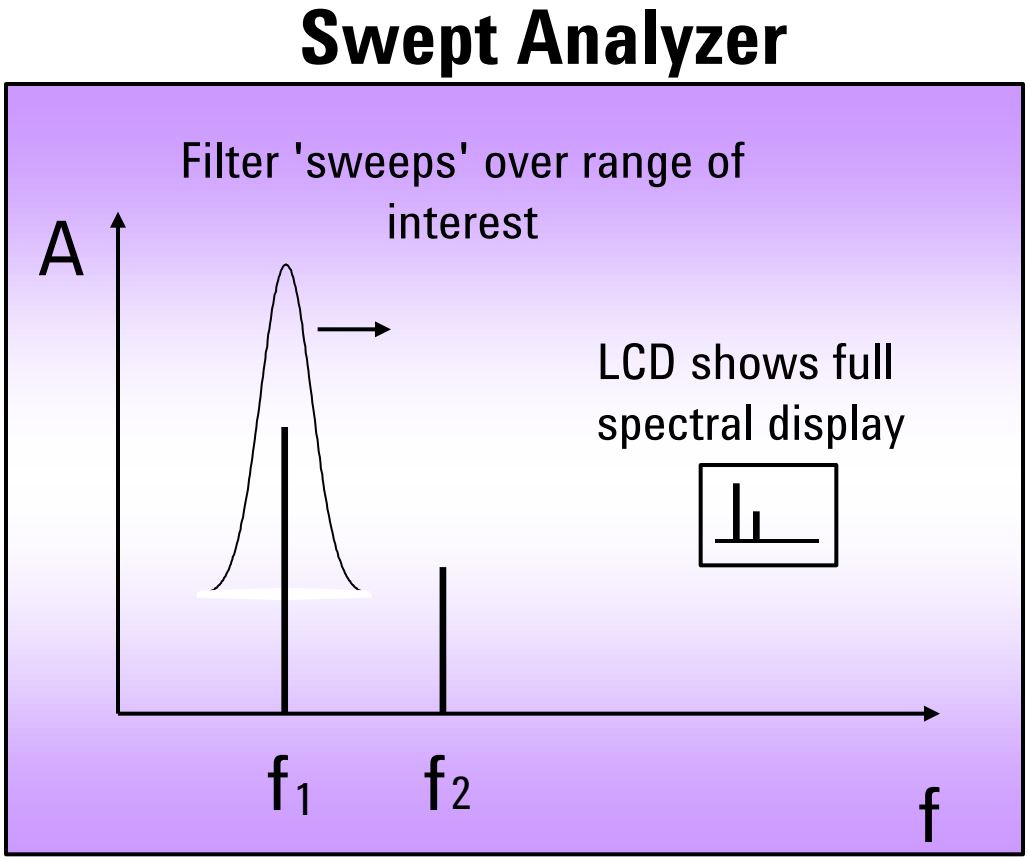
Overview

Different Types of Analyzers



Overview

Different Types of Analyzers



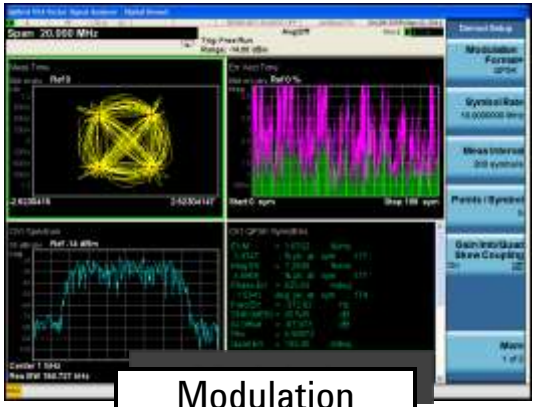
Overview

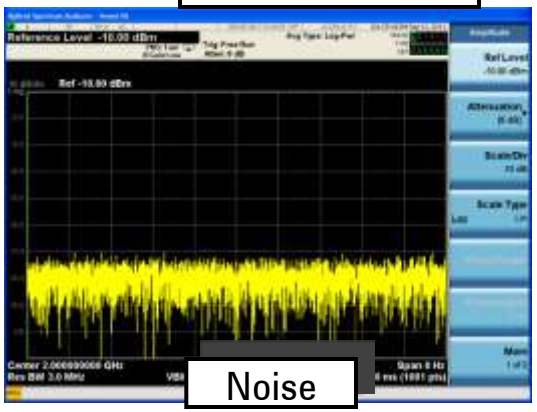
Types of Measurements Available

Frequency, power, modulation, distortion noise

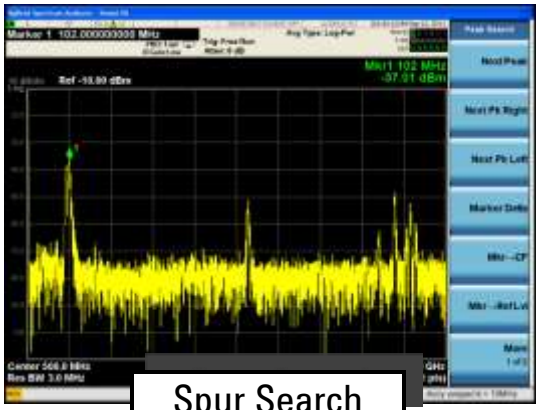
- Spectrum monitoring
- Spurious emissions
- Scalar network analysis
- Noise figure & phase noise
- Harmonic & intermodulation distortion
- Analog, digital, burst & pulsed RF Modulation
- Wide bandwidth vector analysis
- Electromagnetic interference

- *Measurement range (-172 dBm to +30 dBm)*
- *Frequency range (3 Hz to 750 GHz)*


Modulation


Noise


Distortion


Spur Search

Agenda

Introduction

Overview

Theory of Operation:

- Swept Spectrum Analyzer Hardware

Specifications

Modern spectrum analyzer designs & capabilities

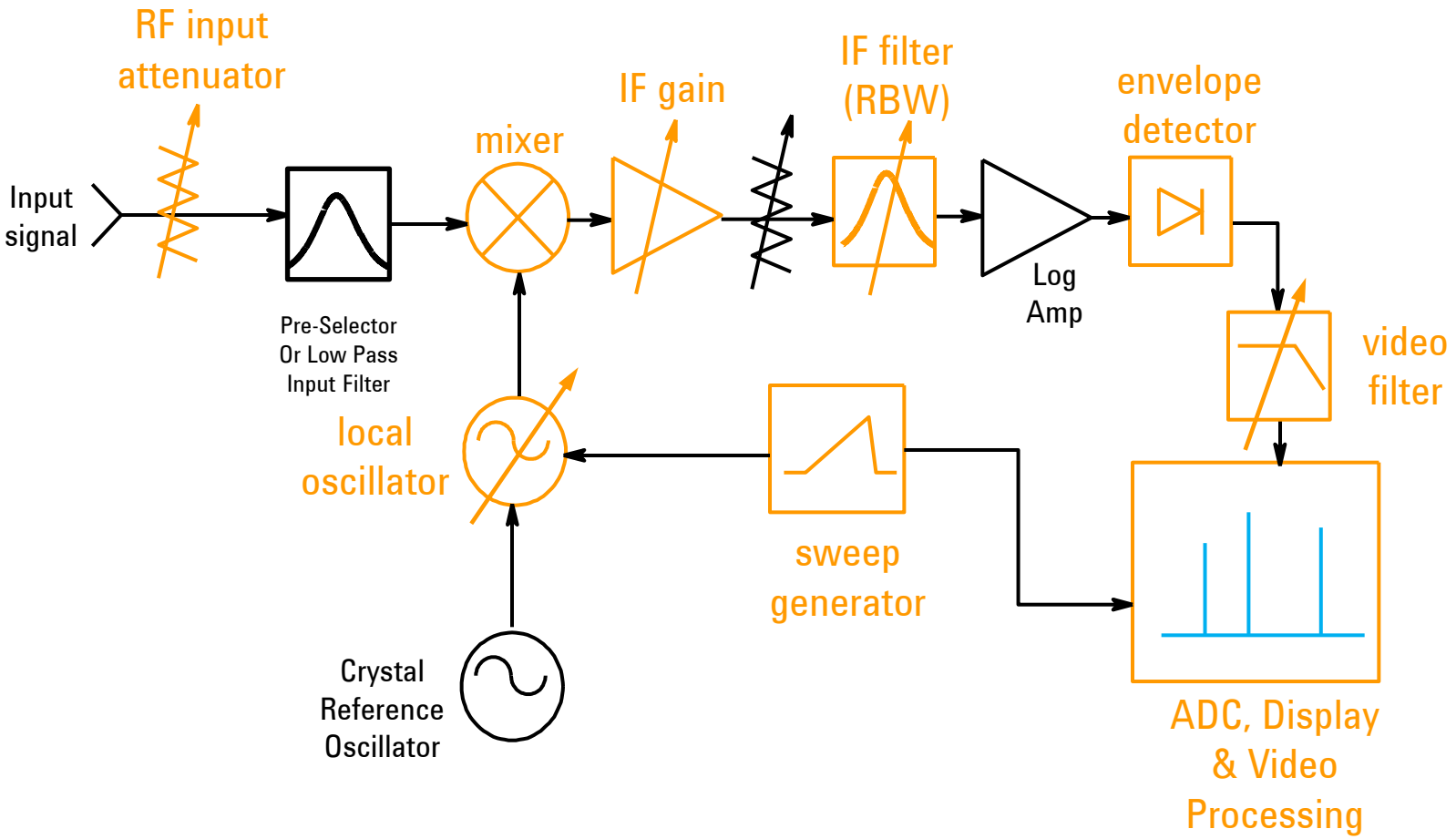
  – Wide Bandwidth Vector Measurements

Wrap-up

Appendix

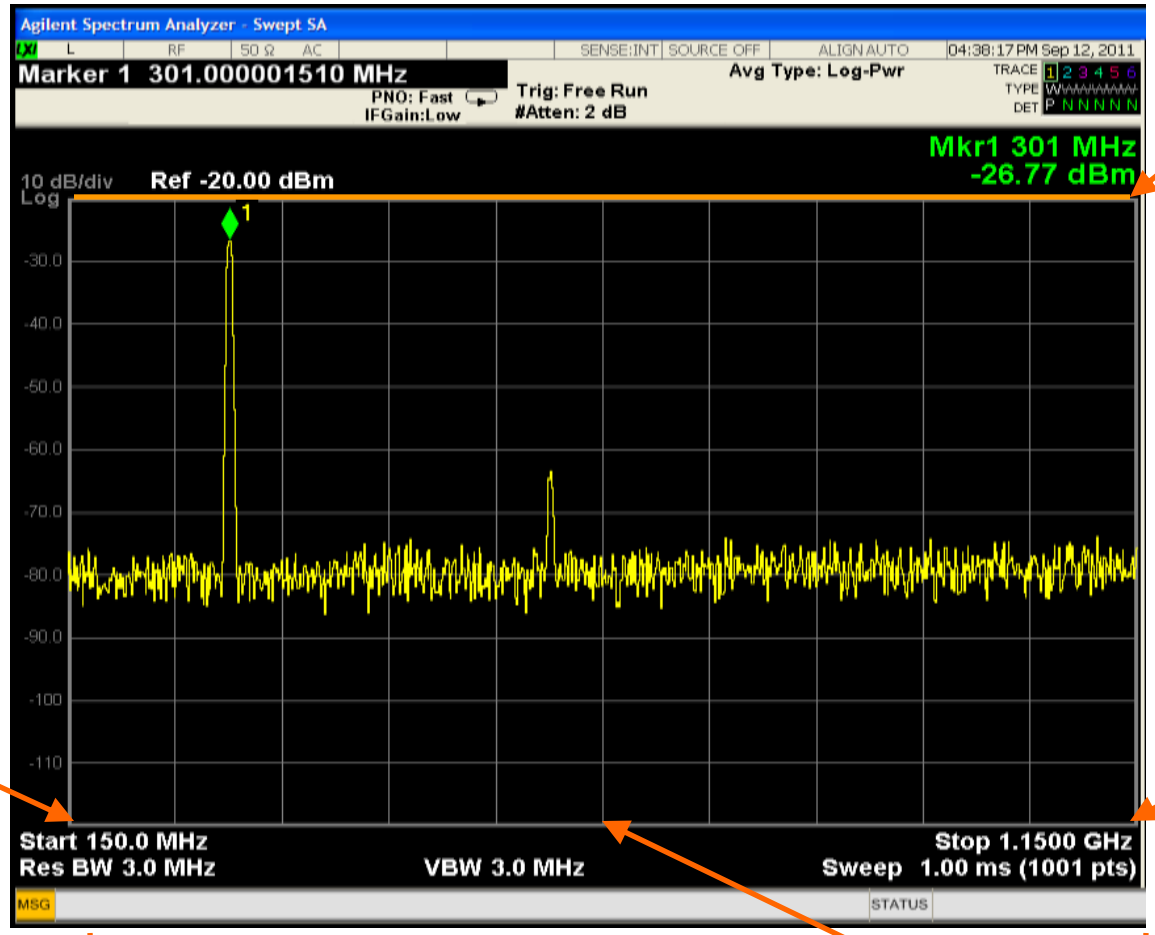
Theory of Operation

Swept Spectrum Analyzer Block Diagram



Theory of Operation

Display terminology



Reference Level

Amplitude

Start Freq.

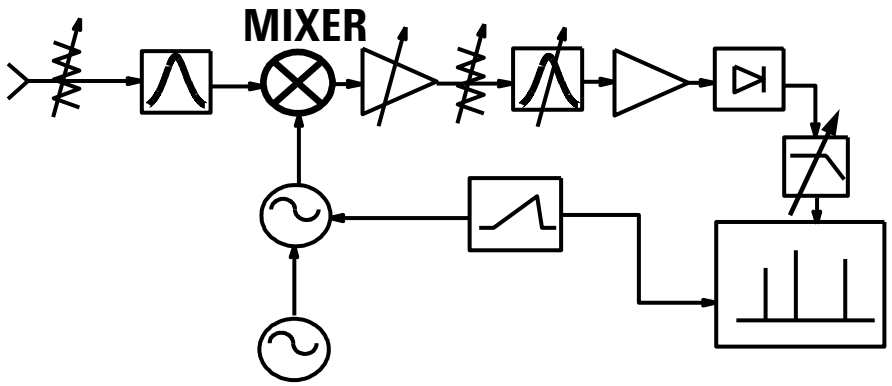
Stop Freq.

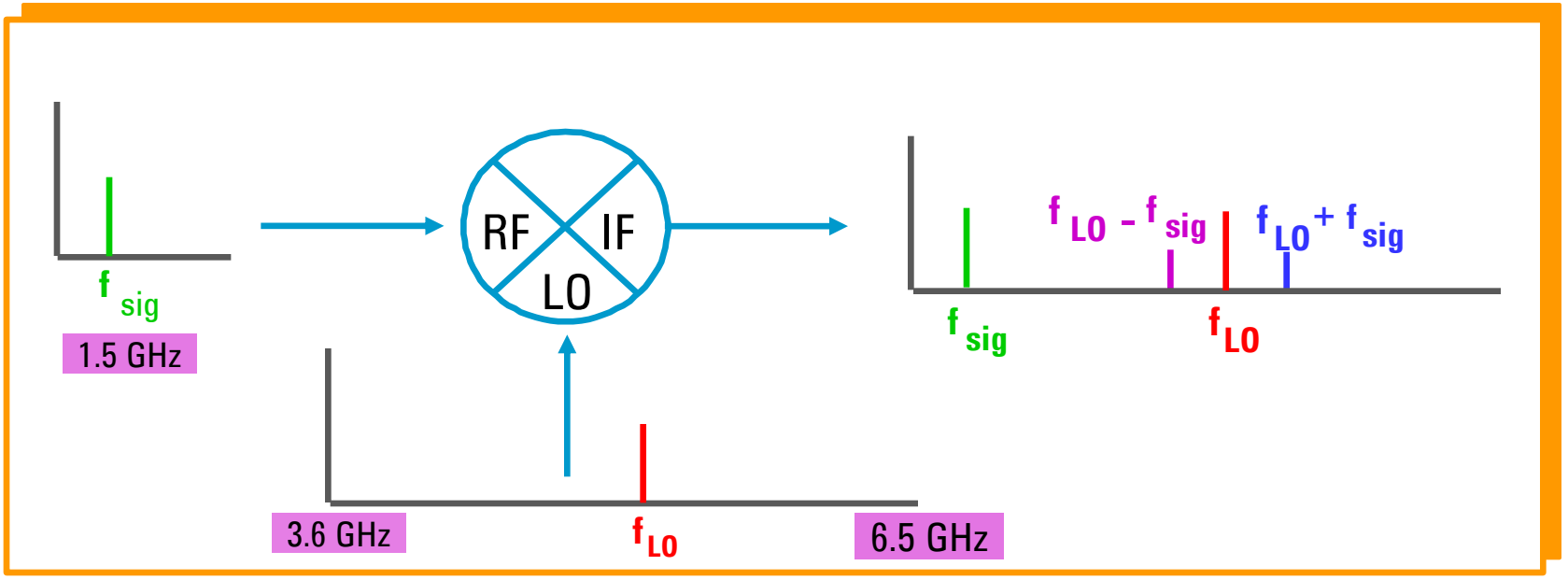
Center Freq.

Freq. Span

Theory of Operation

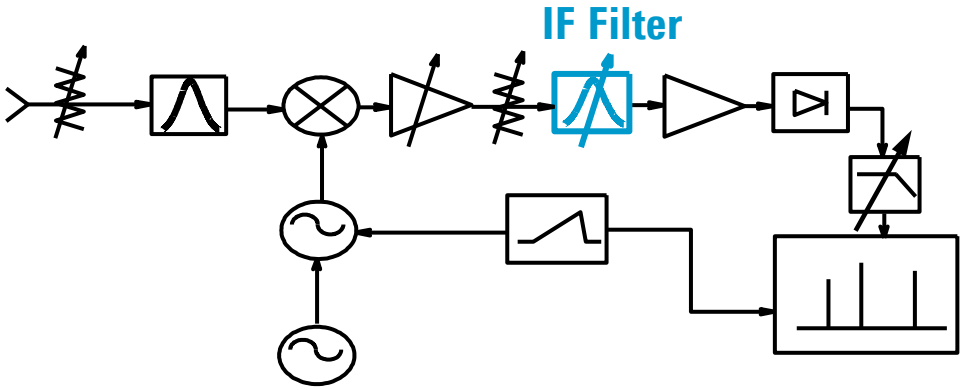
Mixer

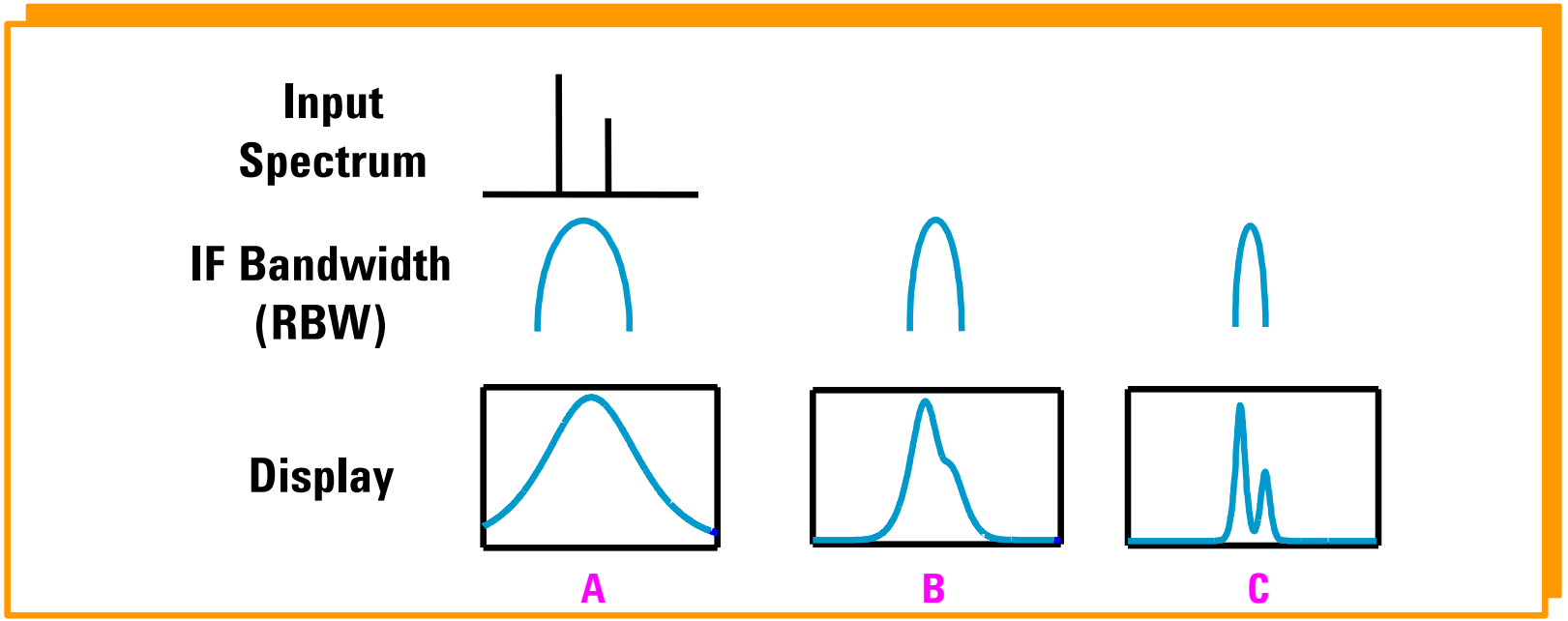




Theory of Operation

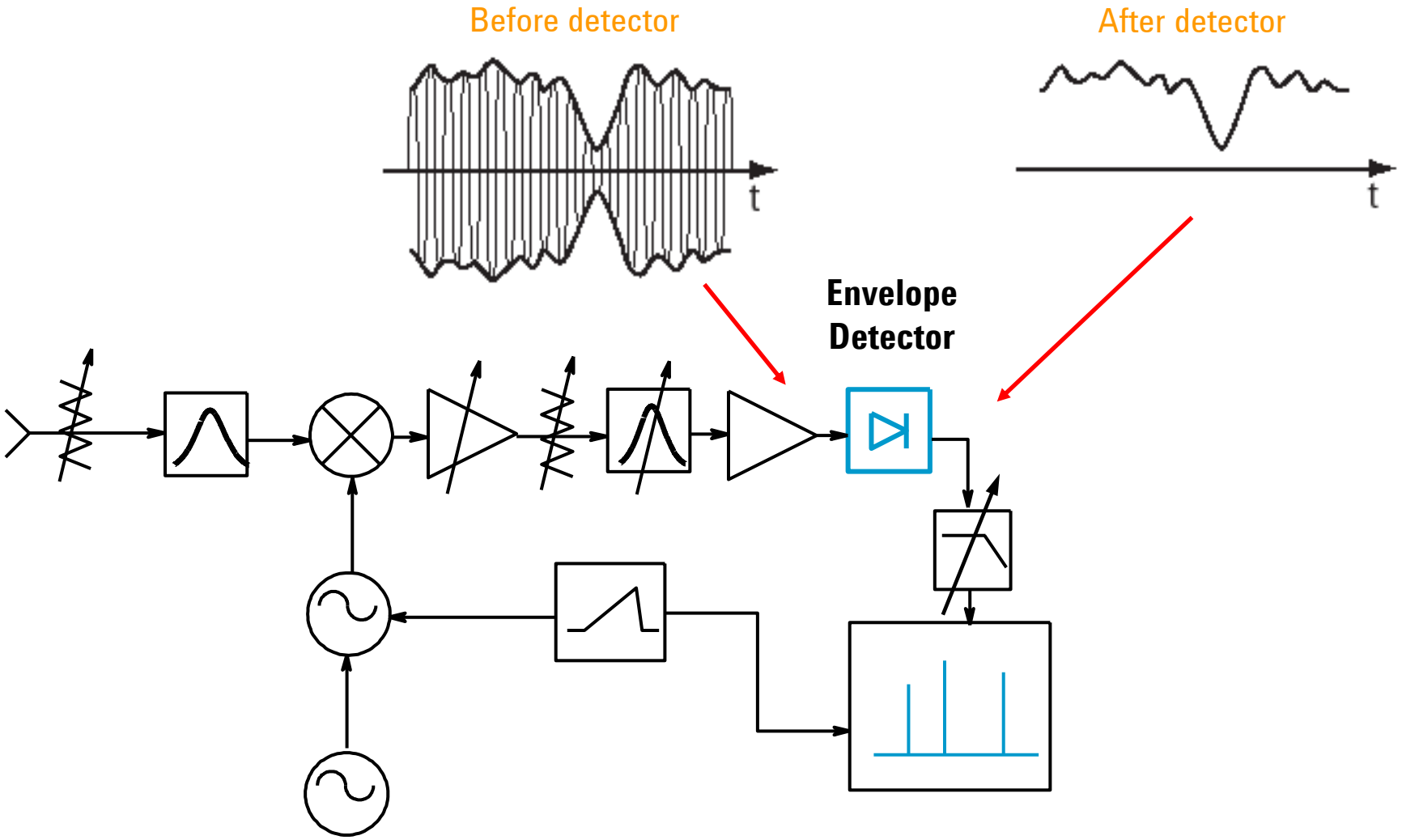
IF Filter (Resolution Bandwidth – RBW)





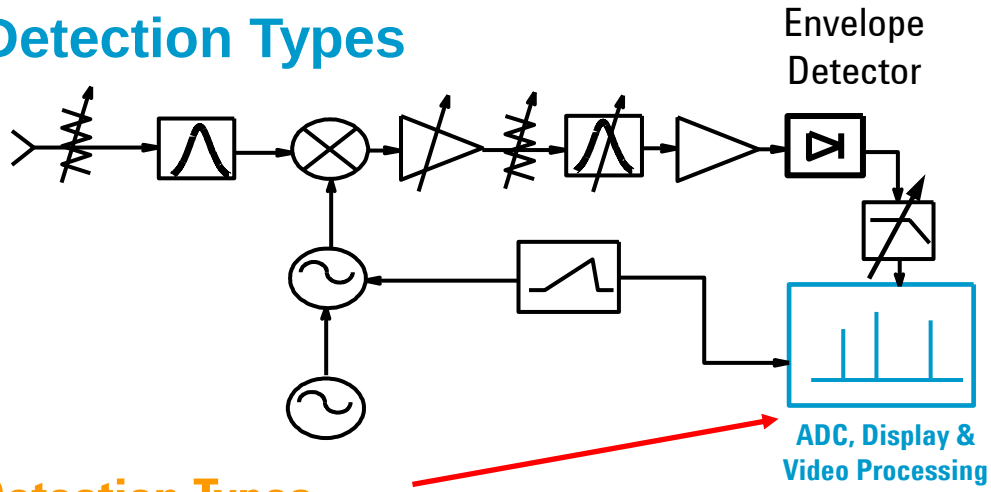
Theory of Operation

Envelope Detector

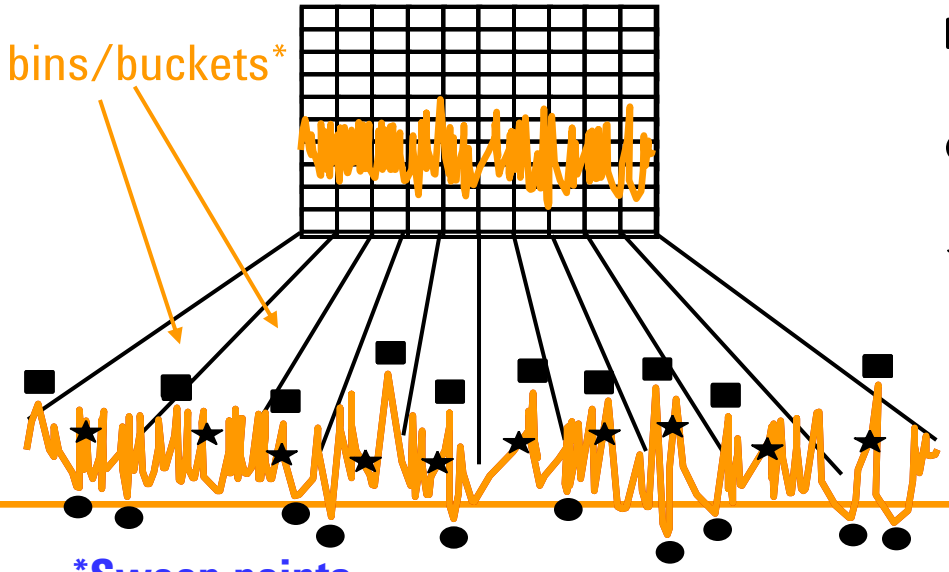


Theory of Operation

Envelope Detector and Detection Types



Digitally Implemented Detection Types

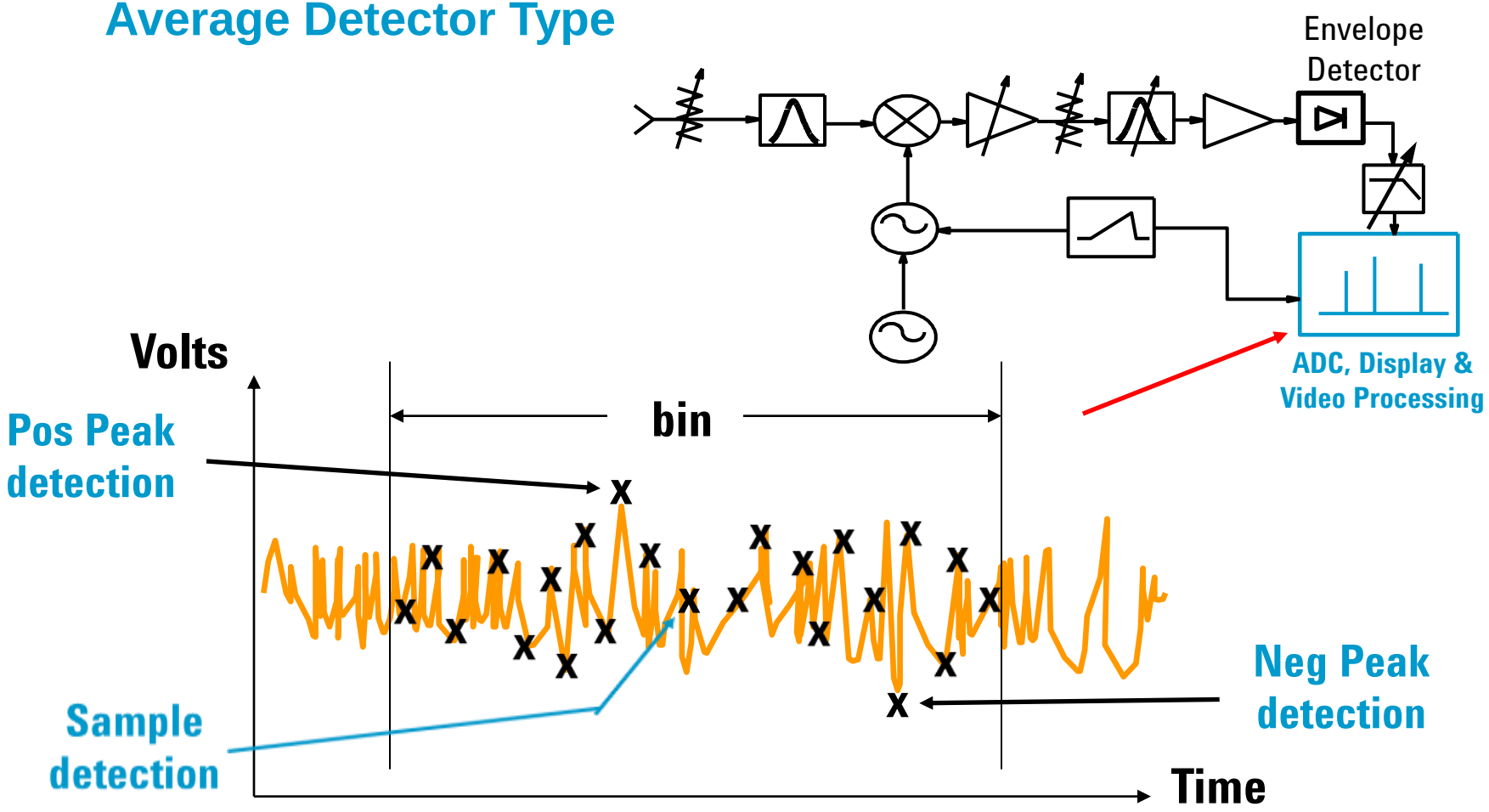


- ■ Positive detection: largest value in bin displayed
- ● Negative detection: smallest value in bin displayed
- ★ Sample detection: middle value in bin displayed

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

Theory of Operation

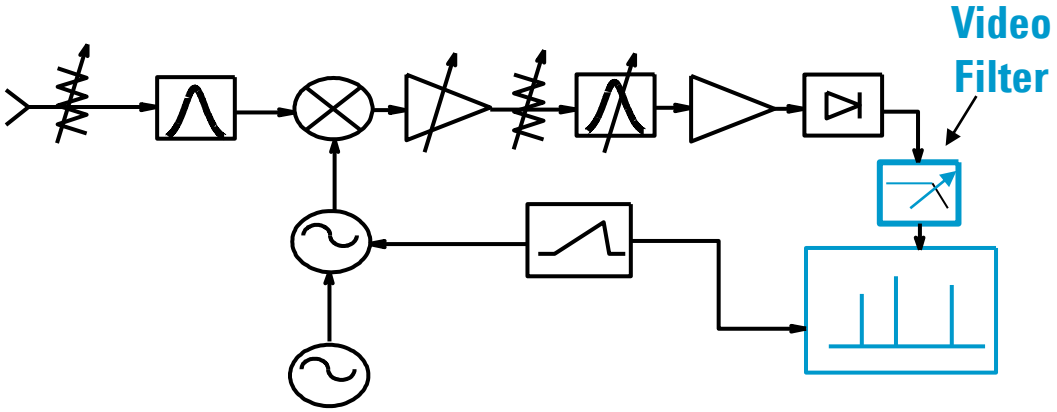
Average Detector Type

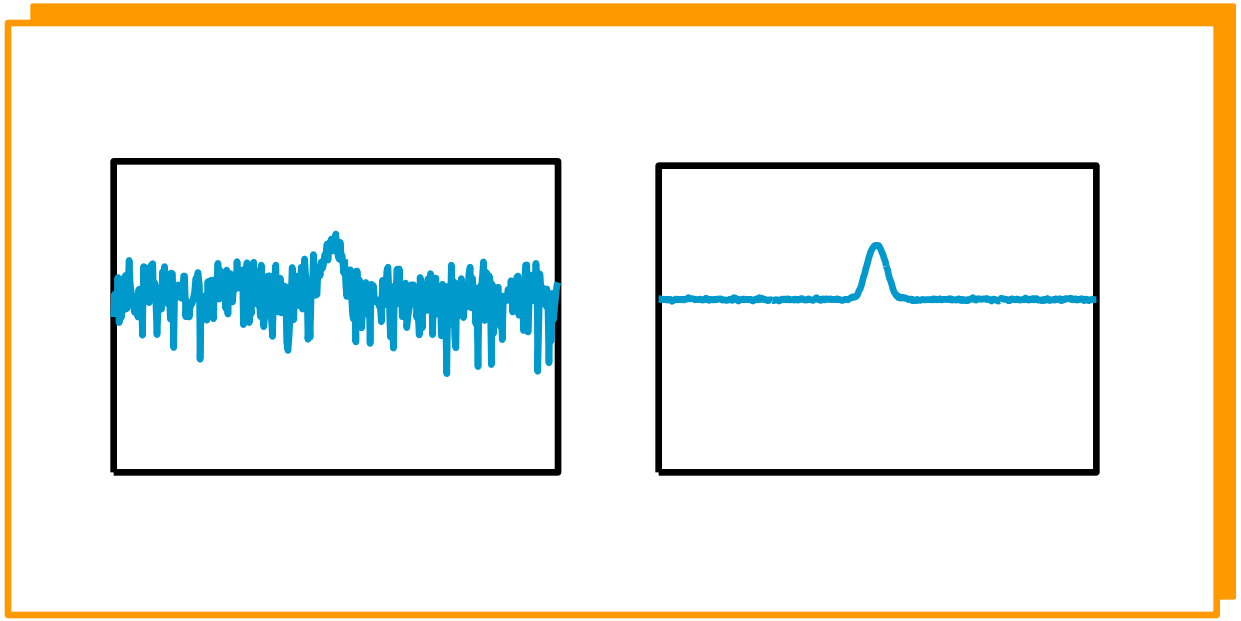


Power Average Detection (rms) = Square root of the sum of the squares of **ALL** of the voltage data values in the bin /50Ω

Theory of Operation

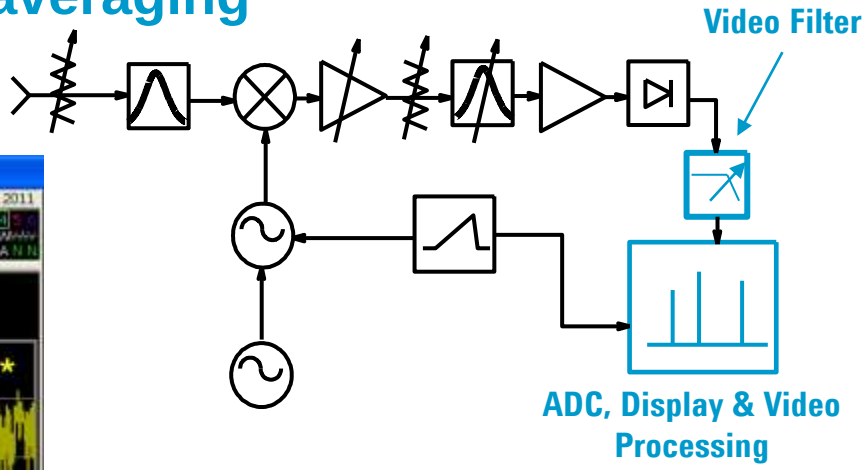
Video Filter (Video Bandwidth – VBW)





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

Agenda

Overview

Theory of Operation

Specifications:

- Which are important and why?

Modern spectrum analyzer designs & capabilities

  – Wide Bandwidth Vector Measurements

Wrap-up

Appendix

Key Specifications

- 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).**

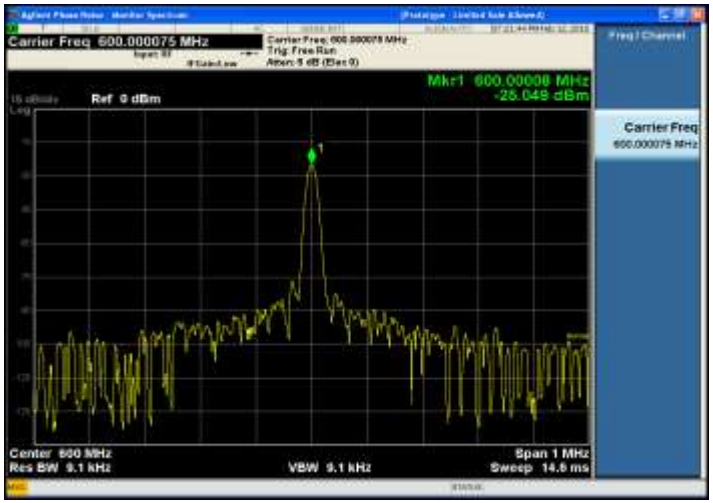
Typical **values describe additional product performance information that is not covered by the product warranty. It is performance beyond specification that 80 % of the units exhibit with a 95 % confidence level over the temperature range 20 to 30° C. Typical performance does not include measurement 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

Frequency Range

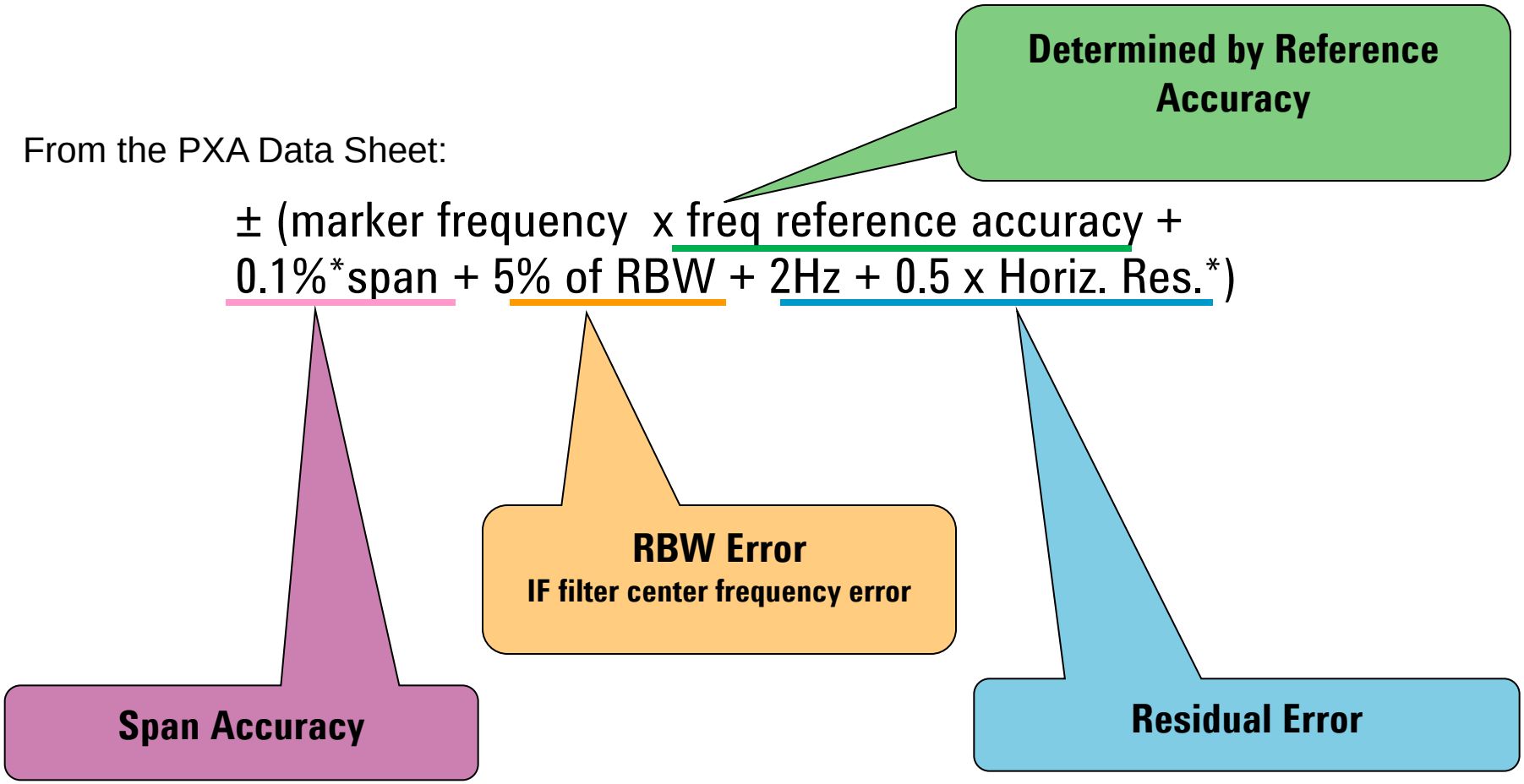
Description	Specifications
Internal Mixing	
Bands	
0	**3 Hz to 3.6 GHz**
1	**3.5 to 8.4 GHz**
2	**8.3 to 13.6 GHz**
3	**13.5 to 17.1 GHz**
4	**17 to 26.5 GHz**
5	**26.4 to 34.5 GHz**
6	**34.4 to 50 GHz**



Specifications

Accuracy: Frequency Readout Accuracy

- From the PXA Data Sheet:



*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:

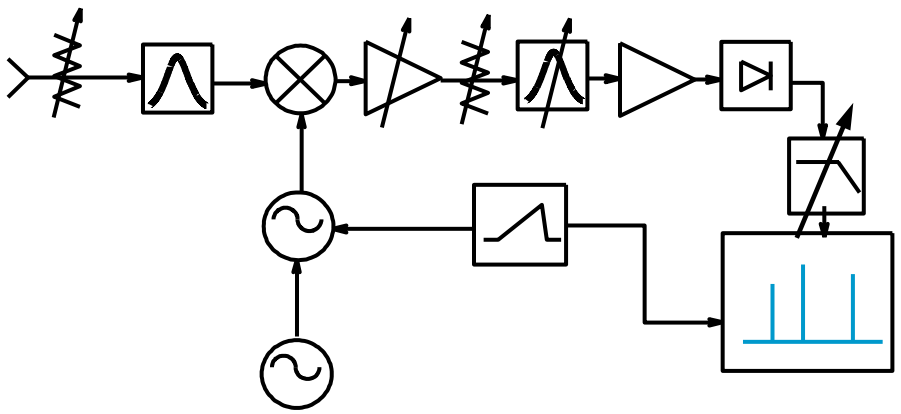
$(1 \times 10^{9}\text{Hz}) \times (\pm 1.55 \times 10^{-7}/\text{Year ref. Error})$	**= 155Hz**
400kHz Span x 0.1%	**= 400Hz**
3kHz RBW x 5%	**= 150Hz**
2Hz + 0.5 x 400kHz/(1000-1)	**= 202Hz**
Total uncertainty	**= ±907Hz**

*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

Amplitude Accuracy

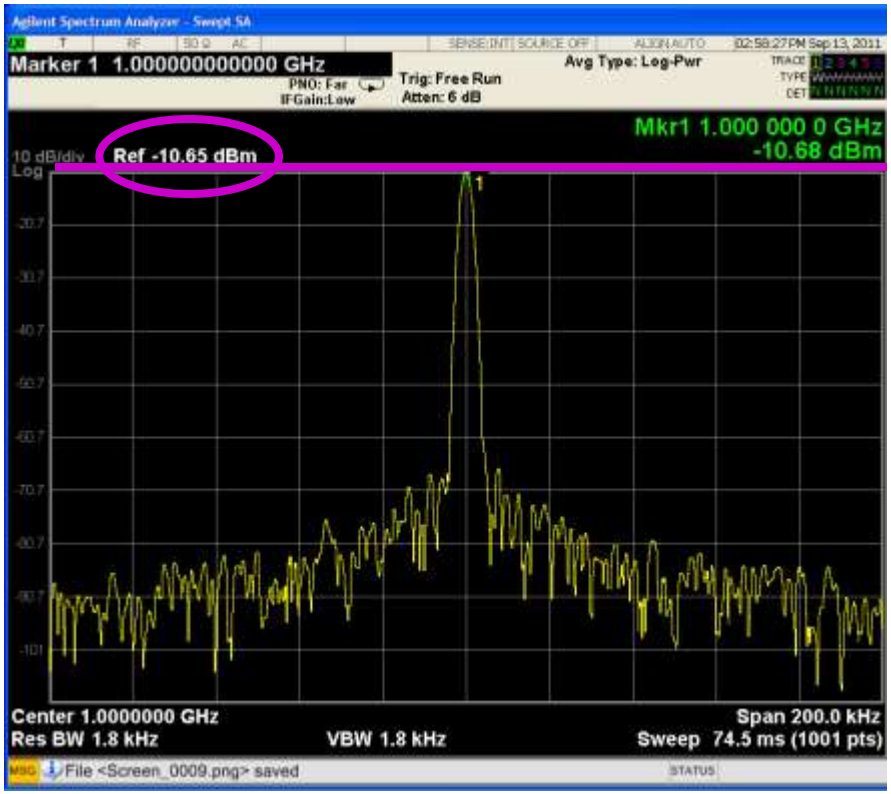


Components which contribute to uncertainty are:

- 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)
- Calibrator (amplitude accuracy)

Specifications

Amplitude Accuracy: Reference Level Switching



Uncertainty applies when changing the Ref. Level

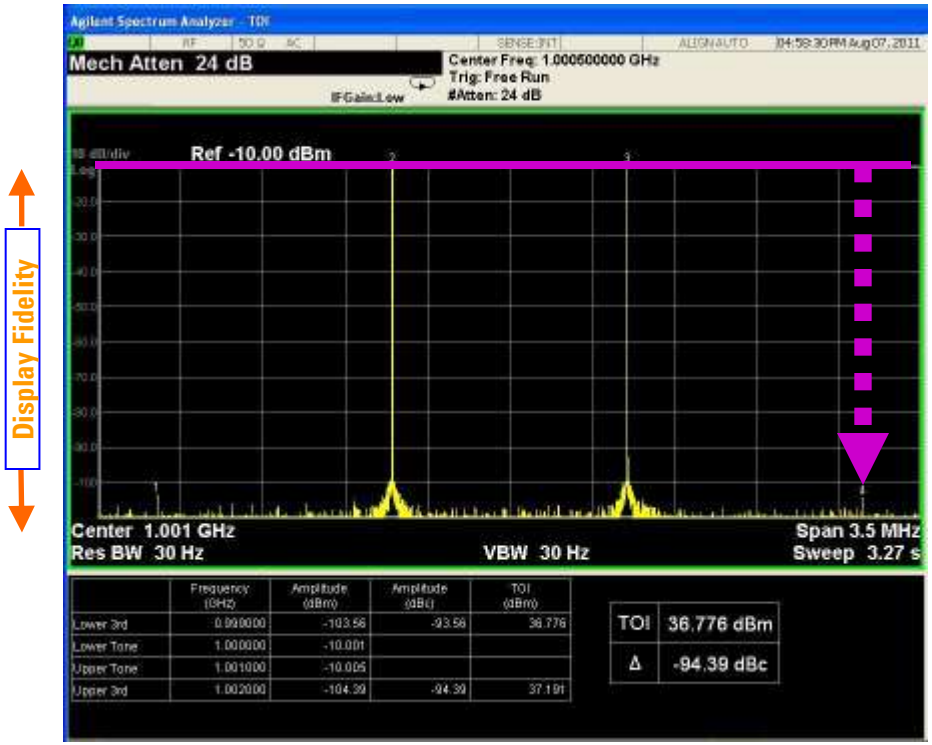
Also called IF Gain Uncertainty

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

Accuracy: Display Fidelity



Display Fidelity includes:

- Log Amp Fidelity
- Envelope Detector Linearity
- Digitizing Circuit Linearity

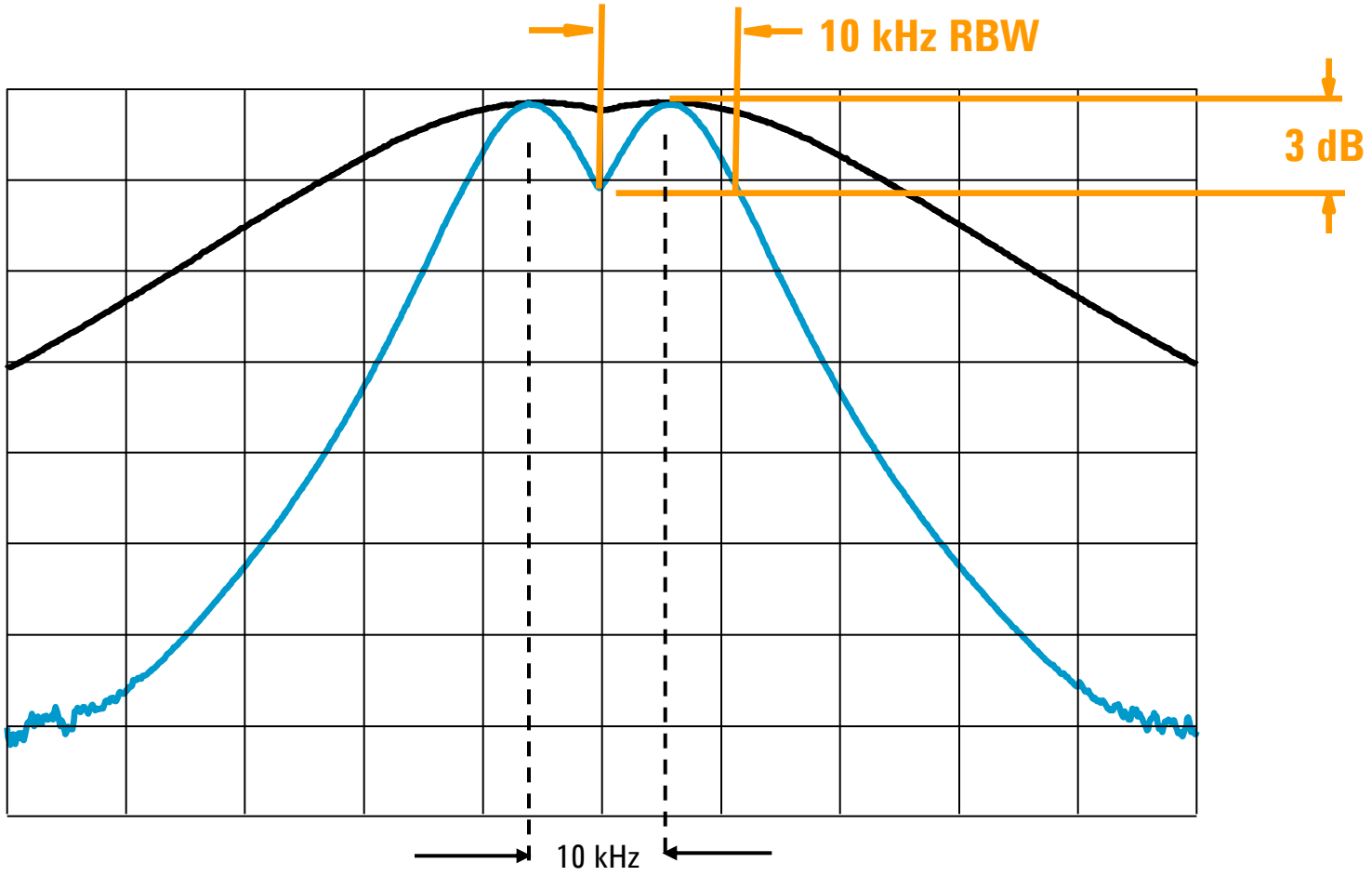
Display fidelity error applies when signals are not at the same reference level amplitude when measured

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

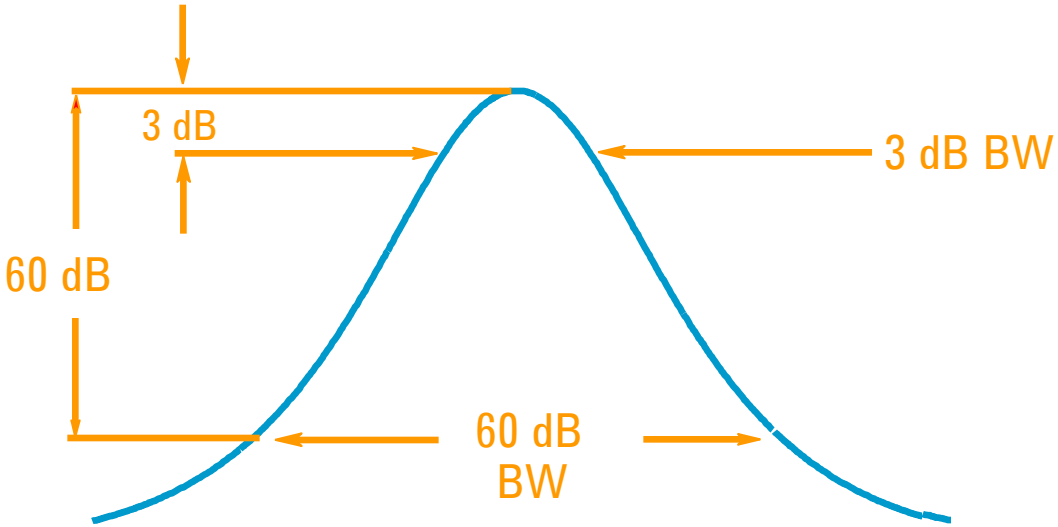
Resolution: Resolution BW



Determines resolvability of equal amplitude signals

Specifications

Resolution BW Selectivity or Shape Factor

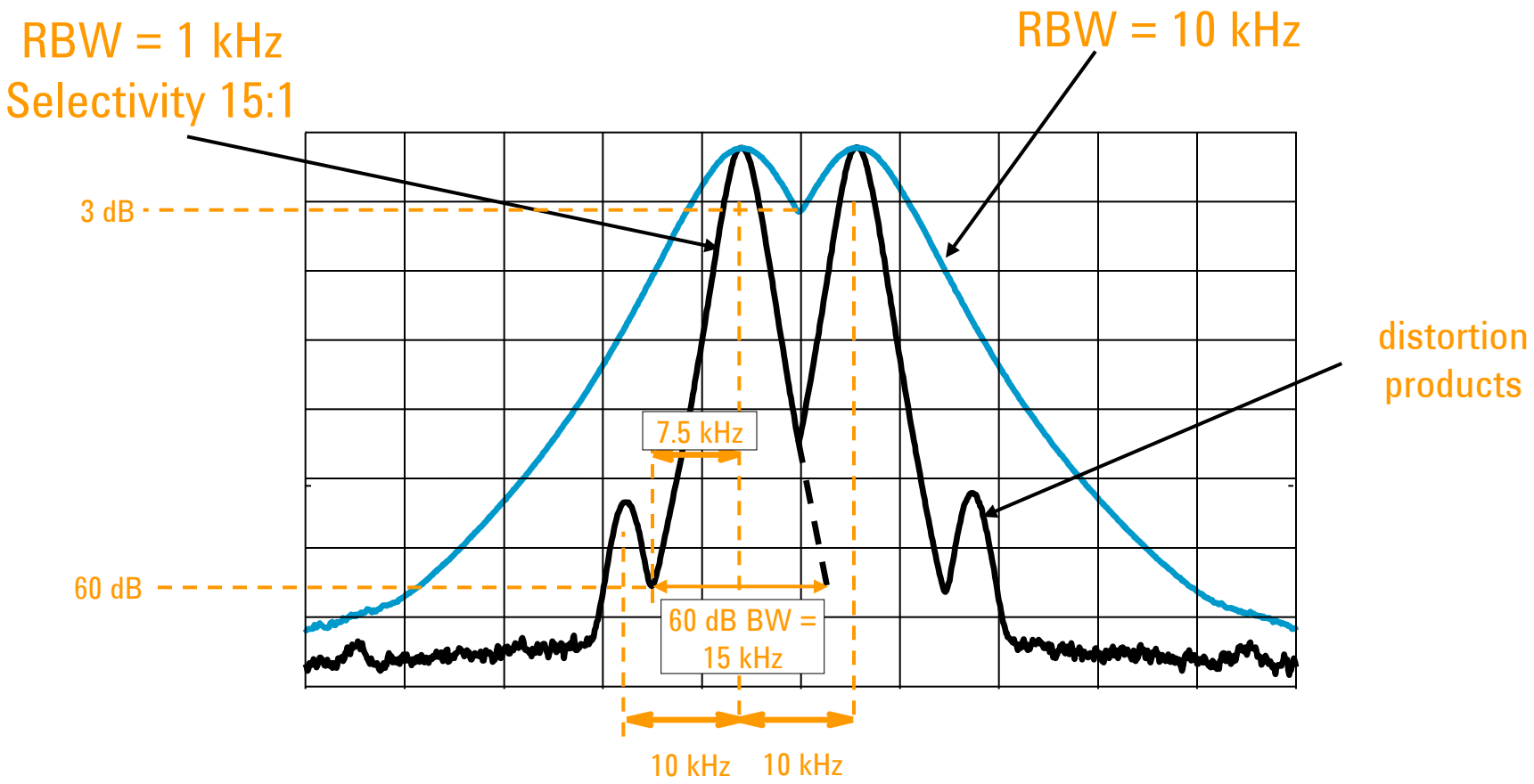


$$\text{Selectivity} = \frac{\text{60 dB BW}}{\text{3 dB BW}}$$

Determines resolvability of unequal amplitude signals

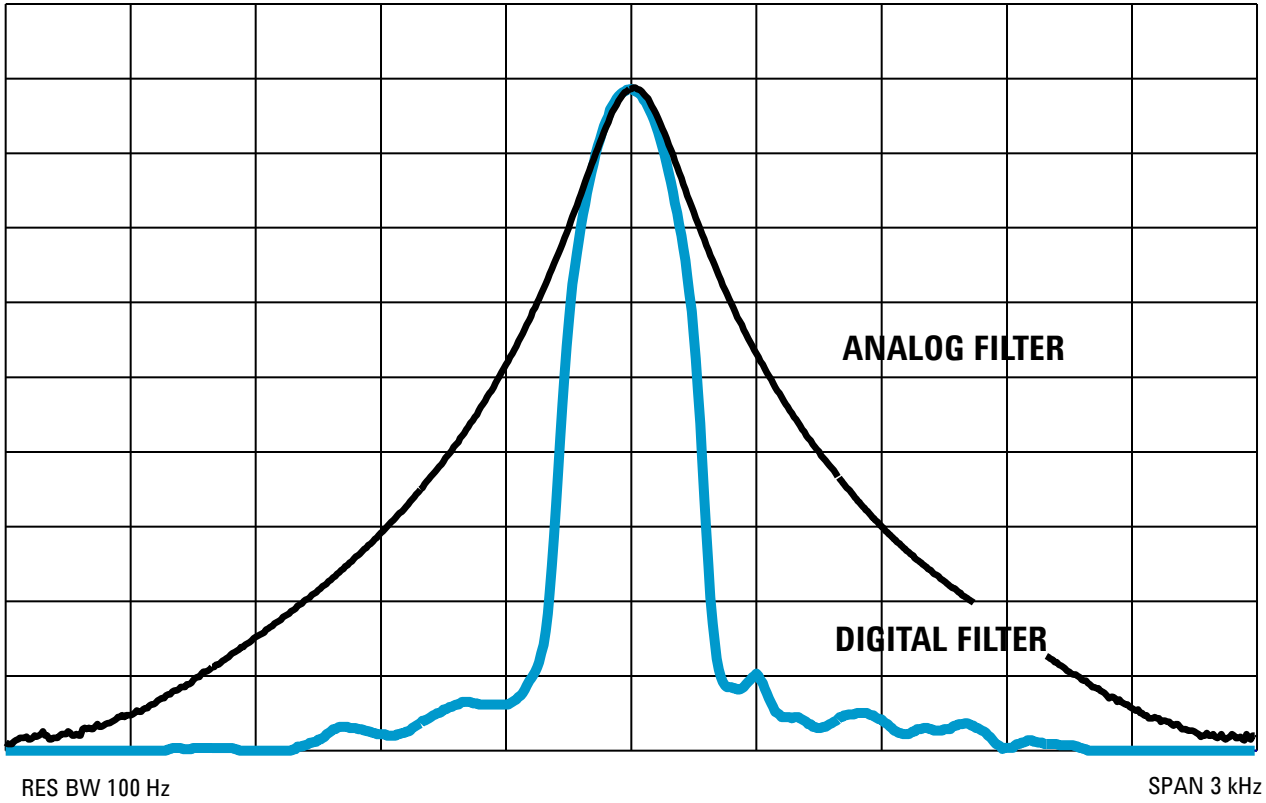
Specifications

Resolution BW Selectivity or Shape Factor



Specifications

Resolution: RBW Type and Selectivity



Typical Selectivity

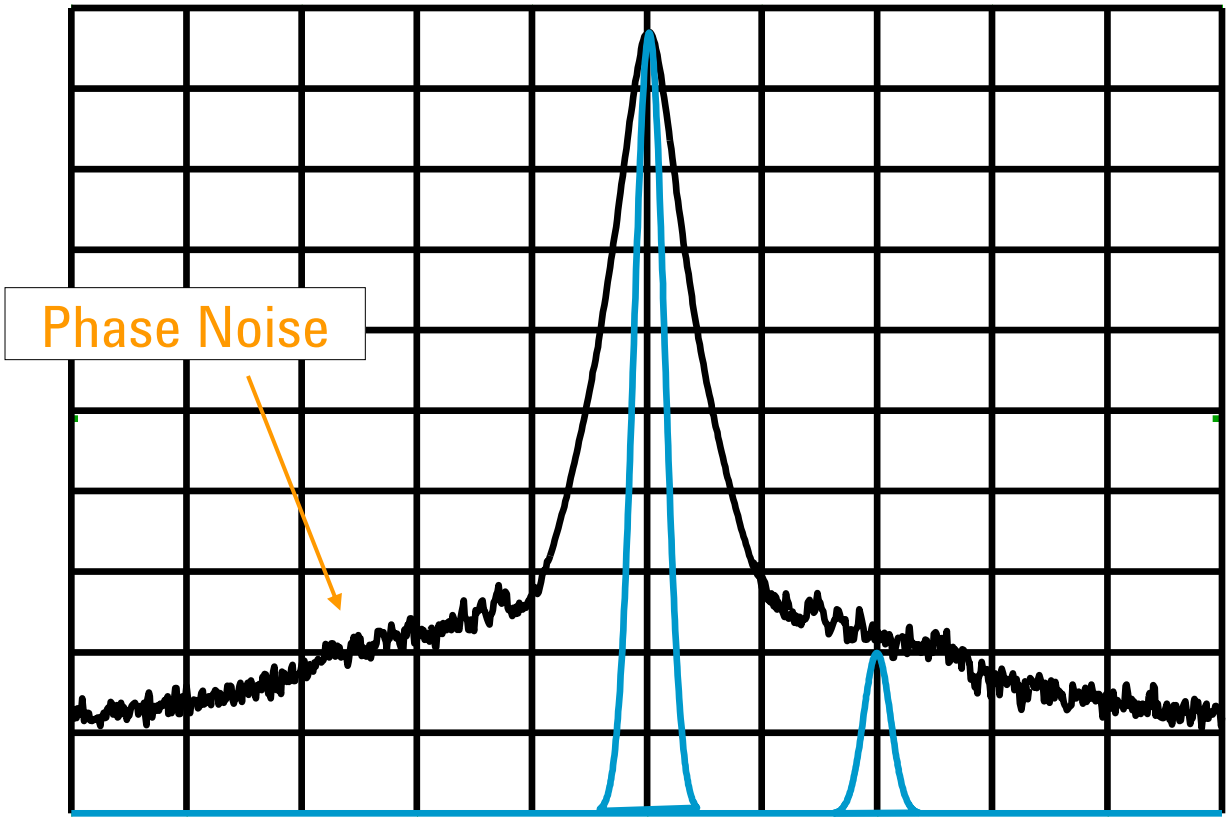
Analog 15:1

Digital ≤5:1

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

Specifications

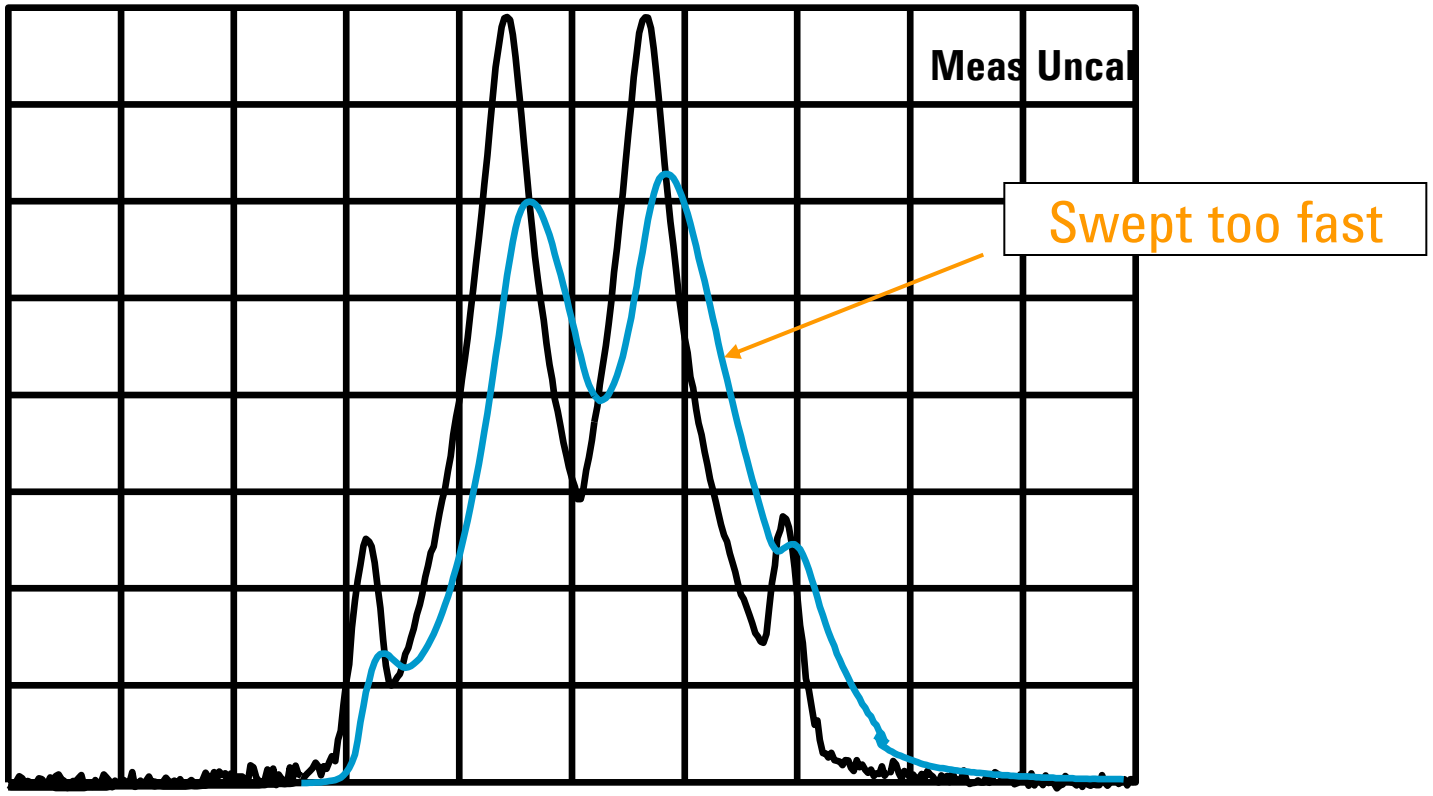
Resolution: Noise Sidebands



Noise Sidebands can prevent resolution of unequal signals

Specifications

Resolution: RBW Determines Sweep Time

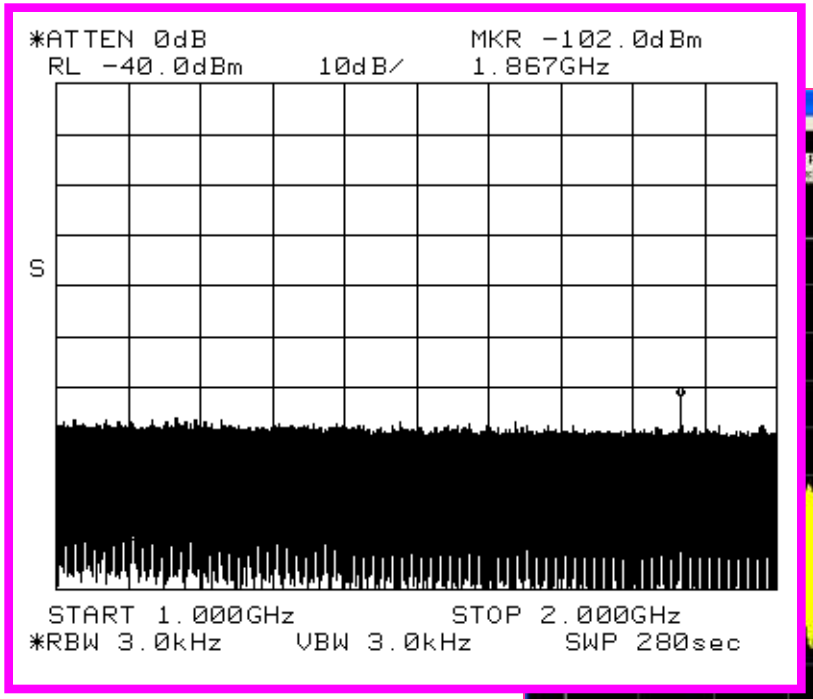


Penalty For Sweeping Too Fast
Is An Uncalibrated Display

Specifications

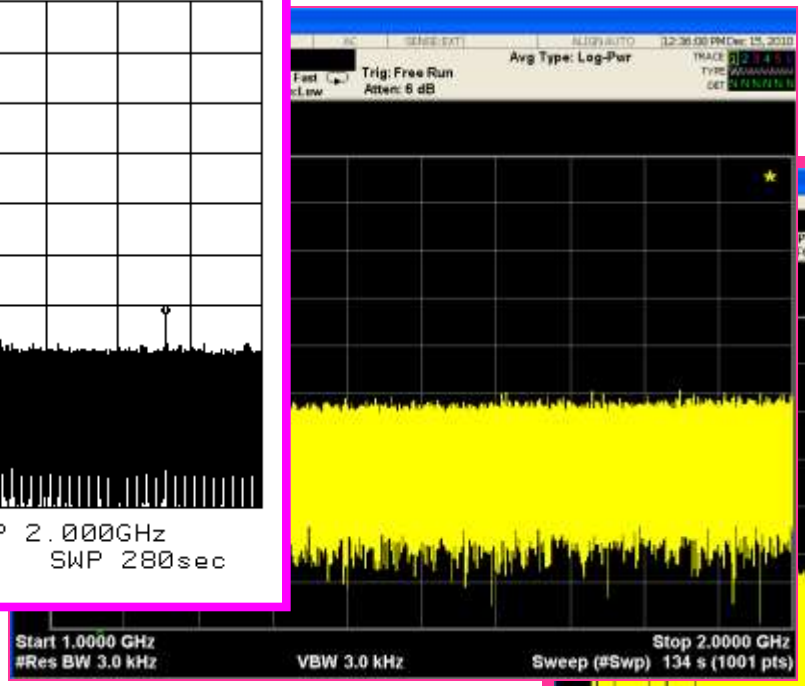
Resolution: RBW Type Determines Sweep Time

8563E Analog RBW



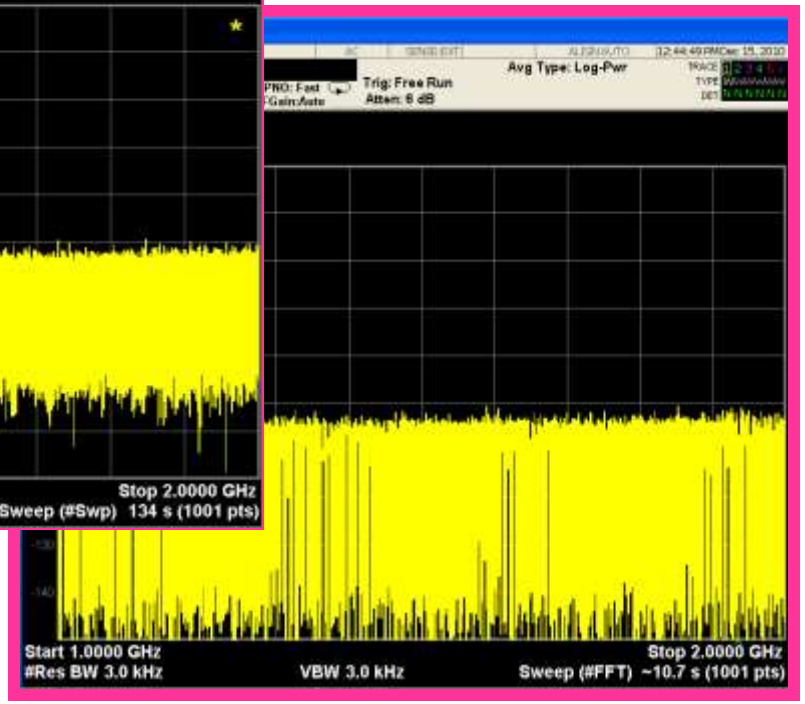
280 sec

PXA Swept RBW



134 sec

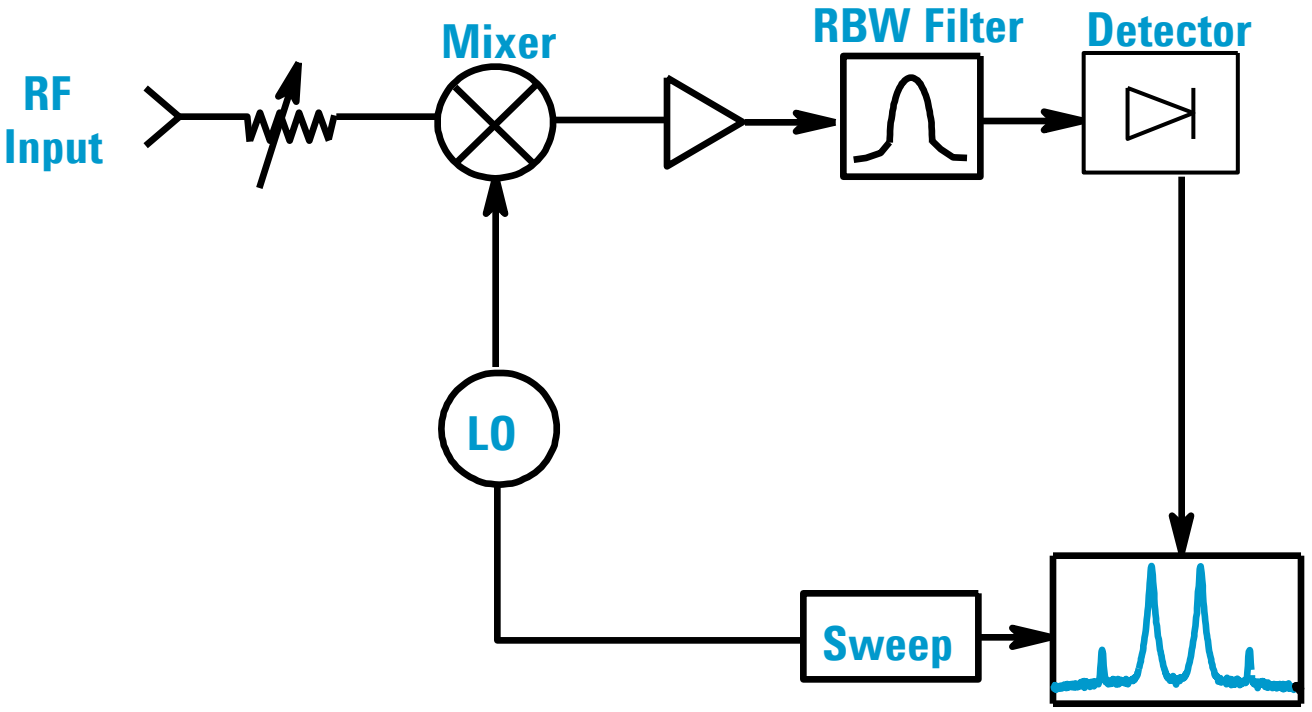
PXA FFT RBW



10.7 sec

Specifications

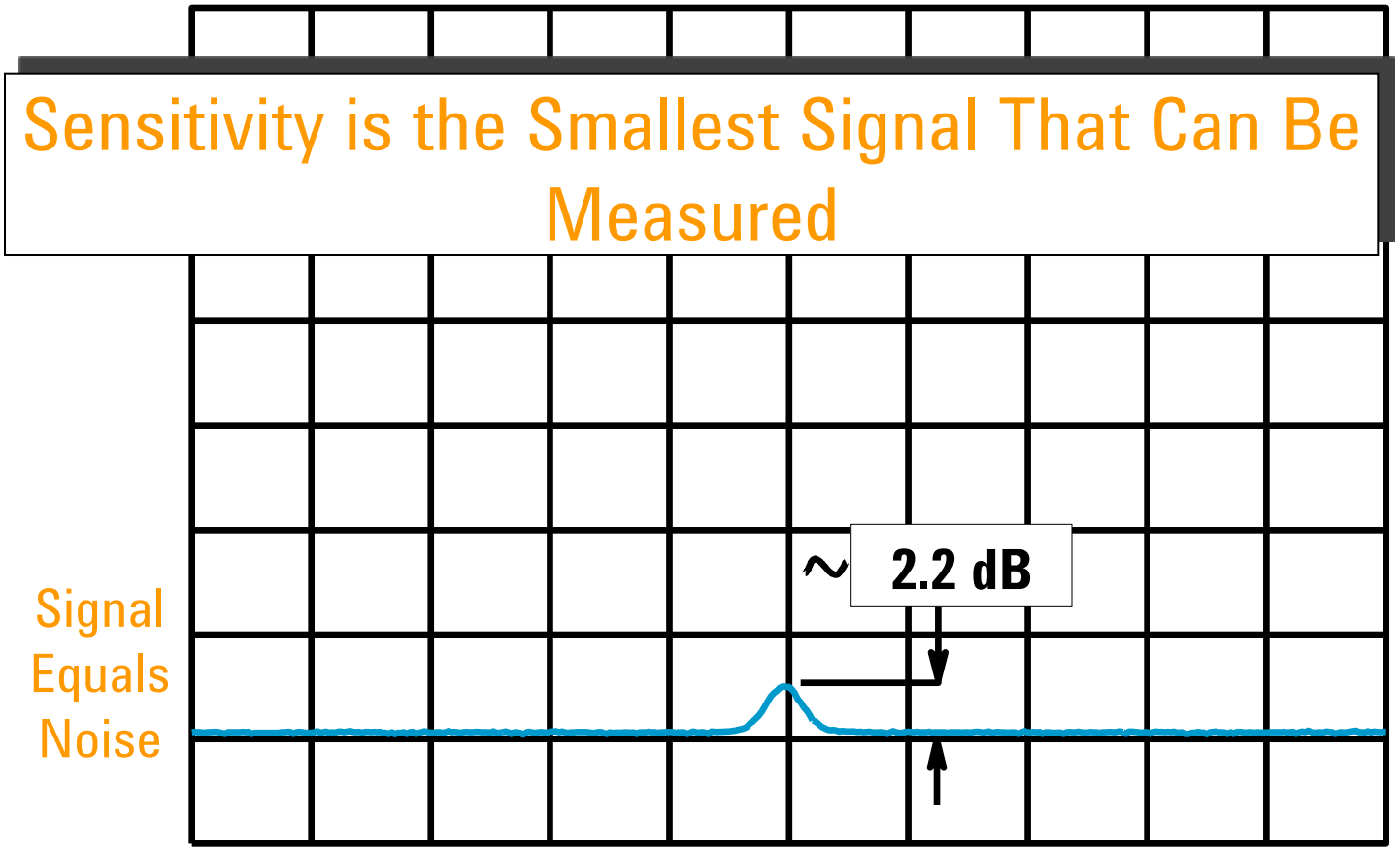
Sensitivity/DANL



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

Specifications

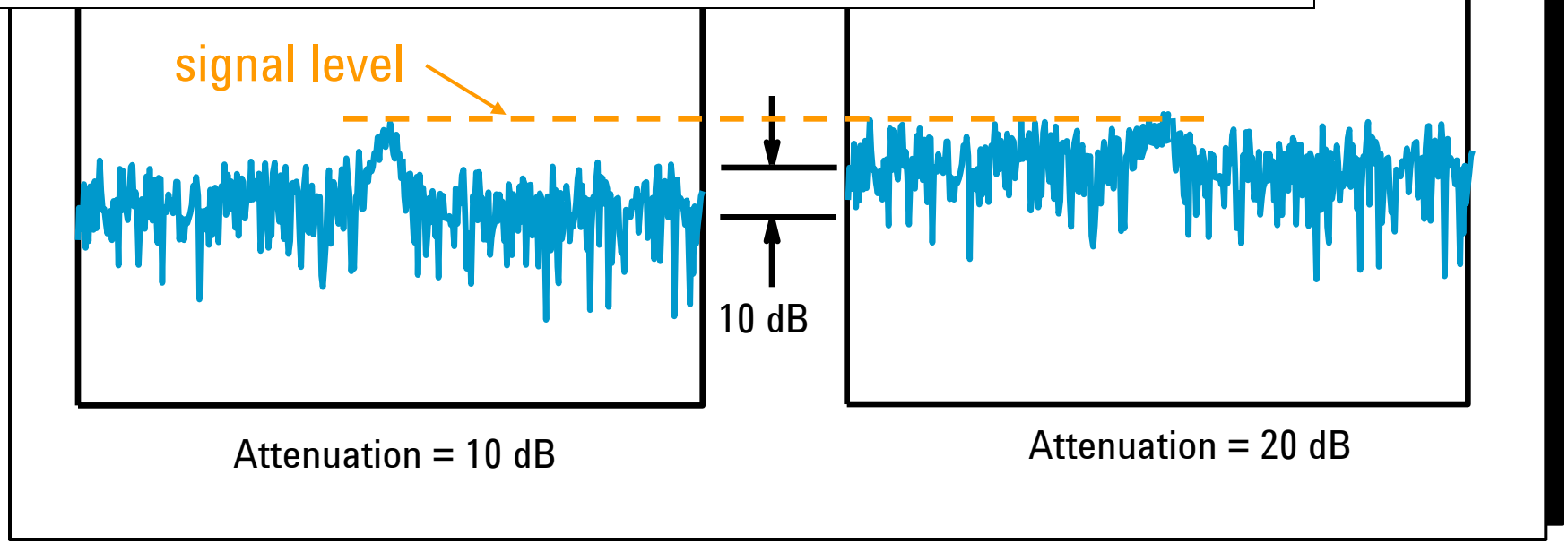
Sensitivity/DANL



Specifications

Sensitivity/DANL

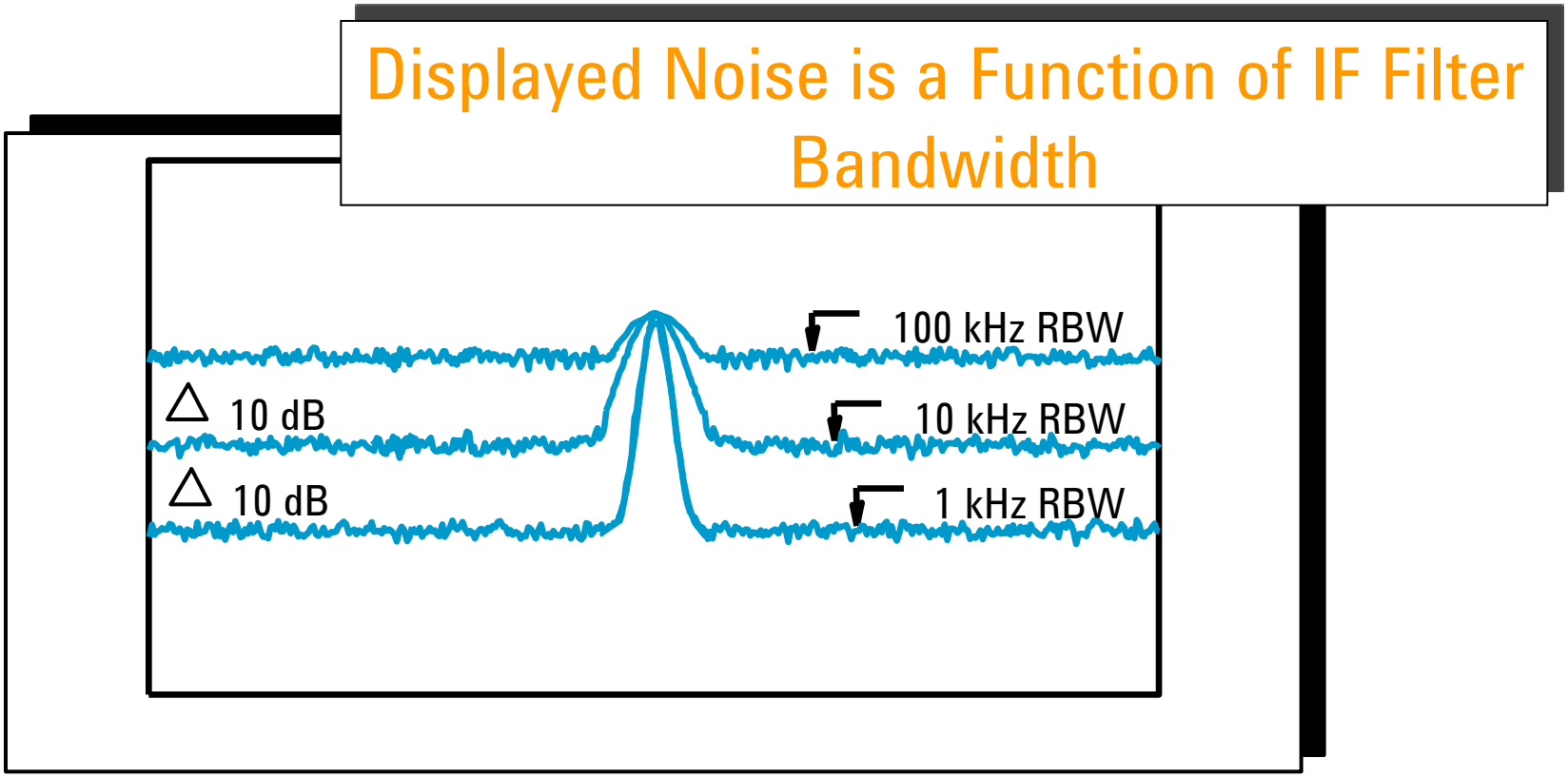
Effective Level of Displayed Noise is a Function of RF Input Attenuation



Signal To Noise Ratio Decreases as RF Input Attenuation is Increased

Specifications

Sensitivity/DANL: IF Filter(RBW)

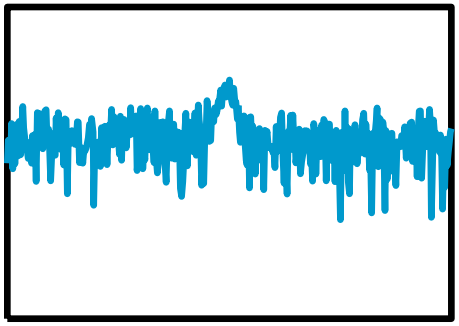


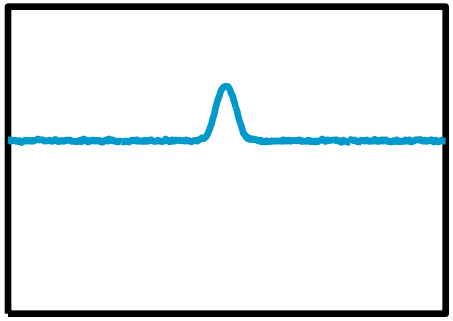
Decreased BW = Decreased Noise

Specifications

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

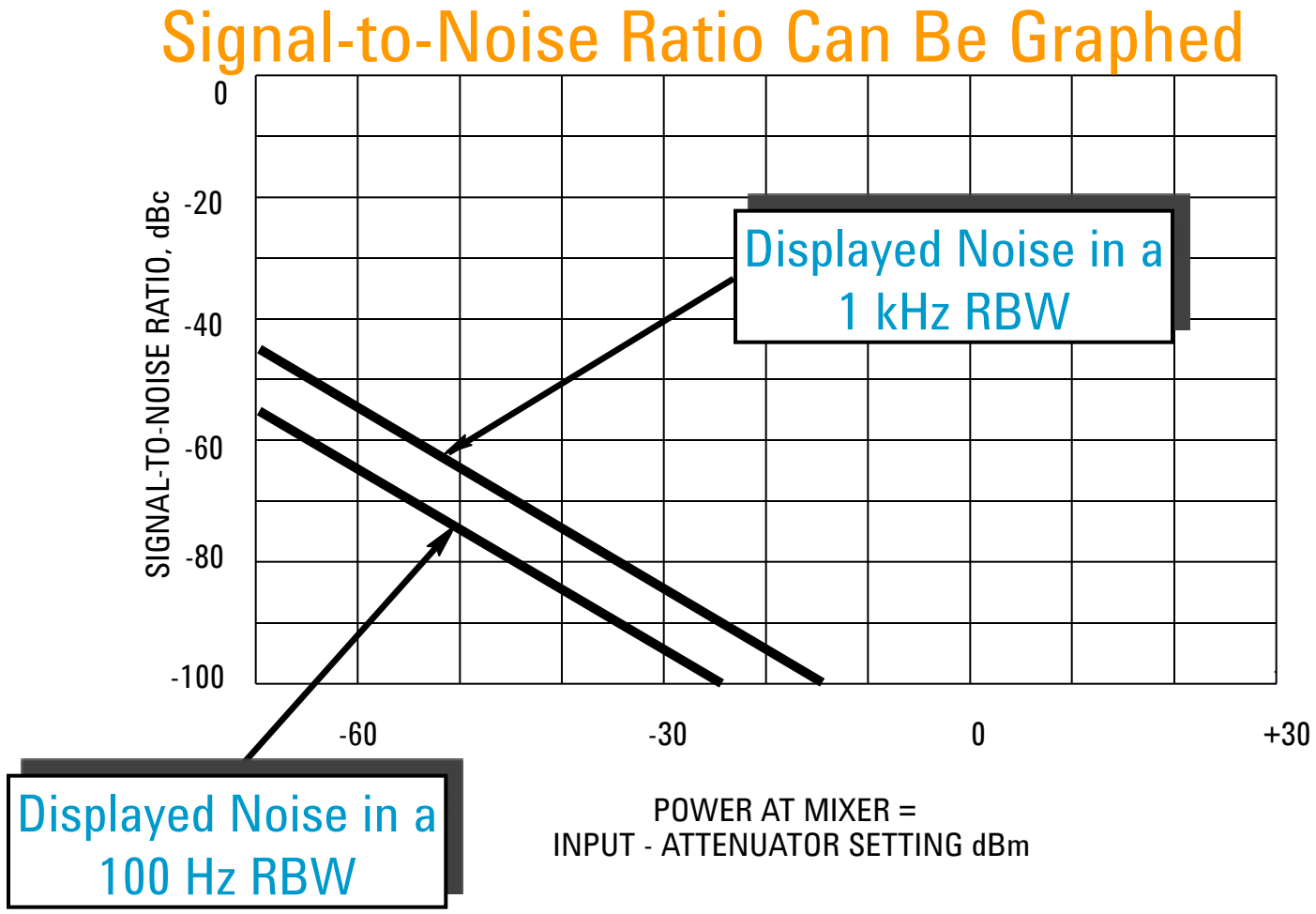
Video BW or Trace Averaging Smoothes Noise for Easier Identification of Low Level Signals





Specifications

Sensitivity/DANL:



Specifications

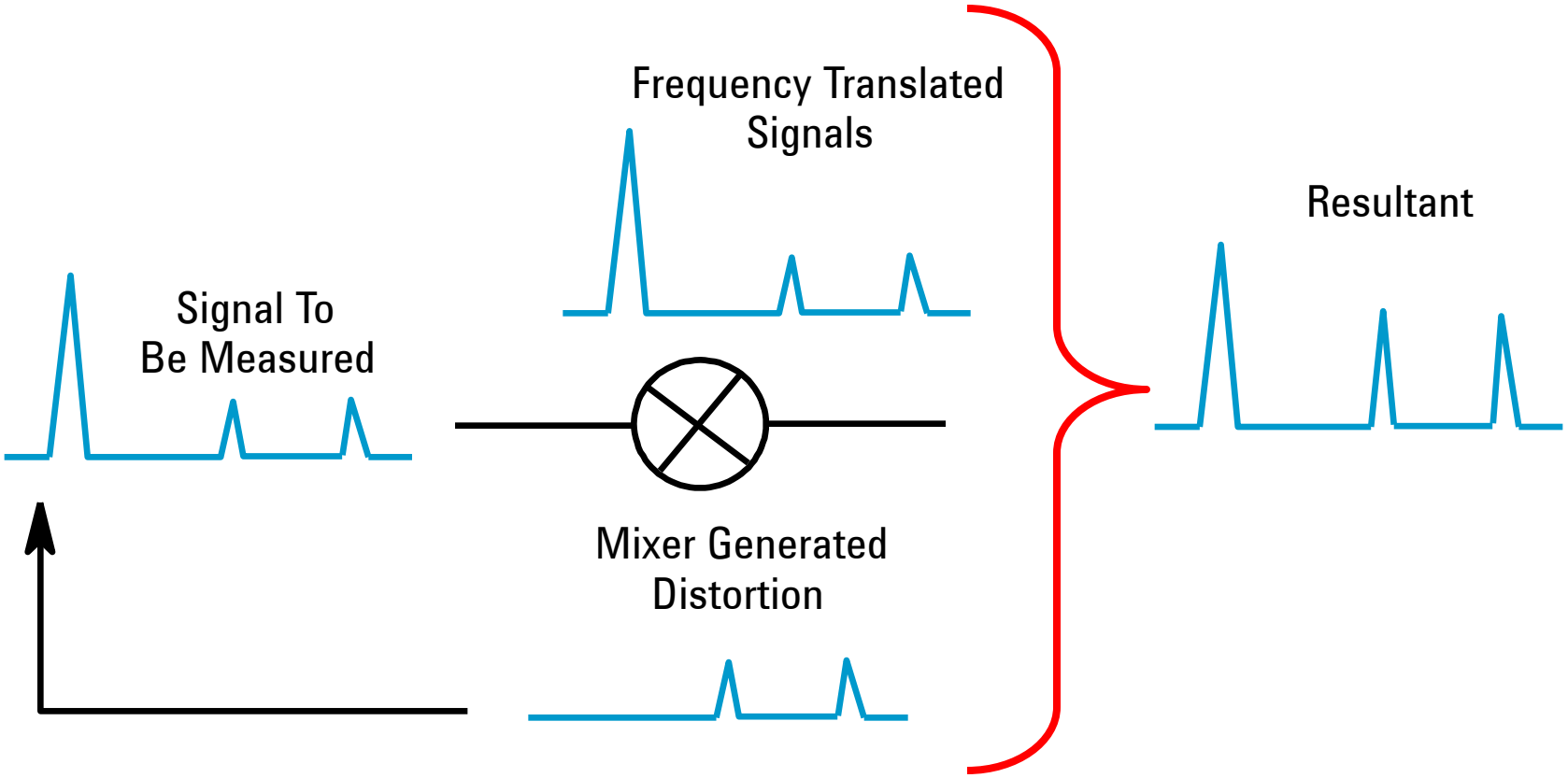
Sensitivity/DANL: Summary

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 only)
- Noise Floor Extension (PXA only)

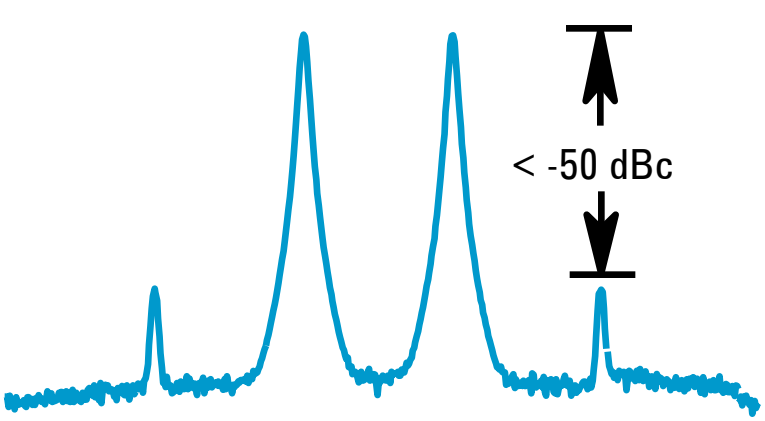
Specifications
Distortion

Mixers Generate Distortion

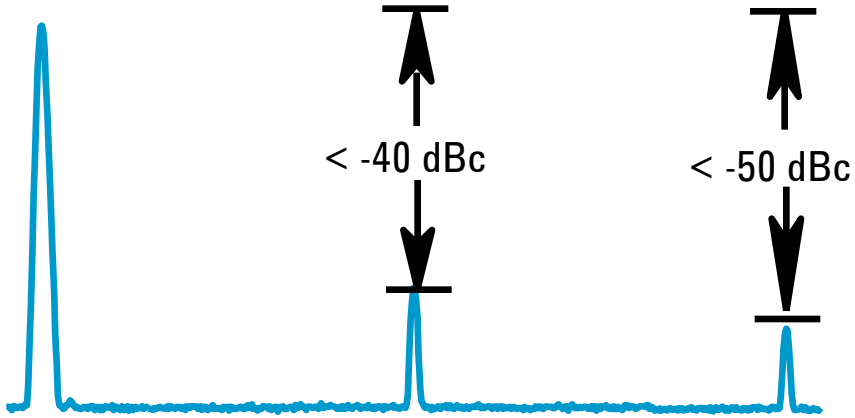


Specifications
Distortion

Most Influential Distortion is the Second and Third Order



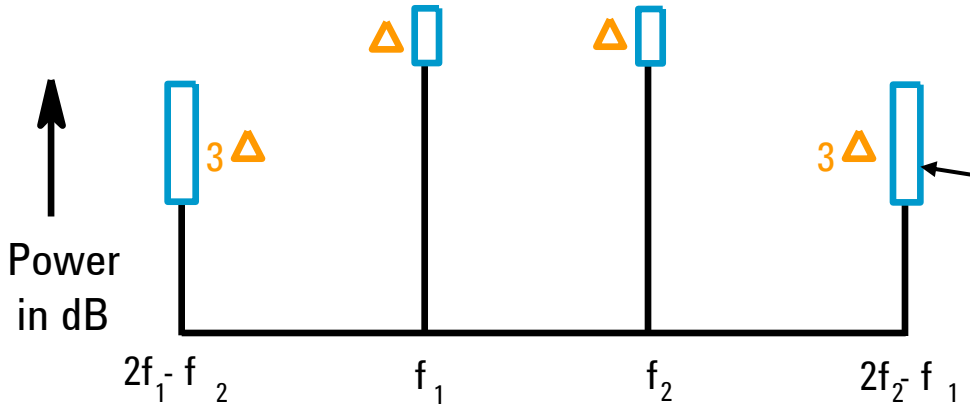
Two-Tone Intermod



Harmonic Distortion

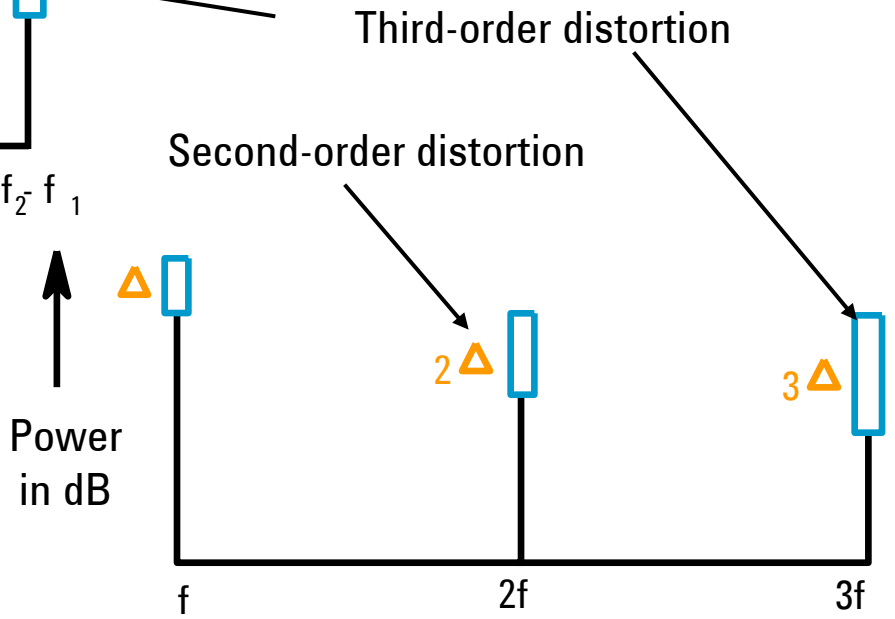
Specifications
Distortion

Distortion Products Increase as a Function of Fundamental's Power



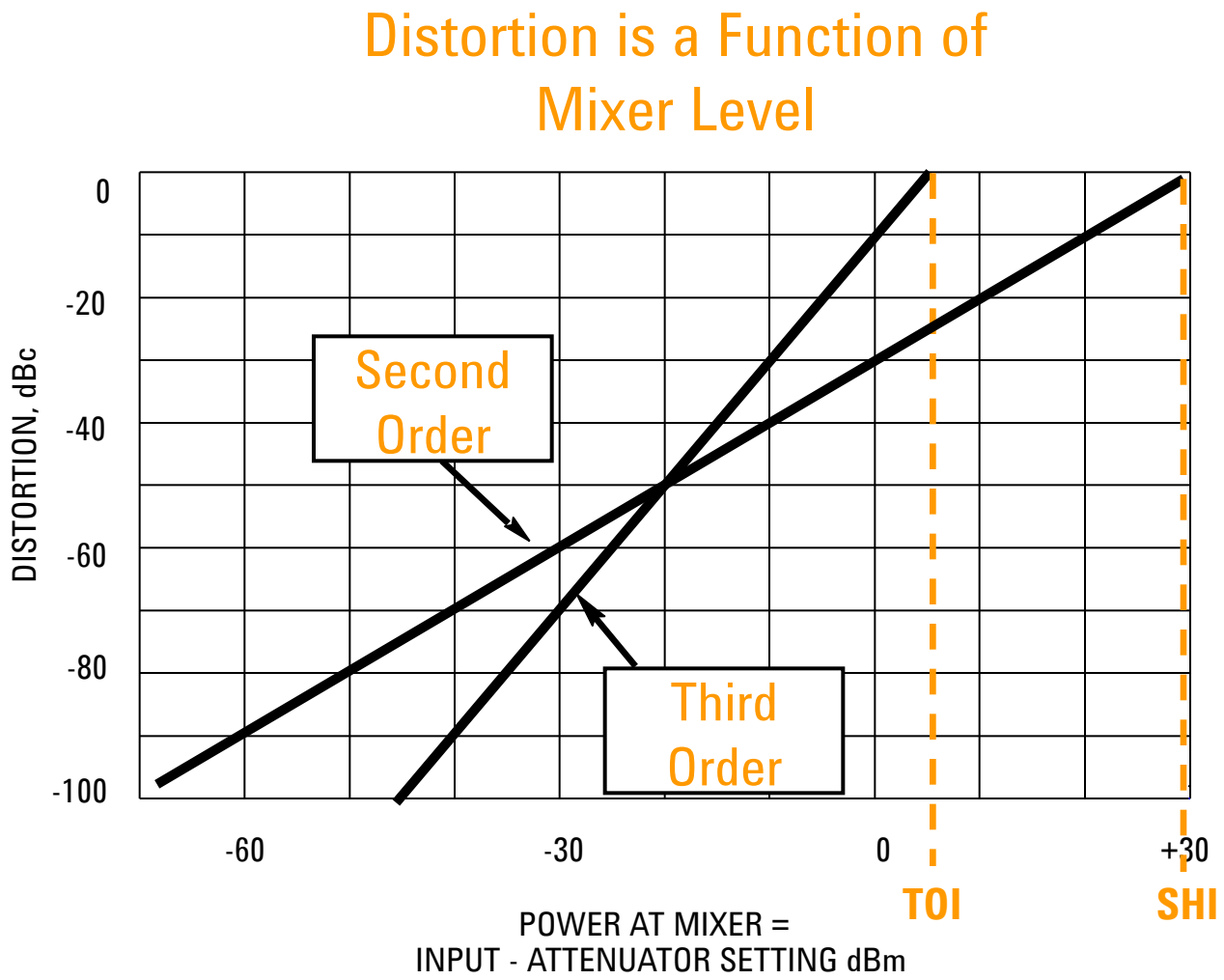
Two-Tone Intermod

Second Order: △2 dB/dB of Fundamental
Third Order: △3 dB/dB of Fundamental



Harmonic Distortion

Specifications
Distortion



Specifications

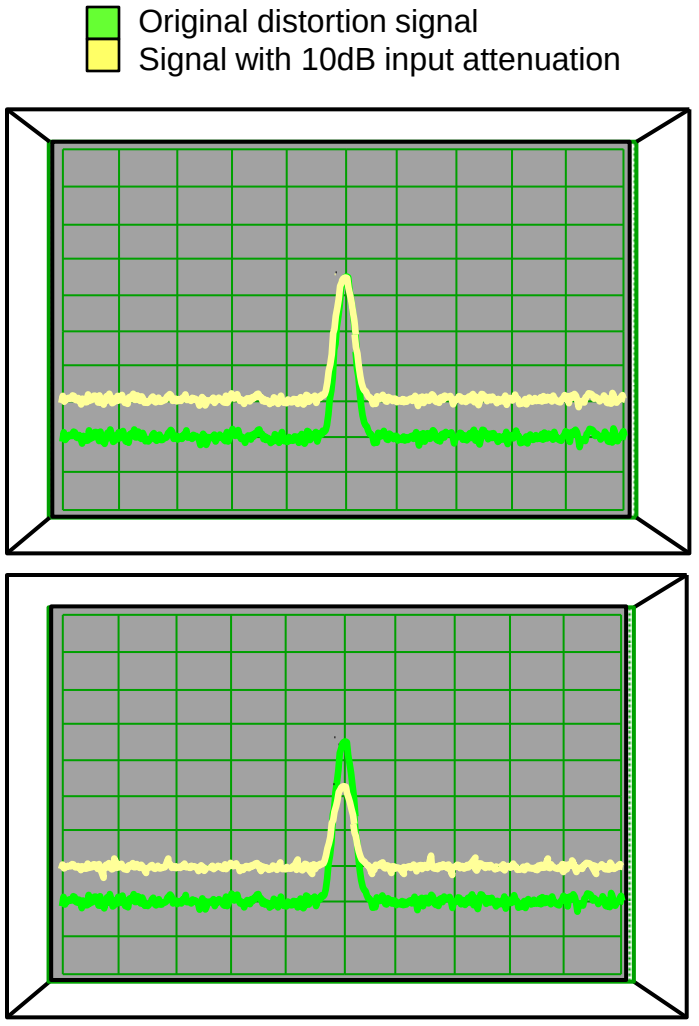
Distortion – Internal or External?

Attenuator Test:
Change power to the mixer

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

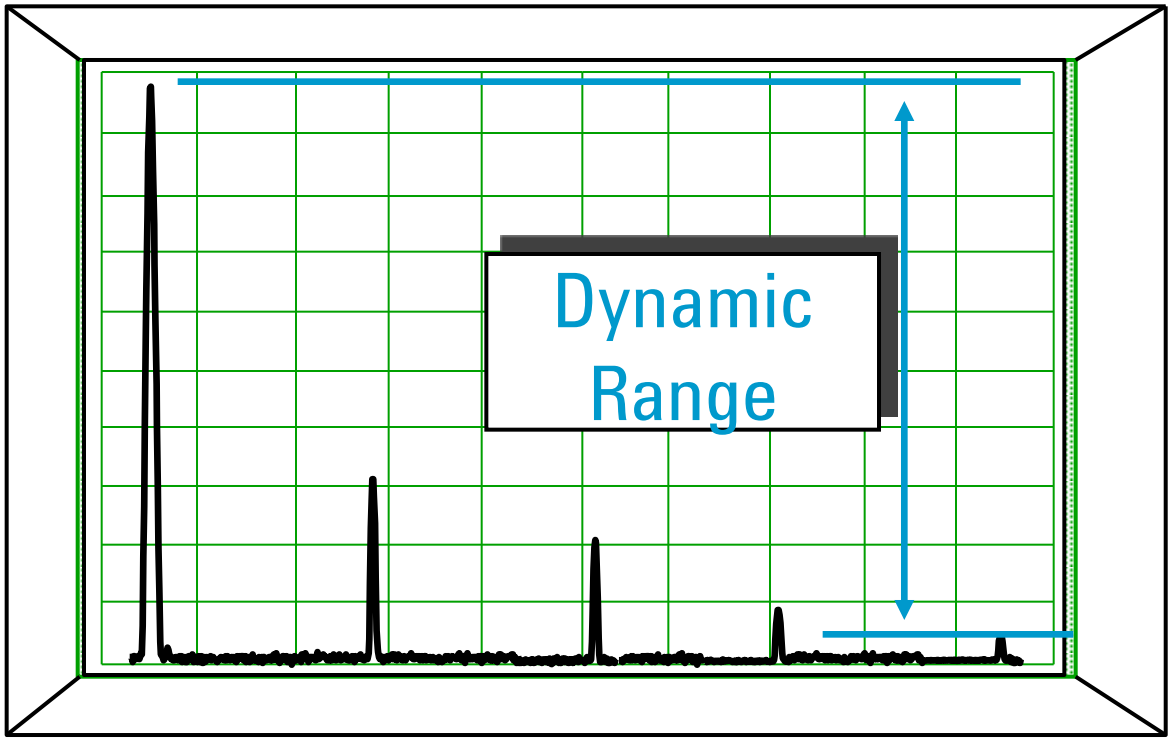
No change in amplitude: distortion is part of input signal (external)

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



Specifications

Spectrum Analyzer Dynamic Range

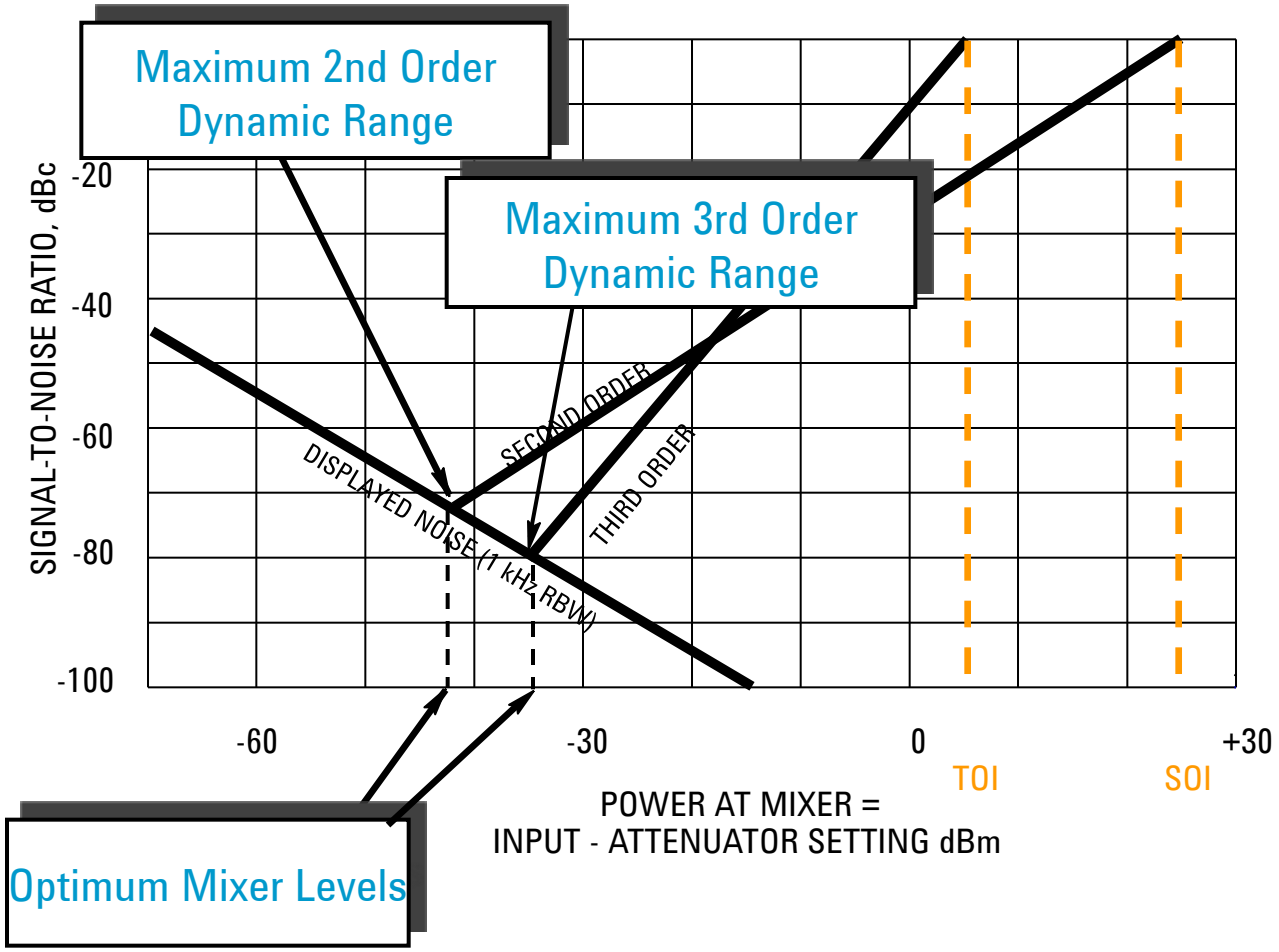


The ratio, expressed in dB, of the largest to the smallest signals simultaneously present at the input of the spectrum analyzer that allows measurement of the smaller signal to a given degree of uncertainty.

Specifications

Dynamic Range

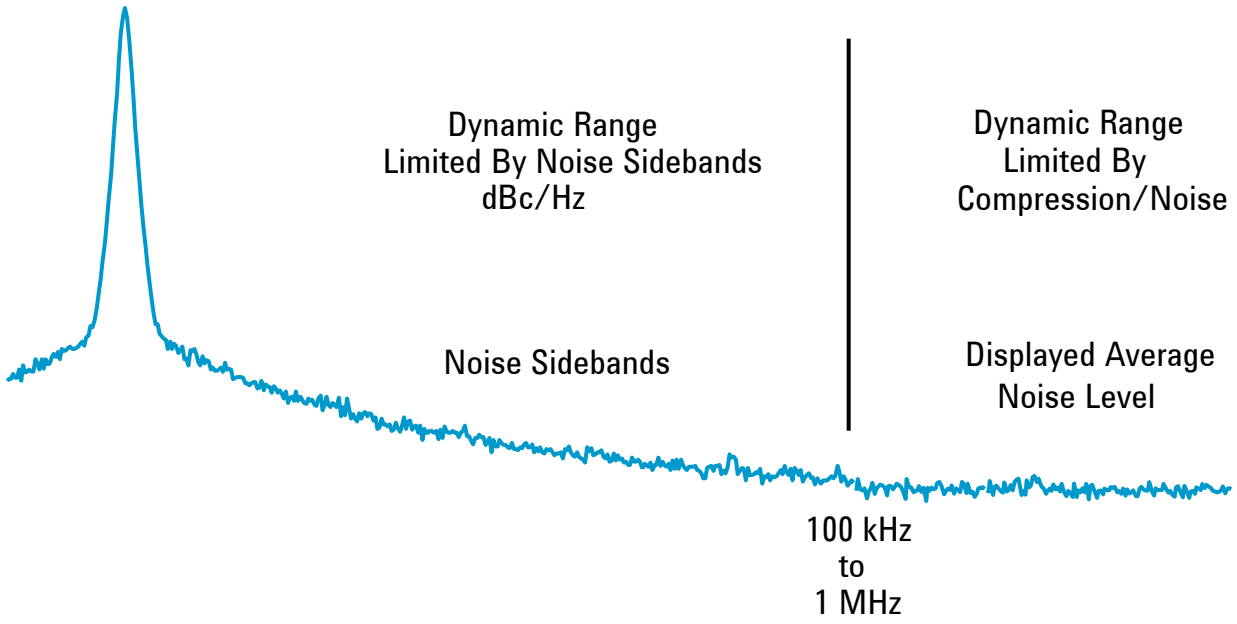
Dynamic Range Can Be Presented Graphically



Specifications

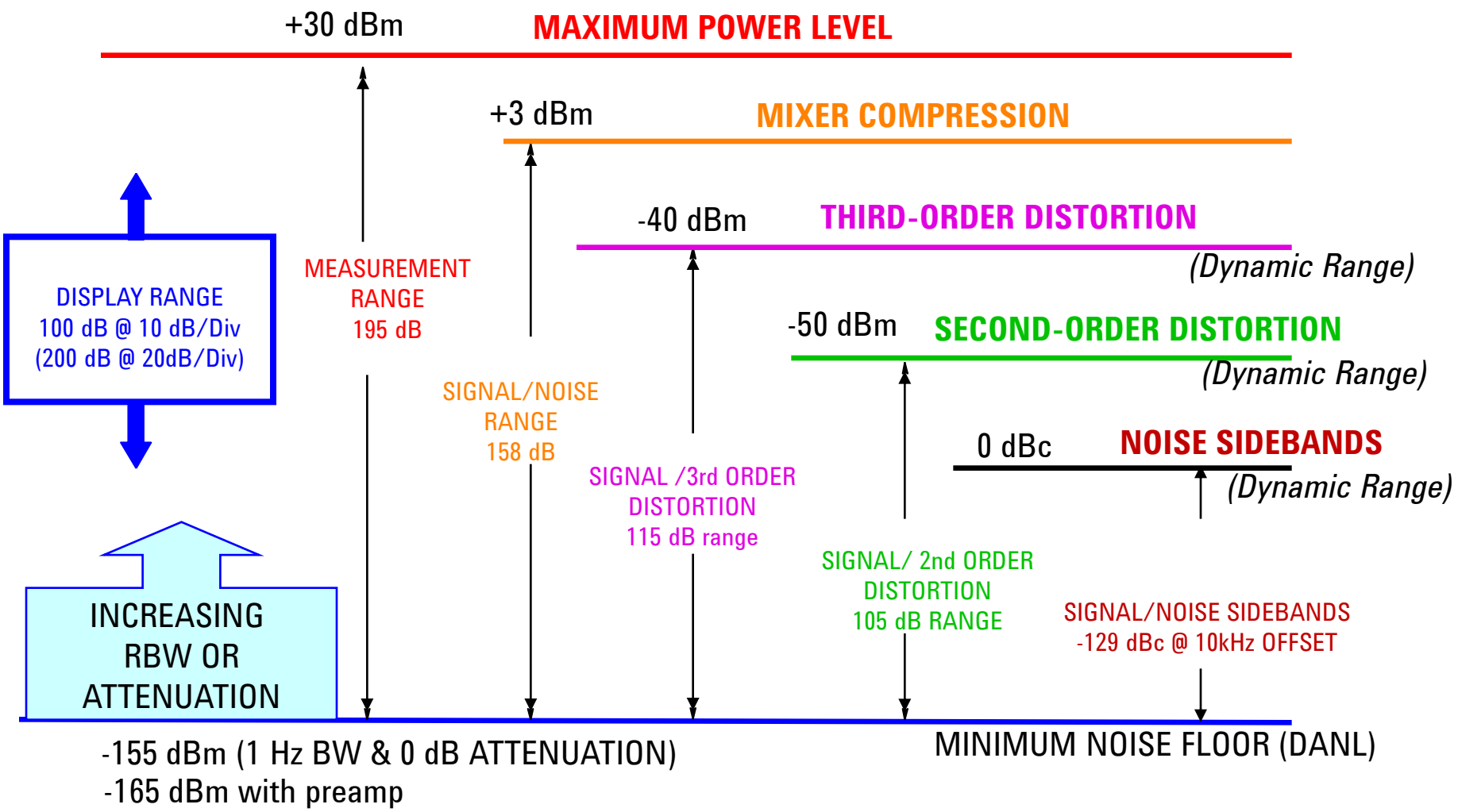
Dynamic Range

Dynamic Range for Spur Search Depends on Closeness to Carrier



Specifications

Dynamic Range 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

Agenda

Introduction

Overview

Theory of Operation

Specifications

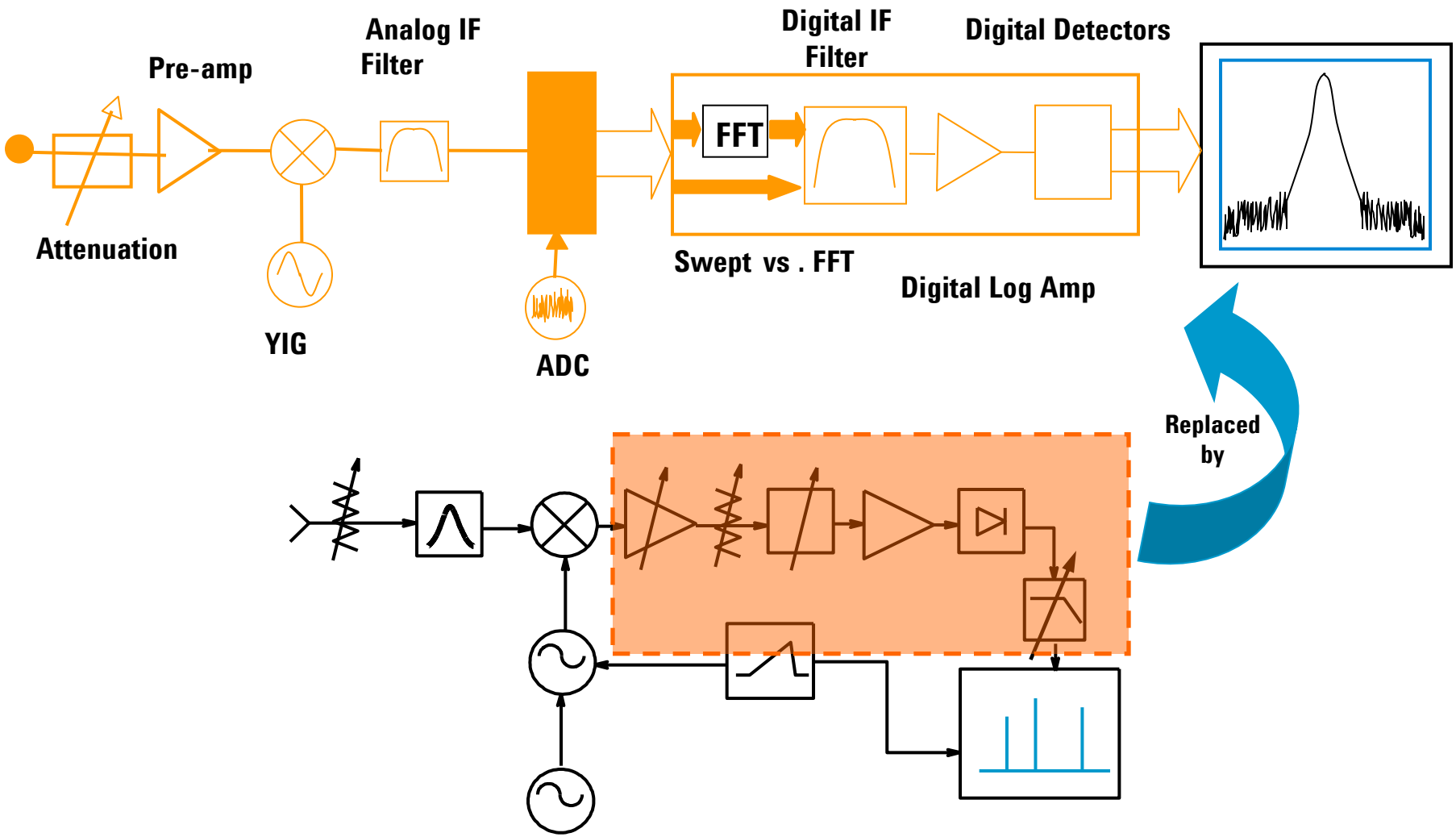
Modern spectrum analyzer designs & capabilities

- Wide Analysis Bandwidth Measurements

Wrap-up

Appendix

Modern Spectrum Analyzer Block Diagram



Modern Spectrum Analyzer - Specifications

Digital IF provides improved accuracy

	PXA	vs. Traditional
• Input impedance mismatch	±0.13	~~±0.29 dB~~
• Input attenuator switching uncertainty	±0.14	~~±0.6 dB~~
• Frequency response	±0.35	~~±1.8 dB~~
• Reference level accuracy	±0.0	~~±1.0 dB~~
• RBW switching uncertainty	±0.03	~~±0.5 dB~~
• Display scale fidelity	±0.07	~~±0.85 dB~~
• Calibrator accuracy	±0.24	~~±0.34 dB~~
Total accuracy (up to 3 GHz)	**±0.59 dB**	vs. ~~**±1.8 dB**~~
95% Confidence	**±0.19 dB**	

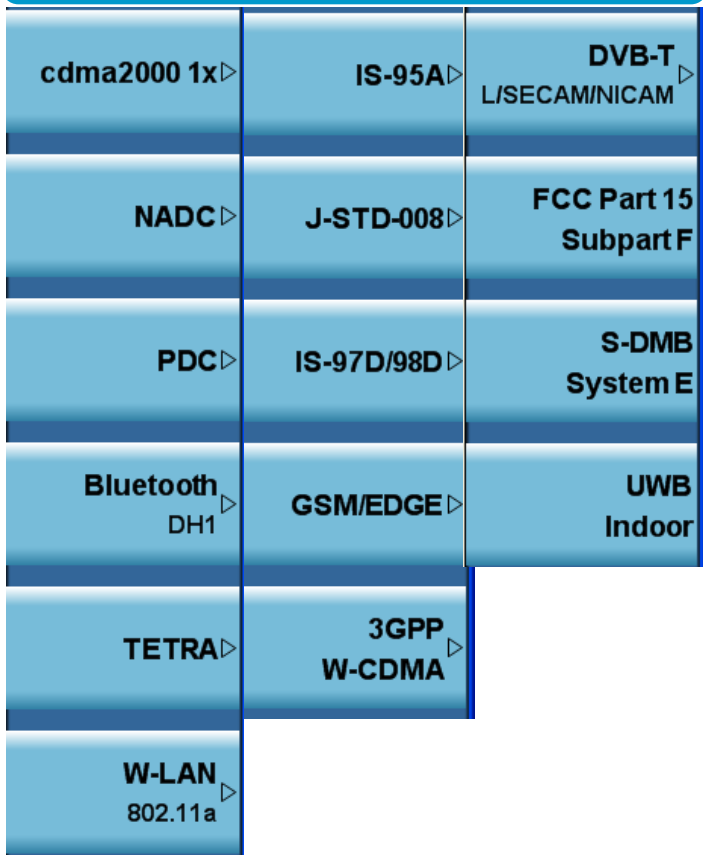
Modern Spectrum Analyzer Features

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
Ext. source control
Noise figure
Code compatibility suite
EMI pre-compliance
Analog demod
Flexible demod
LTE FDD, TDD
W-CDMA/HSPA/HSPA+
GSM/EDGE/EDGE Evo
cdma2000 & 1xEV-DO
cdmaOne
DVB-T/H/C/T2
TD-SCDMA/HSPA
WLAN (802.11a/b/g/p/j)
802.16 OFDMA
Bluetooth

ACPR, Multi-carrier Power

Occupied Bandwidth (OBW)

Spectral Emissions Mask

Phase and Freq. (PFER)

Mod Accuracy (Rho)

Code Domain Power

ORFS (GSM/EDGE)

Spurious Emissions

Power vs Time

Channel power

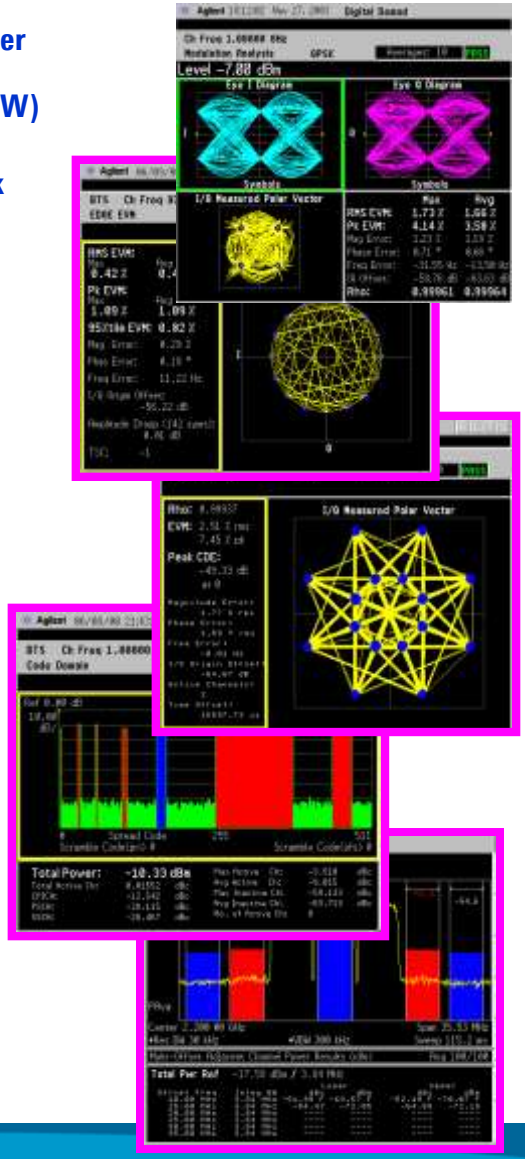
IM distortion

CCDF

ACPR

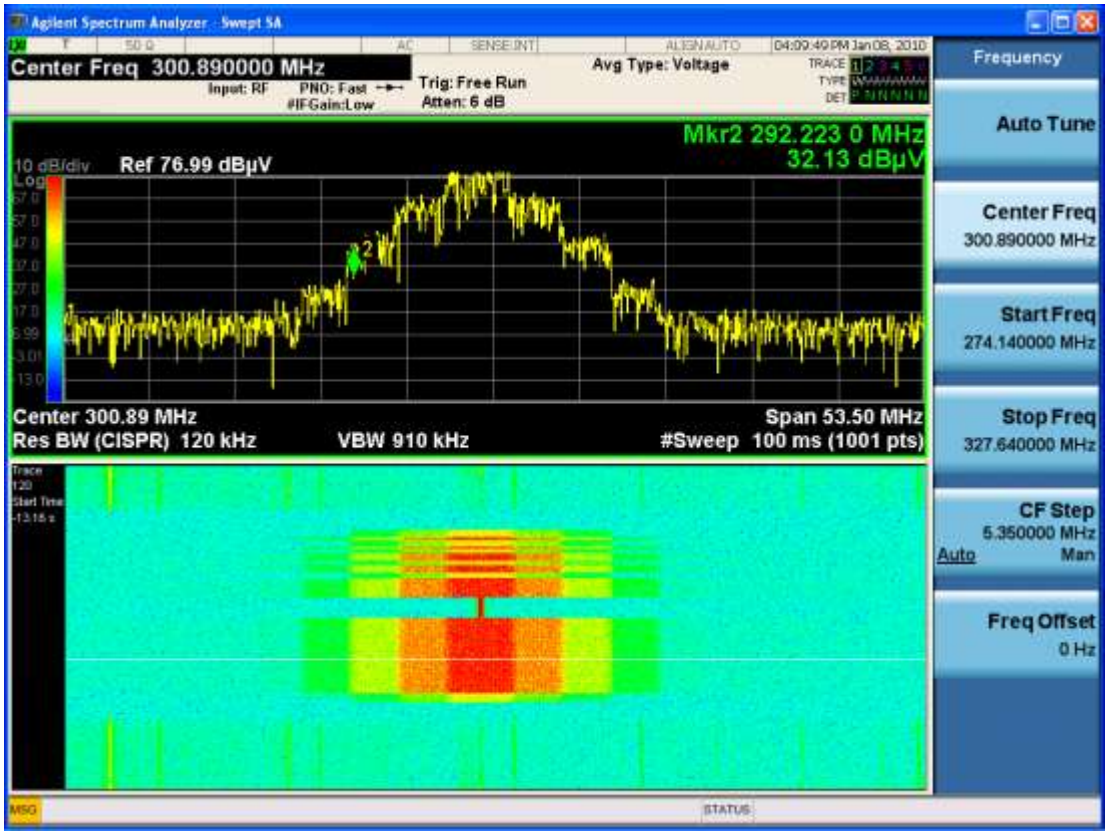
EVM

SEM



Enhanced Display Capabilities
Spectrogram

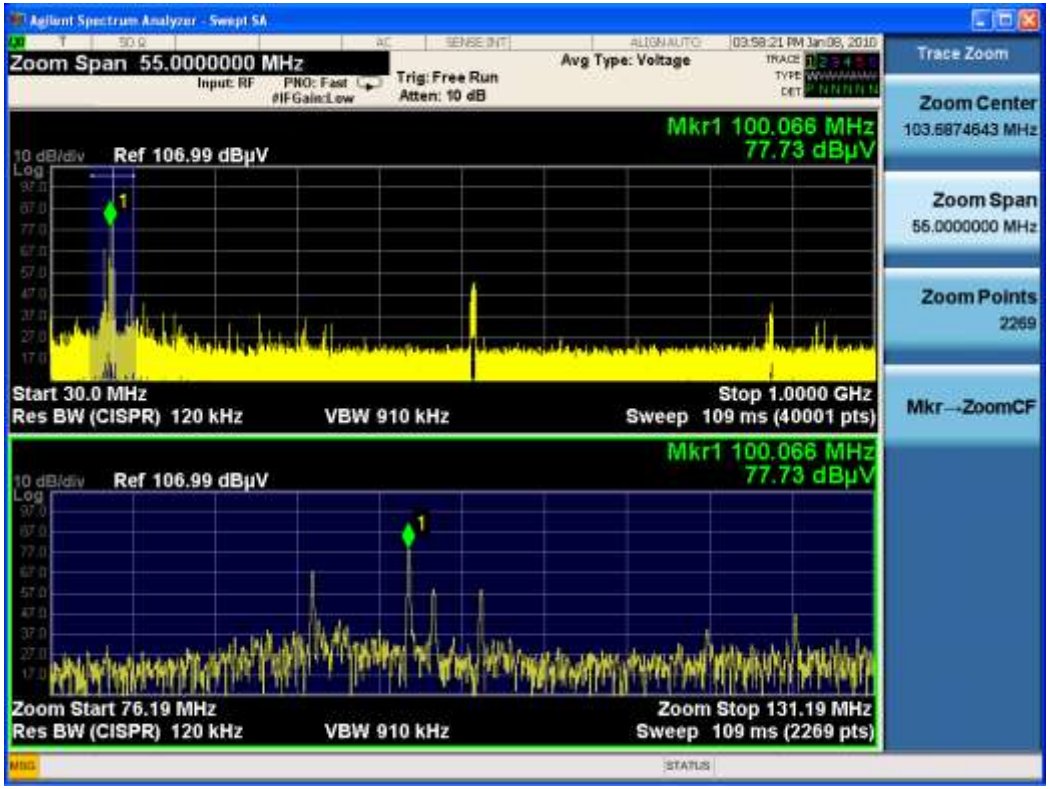
- Allows you to see time history in bottom window
- Amplitude displayed using color
- Great for finding intermittent signals



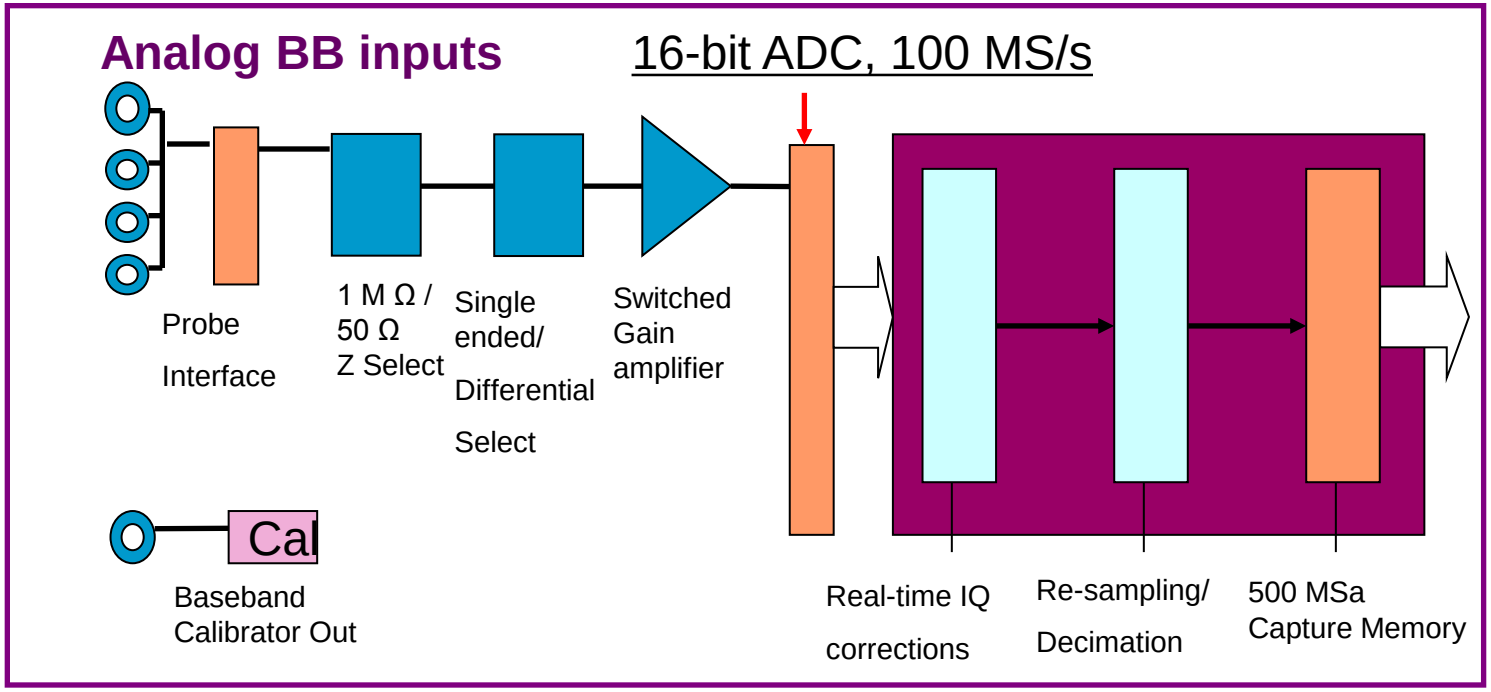
Enhanced Display Capabilities

Trace Zoom

- Allows you to zoom in on your trace data
- Same trace in both screens but bottom screen shows “close up” view with fewer points
- Great to look more closely at high-density traces



PXA/MXA Baseband and RF



Baseband to 40 MHz (for 1ch/2ch)

10, 25 or 40 MHz BW

500 MSa memory

Who needs wide analysis BW?

Modern designs demand more bandwidth for capturing high data rate signals and analyzing the quality of digitally modulated bandwidths

Aerospace and Defense

- Radar – Chirp errors & modulation quality
  Satellite – Capture 36/72 MHz BW's w/high data rates
  Military communications – Capture high data rate digital comms & measure EVM

Emerging communications

- W-LAN, 802.16 (wireless last mile), mesh networks
  - Measure EVM on broadband, high data rate signals

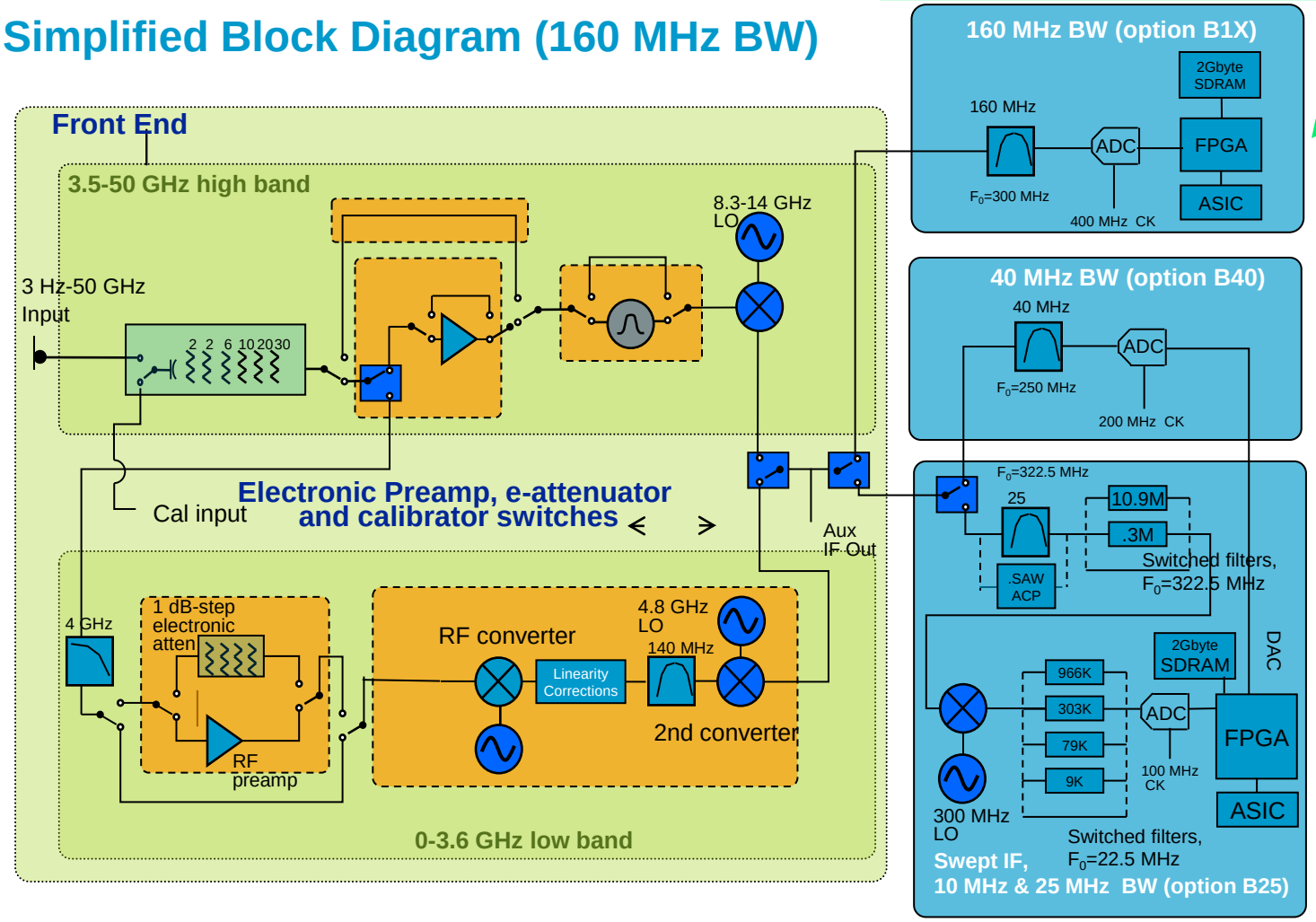
Cellular Communications

- W-CDMA ACPR & Multi-carrier Pre-Distortion
  - High dynamic range over 60 MHz BW to see low level 3rd order distortion for 4 carrier pre-distortion algorithms

PXA Wideband analysis

160 MHz Path
ADC Nominal bits: 14
ADC Effective bits: 11.2
SFDR: up to 75 dBc

PXA Simplified Block Diagram (160 MHz BW)



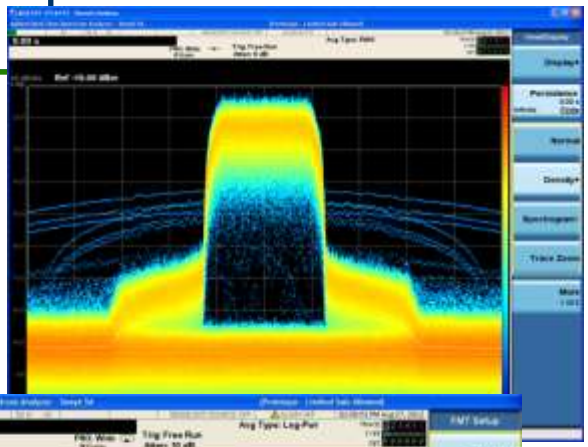
Agilent Real-time spectrum analyzer (RTSA)

Spectrum analysis goes real-time

- Gap-free data acquisition: 292,968 FFT's/sec
- High-speed measurements and display
- Frequency mask trigger (FMT) to capture events

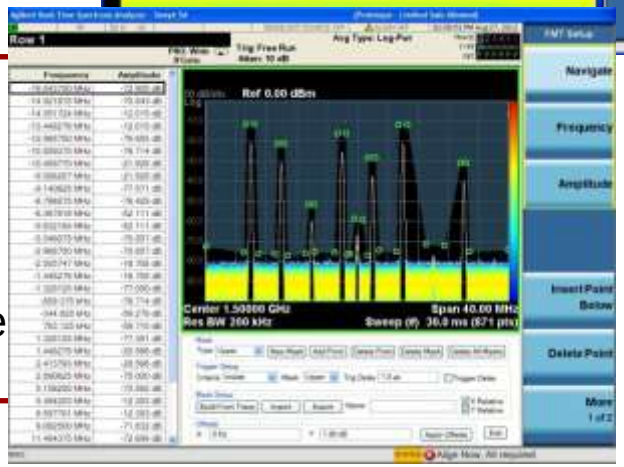
Measurement Contributions

- Short 100% POI duration: 3.57 μs
- 160 MHz wide real-time BW
- Real-time frequency coverage to 50 GHz
- 75 dBc spurious-free dynamic range



License-key upgradable to PXA

- Option RT1 (up to 85 MHz real-time BW)
- Option RT2 (up to 160 MHz real-time BW)
- Purchased with a new PXA or upgrade to existing one
- Requires wide BW option B1X



Agenda

Introduction

Overview

Theory of Operation

Specifications

Modern spectrum analyzer designs & capabilities

- Wide Analysis Bandwidth Measurements

Wrap-up

Appendix

Agilent Technologies' Signal Analysis Portfolio

PXA
X-Series
High-performance
3 Hz to 26.5 GHz
3 Hz to 43/44/50 GHz

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

EXA
X-Series
Economy-class
10 Hz to 26, 32, 44 GHz

CXA
Low-cost
9 kHz to 26.5 GHz

N9320B
Basic performance
9 kHz to 3 GHz

N9922C BSA
9 kHz to 7 GHz

Jan 13

8560EC
Mid-performance

ESA
World's most popular
100 Hz to 26 GHz

CSA
Low cost portable
100 Hz to 7 GHz

PSA
Market leading performance
3 Hz to 50 GHz

N9935/36/37/38A
5 kHz to 9/14/18/26.5 GHz
Handhelds

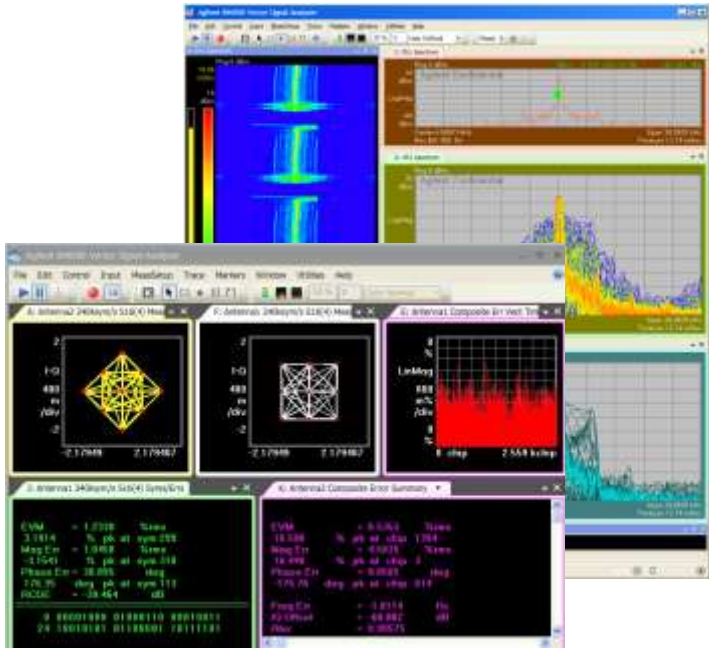
N9340B, N9342/43/44C
100 kHz to 3/7/13.6/20 GHz
Handhelds

X-Series Code Compatibility

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

Agilent Vector Signal Analysis Software

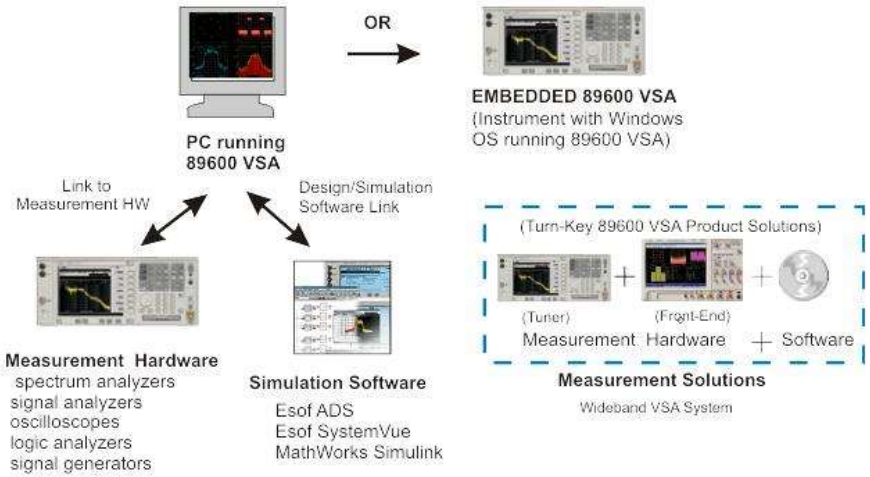
89600B VSA Software



- FFT-based spectrum, time-domain & bit-level modulation analysis
- Support for more than 70 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
- Cellular: LTE (FDD/TDD), W-CDMA HSPA+, LTE Advanced
- Custom OFDM modulation analysis for proprietary signals

- Links to over 30 hardware platforms including: *X-series signal analyzers, 16800 logic analyzers, 90000 X-series scopes, Infiniium scopes, VXI, N7109A Multi Channel Signal Analyzer*
- Runs on external PC linked to hardware or embedded operation on instruments with Windows OS



Basic Spectrum Analyzer Application & Product Notes

A.N. 150 – Spectrum Analysis Basics: #5952-0292EN

A.N. 150-15 - Vector Signal Analysis Basics: #5989-1121EN

Spectrum Analyzer & Signal Analyzer Selection Guide: #5968-3413E

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.agilent.com/find/sa

THANK YOU!